

Specification of the Bluetooth System

Wireless connections made easy

Core System Package [Controller volume]

Covered Core Package version:
2.0 + EDR
Current Master TOC issued:
4 November 2004





Revision History

The Revision History is shown in the “Appendix” on page 51[vol. 0].

Contributors

The persons who contributed to this specification are listed in the “Appendix” on page 51[vol. 0].

Web Site

This specification can also be found on the official Bluetooth web site:
<http://www.bluetooth.com>

Disclaimer and Copyright Notice

The copyright in these specifications is owned by the Promoter Members of Bluetooth SIG, Inc. (“Bluetooth SIG”). Use of these specifications and any related intellectual property (collectively, the “Specification”), is governed by the Promoters Membership Agreement among the Promoter Members and Bluetooth SIG (the “Promoters Agreement”), certain membership agreements between Bluetooth SIG and its Adopter and Associate Members (the “Membership Agreements”) and the Bluetooth Specification Early Adopters Agreements (“1.2 Early Adopters Agreements”) among Early Adopter members of the unincorporated Bluetooth special interest group and the Promoter Members (the “Early Adopters Agreement”). Certain rights and obligations of the Promoter Members under the Early Adopters Agreements have been assigned to Bluetooth SIG by the Promoter Members.

Use of the Specification by anyone who is not a member of Bluetooth SIG or a party to an Early Adopters Agreement (each such person or party, a “Member”), is prohibited. The legal rights and obligations of each Member are governed by their applicable Membership Agreement, Early Adopters Agreement or Promoters Agreement. No license, express or implied, by estoppel or otherwise, to any intellectual property rights are granted herein.

Any use of the Specification not in compliance with the terms of the applicable Membership Agreement, Early Adopters Agreement or Promoters Agreement is prohibited and any such prohibited use may result in termination of the applicable Membership Agreement or Early Adopters Agreement and other liability permitted by the applicable agreement or by applicable law to Bluetooth SIG or any of its members for patent, copyright and/or trademark infringement.



THE SPECIFICATION IS PROVIDED “AS IS” WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, SATISFACTORY QUALITY, OR REASONABLE SKILL OR CARE, OR ANY WARRANTY ARISING OUT OF ANY COURSE OF DEALING, USAGE, TRADE PRACTICE, PROPOSAL, SPECIFICATION OR SAMPLE.

Each Member hereby acknowledges that products equipped with the Bluetooth® technology (“Bluetooth® Products”) may be subject to various regulatory controls under the laws and regulations of various governments worldwide. Such laws and regulatory controls may govern, among other things, the combination, operation, use, implementation and distribution of Bluetooth® Products. Examples of such laws and regulatory controls include, but are not limited to, airline regulatory controls, telecommunications regulations, technology transfer controls and health and safety regulations. Each Member is solely responsible for the compliance by their Bluetooth® Products with any such laws and regulations and for obtaining any and all required authorizations, permits, or licenses for their Bluetooth® Products related to such regulations within the applicable jurisdictions. Each Member acknowledges that nothing in the Specification provides any information or assistance in connection with securing such compliance, authorizations or licenses. NOTHING IN THE SPECIFICATION CREATES ANY WARRANTIES, EITHER EXPRESS OR IMPLIED, REGARDING SUCH LAWS OR REGULATIONS.

ALL LIABILITY, INCLUDING LIABILITY FOR INFRINGEMENT OF ANY INTELLECTUAL PROPERTY RIGHTS OR FOR NONCOMPLIANCE WITH LAWS, RELATING TO USE OF THE SPECIFICATION IS EXPRESSLY DISCLAIMED. BY USE OF THE SPECIFICATION, EACH MEMBER EXPRESSLY WAIVES ANY CLAIM AGAINST BLUETOOTH SIG AND ITS PROMOTER MEMBERS RELATED TO USE OF THE SPECIFICATION.

Bluetooth SIG reserves the right to adopt any changes or alterations to the Specification as it deems necessary or appropriate.

Copyright © 1999, 2000, 2001, 2002, 2003, 2004

Agere Systems, Inc.,
Ericsson Technology Licensing, AB,
IBM Corporation,
Intel Corporation,
Microsoft Corporation,
Motorola, Inc.,
Nokia Corporation,
Toshiba Corporation

*Third-party brands and names are the property of their respective owners.





Part A

RADIO SPECIFICATION

| | |
|---|-----------|
| Contents | 25 |
| 1 Scope | 27 |
| 2 Frequency Bands and Channel Arrangement | 29 |
| 3 Transmitter Characteristics | 31 |
| 3.1 Basic Rate | 32 |
| 3.1.1 Modulation Characteristics | 32 |
| 3.1.2 Spurious Emissions | 33 |
| 3.1.3 Radio Frequency Tolerance | 34 |
| 3.2 Enhanced Data Rate | 34 |
| 3.2.1 Modulation Characteristics | 34 |
| 3.2.2 Spurious Emissions | 37 |
| 3.2.3 Radio Frequency Tolerance | 38 |
| 3.2.4 Relative Transmit Power | 39 |
| 4 Receiver Characteristics | 41 |
| 4.1 Basic Rate | 41 |
| 4.1.1 Actual Sensitivity Level | 41 |
| 4.1.2 Interference Performance | 41 |
| 4.1.3 Out-of-Band Blocking | 42 |
| 4.1.4 Intermodulation Characteristics | 42 |
| 4.1.5 Maximum Usable Level | 43 |
| 4.1.6 Receiver Signal Strength Indicator | 43 |
| 4.1.7 Reference Signal Definition | 43 |
| 4.2 Enhanced Data Rate | 43 |
| 4.2.1 Actual Sensitivity Level | 43 |
| 4.2.2 BER Floor Performance | 43 |
| 4.2.3 Interference Performance | 43 |
| 4.2.4 Maximum Usable Level | 44 |
| 4.2.5 Out-of-Band and Intermodulation Characteristics | 45 |
| 4.2.6 Reference Signal Definition | 45 |
| 5 Appendix A | 47 |
| 5.1 Nominal Test Conditions | 47 |
| 5.1.1 Nominal temperature | 47 |
| 5.1.2 Nominal power source | 47 |
| 5.2 Extreme Test Conditions | 48 |
| 5.2.1 Extreme temperatures | 48 |
| 5.2.2 Extreme power source voltages | 48 |



| | | |
|----------|--|-----------|
| 6 | Appendix B | 49 |
| 7 | Appendix C | 51 |
| 7.1 | Enhanced Data Rate Modulation Accuracy | 51 |

Part B

BASEBAND SPECIFICATION

| | |
|---|-----------|
| Contents | 57 |
| 1 General Description | 63 |
| 1.1 Bluetooth Clock | 64 |
| 1.2 Bluetooth Device Addressing..... | 66 |
| 1.2.1 Reserved addresses | 66 |
| 1.3 Access Codes | 67 |
| 2 Physical Channels | 69 |
| 2.1 Physical Channel Definition | 70 |
| 2.2 Basic Piconet Physical Channel | 70 |
| 2.2.1 Master-slave definition | 70 |
| 2.2.2 Hopping characteristics..... | 71 |
| 2.2.3 Time slots | 71 |
| 2.2.4 Piconet clocks | 72 |
| 2.2.5 Transmit/receive timing | 72 |
| 2.3 Adapted Piconet Physical Channel..... | 75 |
| 2.3.1 Hopping characteristics..... | 75 |
| 2.4 Page Scan Physical Channel | 76 |
| 2.4.1 Clock estimate for paging..... | 76 |
| 2.4.2 Hopping characteristics..... | 76 |
| 2.4.3 Paging procedure timing | 77 |
| 2.4.4 Page response timing | 78 |
| 2.5 Inquiry Scan Physical Channel | 80 |
| 2.5.1 Clock for inquiry | 80 |
| 2.5.2 Hopping characteristics..... | 80 |
| 2.5.3 Inquiry procedure timing..... | 80 |
| 2.5.4 Inquiry response timing | 80 |
| 2.6 Hop Selection | 82 |
| 2.6.1 General selection scheme..... | 82 |
| 2.6.2 Selection kernel | 86 |
| 2.6.3 Adapted hop selection kernel..... | 89 |
| 2.6.4 Control word..... | 90 |
| 3 Physical Links | 95 |
| 3.1 Link Supervision | 95 |



| | | |
|----------|--|------------|
| 4 | Logical Transports | 97 |
| 4.1 | General | 97 |
| 4.2 | Logical Transport Address (LT_ADDR)..... | 97 |
| 4.3 | Synchronous Logical Transports..... | 98 |
| 4.4 | Asynchronous Logical Transport..... | 98 |
| 4.5 | Transmit/Receive Routines | 99 |
| 4.5.1 | TX Routine | 99 |
| 4.5.2 | RX routine | 102 |
| 4.5.3 | Flow control | 103 |
| 4.6 | Active Slave Broadcast Transport..... | 104 |
| 4.7 | Parked Slave Broadcast Transport | 105 |
| 4.7.1 | Parked member address (PM_ADDR) | 105 |
| 4.7.2 | Access request address (AR_ADDR) | 105 |
| 5 | Logical Links | 107 |
| 5.1 | Link Control Logical Link (LC)..... | 107 |
| 5.2 | ACL Control Logical Link (ACL-C) | 107 |
| 5.3 | User Asynchronous/Isochronous Logical Link (ACL-U)..... | 107 |
| 5.3.1 | Pausing the ACL-U logical link | 108 |
| 5.4 | User Synchronous Data Logical Link (SCO-S) | 108 |
| 5.5 | User Extended Synchronous Data Logical Link (eSCO-S) | 108 |
| 5.6 | Logical Link Priorities | 108 |
| 6 | Packets | 109 |
| 6.1 | General Format..... | 109 |
| 6.1.1 | Basic Rate | 109 |
| 6.1.2 | Enhanced Data Rate | 109 |
| 6.2 | Bit Ordering | 110 |
| 6.3 | Access Code | 111 |
| 6.3.1 | Access code types | 111 |
| 6.3.2 | Preamble | 112 |
| 6.3.3 | Sync word..... | 112 |
| 6.3.4 | Trailer | 115 |
| 6.4 | Packet Header | 116 |
| 6.4.1 | LT_ADDR | 116 |
| 6.4.2 | TYPE | 116 |
| 6.4.3 | FLOW | 117 |
| 6.4.4 | ARQN | 117 |
| 6.4.5 | SEQN | 117 |
| 6.4.6 | HEC | 117 |
| 6.5 | Packet Types | 118 |
| 6.5.1 | Common packet types..... | 119 |



| | | |
|----------|--|------------|
| 6.5.2 | SCO packets | 123 |
| 6.5.3 | eSCO packets | 124 |
| 6.5.4 | ACL packets | 126 |
| 6.6 | Payload Format | 128 |
| 6.6.1 | S ynchronous data field | 128 |
| 6.6.2 | Asynchronous data field | 130 |
| 6.7 | Packet Summary | 134 |
| 7 | Bitstream Processing | 137 |
| 7.1 | Error Checking | 138 |
| 7.1.1 | HEC generation | 138 |
| 7.1.2 | CRC generation | 139 |
| 7.2 | Data Whitening | 141 |
| 7.3 | Error Correction | 142 |
| 7.4 | FEC Code: Rate 1/3 | 142 |
| 7.5 | FEC Code: Rate 2/3 | 143 |
| 7.6 | ARQ Scheme | 144 |
| 7.6.1 | Unnumbered ARQ | 144 |
| 7.6.2 | Retransmit filtering | 147 |
| 7.6.3 | Flushing payloads | 150 |
| 7.6.4 | Multi-slave considerations | 150 |
| 7.6.5 | Broadcast packets | 150 |
| 8 | Link Controller Operation | 153 |
| 8.1 | Overview of States | 153 |
| 8.2 | Standby State | 154 |
| 8.3 | Connection Establishment Substates | 154 |
| 8.3.1 | Page scan substate | 154 |
| 8.3.2 | Page substate | 156 |
| 8.3.3 | Page response substates | 159 |
| 8.4 | Device Discovery Substates | 163 |
| 8.4.1 | Inquiry scan substate | 164 |
| 8.4.2 | Inquiry substate | 165 |
| 8.4.3 | Inquiry response substate | 166 |
| 8.5 | Connection State | 167 |
| 8.6 | Active Mode | 168 |
| 8.6.1 | Polling in the active mode | 169 |
| 8.6.2 | SCO | 169 |
| 8.6.3 | eSCO | 171 |
| 8.6.4 | Broadcast scheme | 173 |
| 8.6.5 | Role switch | 175 |



| | | |
|--|---|------------|
| 8.6.6 | Scatternet | 177 |
| 8.6.7 | Hop sequence switching | 178 |
| 8.6.8 | Channel classification and channel map selection | 181 |
| 8.6.9 | Power Management | 182 |
| 8.7 | sniff Mode..... | 183 |
| 8.7.1 | Sniff Transition Mode | 184 |
| 8.8 | Hold Mode..... | 185 |
| 8.9 | Park State..... | 185 |
| 8.9.1 | Beacon train | 186 |
| 8.9.2 | Beacon access window | 189 |
| 8.9.3 | Parked slave synchronization..... | 190 |
| 8.9.4 | Parking | 191 |
| 8.9.5 | Master-initiated unparking | 192 |
| 8.9.6 | Slave-initiated unparking | 192 |
| 8.9.7 | Broadcast scan window..... | 193 |
| 8.9.8 | Polling in the park state | 193 |
| 9 | Audio | 195 |
| 9.1 | LOG PCM CODEC..... | 195 |
| 9.2 | CVSD CODEC | 195 |
| 9.3 | Error Handling | 198 |
| 9.4 | General Audio Requirements..... | 198 |
| 9.4.1 | Signal levels | 198 |
| 9.4.2 | CVSD audio quality | 198 |
| 10 | List of Figures..... | 199 |
| 11 | List of Tables | 203 |
| 12 | Appendix | 203 |
| Appendix A: General Audio Recommendations | | 204 |
| Appendix B: Timers | | 207 |
| Appendix C: | | 209 |
| Recommendations for AFH Operation in Park, Hold and Sniff | | 209 |

Part C

LINK MANAGER PROTOCOL

| | |
|------------------------------|------------|
| Contents | 213 |
| 1 Introduction | 217 |
| 2 General Rules | 219 |
| 2.1 Message Transport | 219 |
| 2.2 Synchronization | 219 |
| 2.3 Packet Format..... | 220 |



| | | |
|----------|--|------------|
| 2.4 | Transactions | 221 |
| 2.4.1 | LMP Response Timeout..... | 222 |
| 2.5 | Error Handling..... | 222 |
| 2.5.1 | Transaction collision resolution | 223 |
| 2.6 | Procedure Rules | 223 |
| 2.7 | General Response Messages | 224 |
| 2.8 | LMP Message Constraints..... | 224 |
| 3 | Device Features | 225 |
| 3.1 | General Description | 225 |
| 3.2 | Feature Definitions..... | 225 |
| 3.3 | Feature Mask Definition | 230 |
| 3.4 | Link Manager Interoperability policy | 232 |
| 4 | Procedure Rules | 233 |
| 4.1 | Connection Control | 233 |
| 4.1.1 | Connection establishment..... | 233 |
| 4.1.2 | Detach..... | 234 |
| 4.1.3 | Power control | 235 |
| 4.1.4 | Adaptive frequency hopping | 237 |
| 4.1.5 | Channel classification | 240 |
| 4.1.6 | Link supervision | 242 |
| 4.1.7 | Channel quality driven data rate change (CQDDR) | 243 |
| 4.1.8 | Quality of service (QoS)..... | 244 |
| 4.1.9 | Paging scheme parameters | 246 |
| 4.1.10 | Control of multi-slot packets..... | 247 |
| 4.1.11 | Enhanced Data Rate..... | 247 |
| 4.2 | Security..... | 249 |
| 4.2.1 | Authentication | 249 |
| 4.2.2 | Pairing..... | 251 |
| 4.2.3 | Change link key | 254 |
| 4.2.4 | Change current link key type..... | 255 |
| 4.2.5 | Encryption | 257 |
| 4.2.6 | Request supported encryption key size | 261 |
| 4.3 | Informational Requests | 262 |
| 4.3.1 | Timing accuracy | 262 |
| 4.3.2 | Clock offset | 263 |
| 4.3.3 | LMP version | 263 |
| 4.3.4 | Supported features | 264 |
| 4.3.5 | Name request | 266 |
| 4.4 | Role Switch..... | 267 |



| | | |
|----------|--|------------|
| 4.4.1 | Slot offset | 267 |
| 4.4.2 | Role switch | 268 |
| 4.5 | Modes of Operation | 270 |
| 4.5.1 | Hold mode | 270 |
| 4.5.2 | Park state | 272 |
| 4.5.3 | Sniff mode | 278 |
| 4.6 | Logical Transports | 281 |
| 4.6.1 | SCO logical transport | 281 |
| 4.6.2 | eSCO logical transport | 284 |
| 4.7 | Test Mode | 289 |
| 4.7.1 | Activation and deactivation of test mode | 289 |
| 4.7.2 | Control of test mode | 290 |
| 4.7.3 | Summary of test mode PDUs | 291 |
| 5 | Summary | 295 |
| 5.1 | PDU Summary | 295 |
| 5.2 | Parameter Definitions | 303 |
| 5.3 | Default Values | 311 |
| 6 | List of Figures | 313 |
| 7 | List of Tables | 317 |

Part D

ERROR CODES

| | |
|---|------------|
| Contents | 321 |
| 1 Overview of Error Codes | 323 |
| 1.1 Usage Descriptions | 323 |
| 1.2 HCI Command Errors | 323 |
| 1.3 List of Error Codes | 324 |
| 2 Error Code Descriptions | 327 |
| 2.1 Unknown HCI Command (0X01) | 327 |
| 2.2 Unknown Connection Identifier (0X02) | 327 |
| 2.3 Hardware Failure (0X03) | 327 |
| 2.4 Page Timeout (0X04) | 327 |
| 2.5 Authentication Failure (0X05) | 327 |
| 2.6 PIN or key Missing (0X06) | 327 |
| 2.7 Memory Capacity Exceeded (0X07) | 327 |
| 2.8 Connection Timeout (0X08) | 328 |
| 2.9 Connection Limit Exceeded (0X09) | 328 |
| 2.10 Synchronous Connection Limit to a Device Exceeded (0X0A) | 328 |
| 2.11 ACL Connection Already Exists (0X0B) | 328 |
| 2.12 Command Disallowed (0X0C) | 328 |



| | | |
|------|---|-----|
| 2.13 | Connection Rejected due to Limited Resources (0X0D) | 328 |
| 2.14 | Connection Rejected due to Security Reasons (0X0E) | 328 |
| 2.15 | Connection Rejected due to Unacceptable BD_ADDR (0X0F)..... | 329 |
| 2.16 | Connection Accept Timeout Exceeded (0X10) | 329 |
| 2.17 | Unsupported Feature or Parameter Value (0X11) | 329 |
| 2.18 | Invalid HCI Command Parameters (0X12) | 329 |
| 2.19 | Remote User Terminated Connection (0X13) | 329 |
| 2.20 | Remote Device Terminated Connection due to Low Resources (0X14)..... | 330 |
| 2.21 | Remote Device Terminated Connection due to Power Off (0X15). | 330 |
| 2.22 | Connection Terminated by Local Host (0X16) | 330 |
| 2.23 | Repeated Attempts (0X17) | 330 |
| 2.24 | Pairing not Allowed (0X18) | 330 |
| 2.25 | Unknown LMP PDU (0X19) | 330 |
| 2.26 | Unsupported Remote Feature / Unsupported LMP Feature (0X1A)..... | 330 |
| 2.27 | SCO Offset Rejected (0X1B) | 330 |
| 2.28 | SCO Interval Rejected (0X1C)..... | 331 |
| 2.29 | SCO Air Mode Rejected (0X1D) | 331 |
| 2.30 | Invalid LMP Parameters (0X1E) | 331 |
| 2.31 | Unspecified Error (0X1F) | 331 |
| 2.32 | Unsupported LMP Parameter Value (0X20) | 331 |
| 2.33 | Role Change Not Allowed (0X21)..... | 331 |
| 2.34 | LMP Response Timeout (0X22)..... | 331 |
| 2.35 | LMP Error Transaction Collision (0X23) | 332 |
| 2.36 | LMP PDU Not Allowed (0X24)..... | 332 |
| 2.37 | Encryption Mode Not Acceptable (0X25)..... | 332 |
| 2.38 | Link Key Can Not be Changed (0X26) | 332 |
| 2.39 | Requested Qos Not Supported (0X27)..... | 332 |
| 2.40 | Instant Passed (0X28) | 332 |
| 2.41 | Pairing with Unit Key Not Supported (0X29)..... | 332 |
| 2.42 | Different Transaction Collision (0x2a)..... | 332 |
| 2.43 | QoS Unacceptable Parameter (0X2C)..... | 332 |
| 2.44 | QoS Rejected (0X2D) | 333 |
| 2.45 | Channel Classification Not Supported (0X2E)..... | 333 |
| 2.46 | Insufficient Security (0X2F)..... | 333 |
| 2.47 | Parameter out of Mandatory Range (0X30)..... | 333 |
| 2.48 | Role Switch Pending (0X32)..... | 333 |
| 2.49 | Reserved Slot Violation (0X34)..... | 333 |
| 2.50 | Role Switch Failed (0X35) | 333 |

Part E



HOST CONTROLLER INTERFACE FUNCTIONAL SPECIFICATION

| | |
|---|------------|
| Contents | 337 |
| 1 Introduction | 343 |
| 1.1 Lower Layers of the Bluetooth Software Stack | 343 |
| 2 Overview of Host Controller Transport Layer..... | 345 |
| 3 Overview of Commands and Events | 347 |
| 3.1 Generic Events..... | 348 |
| 3.2 Device Setup..... | 348 |
| 3.3 Controller Flow Control | 349 |
| 3.4 Controller Information..... | 349 |
| 3.5 Controller Configuration | 350 |
| 3.6 Device Discovery | 351 |
| 3.7 Connection Setup | 353 |
| 3.8 Remote Information..... | 355 |
| 3.9 Synchronous Connections | 356 |
| 3.10 Connection State..... | 357 |
| 3.11 Piconet Structure..... | 358 |
| 3.12 Quality of Service | 359 |
| 3.13 Physical Links | 360 |
| 3.14 Host Flow Control..... | 361 |
| 3.15 Link Information | 362 |
| 3.16 Authentication and Encryption | 363 |
| 3.17 Testing..... | 365 |
| 3.18 Alphabetical List of Commands and Events | 366 |
| 4 HCI Flow Control | 371 |
| 4.1 Host to Controller Data Flow Control | 371 |
| 4.2 Controller to Host Data Flow Control | 372 |
| 4.3 Disconnection Behavior | 373 |
| 4.4 Command Flow Control | 373 |
| 4.5 Command Error Handling | 374 |
| 5 HCI Data Formats | 375 |
| 5.1 Introduction | 375 |
| 5.2 Data and Parameter Formats..... | 375 |
| 5.3 Connection Handles..... | 376 |
| 5.4 Exchange of HCI-Specific Information | 377 |
| 5.4.1 HCI Command Packet..... | 377 |
| 5.4.2 HCI ACL Data Packets..... | 379 |
| 5.4.3 HCI Synchronous Data Packets..... | 381 |
| 5.4.4 HCI Event Packet..... | 382 |
| 6 HCI Configuration Parameters | 383 |



| | | |
|----------|---|------------|
| 6.1 | Scan Enable | 383 |
| 6.2 | Inquiry Scan Interval | 383 |
| 6.3 | Inquiry Scan Window | 384 |
| 6.4 | Inquiry Scan Type | 384 |
| 6.5 | Inquiry Mode | 384 |
| 6.6 | Page Timeout..... | 385 |
| 6.7 | Connection Accept Timeout..... | 385 |
| 6.8 | Page Scan Interval | 386 |
| 6.9 | Page Scan Window | 386 |
| 6.10 | Page Scan Period Mode (Deprecated)..... | 386 |
| 6.11 | Page Scan Type | 387 |
| 6.12 | Voice Setting..... | 387 |
| 6.13 | PIN Type | 388 |
| 6.14 | Link Key | 388 |
| 6.15 | Authentication Enable..... | 388 |
| 6.16 | Encryption Mode..... | 389 |
| 6.17 | Failed Contact Counter | 390 |
| 6.18 | Hold Mode Activity | 390 |
| 6.19 | Link Policy Settings..... | 391 |
| 6.20 | Flush Timeout | 392 |
| 6.21 | Num Broadcast Retransmissions | 392 |
| 6.22 | Link Supervision Timeout..... | 393 |
| 6.23 | Synchronous Flow Control Enable | 393 |
| 6.24 | Local Name..... | 394 |
| 6.25 | Class Of Device | 394 |
| 6.26 | Supported Commands..... | 395 |
| 7 | HCI Commands and Events | 399 |
| 7.1 | Link Control Commands | 399 |
| 7.1.1 | Inquiry Command..... | 399 |
| 7.1.2 | Inquiry Cancel Command..... | 401 |
| 7.1.3 | Periodic Inquiry Mode Command..... | 402 |
| 7.1.4 | Exit Periodic Inquiry Mode Command..... | 405 |
| 7.1.5 | Create Connection Command..... | 406 |
| 7.1.6 | Disconnect Command..... | 409 |
| 7.1.7 | Create Connection Cancel Command | 410 |
| 7.1.8 | Accept Connection Request Command | 412 |
| 7.1.9 | Reject Connection Request Command..... | 414 |
| 7.1.10 | Link Key Request Reply Command | 415 |
| 7.1.11 | Link Key Request Negative Reply Command | 417 |
| 7.1.12 | PIN Code Request Reply Command | 418 |
| 7.1.13 | PIN Code Request Negative Reply Command | 420 |



| | | |
|--------|--|-----|
| 7.1.14 | Change Connection Packet Type Command | 421 |
| 7.1.15 | Authentication Requested Command..... | 424 |
| 7.1.16 | Set Connection Encryption Command | 425 |
| 7.1.17 | Change Connection Link Key Command | 426 |
| 7.1.18 | Master Link Key Command | 427 |
| 7.1.19 | Remote Name Request Command | 428 |
| 7.1.20 | Remote Name Request Cancel Command | 430 |
| 7.1.21 | Read Remote Supported Features Command..... | 431 |
| 7.1.22 | Read Remote Extended Features Command | 432 |
| 7.1.23 | Read Remote Version Information Command..... | 433 |
| 7.1.24 | Read Clock Offset Command..... | 434 |
| 7.1.25 | Read LMP Handle Command | 435 |
| 7.1.26 | Setup Synchronous Connection Command | 437 |
| 7.1.27 | Accept Synchronous Connection Request Command | 442 |
| 7.1.28 | Reject Synchronous Connection Request Command | 446 |
| 7.2 | Link Policy Commands..... | 447 |
| 7.2.1 | Hold Mode Command | 447 |
| 7.2.2 | Sniff Mode Command..... | 449 |
| 7.2.3 | Exit Sniff Mode Command..... | 452 |
| 7.2.4 | Park State Command | 453 |
| 7.2.5 | Exit Park State Command | 455 |
| 7.2.6 | QoS Setup Command | 456 |
| 7.2.7 | Role Discovery Command..... | 458 |
| 7.2.8 | Switch Role Command..... | 459 |
| 7.2.9 | Read Link Policy Settings Command | 460 |
| 7.2.10 | Write Link Policy Settings Command | 461 |
| 7.2.11 | Read Default Link Policy Settings Command | 463 |
| 7.2.12 | Write Default Link Policy Settings Command | 464 |
| 7.2.13 | Flow Specification Command | 465 |
| 7.3 | Controller & Baseband Commands..... | 467 |
| 7.3.1 | Set Event Mask Command..... | 467 |
| 7.3.2 | Reset Command | 469 |
| 7.3.3 | Set Event Filter Command | 470 |
| 7.3.4 | Flush Command..... | 475 |
| 7.3.5 | Read PIN Type Command | 477 |
| 7.3.6 | Write PIN Type Command..... | 478 |
| 7.3.7 | Create New Unit Key Command | 479 |
| 7.3.8 | Read Stored Link Key Command..... | 480 |



| | | |
|--------|---|-----|
| 7.3.9 | Write Stored Link Key Command | 481 |
| 7.3.10 | Delete Stored Link Key Command | 483 |
| 7.3.11 | Write Local Name Command | 484 |
| 7.3.12 | Read Local Name Command | 485 |
| 7.3.13 | Read Connection Accept Timeout Command | 486 |
| 7.3.14 | Write Connection Accept Timeout Command | 487 |
| 7.3.15 | Read Page Timeout Command | 488 |
| 7.3.16 | Write Page Timeout Command | 489 |
| 7.3.17 | Read Scan Enable Command | 490 |
| 7.3.18 | Write Scan Enable Command | 491 |
| 7.3.19 | Read Page Scan Activity Command | 492 |
| 7.3.20 | Write Page Scan Activity Command | 494 |
| 7.3.21 | Read Inquiry Scan Activity Command | 495 |
| 7.3.22 | Write Inquiry Scan Activity Command | 496 |
| 7.3.23 | Read Authentication Enable Command | 497 |
| 7.3.24 | Write Authentication Enable Command | 498 |
| 7.3.25 | Read Encryption Mode Command | 499 |
| 7.3.26 | Write Encryption Mode Command | 500 |
| 7.3.27 | Read Class of Device Command | 501 |
| 7.3.28 | Write Class of Device Command | 502 |
| 7.3.29 | Read Voice Setting Command | 503 |
| 7.3.30 | Write Voice Setting Command | 504 |
| 7.3.31 | Read Automatic Flush Timeout Command | 505 |
| 7.3.32 | Write Automatic Flush Timeout Command | 506 |
| 7.3.33 | Read Num Broadcast Retransmissions Command | 507 |
| 7.3.34 | Write Num Broadcast Retransmissions Command | 508 |
| 7.3.35 | Read Hold Mode Activity Command | 509 |
| 7.3.36 | Write Hold Mode Activity Command | 510 |
| 7.3.37 | Read Transmit Power Level Command | 511 |
| 7.3.38 | Read Synchronous Flow Control Enable Command | 513 |
| 7.3.39 | Write Synchronous Flow Control Enable Command | 514 |
| 7.3.40 | Set Controller To Host Flow Control Command | 515 |
| 7.3.41 | Host Buffer Size Command | 516 |
| 7.3.42 | Host Number Of Completed Packets Command | 518 |
| 7.3.43 | Read Link Supervision Timeout Command | 520 |
| 7.3.44 | Write Link Supervision Timeout Command | 521 |
| 7.3.45 | Read Number Of Supported IAC Command | 523 |
| 7.3.46 | Read Current IAC LAP Command | 524 |



| | | |
|--------|---|-----|
| 7.3.47 | Write Current IAC LAP Command..... | 525 |
| 7.3.48 | Read Page Scan Period Mode Command (Deprecated) .. | 527 |
| 7.3.49 | Write Page Scan Period Mode Command (Deprecated) .. | 528 |
| 7.3.50 | Set AFH Host Channel Classification Command | 529 |
| 7.3.51 | Read Inquiry Scan Type Command | 530 |
| 7.3.52 | Write Inquiry Scan Type Command | 531 |
| 7.3.53 | Read Inquiry Mode Command | 532 |
| 7.3.54 | Write Inquiry Mode Command | 533 |
| 7.3.55 | Read Page Scan Type Command | 534 |
| 7.3.56 | Write Page Scan Type Command | 535 |
| 7.3.57 | Read AFH Channel Assessment Mode Command | 536 |
| 7.3.58 | Write AFH Channel Assessment Mode Command | 537 |
| 7.4 | Informational Parameters..... | 539 |
| 7.4.1 | Read Local Version Information Command..... | 539 |
| 7.4.2 | Read Local Supported Commands Command..... | 541 |
| 7.4.3 | Read Local Supported Features Command..... | 542 |
| 7.4.4 | Read Local Extended Features Command | 543 |
| 7.4.5 | Read Buffer Size Command..... | 545 |
| 7.4.6 | Read BD_ADDR Command..... | 547 |
| 7.5 | Status Parameters..... | 548 |
| 7.5.1 | Read Failed Contact Counter Command | 548 |
| 7.5.2 | Reset Failed Contact Counter Command | 550 |
| 7.5.3 | Read Link Quality Command | 551 |
| 7.5.4 | Read RSSI Command..... | 552 |
| 7.5.5 | Read AFH Channel Map Command | 554 |
| 7.5.6 | Read Clock Command | 556 |
| 7.6 | Testing Commands | 558 |
| 7.6.1 | Read Loopback Mode Command | 558 |
| 7.6.2 | Write Loopback Mode Command..... | 559 |
| 7.6.3 | Enable Device Under Test Mode Command | 562 |
| 7.7 | Events | 563 |
| 7.7.1 | Inquiry Complete Event..... | 563 |
| 7.7.2 | Inquiry Result Event | 564 |
| 7.7.3 | Connection Complete Event..... | 566 |
| 7.7.4 | Connection Request Event..... | 567 |
| 7.7.5 | Disconnection Complete Event | 569 |
| 7.7.6 | Authentication Complete Event..... | 570 |



| | | |
|---|--|------------|
| 7.7.7 | Remote Name Request Complete Event | 571 |
| 7.7.8 | Encryption Change Event | 572 |
| 7.7.9 | Change Connection Link Key Complete Event | 573 |
| 7.7.10 | Master Link Key Complete Event | 574 |
| 7.7.11 | Read Remote Supported Features Complete Event... | 575 |
| 7.7.12 | Read Remote Version Information Complete Event ... | 576 |
| 7.7.13 | QoS Setup Complete Event | 577 |
| 7.7.14 | Command Complete Event | 579 |
| 7.7.15 | Command Status Event | 580 |
| 7.7.16 | Hardware Error Event | 581 |
| 7.7.17 | Flush Occurred Event | 581 |
| 7.7.18 | Role Change Event | 582 |
| 7.7.19 | Number Of Completed Packets Event | 583 |
| 7.7.20 | Mode Change Event | 584 |
| 7.7.21 | Return Link Keys Event | 586 |
| 7.7.22 | PIN Code Request Event | 587 |
| 7.7.23 | Link Key Request Event | 588 |
| 7.7.24 | Link Key Notification Event | 589 |
| 7.7.25 | Loopback Command Event | 590 |
| 7.7.26 | Data Buffer Overflow Event | 590 |
| 7.7.27 | Max Slots Change Event | 591 |
| 7.7.28 | Read Clock Offset Complete Event | 592 |
| 7.7.29 | Connection Packet Type Changed Event | 593 |
| 7.7.30 | QoS Violation Event | 596 |
| 7.7.31 | Page Scan Repetition Mode Change Event | 597 |
| 7.7.32 | Flow Specification Complete Event | 598 |
| 7.7.33 | Inquiry Result with RSSI Event | 600 |
| 7.7.34 | Read Remote Extended Features Complete Event | 602 |
| 7.7.35 | Synchronous Connection Complete Event | 603 |
| 7.7.36 | Synchronous Connection Changed event | 605 |
| 8 | List of Figures | 607 |
| 9 | List of Tables | 609 |
| 10 | Appendix | 609 |
| Appendix A: Deprecated Commands, Events and Configuration Parameters | | 611 |

Part F

MESSAGE SEQUENCE CHARTS



| | |
|--|------------|
| Contents | 621 |
| 1 Introduction | 623 |
| 1.1 Notation | 623 |
| 1.2 Flow of Control | 624 |
| 1.3 Example MSC | 624 |
| 2 Services Without Connection Request | 625 |
| 2.1 Remote Name Request..... | 625 |
| 2.2 One-time Inquiry..... | 626 |
| 2.3 Periodic Inquiry | 628 |
| 3 ACL Connection Establishment and Detachment..... | 631 |
| 3.1 Connection Setup | 632 |
| 4 Optional Activities After ACL Connection Establishment..... | 639 |
| 4.1 Authentication Requested | 639 |
| 4.2 Set Connection Encryption..... | 640 |
| 4.3 Change Connection Link Key..... | 641 |
| 4.4 Master Link Key | 642 |
| 4.5 Read Remote Supported Features | 644 |
| 4.6 Read Remote Extended Features | 644 |
| 4.7 Read Clock Offset..... | 645 |
| 4.8 Read Remote Version Information..... | 645 |
| 4.9 QOS Setup..... | 646 |
| 4.10 Switch Role | 646 |
| 5 Synchronous Connection Establishment and Detachment | 649 |
| 5.1 Synchronous Connection Setup..... | 649 |
| 6 Sniff, Hold and Park | 655 |
| 6.1 sniff Mode..... | 655 |
| 6.2 Hold Mode..... | 656 |
| 6.3 Park State..... | 658 |
| 7 Buffer Management, Flow Control..... | 661 |
| 8 Loopback Mode | 663 |
| 8.1 Local Loopback Mode | 663 |
| 8.2 Remote Loopback Mode | 665 |
| 9 List of Figures..... | 667 |

Part G

SAMPLE DATA

| | |
|---------------------------------------|------------|
| Contents | 671 |
| 1 Encryption Sample Data | 673 |
| 1.1 Generating Kc' from Kc, | 673 |



| | | |
|----------|--|------------|
| 1 | Encryption Sample Data | 673 |
| 1.2 | First Set of Sample Data | 676 |
| 1.3 | Second Set of Sample Data | 684 |
| 1.4 | Third Set of Samples | 692 |
| 1.5 | Fourth Set of Samples | 700 |
| 2 | Frequency Hopping Sample Data | 709 |
| 2.1 | First set | 710 |
| 2.2 | Second set | 716 |
| 2.3 | Third set | 722 |
| 3 | Access Code Sample Data | 729 |
| 4 | HEC and Packet Header Sample Data | 733 |
| 5 | CRC Sample Data | 735 |
| 6 | Complete Sample Packets | 737 |
| 6.1 | Example of DH1 Packet | 737 |
| 6.2 | Example of DM1 Packet | 738 |
| 7 | Whitening Sequence Sample Data | 739 |
| 8 | FEC Sample Data | 743 |
| 9 | Encryption Key Sample Data | 745 |
| 9.1 | Four Tests of E1 | 745 |
| 9.2 | Four Tests of E21 | 750 |
| 9.3 | Three Tests of E22 | 752 |
| 9.4 | Tests of E22 With Pin Augmenting | 754 |
| 9.5 | Four Tests of E3 | 764 |

Part H

SECURITY SPECIFICATION

| | |
|---|------------|
| Contents | 771 |
| 1 Security Overview | 773 |
| 2 Random Number Generation | 775 |
| 3 Key Management | 777 |
| 3.1 Key Types | 777 |
| 3.2 Key Generation and Initialization | 779 |
| 3.2.1 Generation of initialization key, | 780 |
| 3.2.2 Authentication | 780 |
| 3.2.3 Generation of a unit key | 780 |
| 3.2.4 Generation of a combination key | 781 |
| 3.2.5 Generating the encryption key | 782 |
| 3.2.6 Point-to-multipoint configuration | 783 |



| | | |
|----------|---|------------|
| 3.2.7 | Modifying the link keys | 784 |
| 3.2.8 | Generating a master key | 784 |
| 4 | Encryption..... | 787 |
| 4.1 | Encryption Key Size Negotiation..... | 788 |
| 4.2 | Encryption of Broadcast Messages..... | 788 |
| 4.3 | Encryption Concept..... | 789 |
| 4.4 | Encryption Algorithm | 790 |
| 4.4.1 | The operation of the cipher | 792 |
| 4.5 | LFSR Initialization | 793 |
| 4.6 | Key Stream Sequence | 796 |
| 5 | Authentication | 797 |
| 5.1 | Repeated Attempts | 799 |
| 6 | The Authentication And Key-Generating Functions..... | 801 |
| 6.1 | The Authentication Function E1 | 801 |
| 6.2 | The Functions Ar and A'r..... | 803 |
| 6.2.1 | The round computations..... | 803 |
| 6.2.2 | The substitution boxes “e” and “l” | 803 |
| 6.2.3 | Key scheduling | 804 |
| 6.3 | E2-Key Generation Function for Authentication..... | 805 |
| 6.4 | E3-Key Generation Function for Encryption..... | 807 |
| 7 | List of Figures..... | 809 |
| 8 | List of Tables | 811 |



RADIO SPECIFICATION





CONTENTS

| | | |
|----------|---|-----------|
| 1 | Scope | 27 |
| 2 | Frequency Bands and Channel Arrangement | 29 |
| 3 | Transmitter Characteristics | 31 |
| 3.1 | Basic Rate | 32 |
| 3.1.1 | Modulation Characteristics | 32 |
| 3.1.2 | Spurious Emissions | 33 |
| 3.1.2.1 | In-band spurious emission | 33 |
| 3.1.3 | Radio Frequency Tolerance | 34 |
| 3.2 | Enhanced Data Rate | 34 |
| 3.2.1 | Modulation Characteristics | 34 |
| 3.2.1.1 | Modulation Method Overview | 34 |
| 3.2.1.2 | Differential Phase Encoding | 35 |
| 3.2.1.3 | Pulse Shaping | 36 |
| 3.2.1.4 | Modulation Accuracy | 36 |
| 3.2.2 | Spurious Emissions | 37 |
| 3.2.2.1 | In-band Spurious Emission | 37 |
| 3.2.3 | Radio Frequency Tolerance | 38 |
| 3.2.4 | Relative Transmit Power | 39 |
| 4 | Receiver Characteristics | 41 |
| 4.1 | Basic Rate | 41 |
| 4.1.1 | Actual Sensitivity Level | 41 |
| 4.1.2 | Interference Performance | 41 |
| 4.1.3 | Out-of-Band Blocking | 42 |
| 4.1.4 | Intermodulation Characteristics | 42 |
| 4.1.5 | Maximum Usable Level | 43 |
| 4.1.6 | Receiver Signal Strength Indicator | 43 |
| 4.1.7 | Reference Signal Definition | 43 |
| 4.2 | Enhanced Data Rate | 43 |
| 4.2.1 | Actual Sensitivity Level | 43 |
| 4.2.2 | BER Floor Performance | 43 |
| 4.2.3 | Interference Performance | 43 |
| 4.2.4 | Maximum Usable Level | 44 |
| 4.2.5 | Out-of-Band and Intermodulation Characteristics | 45 |
| 4.2.6 | Reference Signal Definition | 45 |
| 5 | Appendix A | 47 |
| 5.1 | Nominal Test Conditions | 47 |
| 5.1.1 | Nominal temperature | 47 |



- 5.1.2 Nominal power source47
 - 5.1.2.1 Mains voltage47
 - 5.1.2.2 Lead-acid battery power sources used in vehicles47
 - 5.1.2.3 Other power sources47
- 5.2 Extreme Test Conditions48
 - 5.2.1 Extreme temperatures.....48
 - 5.2.2 Extreme power source voltages.....48
 - 5.2.2.1 Mains voltage48
 - 5.2.2.2 Lead-acid battery power source used on vehicles48
 - 5.2.2.3 Power sources using other types of batteries 48
 - 5.2.2.4 Other power sources48
- 6 Appendix B49
- 7 Appendix C51
 - 7.1 Enhanced Data Rate Modulation Accuracy51

1 SCOPE

Bluetooth devices operate in the unlicensed 2.4 GHz ISM (Industrial Scientific Medical) band. A frequency hop transceiver is applied to combat interference and fading.

Two modulation modes are defined. A mandatory mode, called Basic Rate, uses a shaped, binary FM modulation to minimize transceiver complexity. An optional mode, called Enhanced Data Rate, uses PSK modulation and has two variants: $\pi/4$ -DQPSK and 8DPSK. The symbol rate for all modulation schemes is 1 Ms/s. The gross air data rate is 1 Mbps for Basic Rate, 2 Mbps for Enhanced Data Rate using $\pi/4$ -DQPSK and 3 Mbps for Enhanced Data Rate using 8DPSK.

For full duplex transmission, a Time Division Duplex (TDD) scheme is used in both modes. This specification defines the requirements for a Bluetooth radio for the Basic Rate and Enhanced Data Rate modes.

Requirements are defined for two reasons:

- Provide compatibility between radios used in the system
- Define the quality of the system

The Bluetooth radio shall fulfil the stated requirements under the operating conditions specified in [Appendix A](#) and [Appendix B](#). The radio parameters shall be measured according to the methods described in the RF Test Specification.

This specification is based on the established regulations for Europe, Japan and North America. The standard documents listed below are only for information, and are subject to change or revision at any time.

Europe:

Approval Standards: European Telecommunications Standards Institute, ETSI

Documents: EN 300 328, ETS 300-826

Approval Authority: National Type Approval Authorities

Japan:

Approval Standards: Association of Radio Industries and Businesses, ARIB

Documents: ARIB STD-T66

Approval Authority: Ministry of Post and Telecommunications, MPT.

**North America:**

Approval Standards: Federal Communications Commission, FCC, USA

Documents: CFR47, Part 15, Sections 15.205, 15.209, 15.247 and 15.249

Approval Standards: Industry Canada, IC, Canada

Documents: GL36

Approval Authority: FCC (USA), Industry Canada (Canada)

2 FREQUENCY BANDS AND CHANNEL ARRANGEMENT

The Bluetooth system operates in the 2.4 GHz ISM band. This frequency band is 2400 - 2483.5 MHz.

| Regulatory Range | RF Channels |
|------------------|--------------------------------|
| 2.400-2.4835 GHz | $f=2402+k$ MHz, $k=0,\dots,78$ |

Table 2.1: Operating frequency bands

RF channels are spaced 1 MHz and are ordered in channel number k as shown in [Table 2.1](#). In order to comply with out-of-band regulations in each country, a guard band is used at the lower and upper band edge.

| Lower Guard Band | Upper Guard Band |
|------------------|------------------|
| 2 MHz | 3.5 MHz |

Table 2.2: Guard Bands



3 TRANSMITTER CHARACTERISTICS

The requirements stated in this section are given as power levels at the antenna connector of the Bluetooth device. If the device does not have a connector, a reference antenna with 0 dBi gain is assumed.

Due to difficulty in measurement accuracy in radiated measurements, systems with an integral antenna should provide a temporary antenna connector during type approval.

If transmitting antennas of directional gain greater than 0 dBi are used, the applicable paragraphs in EN 300 328, EN 301 489-17 and FCC part 15 shall be compensated for.

The device is classified into three power classes.

| Power Class | Maximum Output Power (P _{max}) | Nominal Output Power | Minimum Output Power ¹ | Power Control |
|-------------|--|----------------------|-----------------------------------|---|
| 1 | 100 mW (20 dBm) | N/A | 1 mW (0 dBm) | P _{min} < +4 dBm to P _{max} Optional: P _{min} ² to P _{max} |
| 2 | 2.5 mW (4 dBm) | 1 mW (0 dBm) | 0.25 mW (-6 dBm) | Optional: P _{min} ² to P _{max} |
| 3 | 1 mW (0 dBm) | N/A | N/A | Optional: P _{min} ² to P _{max} |

Table 3.1: Power classes

1. Minimum output power at maximum power setting.
2. The lower power limit P_{min} < -30 dBm is suggested but is not mandatory, and may be chosen according to application needs.

Power class 1 device shall implement power control. The power control is used for limiting the transmitted power over +4 dBm. Power control capability under +4 dBm is optional and could be used for optimizing the power consumption and overall interference level. The power steps shall form a monotonic sequence, with a maximum step size of 8 dB and a minimum step size of 2 dB. A class 1 device with a maximum transmit power of +20 dBm shall be able to control its transmit power down to 4 dBm or less.

Devices with power control capability optimizes the output power in a physical link with LMP commands (see [Link Manager Protocol](#)). It is done by measuring RSSI and reporting back if the transmission power shall be increased or decreased if possible.

In a connection, the output power shall not exceed the maximum output power of power class 2 for transmitting packets if the receiving device does not support the necessary messaging for sending the power control messages, see

Link Manager Protocol [Section 4.1.3 on page 235](#). In this case, the transmitting device shall comply with the rules of a class 2 or class 3 device.

If a class 1 device is paging or inquiring very close to another device, the input power can be larger than the requirement in [Section 4.1.5 on page 43](#). This can cause the receiving device to fail to respond. It may therefore be useful to page at Class 2 or 3 power in addition to paging at power class 1.

Devices shall not exceed the maximum allowed transmit power levels set by controlling regulatory bodies. The maximum allowed transmit power level may depend upon the modulation mode.

3.1 BASIC RATE

3.1.1 Modulation Characteristics

The Modulation is GFSK (Gaussian Frequency Shift Keying) with a bandwidth-bit period product $BT=0.5$. The Modulation index shall be between 0.28 and 0.35. A binary one shall be represented by a positive frequency deviation, and a binary zero shall be represented by a negative frequency deviation. The symbol timing shall be less than ± 20 ppm.

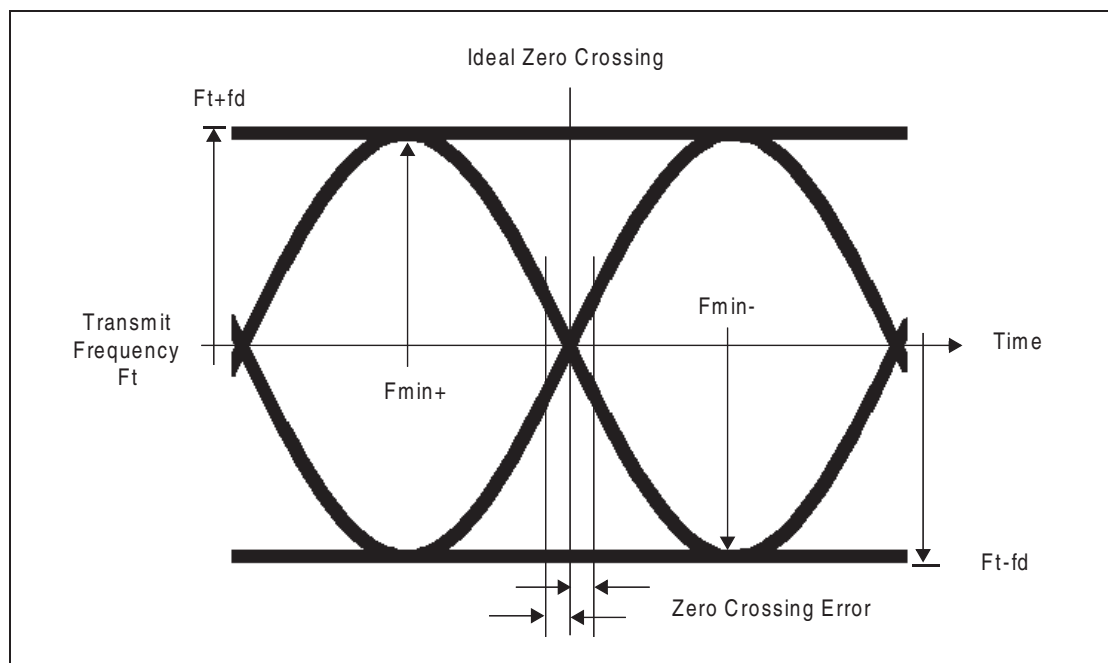


Figure 3.1: GFSK parameters definition.

For each transmission, the minimum frequency deviation, $F_{min} = \min\{|F_{min+}|, |F_{min-}|\}$, which corresponds to 1010 sequence shall be no smaller than $\pm 80\%$ of the frequency deviation (f_d) with respect to the transmit frequency F_t , which corresponds to a 00001111 sequence.



In addition, the minimum frequency deviation shall never be smaller than 115 kHz. The data transmitted has a symbol rate of 1 Ms/s.

The zero crossing error is the time difference between the ideal symbol period and the measured crossing time. This shall be less than $\pm 1/8$ of a symbol period.

3.1.2 Spurious Emissions

In-band spurious emissions shall be measured with a frequency hopping radio transmitting on one RF channel and receiving on a second RF channel; this means that the synthesizer may change RF channels between reception and transmission, but always returns to the same transmit RF channel. There will be no reference in this document to out of ISM band spurious emissions; the equipment manufacturer is responsible for compliance in the intended country of use.

3.1.2.1 In-band spurious emission

Within the ISM band the transmitter shall pass a spectrum mask, given in [Table 3.2](#). The spectrum shall comply with the 20dB bandwidth definition in FCC part 15.247 and shall be measured accordingly. In addition to the FCC requirement an adjacent channel power on adjacent channels with a difference in RF channel number of two or greater is defined. This adjacent channel power is defined as the sum of the measured power in a 1 MHz RF channel. The transmitted power shall be measured in a 100 kHz bandwidth using maximum hold. The device shall transmit on RF channel M and the adjacent channel power shall be measured on RF channel number N. The transmitter shall transmit a pseudo random data pattern in the payload throughout the test.

| Frequency offset | Transmit Power |
|------------------------------------|----------------|
| ± 500 kHz | -20 dBc |
| 2MHz ($ M-N = 2$) | -20 dBm |
| 3MHz or greater ($ M-N \geq 3$) | -40 dBm |

Table 3.2: Transmit Spectrum mask.

Note: If the output power is less than 0dBm then, wherever appropriate, the FCC's 20 dB relative requirement overrules the absolute adjacent channel power requirement stated in the above table.

Exceptions are allowed in up to three bands of 1 MHz width centered on a frequency which is an integer multiple of 1 MHz. They shall comply with an absolute value of -20 dBm.



3.1.3 Radio Frequency Tolerance

The transmitted initial center frequency shall be within ± 75 kHz from F_c . The initial frequency accuracy is defined as being the frequency accuracy before any packet information is transmitted. Note that the frequency drift requirement is not included in the ± 75 kHz.

The limits on the transmitter center frequency drift within a packet are specified in [Table 3.3](#). The different packets are defined in the Baseband Specification.

| Duration of Packet | Frequency Drift |
|---------------------------------|-----------------|
| Max length one slot packet | ± 25 kHz |
| Max length three slot packet | ± 40 kHz |
| Max length five slot packet | ± 40 kHz |
| Maximum drift rate ¹ | 400 Hz/ μ s |

Table 3.3: Maximum allowable frequency drifts in a packet.

1. The maximum drift rate is allowed anywhere in a packet.

3.2 ENHANCED DATA RATE

A key characteristic of the Enhanced Data Rate mode is that the modulation scheme is changed within the packet. The access code and packet header, as defined in [Table 6.1](#) in the [Baseband Specification](#), are transmitted with the Basic Rate 1 Mbps GFSK modulation scheme, whereas the subsequent synchronization sequence, payload, and trailer sequence are transmitted using the Enhanced Data Rate PSK modulation scheme.

3.2.1 Modulation Characteristics

During access code and packet header transmission the Basic Rate GFSK modulation scheme shall be used. During the transmission of the synchronization sequence, payload, and trailer sequence a PSK type of modulation with a data rate of 2 Mbps or optionally 3 Mbps shall be used. The following subsections specify the PSK modulation for this transmission.

3.2.1.1 Modulation Method Overview

The PSK modulation format defined for the 2 Mbps transmission shall be $\pi/4$ rotated differential encoded quaternary phase shift keying ($\pi/4$ -DQPSK).

The PSK modulation format defined for the 3 Mbps transmission shall be differential encoded 8-ary phase shift keying (8DPSK).

The modulation shall employ square-root raised cosine pulse shaping to generate the equivalent lowpass information-bearing signal $v(t)$. The output of the transmitter shall be a bandpass signal that can be represented as

$$S(t) = \text{Re} \left[v(t) e^{j2\pi F_c t} \right] \quad (\text{EQ 1})$$

with F_c denoting the carrier frequency.

3.2.1.2 Differential Phase Encoding

For the M-ary modulation, the binary data stream $\{b_n\}$, $n=1,2,3, \dots N$, shall be mapped onto a corresponding sequence $\{S_k\}$, $k=1,2, \dots N/\log_2(M)$ of complex valued signal points. $M=4$ applies for 2 Mbps and $M=8$ applies for 3 Mbps. Gray coding shall be applied as shown in [Table 3.4](#) and [Table 3.5](#). In the event that the length of the binary data stream N is not an integer multiple of $\log_2(M)$, the last symbol of the sequence $\{S_k\}$ shall be formed by appending data zeros to the appropriate length. The signal points S_k shall be defined by:

$$S_k = S_{k-1} e^{j\phi_k} \quad k = 1, 2, \dots N/\log_2(M) \quad (\text{EQ 2})$$

$$S_0 = e^{j\phi} \quad \text{with } \phi \in [0, 2\pi) \quad (\text{EQ 3})$$

The relationship between the binary input b_k and the phase ϕ_k shall be as defined in [Table 3.4](#) for the 2 Mbps transmission and in [Table 3.5](#) for the 3 Mbps transmission.

| b_{2k-1} | b_{2k} | ϕ_k |
|------------|----------|-----------|
| 0 | 0 | $\pi/4$ |
| 0 | 1 | $3\pi/4$ |
| 1 | 1 | $-3\pi/4$ |
| 1 | 0 | $-\pi/4$ |

Table 3.4: $\pi/4$ -DQPSK mapping.

| b_{3k-2} | b_{3k-1} | b_{3k} | φ_k |
|------------|------------|----------|-------------|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | $\pi/4$ |
| 0 | 1 | 1 | $\pi/2$ |
| 0 | 1 | 0 | $3\pi/4$ |
| 1 | 1 | 0 | π |
| 1 | 1 | 1 | $-3\pi/4$ |
| 1 | 0 | 1 | $-\pi/2$ |
| 1 | 0 | 0 | $-\pi/4$ |

Table 3.5: 8DPSK mapping.

3.2.1.3 Pulse Shaping

The lowpass equivalent information-bearing signal $v(t)$ shall be generated according to

$$v(t) = \sum_k S_k p(t - kT) \quad (\text{EQ 4})$$

in which the symbol period T shall be $1\mu\text{s}$.

The frequency spectrum $P(f)$, which corresponds to the square-root raised cosine pulse $p(t)$ of the pulse shaping filter is:

$$|P(f)| = \begin{cases} 1 & 0 \leq |f| \leq \frac{1-\beta}{2T} \\ \sqrt{\frac{1}{2} \left(1 - \sin \left(\frac{\pi(2fT-1)}{2\beta} \right) \right)} & \frac{1-\beta}{2T} \leq |f| \leq \frac{1+\beta}{2T} \\ 0 & \text{elsewhere} \end{cases} \quad (\text{EQ 5})$$

The roll off factor β shall be 0.4.

3.2.1.4 Modulation Accuracy

The measurement of modulation accuracy utilizes differential error vector magnitude (DEVM) with tracking of the carrier frequency drift. The definition of DEVM and the derivation of the RMS and peak measures of DEVM are given in 51.



The DEVM shall be measured over the synchronization sequence and payload portions of the packet, but not the trailer symbols. For each modulation method and each measurement carrier frequency, DEVM measurement is made over a total of 200 non-overlapping blocks, where each block contains 50 symbols.

The transmitted packets shall be the longest supported packet type for each modulation method, as defined in [Table 6.9](#) and [Table 6.10](#) in the Baseband part.

The DEVM is measured using a square-root raised cosine filter, with a roll-off of 0.4 and a 3 dB bandwidth of ± 500 kHz.

3.2.1.4.1 RMS DEVM

The RMS DEVM for any of the measured blocks shall not exceed 0.20 for $\pi/4$ -DQPSK and 0.13 for 8DPSK.

3.2.1.4.2 99% DEVM

The 99% DEVM (defined as the DEVM value for which 99% of measured symbols have a lower DEVM) shall not exceed 0.30 for $\pi/4$ -DQPSK and 0.20 for 8DPSK.

3.2.1.4.3 Peak DEVM

The Peak DEVM shall not exceed 0.35 for $\pi/4$ -DQPSK and 0.25 for 8DPSK.

3.2.2 Spurious Emissions

In-band spurious emissions shall be measured with a frequency hopping radio transmitting on one RF channel and receiving on a second RF channel; this means that the synthesizer may change RF channels between reception and transmission, but always returns to the same transmit RF channel. There will be no reference in this document to out of ISM band spurious emissions; the equipment manufacturer is responsible for compliance in the intended country of use.

3.2.2.1 In-band Spurious Emission

Within the ISM band the power spectral density of the transmitter shall comply with the following requirements when sending pseudo random data. All power measurements shall use a 100 kHz bandwidth with maximum hold. The power measurements between 1 MHz and 1.5 MHz from the carrier shall be at least 26 dB below the maximum power measurement up to 500 kHz from the carrier. The adjacent channel power for channels at least 2 MHz from the carrier is defined as the sum of the power measurements over a 1 MHz channel and shall not exceed -20 dBm for the second adjacent channels and -40 dBm for the third and subsequent adjacent channels. These requirements shall apply to

the transmitted signal from the start of the guard time to the end of the power down ramp. The spectral mask is illustrated in [Figure 3.2](#).

Exceptions are allowed in up to 3 bands of 1 MHz width centered on a frequency which is an integer multiple of 1 MHz. They shall comply with an absolute value of -20 dBm.

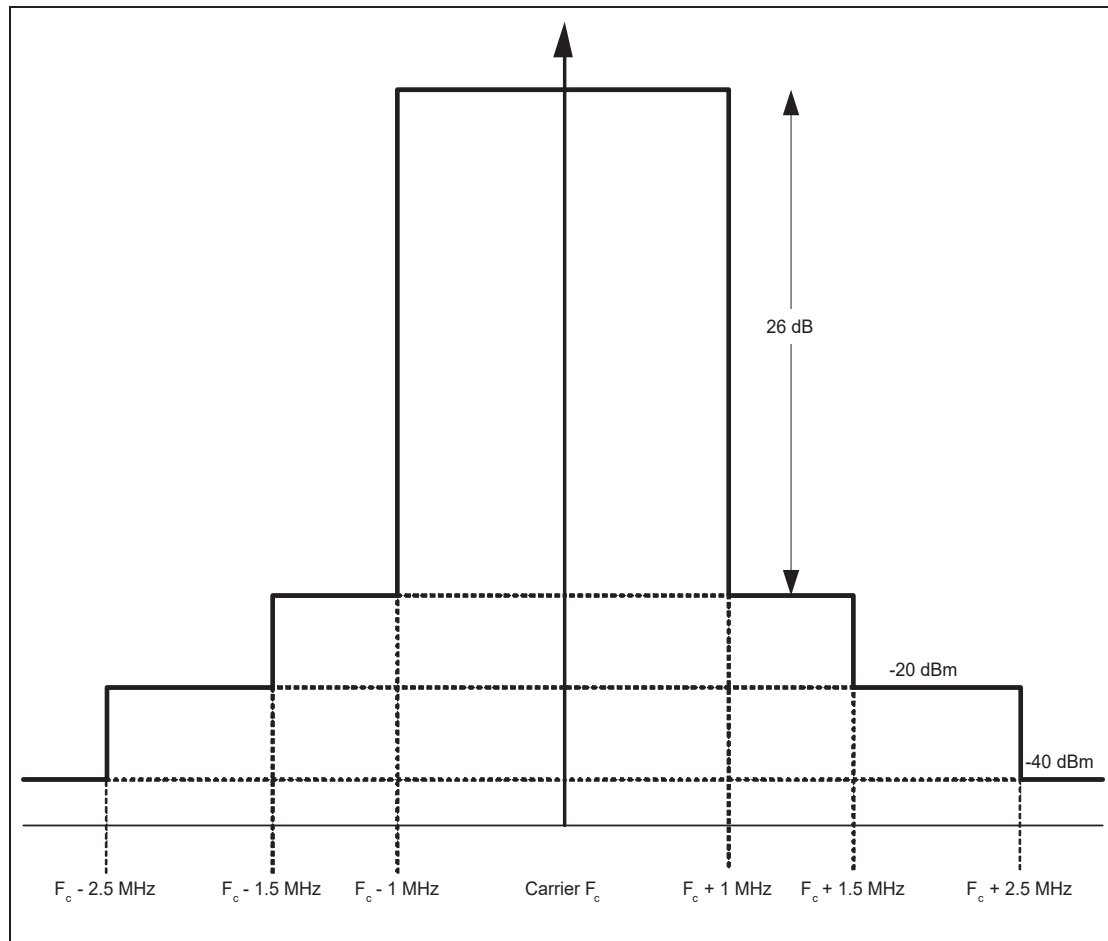


Figure 3.2: Transmitter spectrum mask

3.2.3 Radio Frequency Tolerance

The same carrier frequencies F_c as used for Basic Rate transmissions shall be used for the Enhanced Data Rate transmissions. The transmitted initial center frequency accuracy shall be within ± 75 kHz from F_c . The maximum excursion from F_c (frequency offset plus drift) shall not exceed ± 75 kHz.

The initial frequency accuracy is defined as being the frequency accuracy before any information is transmitted.

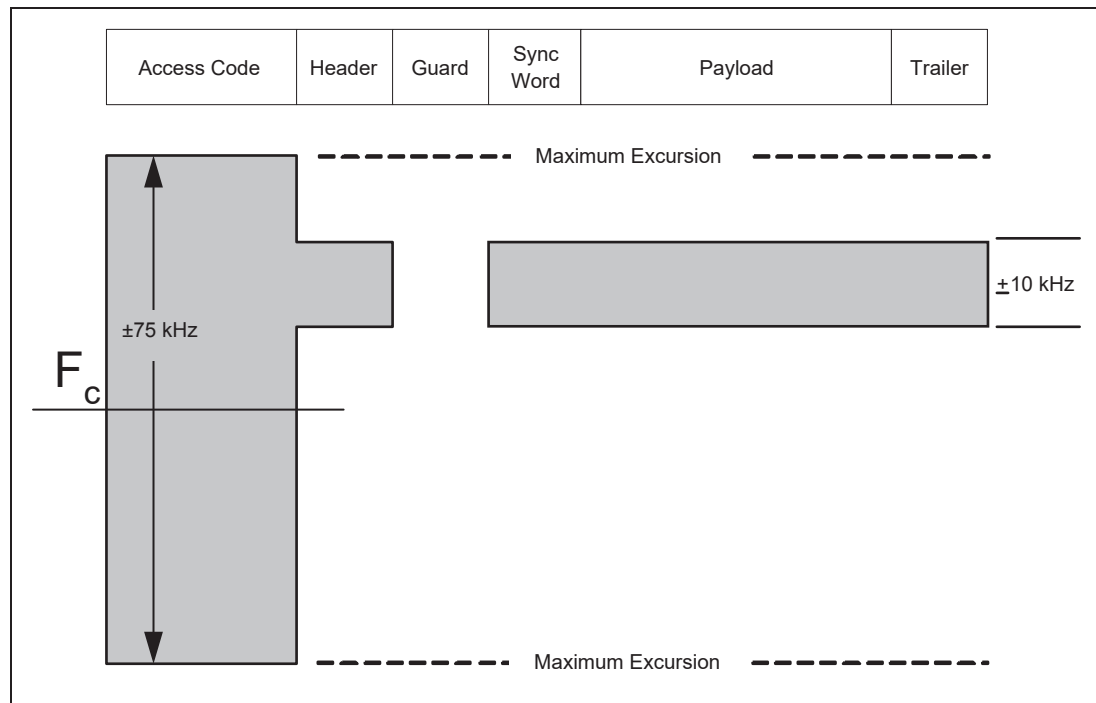


Figure 3.3: Carrier frequency mask

The requirements on accuracy and stability are illustrated by [Figure 3.3](#) for the Enhanced Data Rate packet format defined in 55. The higher frequency accuracy requirement shall start at the first symbol of the header. The maximum drift over the header, synchronization sequence and payload shall be ± 10 kHz.

3.2.4 Relative Transmit Power

The requirement on the relative power of the GFSK and PSK portions of the Enhanced Data Rate packet is defined as follows. The average power level during the transmission of access code and header is denoted as P_{GFSK} and the average power level during the transmission of the synchronization sequence and the payload is denoted as P_{DPSK} . The following inequalities shall be satisfied independently for every Enhanced Data Rate packet transmitted:

$$(P_{\text{GFSK}} - 4 \text{ dB}) < P_{\text{DPSK}} < (P_{\text{GFSK}} + 1 \text{ dB})$$



4 RECEIVER CHARACTERISTICS

The receiver characteristics shall be measured using loopback as defined in [Section 1, “Test Methodology,” on page 231](#).

The reference sensitivity level referred to in this chapter is -70 dBm.

4.1 BASIC RATE

4.1.1 Actual Sensitivity Level

The actual sensitivity level is defined as the input level for which a raw bit error rate (BER) of 0.1% is met. The receiver sensitivity shall be below or equal to -70 dBm with any Bluetooth transmitter compliant to the transmitter specification specified in [Section 3 on page 31](#).

4.1.2 Interference Performance

The interference performance on Co-channel and adjacent 1 MHz and 2 MHz shall be measured with the wanted signal 10 dB over the reference sensitivity level. For interference performance on all other RF channels the wanted signal shall be 3 dB over the reference sensitivity level. If the frequency of an interfering signal is outside of the band 2400-2483.5 MHz, the out-of-band blocking specification (see [Section 4.1.3 on page 42](#)) shall apply. The interfering signal shall be Bluetooth-modulated (see [Section 4.1.7 on page 43](#)). The BER shall be $\leq 0.1\%$ for all the signal-to-interference ratios listed in [Table 4.1](#):

| Frequency of Interference | Ratio |
|--|--------|
| Co-Channel interference, $C/I_{\text{co-channel}}$ | 11 dB |
| Adjacent (1 MHz) interference, $C/I_{1\text{MHz}}$ | 0 dB |
| Adjacent (2 MHz) interference, $C/I_{2\text{MHz}}$ | -30 dB |
| Adjacent (≥ 3 MHz) interference, $C/I_{\geq 3\text{MHz}}$ | -40 dB |
| Image frequency Interference ^{1 2} , C/I_{Image} | -9 dB |
| Adjacent (1 MHz) interference to in-band image frequency, $C/I_{\text{Image} \pm 1\text{MHz}}$ | -20 dB |

Table 4.1: Interference performance

1. In-band image frequency

2. If the image frequency $\neq n \cdot 1$ MHz, then the image reference frequency is defined as the closest $n \cdot 1$ MHz frequency.

If two adjacent channel specifications from [Table 4.1](#) are applicable to the same channel, the more relaxed specification applies.

These specifications are only to be tested at nominal temperature conditions with a device receiving on one RF channel and transmitting on a second RF channel;



this means that the synthesizer may change RF channels between reception and transmission, but always returns to the same receive RF channel.

RF channels where the requirements are not met are called spurious response RF channels. Five spurious response RF channels are allowed at RF channels with a distance of ≥ 2 MHz from the wanted signal. On these spurious response RF channels a relaxed interference requirement $C/I = -17$ dB shall be met.

4.1.3 Out-of-Band Blocking

The out-of-band suppression (or rejection) shall be measured with the wanted signal 3 dB over the reference sensitivity level. The interfering signal shall be a continuous wave signal. The BER shall be $\leq 0.1\%$. The out-of-band blocking shall fulfil the following requirements:

| Interfering Signal Frequency | Interfering Signal Power Level |
|------------------------------|--------------------------------|
| 30 MHz - 2000 MHz | -10 dBm |
| 2000 - 2399 MHz | -27 dBm |
| 2484 – 3000 MHz | -27 dBm |
| 3000 MHz – 12.75 GHz | -10 dBm |

Table 4.2: Out-of-band suppression (or rejection) requirements.

24 exceptions are permitted which are dependent upon the given RF channel and are centered at a frequency which is an integer multiple of 1 MHz. For at least 19 of these spurious response frequencies, a reduced interference level of at least -50dBm is allowed in order to achieve the required BER=0.1% performance, whereas for a maximum of 5 of the spurious frequencies the interference level may be assumed arbitrarily lower.

4.1.4 Intermodulation Characteristics

The reference sensitivity performance, BER = 0.1%, shall be met under the following conditions:

- The wanted signal shall be at frequency f_0 with a power level 6 dB over the reference sensitivity level.
- A static sine wave signal shall be at a frequency f_1 with a power level of -39 dBm.
- A Bluetooth modulated signal (see [Section 4.1.7 on page 43](#)) shall be at f_2 with a power level of -39 dBm.

Frequencies f_0 , f_1 and f_2 shall be chosen such that $f_0 = 2f_1 - f_2$ and $|f_2 - f_1| = n \cdot 1$ MHz, where n can be 3, 4, or 5. The system shall fulfill at least one of the three alternatives ($n=3, 4$, or 5).



4.1.5 Maximum Usable Level

The maximum usable input level that the receiver operates at shall be greater than -20 dBm. The BER shall be less than or equal to 0.1% at -20 dBm input power.

4.1.6 Receiver Signal Strength Indicator

If a device supports Receive Signal Strength Indicator (RSSI) the accuracy shall be +/- 6 dBm.

4.1.7 Reference Signal Definition

A Bluetooth modulated interfering signal shall be defined as:

Modulation = GFSK

Modulation index = $0.32 \pm 1\%$

BT = $0.5 \pm 1\%$

Bit Rate = 1 Mbps ± 1 ppm

Modulating Data for wanted signal = PRBS9

Modulating Data for interfering signal = PRBS 15

Frequency accuracy better than ± 1 ppm.

4.2 ENHANCED DATA RATE

4.2.1 Actual Sensitivity Level

The actual sensitivity level shall be defined as the input level for which a raw bit error rate (BER) of 0.01% is met. The requirement for a Bluetooth $\pi/4$ -DQPSK and 8DPSK Enhanced Data Rate receiver shall be an actual sensitivity level of -70 dBm or better. The receiver shall achieve the -70 dBm sensitivity level with any Bluetooth transmitter compliant to the Enhanced Data Rate transmitter specification as defined in Section 3.2.

4.2.2 BER Floor Performance

The receiver shall achieve a BER less than 0.001% at 10 dB above the reference sensitivity level.

4.2.3 Interference Performance

The interference performance for co-channel and adjacent 1 MHz and 2 MHz channels shall be measured with the wanted signal 10 dB above the reference sensitivity level. On all other frequencies the wanted signal shall be 3 dB above the reference sensitivity level. The requirements in this section shall only apply if the frequency of the interferer is inside of the band 2400-2483.5 MHz.



The interfering signal for co-channel interference shall be similarly modulated as the desired signal. The interfering signal for other channels shall be equivalent to a nominal Bluetooth Basic Rate GFSK transmitter. The interfering signal shall carry random data.

A BER of 0.1% or better shall be achieved for the signal to interference ratios defined in [Table 4.3](#).

| Frequency of Interference | $\pi/4$ -DQPSK Ratio | 8DPSK Ratio |
|--|----------------------|-------------|
| Co-Channel interference, $C/I_{\text{co-channel}}$ | 13 dB | 21 dB |
| Adjacent (1 MHz) interference ¹ , $C/I_{1\text{MHz}}$ | 0 dB | 5 dB |
| Adjacent (2MHz) interference ¹ , $C/I_{2\text{MHz}}$ | -30 dB | -25 dB |
| Adjacent ($\geq 3\text{MHz}$) interference ¹ | -40 dB | -33 dB |
| Image frequency interference ^{1,2,3} , C/I_{Image} | -7 dB | 0 dB |
| Adjacent (1 MHz) interference to in-band image frequency ^{1,2,3} , $C/I_{\text{Image} \pm 1\text{MHz}}$ | -20 dB | -13 dB |

Table 4.3: Interference Performance

1. If two adjacent channel specifications from Table 4.3 are applicable to the same channel, the more relaxed specification applies.
2. In-band image frequency.
3. If the image frequency is not equal to $n \cdot 1\text{ MHz}$, then the image reference frequency is defined as the closest $n \cdot 1\text{ MHz}$ frequency.

These specifications are only to be tested at nominal temperature conditions with a receiver hopping on one frequency; this means that the synthesizer may change frequency between receive slot and transmit slot, but always returns to the same receive frequency.

Frequencies where the requirements are not met are called spurious response frequencies. Five spurious response frequencies are allowed at frequencies with a distance of $\geq 2\text{ MHz}$ from the wanted signal. On these spurious response frequencies a relaxed interference requirement $C/I = -15\text{ dB}$ for $\pi/4$ -DQPSK and $C/I = -10\text{ dB}$ for 8DPSK shall be met.

4.2.4 Maximum Usable Level

The maximum usable input level that the receiver operates at shall be greater than -20 dBm . The BER shall be less than or equal to 0.1% at -20 dBm input power.



4.2.5 Out-of-Band and Intermodulation Characteristics

Note: The Basic Rate out-of-band blocking and intermodulation requirements ensure adequate Enhanced Data Rate performance, and therefore there are no specific requirements for Enhanced Data Rate.

4.2.6 Reference Signal Definition

A 2 Mbps Bluetooth signal used as "wanted" or "interfering signal" is defined as:

Modulation = $\pi/4$ -DQPSK

Symbol Rate = 1 Msym/s \pm 1 ppm

Frequency accuracy better than ± 1 ppm

Modulating Data for wanted signal = PRBS9

Modulating Data for interfering signal = PRBS15

RMS Differential Error Vector Magnitude < 5%

Average power over the GFSK and DPSK portions of the packet shall be equal to within ± 1 dB

A 3 Mbps Bluetooth signal used as "wanted" or "interfering signal" is defined as:

Modulation = 8DPSK

Symbol Rate = 1 Msym/s \pm 1 ppm

Frequency accuracy better than ± 1 ppm

Modulating Data for wanted signal = PRBS9

Modulating Data for interfering signal = PRBS15

RMS Differential Error Vector Magnitude < 5%

Average power over the GFSK and DPSK portions of the packet shall be equal to within ± 1 dB



5 APPENDIX A

5.1 NOMINAL TEST CONDITIONS

5.1.1 Nominal temperature

The nominal temperature conditions for tests shall be +15 to +35 °C. When it is impractical to carry out the test under this condition a note to this effect, stating the ambient temperature, shall be recorded. The actual value during the test shall be recorded in the test report.

5.1.2 Nominal power source

5.1.2.1 Mains voltage

The nominal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. The nominal voltage shall be the declared voltage or any of the declared voltages for which the equipment was designed. The frequency of the test power source corresponding to the AC mains shall be within 2% of the nominal frequency.

5.1.2.2 Lead-acid battery power sources used in vehicles

When radio equipment is intended for operation from the alternator-fed lead-acid battery power sources which are standard in vehicles, then the nominal test voltage shall be 1.1 times the nominal voltage of the battery (6V, 12V, etc.).

5.1.2.3 Other power sources

For operation from other power sources or types of battery (primary or secondary), the nominal test voltage shall be as declared by the equipment manufacturer. This shall be recorded in the test report.

5.2 EXTREME TEST CONDITIONS

5.2.1 Extreme temperatures

The extreme temperature range shall be the largest temperature range given by the combination of:

- The minimum temperature range 0 °C to +35 °C
- The product operating temperature range declared by the manufacturer.

This extreme temperature range and the declared operating temperature range shall be recorded in the test report.

5.2.2 Extreme power source voltages

Tests at extreme power source voltages specified below are not required when the equipment under test is designed for operation as part of and powered by another system or piece of equipment. Where this is the case, the limit values of the host system or host equipment shall apply. The appropriate limit values shall be declared by the manufacturer and recorded in the test report.

5.2.2.1 Mains voltage

The extreme test voltage for equipment to be connected to an AC mains source shall be the nominal mains voltage $\pm 10\%$.

5.2.2.2 Lead-acid battery power source used on vehicles

When radio equipment is intended for operation from the alternator-fed lead-acid battery power sources which are standard in vehicles, then extreme test voltage shall be 1.3 and 0.9 times the nominal voltage of the battery (6V, 12V etc.)

5.2.2.3 Power sources using other types of batteries

The lower extreme test voltage for equipment with power sources using the following types of battery, shall be

- a) for Leclanché, alkaline, or lithium type battery: 0.85 times the nominal voltage of the battery
- b) for mercury or nickel-cadmium types of battery: 0.9 times the nominal voltage of the battery.

In both cases, the upper extreme test voltage shall be 1.15 times the nominal voltage of the battery.

5.2.2.4 Other power sources

For equipment using other power sources, or capable of being operated from a variety of power sources (primary or secondary), the extreme test voltages shall be those declared by the manufacturer. These shall be recorded in the test report.

6 APPENDIX B

The Basic Rate radio parameters shall be tested in the following conditions

| Parameter | Temperature | Power source |
|--------------------------------------|-------------|--------------|
| Output Power | ETC | ETC |
| Power control | NTC | NTC |
| Modulation index | ETC | ETC |
| Initial Carrier Frequency accuracy | ETC | ETC |
| Carrier Frequency drift | ETC | ETC |
| Conducted in-band spurious emissions | ETC | ETC |
| Radiated in-band emissions | NTC | NTC |
| Sensitivity | ETC | ETC |
| Interference Performance | NTC | NTC |
| Intermodulation Characteristics | NTC | NTC |
| Out-of-band blocking | NTC | NTC |
| Maximum Usable Level | NTC | NTC |
| Receiver Signal Strength Indicator | NTC | NTC |

ETC = Extreme Test Conditions

NTC = Nominal Test Conditions

The Enhanced Data Rate radio parameters shall be tested in the following conditions

| Parameter | Temperature | Power source |
|-----------------------------|-------------|--------------|
| Modulation accuracy | ETC | ETC |
| Carrier frequency stability | ETC | ETC |
| In-band spurious emissions | ETC | ETC |
| Relative transmit power | ETC | ETC |
| Sensitivity | ETC | ETC |
| BER floor sensitivity | NTC | NTC |
| Interference Performance | NTC | NTC |
| Maximum usable level | NTC | NTC |

ETC = Extreme Test Conditions

NTC = Nominal Test Conditions



7 APPENDIX C

7.1 ENHANCED DATA RATE MODULATION ACCURACY

The Enhanced Data Rate modulation accuracy is defined by the differential error vector, being the difference between the vectors representing consecutive symbols of the transmitted signal, after passing the signal through a specified measurement filter, sampling it at the symbol rate with an optimum sampling phase and compensating it for carrier frequency error and for the ideal carrier phase changes. The magnitude of the normalized differential error vector is called the Differential Error Vector Magnitude (DEVM). The objective of the DEVM is to estimate the modulation errors that would be perceived by a differential receiver.

In an ideal transmitter, the input bit sequence $\{b_j\}$ is mapped onto a complex valued symbol sequence $\{S_k\}$. Subsequently, this symbol sequence is transformed into a baseband signal $S(t)$ by means of a pulse-shaping filter.

In an actual transmitter implementation, the bit sequence $\{b_j\}$ generates a baseband equivalent transmitted signal $Y(t)$. This signal $Y(t)$ contains, besides the desired component $S(t)$, multiple distortion components. This is illustrated in Figure 7.1.

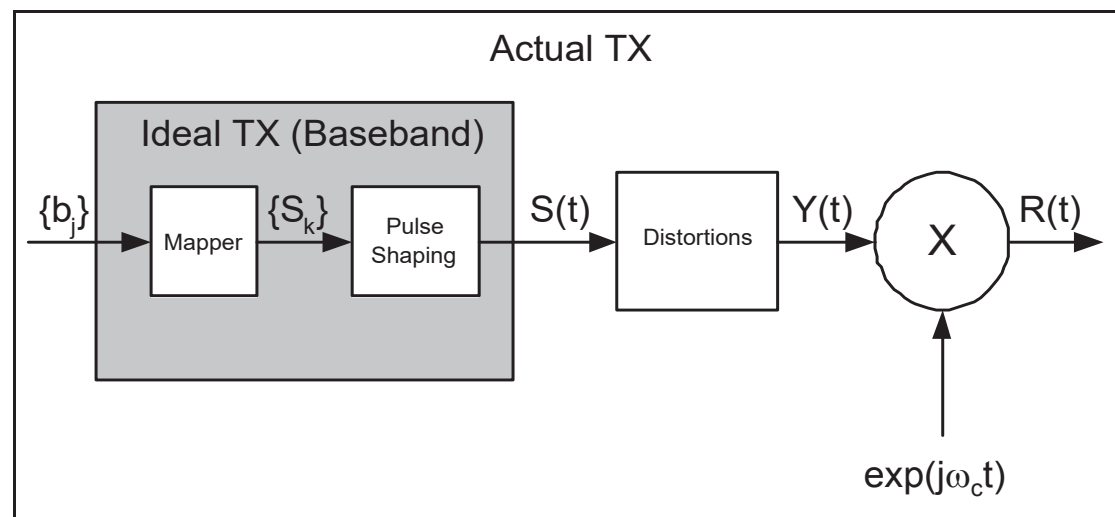


Figure 7.1: TX model.

Let $Z(t)$ be the output of the measurement filter after first compensating the received signal for the initial center frequency error, ω_i , of the received packet, i.e. the output after down conversion and filtering the transmit signal $R(t)$ (see Figure 7.2). The measurement filter is defined by a square-root raised cosine shaping filter with a roll-off factor equal to 0.4 and 3 dB bandwidth of ± 500 kHz.



Let $\{Z_k(\varepsilon)\}$ be the sequence of samples obtained by sampling the signal $Z(t)$ with a sampling period equal to the symbol period T and a sampling phase equal to ε such that $Z_k(\varepsilon) = Z((k+\varepsilon)T)$. Note that this sequence $\{Z_k(\varepsilon)\}$ would coincide with the symbol sequence $\{S_k\}$ if no distortion is present and the correct timing phase ε is chosen.

To reflect the behavior of a typical differential receiver, the sample sequence $\{Z_k(\varepsilon)\}$ should be compensated for carrier frequency drift. Therefore, the sequence $\{Z_k(\varepsilon)\}$ is multiplied by a factor W^{-k} in which $W = e^{j\omega T}$ accounts for the frequency offset ω . A constant value of ω is used for each DEVM block of $N = 50$ symbols, but ω may vary between DEVM blocks (note that the values of ω can be used to measure carrier frequency drift).

In addition, $\{Z_k(\varepsilon)\}$ is compensated for the ideal phase changes between symbols by multiplying it with the complex conjugate of the symbol sequence $\{S_k\}$. However, it is not necessary to compensate $\{Z_k(\varepsilon)\}$ for initial carrier phase or output power of the transmitter.

Let $\{Q_k(\varepsilon, \omega)\}$ denote the compensated sequence $\{Z_k(\varepsilon)\}$, where the ideal phase changes have been removed and ε and ω are chosen optimally to minimize the DEVM, (i.e. remove time and frequency uncertainty). For a transmitter with no distortions other than a constant frequency error, $\{Q_k(\varepsilon, \omega)\}$ is a complex constant that depends on the initial carrier phase and the output power of the transmitter.

The differential error sequence $\{E_k(\varepsilon, \omega)\}$ is defined as the difference between $\{Q_k(\varepsilon, \omega)\}$ and $\{Q_{k-1}(\varepsilon, \omega)\}$. This reflects the modulation errors that would be perceived by a differential receiver. For a transmitter with no distortions other than a constant frequency error, $\{E_k(\varepsilon, \omega)\}$ is zero.

The definitions of the DEVM measures are based upon this differential error sequence $\{E_k(\varepsilon, \omega)\}$. The generation of the error sequence is depicted in [Figure 7.2](#).

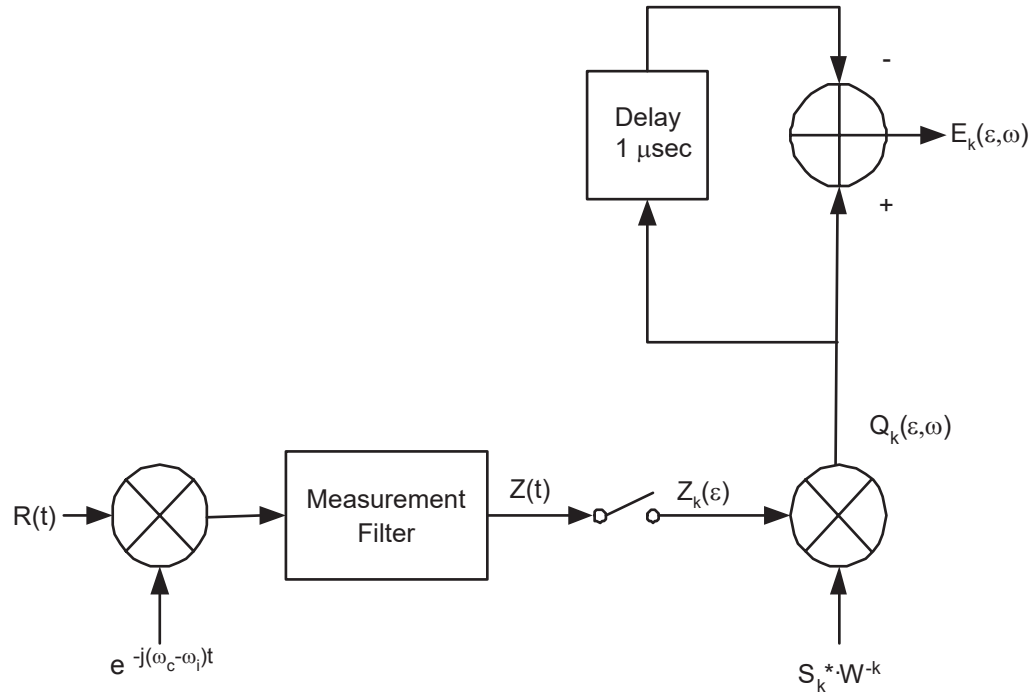


Figure 7.2: Error sequence generation.

RMS DEVM

The root mean squared DEVM (RMS DEVM) computed over $N = 50$ symbols is defined as:

$$RMS\ DEVM = \min_{\varepsilon, \omega} \left\{ \sqrt{\frac{\sum_{k=1}^N |E_k(\varepsilon, \omega)|^2}{\sum_{k=1}^N |Q_k(\varepsilon, \omega)|^2}} \right\}$$

As can be seen from the expression above, the RMS DEVM is the square-root of the normalized power of the error.

Peak DEVM

The DEVM at symbol k is defined as


$$DEVM(k) = \sqrt{\frac{\left| E_k(\varepsilon_0, \omega_0) \right|^2}{\sum_{j=1}^N \left| Q_j(\varepsilon_0, \omega_0) \right|^2 / N}} \quad (\text{EQ 6})$$

where ε_0 and ω_0 are the values for ε and ω used to calculate the RMS DEVM.

The peak DEVM is defined as:

$$Peak\ DEVM = \max_k \{DEVM(k)\} \quad (\text{EQ 7})$$

BASEBAND SPECIFICATION



This document describes the specification of the Bluetooth link controller which carries out the baseband protocols and other low-level link routines.



CONTENTS

| | | |
|----------|--|-----------|
| 1 | General Description | 63 |
| 1.1 | Bluetooth Clock | 64 |
| 1.2 | Bluetooth Device Addressing | 66 |
| 1.2.1 | Reserved addresses | 66 |
| 1.3 | Access Codes | 67 |
| 2 | Physical Channels..... | 69 |
| 2.1 | Physical Channel Definition | 70 |
| 2.2 | Basic Piconet Physical Channel..... | 70 |
| 2.2.1 | Master-slave definition | 70 |
| 2.2.2 | Hopping characteristics | 71 |
| 2.2.3 | Time slots | 71 |
| 2.2.4 | Piconet clocks | 72 |
| 2.2.5 | Transmit/receive timing | 72 |
| 2.2.5.1 | Piconet physical channel timing..... | 73 |
| 2.2.5.2 | Piconet physical channel re-synchronization .. | 74 |
| 2.3 | Adapted Piconet Physical Channel..... | 75 |
| 2.3.1 | Hopping characteristics | 75 |
| 2.4 | Page Scan Physical Channel..... | 76 |
| 2.4.1 | Clock estimate for paging..... | 76 |
| 2.4.2 | Hopping characteristics | 76 |
| 2.4.3 | Paging procedure timing | 77 |
| 2.4.4 | Page response timing..... | 78 |
| 2.5 | Inquiry Scan Physical Channel | 80 |
| 2.5.1 | Clock for inquiry..... | 80 |
| 2.5.2 | Hopping characteristics | 80 |
| 2.5.3 | Inquiry procedure timing..... | 80 |
| 2.5.4 | Inquiry response timing | 80 |
| 2.6 | Hop Selection..... | 82 |
| 2.6.1 | General selection scheme..... | 82 |
| 2.6.2 | Selection kernel..... | 86 |
| 2.6.2.1 | First addition operation | 86 |
| 2.6.2.2 | XOR operation | 87 |
| 2.6.2.3 | Permutation operation..... | 87 |
| 2.6.2.4 | Second addition operation | 88 |
| 2.6.2.5 | Register bank..... | 88 |
| 2.6.3 | Adapted hop selection kernel | 89 |
| 2.6.3.1 | Channel re-mapping function..... | 89 |
| 2.6.4 | Control word | 90 |



| | | |
|----------|--|------------|
| 2.6.4.1 | Page scan and inquiry scan hopping sequences | 91 |
| 2.6.4.2 | Page hopping sequence | 92 |
| 2.6.4.3 | Slave page response hopping sequence | 92 |
| 2.6.4.4 | Master page response hopping sequence | 93 |
| 2.6.4.5 | Inquiry hopping sequence | 93 |
| 2.6.4.6 | Inquiry response hopping sequence | 94 |
| 2.6.4.7 | Basic and adapted channel hopping sequence | 94 |
| 3 | Physical Links | 95 |
| 3.1 | Link Supervision | 95 |
| 4 | Logical Transports | 97 |
| 4.1 | General | 97 |
| 4.2 | Logical Transport Address (LT_ADDR) | 97 |
| 4.3 | Synchronous Logical Transports | 98 |
| 4.4 | Asynchronous Logical Transport | 98 |
| 4.5 | Transmit/Receive Routines | 99 |
| 4.5.1 | TX Routine | 99 |
| 4.5.1.1 | ACL traffic | 100 |
| 4.5.1.2 | SCO traffic | 101 |
| 4.5.1.3 | Mixed data/voice traffic | 101 |
| 4.5.1.4 | eSCO Traffic | 102 |
| 4.5.1.5 | Default packet types | 102 |
| 4.5.2 | RX routine | 102 |
| 4.5.3 | Flow control | 103 |
| 4.5.3.1 | Destination control | 104 |
| 4.5.3.2 | Source control | 104 |
| 4.6 | Active Slave Broadcast Transport | 104 |
| 4.7 | Parked Slave Broadcast Transport | 105 |
| 4.7.1 | Parked member address (PM_ADDR) | 105 |
| 4.7.2 | Access request address (AR_ADDR) | 105 |
| 5 | Logical Links | 107 |
| 5.1 | Link Control Logical Link (LC) | 107 |
| 5.2 | ACL Control Logical Link (ACL-C) | 107 |
| 5.3 | User Asynchronous/Isochronous Logical Link (ACL-U) | 107 |
| 5.3.1 | Pausing the ACL-U logical link | 108 |
| 5.4 | User Synchronous Data Logical Link (SCO-S) | 108 |
| 5.5 | User Extended Synchronous Data Logical Link (eSCO-S) | 108 |
| 5.6 | Logical Link Priorities | 108 |
| 6 | Packets | 109 |
| 6.1 | General Format | 109 |
| 6.1.1 | Basic Rate | 109 |



| | | |
|---------|---|-----|
| 6.1.2 | Enhanced Data Rate | 109 |
| 6.2 | Bit Ordering | 110 |
| 6.3 | Access Code | 111 |
| 6.3.1 | Access code types | 111 |
| 6.3.2 | Preamble | 112 |
| 6.3.3 | Sync word | 112 |
| 6.3.3.1 | Synchronization word definition | 112 |
| 6.3.3.2 | Pseudo-random noise sequence generation | 115 |
| 6.3.4 | Trailer | 115 |
| 6.4 | Packet Header | 116 |
| 6.4.1 | LT_ADDR | 116 |
| 6.4.2 | TYPE | 116 |
| 6.4.3 | FLOW | 117 |
| 6.4.4 | ARQN | 117 |
| 6.4.5 | SEQN | 117 |
| 6.4.6 | HEC | 117 |
| 6.5 | Packet Types | 118 |
| 6.5.1 | Common packet types | 119 |
| 6.5.1.1 | ID packet | 119 |
| 6.5.1.2 | NULL packet | 120 |
| 6.5.1.3 | POLL packet | 120 |
| 6.5.1.4 | FHS packet | 120 |
| 6.5.1.5 | DM1 packet | 122 |
| 6.5.2 | SCO packets | 123 |
| 6.5.2.1 | HV1 packet | 123 |
| 6.5.2.2 | HV2 packet | 123 |
| 6.5.2.3 | HV3 packet | 123 |
| 6.5.2.4 | DV packet | 123 |
| 6.5.3 | eSCO packets | 124 |
| 6.5.3.1 | EV3 packet | 124 |
| 6.5.3.2 | EV4 packet | 124 |
| 6.5.3.3 | EV5 packet | 124 |
| 6.5.3.4 | 2-EV3 packet | 124 |
| 6.5.3.5 | 2-EV5 packet | 125 |
| 6.5.3.6 | 3-EV3 packet | 125 |
| 6.5.3.7 | 3-EV5 packet | 125 |
| 6.5.4 | ACL packets | 126 |
| 6.5.4.1 | DM1 packet | 126 |
| 6.5.4.2 | DH1 packet | 126 |
| 6.5.4.3 | DM3 packet | 126 |
| 6.5.4.4 | DH3 packet | 126 |
| 6.5.4.5 | DM5 packet | 126 |
| 6.5.4.6 | DH5 packet | 127 |



| | | |
|----------|---|------------|
| 6.5.4.7 | AUX1 packet..... | 127 |
| 6.5.4.8 | 2-DH1 packet..... | 127 |
| 6.5.4.9 | 2-DH3 packet..... | 127 |
| 6.5.4.10 | 2-DH5 packet..... | 127 |
| 6.5.4.11 | 3-DH1 packet..... | 127 |
| 6.5.4.12 | 3-DH3 packet..... | 128 |
| 6.5.4.13 | 3-DH5 packet..... | 128 |
| 6.6 | Payload Format | 128 |
| 6.6.1 | Synchronous data field..... | 128 |
| 6.6.2 | Asynchronous data field..... | 130 |
| 6.7 | Packet Summary | 134 |
| 7 | Bitstream Processing | 137 |
| 7.1 | Error Checking..... | 138 |
| 7.1.1 | HEC generation | 138 |
| 7.1.2 | CRC generation | 139 |
| 7.2 | Data Whitening | 141 |
| 7.3 | Error Correction | 142 |
| 7.4 | FEC Code: Rate 1/3 | 142 |
| 7.5 | FEC Code: Rate 2/3 | 143 |
| 7.6 | ARQ Scheme..... | 144 |
| 7.6.1 | Unnumbered ARQ..... | 144 |
| 7.6.2 | Retransmit filtering | 147 |
| 7.6.2.1 | Initialization of SEQN at start of new connection | 148 |
| 7.6.2.2 | ACL and SCO retransmit filtering | 148 |
| 7.6.2.3 | eSCO retransmit filtering | 149 |
| 7.6.2.4 | FHS retransmit filtering..... | 149 |
| 7.6.2.5 | Packets without CRC retransmit filtering | 149 |
| 7.6.3 | Flushing payloads | 150 |
| 7.6.4 | Multi-slave considerations..... | 150 |
| 7.6.5 | Broadcast packets..... | 150 |
| 8 | Link Controller Operation | 153 |
| 8.1 | Overview of States..... | 153 |
| 8.2 | Standby State..... | 154 |
| 8.3 | Connection Establishment Substates | 154 |
| 8.3.1 | Page scan substate..... | 154 |
| 8.3.2 | Page substate | 156 |
| 8.3.3 | Page response substates..... | 159 |
| 8.3.3.1 | Slave response substate | 160 |
| 8.3.3.2 | Master response substate | 162 |
| 8.4 | Device Discovery Substates | 163 |
| 8.4.1 | Inquiry scan substate | 164 |



| | | |
|-----------|---|------------|
| 8.4.2 | Inquiry substate | 165 |
| 8.4.3 | Inquiry response substate | 166 |
| 8.5 | Connection State | 167 |
| 8.6 | Active Mode | 168 |
| 8.6.1 | Polling in the active mode | 169 |
| 8.6.2 | SCO | 169 |
| 8.6.3 | eSCO | 171 |
| 8.6.4 | Broadcast scheme | 173 |
| 8.6.5 | Role switch | 175 |
| 8.6.6 | Scatternet | 177 |
| 8.6.6.1 | Inter-piconet communications | 177 |
| 8.6.7 | Hop sequence switching | 178 |
| 8.6.8 | Channel classification and channel map selection | 181 |
| 8.6.9 | Power Management | 182 |
| 8.6.9.1 | Packet handling | 182 |
| 8.6.9.2 | Slot occupancy | 182 |
| 8.6.9.3 | Recommendations for low-power operation . | 182 |
| 8.6.9.4 | Enhanced Data Rate | 183 |
| 8.7 | sniff Mode | 183 |
| 8.7.1 | Sniff Transition Mode | 184 |
| 8.8 | Hold Mode | 185 |
| 8.9 | Park State | 185 |
| 8.9.1 | Beacon train | 186 |
| 8.9.2 | Beacon access window | 189 |
| 8.9.3 | Parked slave synchronization | 190 |
| 8.9.4 | Parking | 191 |
| 8.9.5 | Master-initiated unparking | 192 |
| 8.9.6 | Slave-initiated unparking | 192 |
| 8.9.7 | Broadcast scan window | 193 |
| 8.9.8 | Polling in the park state | 193 |
| 9 | Audio | 195 |
| 9.1 | LOG PCM CODEC | 195 |
| 9.2 | CVSD CODEC | 195 |
| 9.3 | Error Handling | 198 |
| 9.4 | General Audio Requirements | 198 |
| 9.4.1 | Signal levels | 198 |
| 9.4.2 | CVSD audio quality | 198 |
| 10 | List of Figures | 199 |
| 11 | List of Tables | 203 |



12 Appendix..... 203

1 GENERAL DESCRIPTION

This part specifies the normal operation of a Bluetooth baseband.

The Bluetooth system provides a point-to-point connection or a point-to-multipoint connection, see (a) and (b) in [Figure 1.1 on page 63](#). In a point-to-point connection the physical channel is shared between two Bluetooth devices. In a point-to-multipoint connection, the physical channel is shared among several Bluetooth devices. Two or more devices sharing the same physical channel form a *piconet*. One Bluetooth device acts as the master of the piconet, whereas the other device(s) act as slave(s). Up to seven slaves can be active in the piconet. Additionally, many more slaves can remain connected in a parked state. These parked slaves are not active on the channel, but remain synchronized to the master and can become active without using the connection establishment procedure. Both for active and parked slaves, the channel access is controlled by the master.

Piconets that have common devices are called a *scatternet*, see (c) in [Figure 1.1 on page 63](#). Each piconet only has a single master, however, slaves can participate in different piconets on a time-division multiplex basis. In addition, a master in one piconet can be a slave in other piconets. Piconets shall not be frequency synchronized and each piconet has its own hopping sequence.

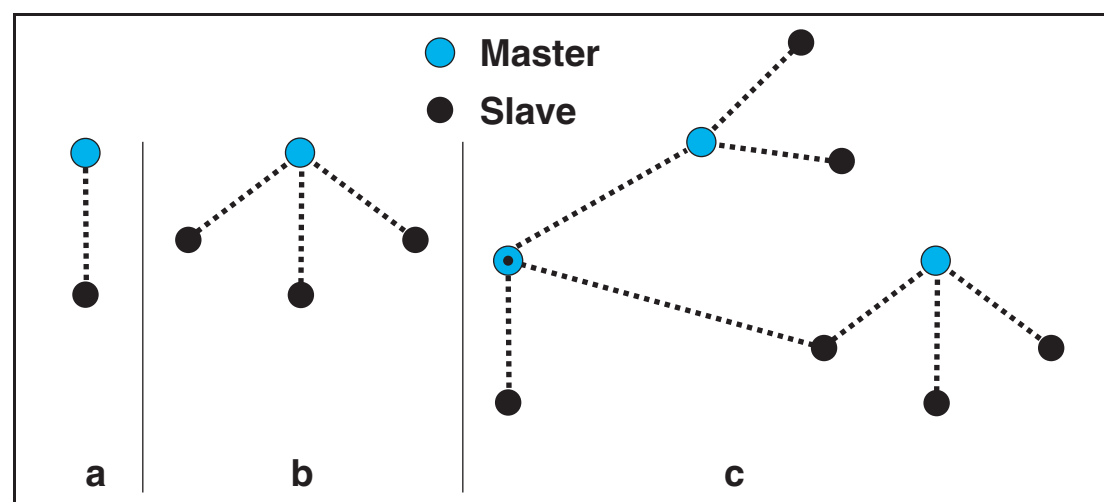


Figure 1.1: Piconets with a single slave operation (a), a multi-slave operation (b) and a scatternet operation (c).

Data is transmitted over the air in packets. Two modulation modes are defined: a mandatory mode called Basic Rate and an optional mode called Enhanced Data Rate. The symbol rate for all modulation schemes is 1 Ms/s. The gross air data rate is 1 Mbps for Basic Rate. Enhanced Data Rate has a primary modulation mode that provides a gross air data rate of 2 Mbps, and a secondary modulation mode that provides a gross air data rate of 3 Mbps.

The general Basic Rate packet format is shown in [Figure 1.2](#). Each packet consists of 3 entities: the access code, the header, and the payload.

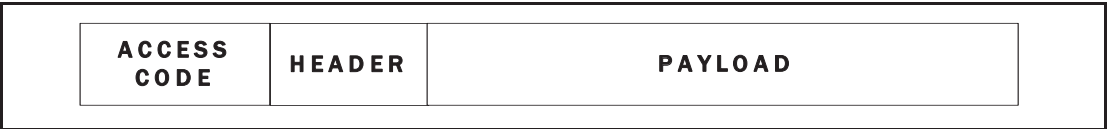


Figure 1.2: Standard Basic Rate packet format.

The general Enhanced Data Rate packet format is shown in Standard Enhanced Data Rate packet format. Each packet consists of 6 entities: the access code, the header, the guard period, the synchronization sequence, the Enhanced Data Rate payload and the trailer. The access code and header use the same modulation scheme as for Basic Rate packets while the synchronization sequence, the Enhanced Data Rate payload and the trailer use the Enhanced Data Rate modulation scheme. The guard time allows for the transition between the modulation schemes.

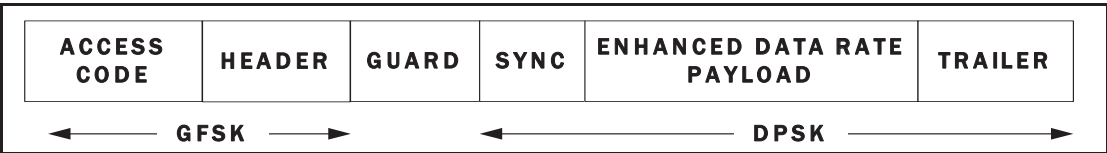


Figure 1.3: Standard Enhanced Data Rate packet format

1.1 BLUETOOTH CLOCK

Every Bluetooth device shall have a native clock that shall be derived from a free running system clock. For synchronization with other devices, offsets are used that, when added to the native clock, provide temporary Bluetooth clocks that are mutually synchronized. It should be noted that the Bluetooth clock has no relation to the time of day; it may therefore be initialized to any value. The clock has a cycle of about a day. If the clock is implemented with a counter, a 28-bit counter is required that shall wrap around at $2^{28}-1$. The least significant bit (LSB) shall tick in units of 312.5 μ s (i.e. half a time slot), giving a clock rate of 3.2 kHz.

The clock determines critical periods and triggers the events in the device. Four periods are important in the Bluetooth system: 312.5 μ s, 625 μ s, 1.25 ms, and 1.28 s; these periods correspond to the timer bits CLK₀, CLK₁, CLK₂, and CLK₁₂, respectively, see [Figure 1.4 on page 65](#).

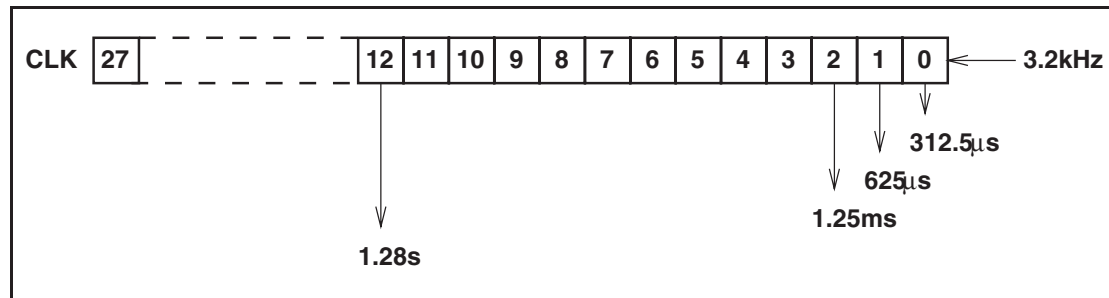


Figure 1.4: Bluetooth clock.

In the different modes and states a device can reside in, the clock has different appearances:

- CLKN native clock
- CLKE estimated clock
- CLK master clock

CLKN is the native clock and shall be the reference to all other clock appearances. In STANDBY and in Park, Hold and Sniff mode the native clock may be driven by a low power oscillator (LPO) with worst case accuracy (+/-250ppm). Otherwise, the native clock shall be driven by the reference crystal oscillator with worst case accuracy of +/-20ppm.

See [Section 2.2.4 on page 72](#) for the definition of CLK and [Section 2.4.1 on page 76](#) for the definition of CLKE.

The master shall never adjust its native clock during the existence of the piconet.



1.2 BLUETOOTH DEVICE ADDRESSING

Each Bluetooth device shall be allocated a unique 48-bit Bluetooth device address (BD_ADDR). This address shall be obtained from the IEEE Registration Authority. The address is divided into the following three fields:

- LAP field: lower address part consisting of 24 bits
- UAP field: upper address part consisting of 8 bits
- NAP field: non-significant address part consisting of 16 bits

The LAP and UAP form the significant part of the BD_ADDR. The bit pattern in [Figure 1.5](#) is an example BD_ADDR.

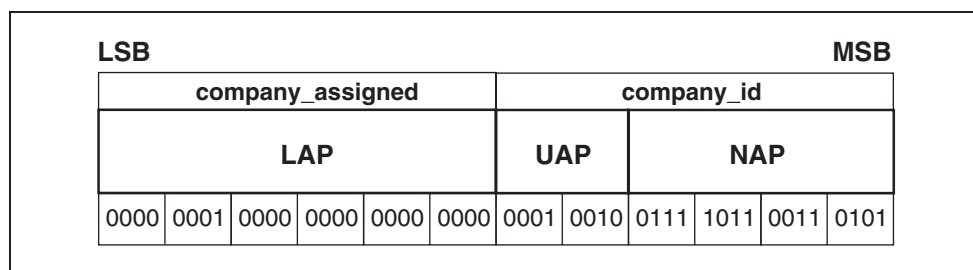


Figure 1.5: Format of BD ADDR.

The BD_ADDR may take any values except the 64 reserved LAP values for general and dedicated inquiries (see [Section 1.2.1 on page 66](#)).

1.2.1 Reserved addresses

A block of 64 contiguous LAPs is reserved for inquiry operations; one LAP common to all devices is reserved for general inquiry, the remaining 63 LAPs are reserved for dedicated inquiry of specific classes of devices (see [Assigned Numbers](#) on the web site¹). The same LAP values are used regardless of the contents of UAP and NAP. Consequently, none of these LAPs can be part of a user BD_ADDR.

The reserved LAP addresses are 0x9E8B00-0x9E8B3F. The general inquiry LAP is 0x9E8B33. All addresses have the LSB at the rightmost position, hexadecimal notation. The default check initialization (DCI) is used as the UAP whenever one of the reserved LAP addresses is used. The DCI is defined to be 0x00 (hexadecimal).

1. https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers

1.3 ACCESS CODES

In the Bluetooth system all transmissions over the physical channel begin with an access code. Three different access codes are defined, see also [Section 6.3.1 on page 111](#):

- device access code (DAC)
- channel access code (CAC)
- inquiry access code (IAC)

All access codes are derived from the LAP of a device address or an inquiry address. The device access code is used during **page**, **page scan** and **page response** substates and shall be derived from the paged device's BD_ADDR. The channel access code is used in the **CONNECTION** state and forms the beginning of all packets exchanged on the piconet physical channel. The channel access code shall be derived from the LAP of the master's BD_ADDR. Finally, the inquiry access code shall be used in the **inquiry** substate. There is one general IAC (GIAC) for general inquiry operations and there are 63 dedicated IACs (DIACs) for dedicated inquiry operations.

The access code also indicates to the receiver the arrival of a packet. It is used for timing synchronization and offset compensation. The receiver correlates against the entire synchronization word in the access code, providing very robust signalling.



2 PHYSICAL CHANNELS

The lowest architectural layer in the Bluetooth system is the physical channel. A number of types of physical channels are defined. All Bluetooth physical channels are characterized by the combination of a pseudo-random frequency hopping sequence, the specific slot timing of the transmissions, the access code and packet header encoding. These aspects, together with the range of the transmitters, define the signature of the physical channel. For the basic and adapted piconet physical channels frequency hopping is used to change frequency periodically to reduce the effects of interference and to satisfy local regulatory requirements.

Two devices that wish to communicate use a shared physical channel for this communication. To achieve this, their transceivers must be tuned to the same RF frequency at the same time, and they must be within a nominal range of each other.

Given that the number of RF carriers is limited and that many Bluetooth devices may be operating independently within the same spatial and temporal area there is a strong likelihood of two independent Bluetooth devices having their transceivers tuned to the same RF carrier, resulting in a physical channel collision. To mitigate the unwanted effects of this collision each transmission on a physical channel starts with an access code that is used as a correlation code by devices tuned to the physical channel. This channel access code is a property of the physical channel. The access code is always present at the start of every transmitted packet.

Four Bluetooth physical channels are defined. Each is optimized and used for a different purpose. Two of these physical channels (the basic piconet channel and adapted piconet channel) are used for communication between connected devices and are associated with a specific piconet. The remaining physical channels are used for discovering (the inquiry scan channel) and connecting (the page scan channel) Bluetooth devices.

A Bluetooth device can only use one of these physical channels at any given time. In order to support multiple concurrent operations the device uses time-division multiplexing between the channels. In this way a Bluetooth device can appear to operate simultaneously in several piconets, as well as being discoverable and connectable.

Whenever a Bluetooth device is synchronized to the timing, frequency and access code of a physical channel it is said to be 'connected' to this channel (whether or not it is actively involved in communications over the channel.) At a minimum, a device need only be capable of connection to one physical channel at a time, however, advanced devices may be capable of connecting simultaneously to more than one physical channel, but the specification does not assume that this is possible.

2.1 PHYSICAL CHANNEL DEFINITION

Physical channels are defined by a pseudo-random RF channel hopping sequence, the packet (slot) timing and an access code. The hopping sequence is determined by the UAP and LAP of a Bluetooth device address and the selected hopping sequence. The phase in the hopping sequence is determined by the Bluetooth clock. All physical channels are subdivided into time slots whose length is different depending on the physical channel. Within the physical channel, each reception or transmission event is associated with a time slot or time slots. For each reception or transmission event an RF channel is selected by the hop selection kernel (see [Section 2.6 on page 82](#)). The maximum hop rate is 1600 hops/s in the **CONNECTION** state and the maximum is 3200 hops/s in the **inquiry** and **page** substates.

The following physical channels are defined:

- basic piconet physical channel
- adapted piconet physical channel
- page scan physical channel
- inquiry scan physical channel

2.2 BASIC PICONET PHYSICAL CHANNEL

During the **CONNECTION** state the basic piconet physical channel is used by default. The adapted piconet physical channel may also be used. The adapted piconet physical channel is identical to the basic piconet physical channel except for the differences listed in [Section 2.3 on page 75](#).

2.2.1 Master-slave definition

The basic piconet physical channel is defined by the master of the piconet. The master controls the traffic on the piconet physical channel by a polling scheme. (see [Section 8.5 on page 167](#))

By definition, the device that initiates a connection by paging is the master. Once a piconet has been established, master-slave roles may be exchanged. This is described in [Section 8.6.5 on page 175](#).

2.2.2 Hopping characteristics

The basic piconet physical channel is characterized by a pseudo-random hopping through all 79 RF channels. The frequency hopping in the piconet physical channel is determined by the Bluetooth clock and BD_ADDR of the master. When the piconet is established, the master clock is communicated to the slaves. Each slave shall add an offset to its native clock to synchronize with the master clock. Since the clocks are independent, the offsets must be updated regularly. All devices participating in the piconet are time-synchronized and hop-synchronized to the channel.

The basic piconet physical channel uses the basic channel hopping sequence and is described in [Section 2.6 on page 82](#).

2.2.3 Time slots

The basic piconet physical channel is divided into time slots, each 625 μ s in length. The time slots are numbered according to the most significant 27 bits of the Bluetooth clock CLK_{28-1} of the piconet master. The slot numbering ranges from 0 to $2^{27}-1$ and is cyclic with a cycle length of 2^{27} . The time slot number is denoted as k .

A TDD scheme is used where master and slave alternatively transmit, see [Figure 2.1 on page 71](#). The packet start shall be aligned with the slot start. Packets may extend over up to five time slots.

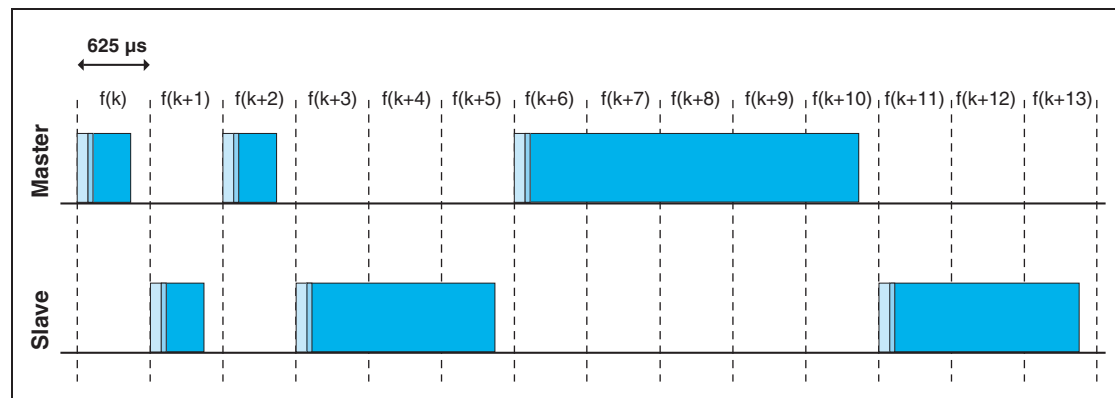


Figure 2.1: Multi-slot packets

The term *slot pairs* is used to indicate two adjacent time slots starting with a master-to-slave transmission slot.

2.2.4 Piconet clocks

CLK is the master clock of the piconet. It shall be used for all timing and scheduling activities in the piconet. All devices shall use the CLK to schedule their transmission and reception. The CLK shall be derived from the native clock CLKN (see [Section 1.1 on page 64](#)) by adding an offset, see [Figure 2.2 on page 72](#). The offset shall be zero for the master since CLK is identical to its own native clock CLKN. Each slave shall add an appropriate offset to its CLKN such that the CLK corresponds to the CLKN of the master. Although all CLKNs in the devices run at the same nominal rate, mutual drift causes inaccuracies in CLK. Therefore, the offsets in the slaves must be regularly updated such that CLK is approximately CLKN of the master.

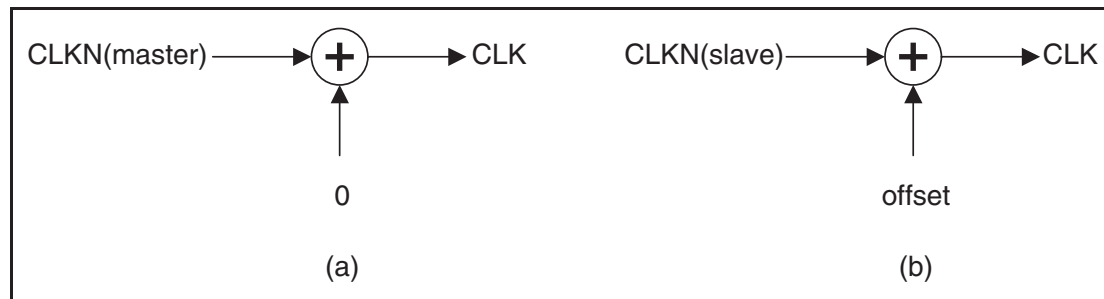


Figure 2.2: Derivation of CLK in master (a) and in slave (b).

2.2.5 Transmit/receive timing

The master transmission shall always start at even numbered time slots ($CLK_1=0$) and the slave transmission shall always start at odd numbered time slots ($CLK_1=1$). Due to packet types that cover more than a single slot, master transmission may continue in odd numbered slots and slave transmission may continue in even numbered slots, see [Figure 2.1 on page 71](#).

All timing diagrams shown in this chapter are based on the signals as present at the antenna. The term “exact” when used to describe timing refers to an ideal transmission or reception and neglects timing jitter and clock frequency imperfections.

The average timing of packet transmission shall not drift faster than 20 ppm relative to the ideal slot timing of 625 μ s. The instantaneous timing shall not deviate more than 1 μ s from the average timing. Thus, the absolute packet transmission timing t_k of slot boundary k shall fulfill the equation:

$$t_k = \left(\sum_{i=1}^k (1 + d_i) T_N \right) + j_k + \text{offset}, \quad (\text{EQ } 1)$$

where T_N is the nominal slot length (625 μ s), j_k denotes jitter ($|j_k| \leq 1 \mu$ s) at the start of slot k , and, d_k , denotes the drift ($|d_k| \leq 20 \text{ ppm}$) within slot k . The jitter and drift may vary arbitrarily within the given limits for every slot, while *offset* is an arbitrary but fixed constant. For hold, park and sniff the drift and jitter parameters specified in Link Manager Protocol [\[Part C\] Section 4.3.1 on page 262](#) apply.

2.2.5.1 Piconet physical channel timing

In the figures, only single-slot packets are shown as an example.

The master TX/RX timing is shown in Figure 2.3 on page 73. In Figure 2.3 and Figure 2.4 the channel hopping frequencies are indicated by $f(k)$ where k is the time slot number. After transmission, a return packet is expected $N \times 625 \mu\text{s}$ after the start of the TX packet where N is an odd, integer larger than 0. N depends on the type of the transmitted packet.

To allow for some time slipping, an uncertainty window is defined around the exact receive timing. During normal operation, the window length shall be $20 \mu\text{s}$, which allows the RX packet to arrive up to $10 \mu\text{s}$ too early or $10 \mu\text{s}$ too late. It is recommended that slaves implement variable sized windows or time tracking to accommodate a master's absence of more than 250ms.

During the beginning of the RX cycle, the access correlator shall search for the correct channel access code over the uncertainty window. If an event trigger does not occur the receiver may go to sleep until the next RX event. If in the course of the search, it becomes apparent that the correlation output will never exceed the final threshold, the receiver may go to sleep earlier. If a trigger event occurs, the receiver shall remain open to receive the rest of the packet unless the packet is for another device, a non-recoverable header error is detected, or a non-recoverable payload error is detected.

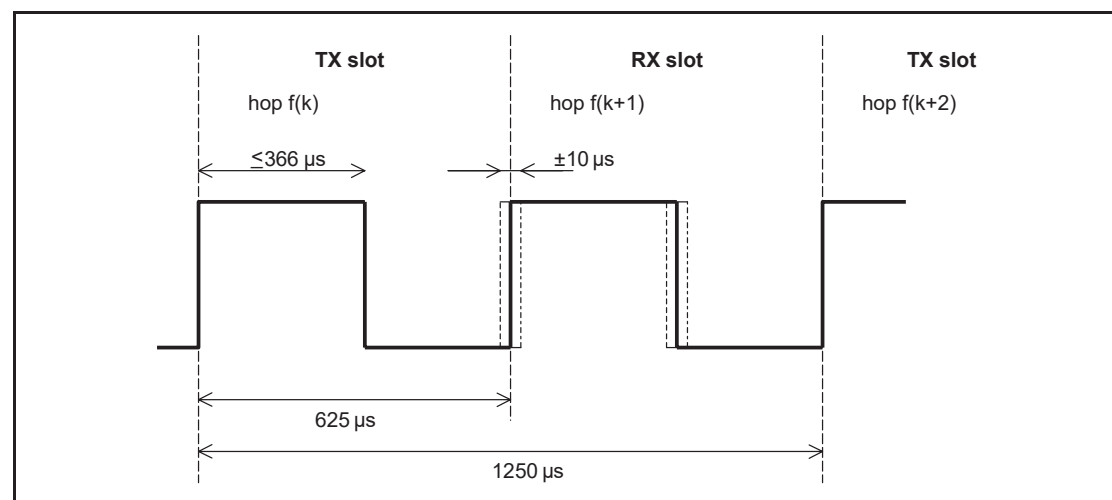


Figure 2.3: RX/TX cycle of master transceiver in normal mode for single-slot packets.

Each master transmission shall be derived from bit 2 of the Master's native Bluetooth clock, thus the current transmission will be scheduled $M \times 1250 \mu\text{s}$ after the start of the previous master TX burst where M depends on the transmitted and received packet type and is an even, integer larger than 0. The master TX timing shall be derived from the master's native Bluetooth clock, and thus it will not be affected by time drifts in the slave(s).

Slaves maintain an estimate of the master's native clock by adding a timing offset to the slave's native clock (see [Section 2.2.4 on page 72](#)). This offset shall be updated each time a packet is received from the master. By comparing the exact RX timing of the received packet with the estimated RX timing, slaves shall correct the offset for any timing misalignments. Since only the channel access code is required to synchronize the slave, slave RX timing can be corrected with any packet sent in the master-to-slave transmission slot.

The slave's TX/RX timing is shown in [Figure 2.4 on page 74](#). The slave's transmission shall be scheduled $N \times 625\mu\text{s}$ after the start of the slave's RX packet where N is an odd, positive integer larger than 0. If the slave's RX timing drifts, so will its TX timing. During periods when a slave is in the active mode (see [Section 8.6 on page 168](#)) and is not able to receive any valid channel access codes from the master, the slave may increase its receive uncertainty window and/or use predicted timing drift to increase the probability of receiving the master's bursts when reception resumes.

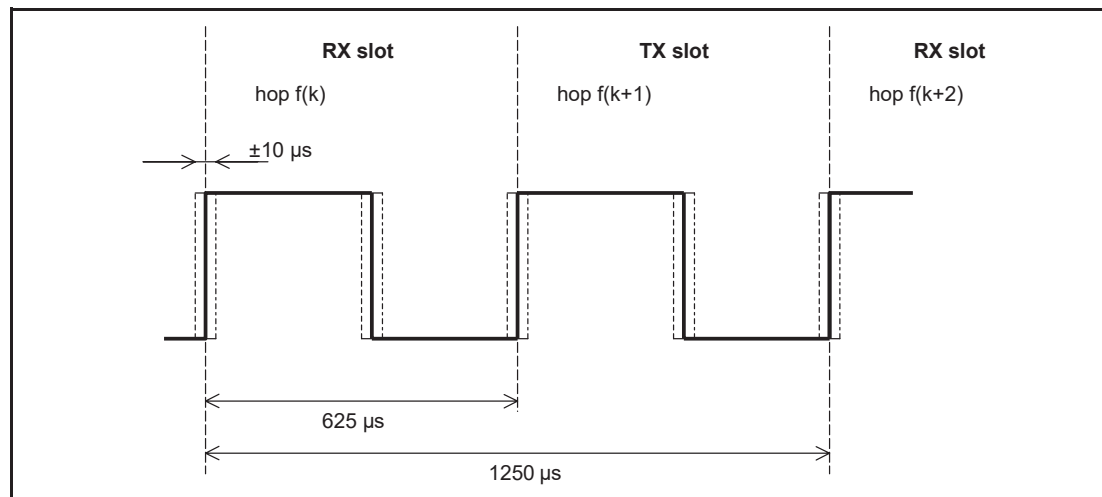


Figure 2.4: RX/TX cycle of slave transceiver in normal mode for single-slot packets.

2.2.5.2 Piconet physical channel re-synchronization

In the piconet physical channel, a slave may lose synchronization if it does not receive a packet from the master at least every 250ms (or less if the low power clock is used). This may occur in sniff, hold, park, in a scatternet or due to interference. When re-synchronizing to the piconet physical channel a slave device shall listen for the master before it may send information. In this case, the length of the search window in the slave device may be increased from 20 μs to a larger value $X\mu\text{s}$ as illustrated in [Figure 2.5 on page 75](#). Note that only RX hop frequencies are used. The hop frequency used in the master-to-slave (RX) slot shall also be used in the uncertainty window, even when it is extended into the preceding time interval normally used for the slave-to-master (TX) slot.

If the length of search window, X , exceeds $1250\ \mu\text{s}$, consecutive windows shall avoid overlapping search windows. Consecutive windows should instead be centered at $f(k)$, $f(k+4)$, ... $f(k+4i)$ (where 'i' is an integer), which gives a maximum value $X=2500\ \mu\text{s}$, or even at $f(k)$, $f(k+6)$, ... $f(k+6i)$ which gives a maximum value $X=3750\ \mu\text{s}$. The RX hop frequencies used shall correspond to the master-to-slave transmission slots.

It is recommended that single slot packets are transmitted by the master during slave re-synchronization.

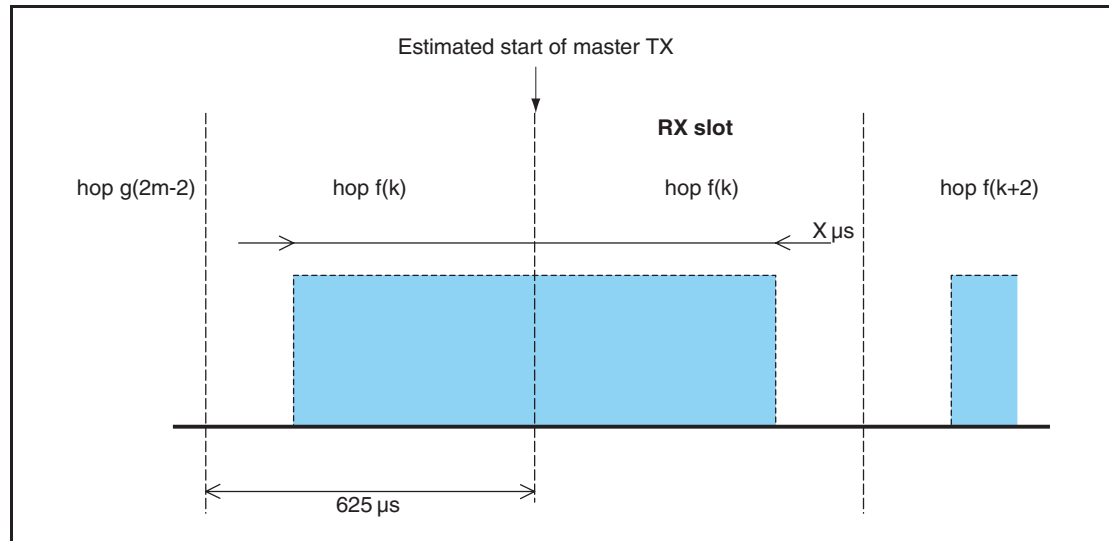


Figure 2.5: RX timing of slave returning from hold mode.

2.3 ADAPTED PICONET PHYSICAL CHANNEL

2.3.1 Hopping characteristics

The adapted piconet physical channel shall use at least N_{\min} RF channels (where N_{\min} is 20).

The adapted piconet physical channel uses the adapted channel hopping sequence described in [Section 2.6 on page 82](#).

Adapted piconet physical channels can be used for connected devices that have adaptive frequency hopping (AFH) enabled. There are two distinctions between basic and adapted piconet physical channels. The first is that the same channel mechanism that makes the slave frequency the same as the preceding master transmission. The second aspect is that the adapted piconet physical channel may be based on less than the full 79 frequencies of the basic piconet physical channel.

2.4 PAGE SCAN PHYSICAL CHANNEL

Although master and slave roles are not defined prior to a connection, the term *master* is used for the paging device (that becomes a master in the **CONNECTION** state) and *slave* is used for the page scanning device (that becomes a slave in the **CONNECTION** state).

2.4.1 Clock estimate for paging

A paging device uses an estimate of the native clock of the page scanning device, CLKE; i.e. an offset shall be added to the CLKN of the pager to approximate the CLKN of the recipient, see [Figure 2.6 on page 76](#). CLKE shall be derived from the reference CLKN by adding an offset. By using the CLKN of the recipient, the pager might be able to speed up the connection establishment.

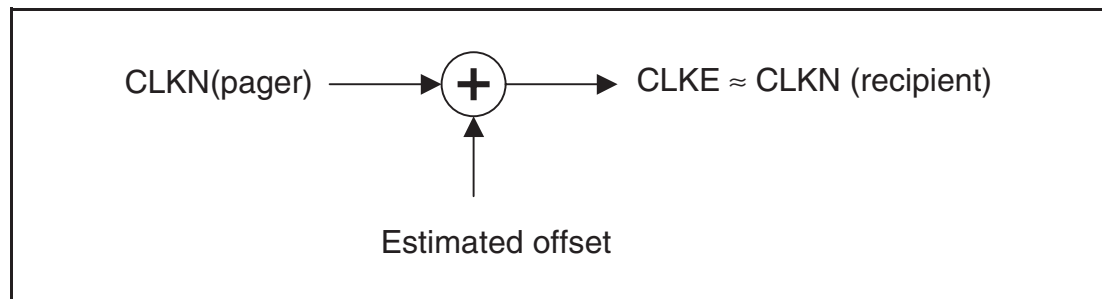


Figure 2.6: Derivation of CLKE.

2.4.2 Hopping characteristics

The page scan physical channel follows a slower hopping pattern than the basic piconet physical channel and is a short pseudo-random hopping sequence through the RF channels. The timing of the page scan channel shall be determined by the native Bluetooth clock of the scanning device. The frequency hopping sequence is determined by the Bluetooth address of the scanning device.

The page scan physical channel uses the page, master page response, slave page response, and page scan hopping sequences specified in [Section 2.6 on page 82](#).

2.4.3 Paging procedure timing

During the paging procedure, the master shall transmit paging messages (see [Table 8.3 on page 159](#)) corresponding to the slave to be connected. Since the paging message is a very short packet, the hop rate is 3200 hops/s. In a single TX slot interval, the paging device shall transmit on two different hop frequencies. In [Figure 2.7](#) through [Figure 2.11](#), $f(k)$ is used for the frequencies of the page hopping sequence and $f'(k)$ denotes the corresponding page response sequence frequencies. The first transmission starts where $CLK_0 = 0$ and the second transmission starts where $CLK_0 = 1$.

In a single RX slot interval, the paging device shall listen for the slave page response message on two different hop frequencies. Similar to transmission, the nominal reception starts where $CLK_0 = 0$ and the second reception nominally starts where $CLK_0 = 1$; see [Figure 2.7 on page 77](#). During the TX slot, the paging device shall send the paging message at the TX hop frequencies $f(k)$ and $f(k+1)$. In the RX slot, it shall listen for a response on the corresponding RX hop frequencies $f'(k)$ and $f'(k+1)$. The listening periods shall be exactly timed 625 μ s after the corresponding paging packets, and shall include a ± 10 μ s uncertainty window.

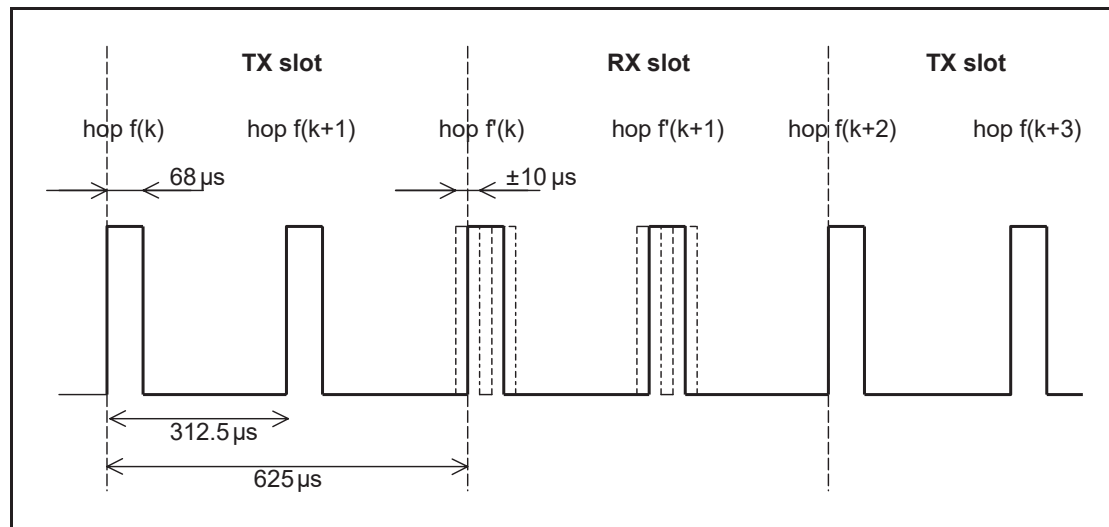


Figure 2.7: RX/TX cycle of transceiver in PAGE mode.

2.4.4 Page response timing

At connection setup a master page response packet is transmitted from the master to the slave (see [Table 8.3 on page 159](#)). This packet establishes the timing and frequency synchronization. After the slave device has received the page message, it shall return a response message that consists of the slave page response packet and shall follow 625 μs after the receipt of the page message. The master shall send the master page response packet in the TX slot following the RX slot in which it received the slave response, according to the RX/TX timing of the master. The time difference between the slave page response and master page response message will depend on the timing of the page message the slave received. In [Figure 2.8 on page 78](#), the slave receives the paging message sent **first** in the master-to-slave slot. It then responds with a first slave page response packet in the first half of the slave-to-master slot. The timing of the master page response packet is based on the timing of the page message sent first in the preceding master-to-slave slot: there is an exact 1250 μs delay between the first page message and the master page response packet. The packet is sent at the hop frequency $f(k+1)$ which is the hop frequency following the hop frequency $f(k)$ the page message was received in.

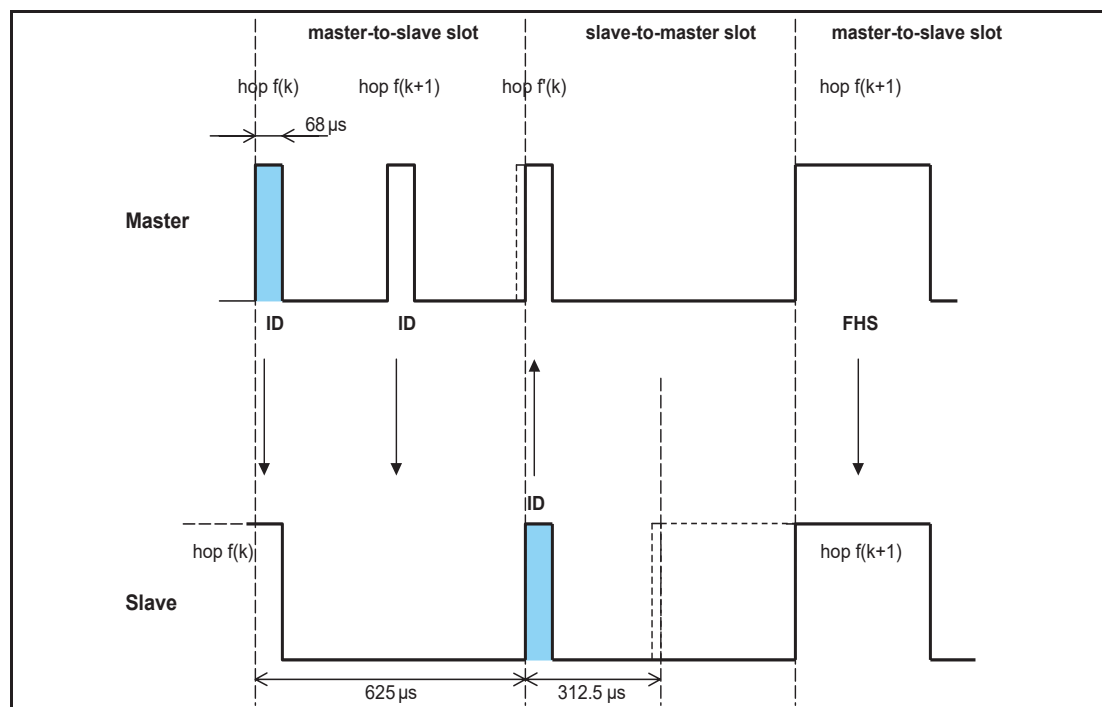


Figure 2.8: Timing of page response packets on successful page in first half slot

In [Figure 2.9 on page 79](#), the slave receives the paging message sent **second** in the master-to-slave slot. It then responds with a slave page response packet in the second half of the slave-to-master slot exactly 625 μs after the receipt of the page message. The timing of the master page response packet is still based on the timing of the page message sent **first** in the preceding master-to-slave slot: there is an exact 1250 μs delay between the **first** page message and the master page response packet. The packet is sent at the hop frequency $f(k+2)$ which is the hop frequency following the hop frequency $f(k+1)$ the page message was received in.

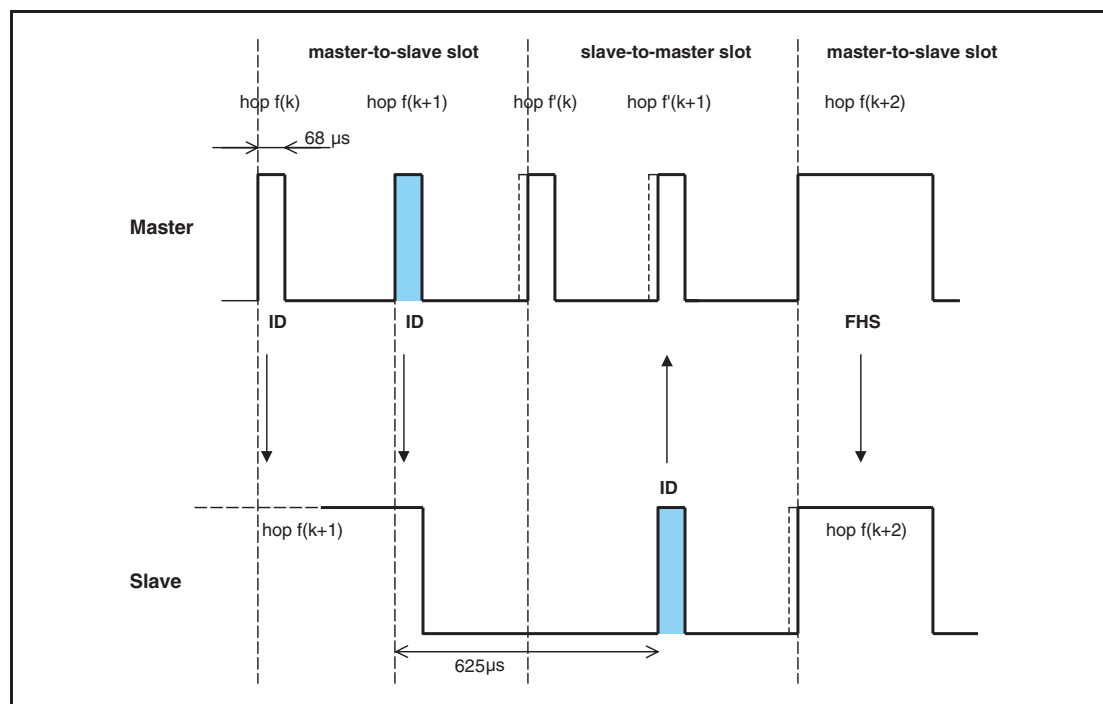


Figure 2.9: Timing of page response packets on successful page in second half slot

The slave shall adjust its RX/TX timing according to the reception of the master page response packet (and not according to the reception of the page message). That is, the second slave page response message that acknowledges the reception of the master page response packet shall be transmitted 625 μs after the start of the master page response packet.



2.5 INQUIRY SCAN PHYSICAL CHANNEL

Although master and slave roles are not defined prior to a connection, the term *master* is used for the inquiring device and *slave* is used for the inquiry scanning device.

2.5.1 Clock for inquiry

The clock used for inquiry and inquiry scan shall be the device's native clock.

2.5.2 Hopping characteristics

The inquiry scan channel follows a slower hopping pattern than the piconet physical channel and is a short pseudo-random hopping sequence through the RF channels. The timing of the inquiry scan channel is determined by the native Bluetooth clock of the scanning device while the frequency hopping sequence is determined by the general inquiry access code.

The inquiry scan physical channel uses the inquiry, inquiry response, and inquiry scan hopping sequences described in [Section 2.6 on page 82](#).

2.5.3 Inquiry procedure timing

During the inquiry procedure, the master shall transmit inquiry messages with the general or dedicated inquiry access code. The timing for inquiry is the same as for paging (see [Section 2.4.3 on page 77](#)).

2.5.4 Inquiry response timing

An inquiry response packet is transmitted from the slave to the master after the slave has received an inquiry message (see [Table 8.5 on page 167](#)). This packet contains information necessary for the inquiring master to page the slave (see definition of the FHS packet in [Section 6.5.1.4 on page 120](#)) and follows 625 μ s after the receipt of the inquiry message. In [Figure 2.10](#) and [Figure 2.11](#), $f(k)$ is used for the frequencies of the inquiry hopping sequence and $f'(k)$ denotes the corresponding inquiry response sequence frequency. The packet is received by the master at the hop frequency $f'(k)$ when the inquiry message received by the slave was first in the master-to-slave slot.

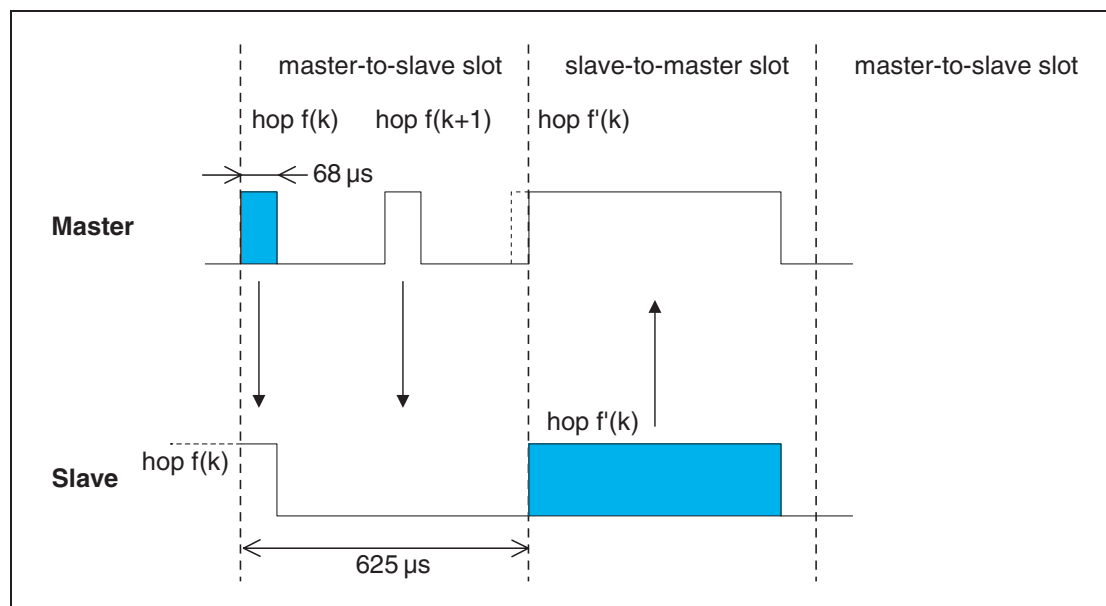


Figure 2.10: Timing of inquiry response packet on successful inquiry in first half slot

When the inquiry message received by the slave was the second in the master-to-slave slot the packet is received by the master at the hop frequency $f'(k+1)$.

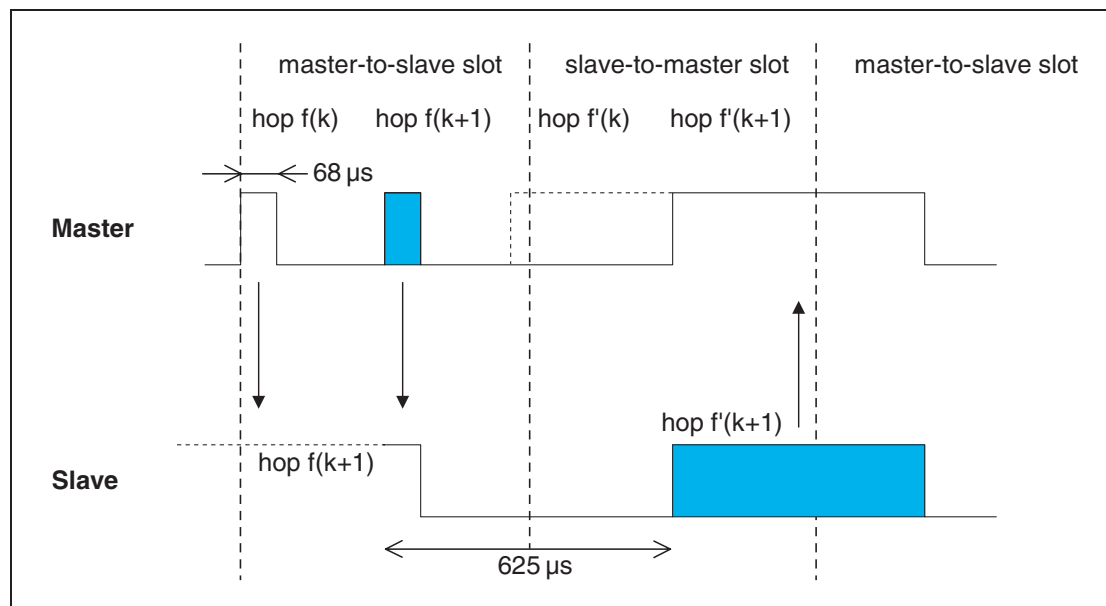


Figure 2.11: Timing of inquiry response packet on successful inquiry in second half slot



2.6 HOP SELECTION

Bluetooth devices shall use the hopping kernel as defined in the following sections.

In total, six types of hopping sequence are defined – five for the basic hop system and one for an adapted set of hop locations used by adaptive frequency hopping (AFH). These sequences are:

- A **page hopping sequence** with 32 wake-up frequencies distributed equally over the 79 MHz, with a period length of 32;
- A **page response hopping sequence** covering 32 response frequencies that are in a one-to-one correspondence to the current page hopping sequence. The master and slave use different rules to obtain the same sequence;
- An **inquiry hopping sequence** with 32 wake-up frequencies distributed equally over the 79 MHz, with a period length of 32;
- An **inquiry response hopping sequence** covering 32 response frequencies that are in a one-to-one correspondence to the current inquiry hopping sequence.
- A **basic channel hopping sequence** which has a very long period length, which does not show repetitive patterns over a short time interval, and which distributes the hop frequencies equally over the 79 MHz during a short time interval.
- An **adapted channel hopping sequence** derived from the basic channel hopping sequence which uses the same channel mechanism and may use fewer than 79 frequencies. The adapted channel hopping sequence is only used in place of the basic channel hopping sequence. All other hopping sequences are not affected by hop sequence adaptation.

2.6.1 General selection scheme

The selection scheme consists of two parts:

- selecting a sequence;
- mapping this sequence onto the hop frequencies;

The general block diagram of the hop selection scheme is shown in [Figure 2.12 on page 83](#). The mapping from the input to a particular RF channel index is performed in the selection box.

The inputs to the selection box are the selected clock, frozen clock, N , k_{offset} , address, sequence selection and AFH_channel_map. The source of the clock input depends on the hopping sequence selected. Additionally, each hopping sequence uses different bits of the clock (see [Table 2.2 on page 91](#)). N and k_{offset} are defined in [Section 2.6.4 on page 90](#).

The *sequence selection* input can be set to the following values:

- page scan
- inquiry scan
- page
- inquiry
- master page response
- slave page response
- inquiry response
- basic channel
- adapted channel

The address input consists of 28 bits including the entire LAP and the 4 LSBs of the UAP. This is designated as the UAP/LAP. When the basic or adapted channel hopping sequence is selected, the Bluetooth device address of the master (BD_ADDR) shall be used. When the page, master page response, slave page response, or page scan hopping sequences are selected the BD_ADDR given by the Host of the paged device shall be used (see HCI Create Connection Command [\[Part E\] Section 7.1.5 on page 406](#)). When the inquiry, inquiry response, or inquiry scan hopping sequences are selected, the UAP/LAP corresponding to the GIAC shall be used even if it concerns a DIAC. Whenever one of the reserved BD_ADDRs (see [Section 1.2.1 on page 66](#)) is used for generating a frequency hop sequence, the UAP shall be replaced by the default check initialization (DCI, see [Section 7.1 on page 138](#)). The hopping sequence is selected by the sequence selection input to the selection box.

When the adapted channel hopping sequence is selected, the *AFH_channel_map* is an additional input to the selection box. The *AFH_channel_map* indicates which channels shall be *used* and which shall be *unused*. These terms are defined in [Section 2.6.3 on page 89](#).

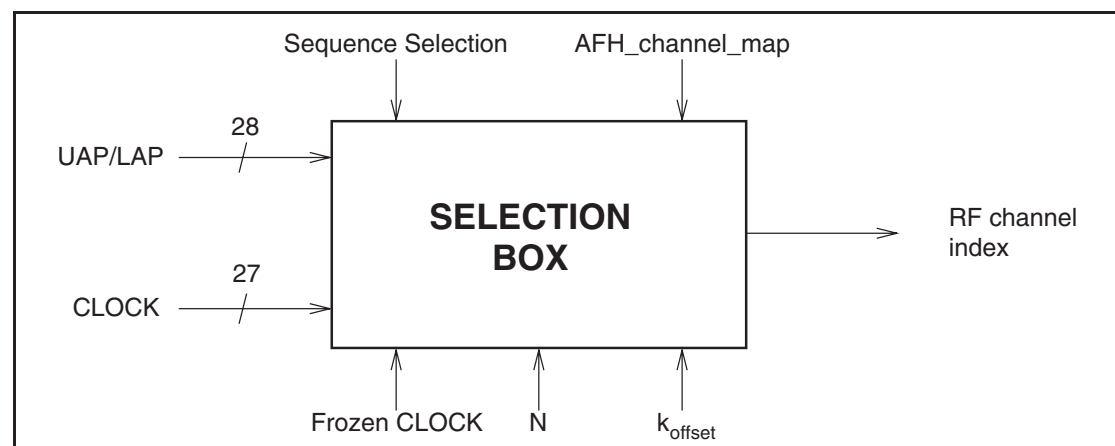


Figure 2.12: General block diagram of hop selection scheme.



The output, *RF channel index*, constitutes a pseudo-random sequence. The RF channel index is mapped to RF channel frequencies using the equation in [Table 2.1 on page 29](#) in the Radio Specification.

The selection scheme chooses a segment of 32 hop frequencies spanning about 64 MHz and visits these hops in a pseudo-random order. Next, a different 32-hop segment is chosen, etc. In the page, master page response, slave page response, page scan, inquiry, inquiry response and inquiry scan hopping sequences, the same 32-hop segment is used all the time (the segment is selected by the address; different devices will have different paging segments). When the basic channel hopping sequence is selected, the output constitutes a pseudo-random sequence that slides through the 79 hops. The principle is depicted in [Figure 2.13 on page 84](#).

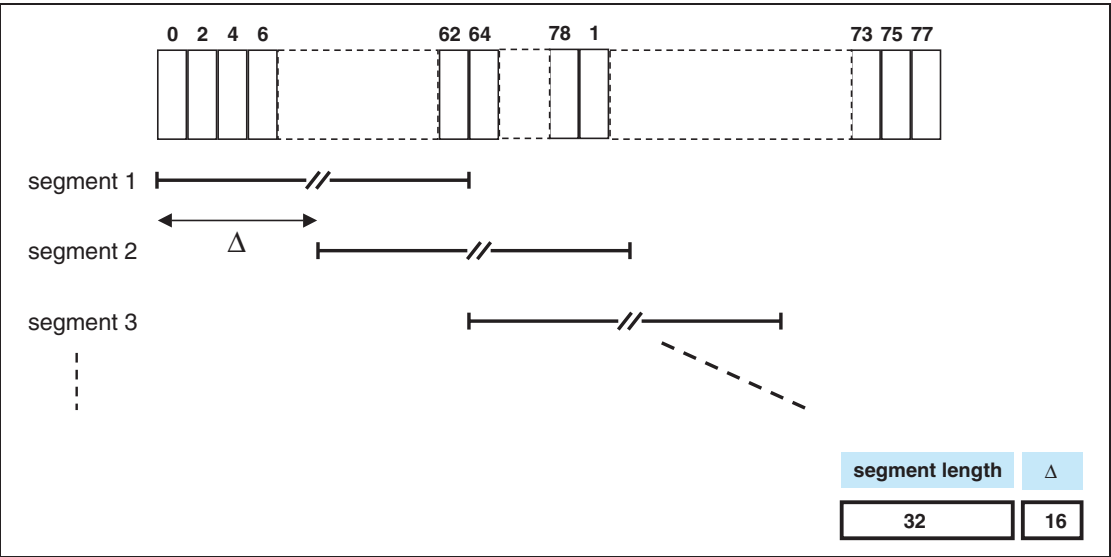


Figure 2.13: Hop selection scheme in CONNECTION state.

The RF frequency shall remain fixed for the duration of the packet. The RF frequency for the packet shall be derived from the Bluetooth clock value in the first slot of the packet. The RF frequency in the first slot after a multi-slot packet shall use the frequency as determined by the Bluetooth clock value for that slot. [Figure 2.14 on page 85](#) illustrates the hop definition on single- and multi-slot packets.

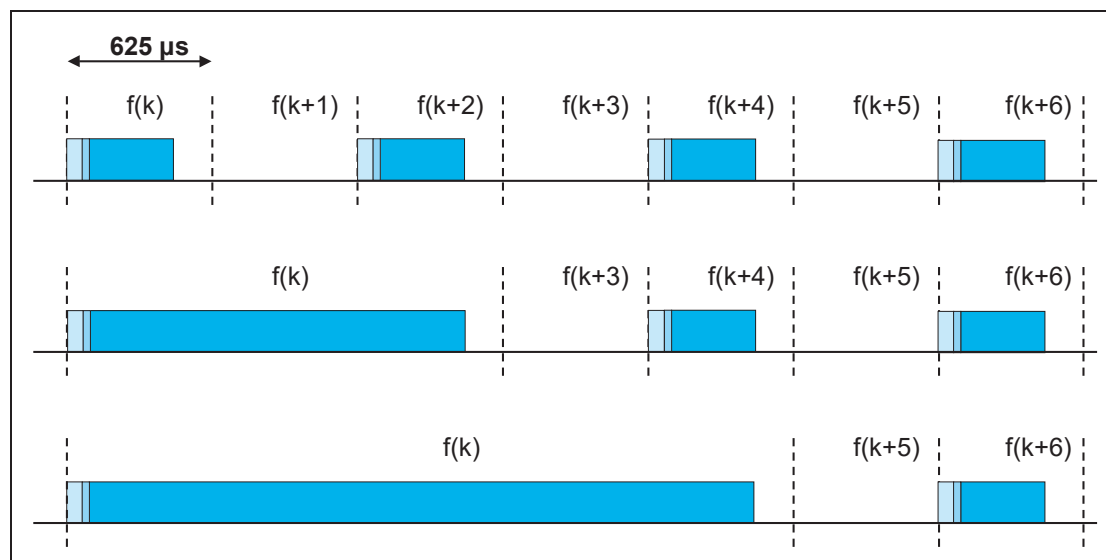


Figure 2.14: Single- and multi-slot packets.

When the adapted channel hopping sequence is used, the pseudo-random sequence contains only frequencies that are in the RF channel set defined by the *AFH_channel_map* input. The adapted sequence has similar statistical properties to the non-adapted hop sequence. In addition, the slave responds with its packet on the same RF channel that was used by the master to address that slave (or would have been in the case of a synchronous reserved slot without a validly received master-to-slave transmission). This is called the *same channel mechanism* of AFH. Thus, the RF channel used for the master to slave packet is also used for the immediately following slave to master packet. An example of the same channel mechanism is illustrated in Figure 2.15 on page 85. The same channel mechanism shall be used whenever the adapted channel hopping sequence is selected.

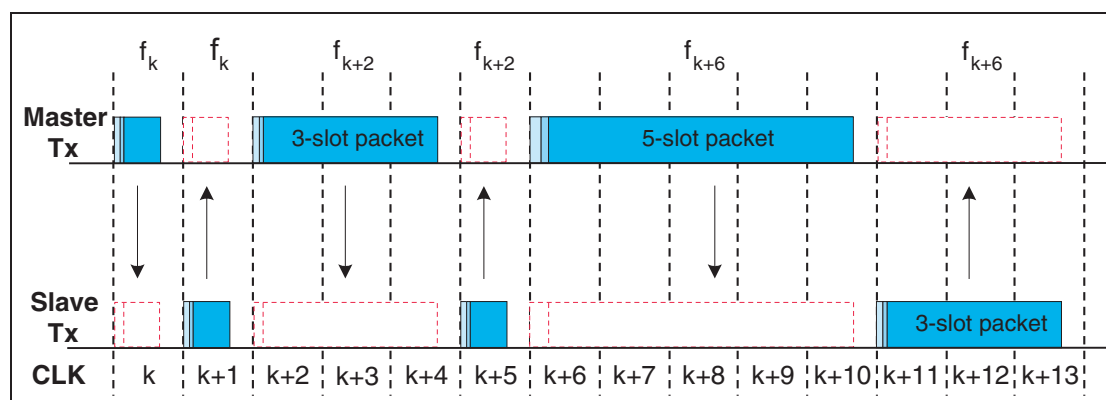


Figure 2.15: Example of the same channel mechanism.

2.6.2 Selection kernel

The basic hop selection kernel shall be as shown in [Figure 2.16 on page 86](#) and is used for the page, page response, inquiry, inquiry response and basic channel hopping selection kernels. In these substates the AFH_channel_map input is unused. The adapted channel hopping selection kernel is described in [Section 2.6.3 on page 89](#). The X input determines the phase in the 32-hop segment, whereas Y1 and Y2 selects between master-to-slave and slave-to-master. The inputs A to D determine the ordering within the segment, the inputs E and F determine the mapping onto the hop frequencies. The kernel addresses a register containing the RF channel indices. This list is ordered so that first all even RF channel indices are listed and then all odd hop frequencies. In this way, a 32-hop segment spans about 64 MHz.

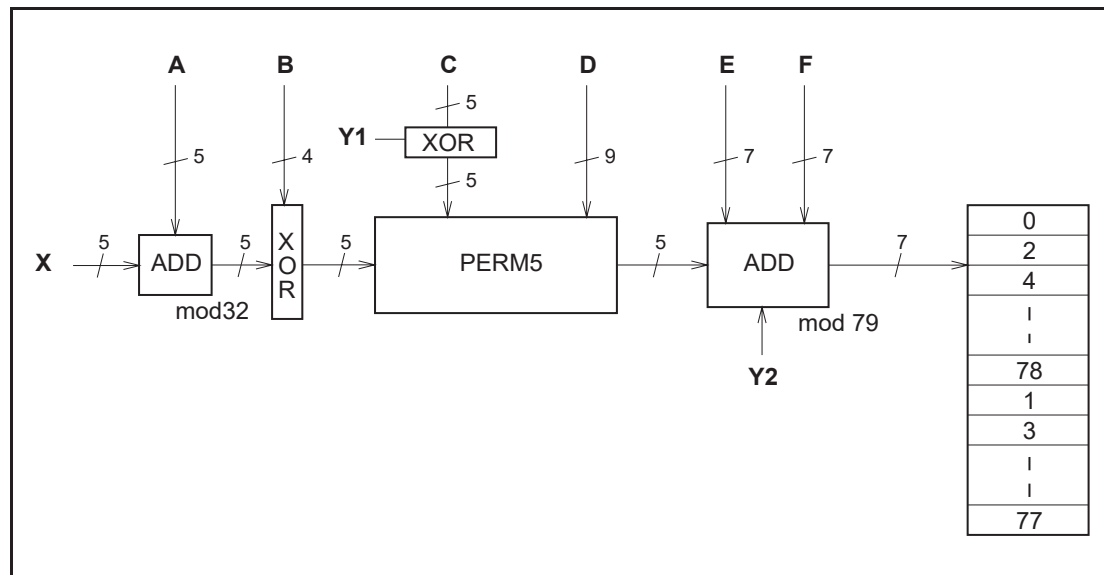


Figure 2.16: Block diagram of the basic hop selection kernel for the hop system.

The selection procedure consists of an addition, an XOR operation, a permutation operation, an addition, and finally a register selection. In the remainder of this chapter, the notation A_i is used for bit i of the BD_ADDR.

2.6.2.1 First addition operation

The first addition operation only adds a constant to the phase and applies a modulo 32 operation. For the page hopping sequence, the first addition is redundant since it only changes the phase within the segment. However, when different segments are concatenated (as in the basic channel hopping sequence), the first addition operation will have an impact on the resulting sequence.

2.6.2.2 XOR operation

Let Z' denote the output of the first addition. In the XOR operation, the four LSBs of Z' are modulo-2 added to the address bits A_{22-19} . The operation is illustrated in [Figure 2.17 on page 87](#).

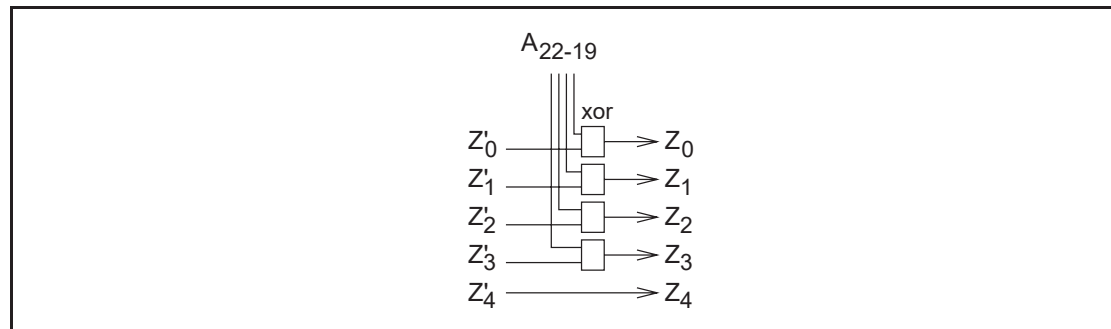


Figure 2.17: XOR operation for the hop system.

2.6.2.3 Permutation operation

The permutation operation involves the switching from 5 inputs to 5 outputs for the hop system, controlled by the control word. The permutation or switching box shall be as shown in [Figure 2.18 on page 88](#). It consists of 7 stages of butterfly operations. The control of the butterflies by the control signals P is shown in [Table 2.1](#). P_{0-8} corresponds to D_{0-8} , and, P_{i+9} corresponds to $C_i \oplus Y1$ for $i = 0 \dots 4$ in [Figure 2.16](#).

| Control signal | Butterfly | Control signal | Butterfly |
|----------------|----------------|----------------|----------------|
| P_0 | $\{Z_0, Z_1\}$ | P_8 | $\{Z_1, Z_4\}$ |
| P_1 | $\{Z_2, Z_3\}$ | P_9 | $\{Z_0, Z_3\}$ |
| P_2 | $\{Z_1, Z_2\}$ | P_{10} | $\{Z_2, Z_4\}$ |
| P_3 | $\{Z_3, Z_4\}$ | P_{11} | $\{Z_1, Z_3\}$ |
| P_4 | $\{Z_0, Z_4\}$ | P_{12} | $\{Z_0, Z_3\}$ |
| P_5 | $\{Z_1, Z_3\}$ | P_{13} | $\{Z_1, Z_2\}$ |
| P_6 | $\{Z_0, Z_2\}$ | | |
| P_7 | $\{Z_3, Z_4\}$ | | |

Table 2.1: Control of the butterflies for the hop system

The Z input is the output of the XOR operation as described in the previous section. The butterfly operation can be implemented with multiplexers as depicted in [Figure 2.19 on page 88](#).

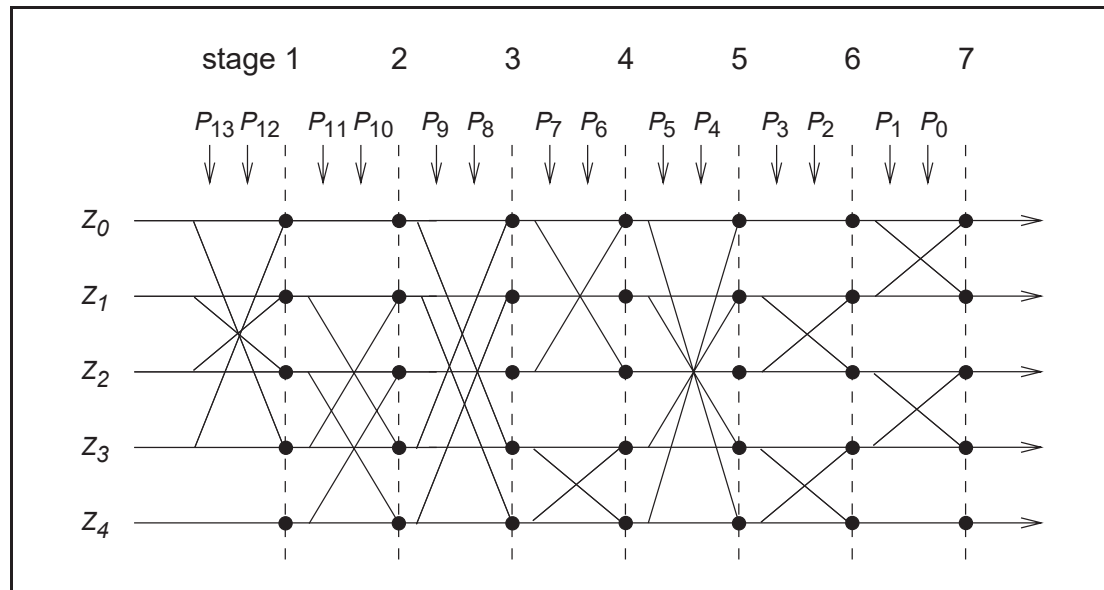


Figure 2.18: Permutation operation for the hop system.

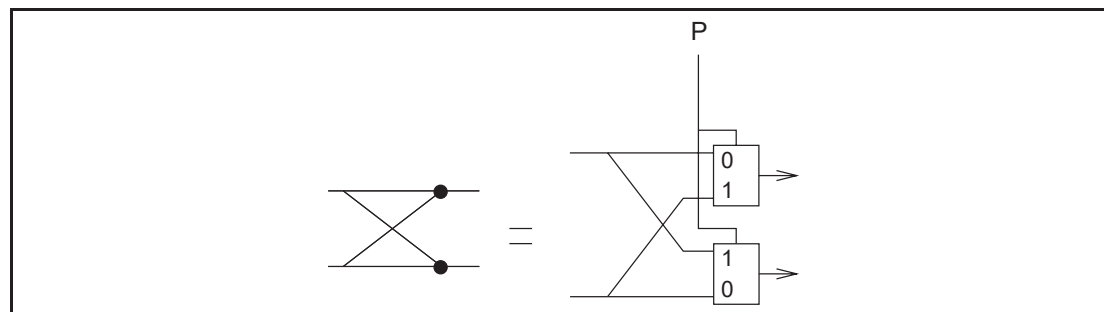


Figure 2.19: Butterfly implementation.

2.6.2.4 Second addition operation

The addition operation only adds a constant to the output of the permutation operation. The addition is applied modulo 79.

2.6.2.5 Register bank

The output of the adder addresses a bank of 79 registers. The registers are loaded with the synthesizer code words corresponding to the hop frequencies 0 to 78. Note that the upper half of the bank contains the even hop frequencies, whereas the lower half of the bank contains the odd hop frequencies.

2.6.3 Adapted hop selection kernel

The adapted hop selection kernel is based on the basic hop selection kernel defined in the preceding sections.

The inputs to the adapted hop selection kernel are the same as for the basic hop system kernel except that the input *AFH_channel_map* (defined in Link Manager Protocol [Part C] Section 5.2 on page 303) is used. The *AFH_channel_map* indicates which RF channels shall be *used* and which shall be *unused*. When hop sequence adaptation is enabled, the number of *used* RF channels may be reduced from 79 to some smaller value N . All devices shall be capable of operating on an adapted hop sequence (AHS) with $N_{min} \leq N \leq 79$, with any combination of *used* RF channels within the *AFH_channel_map* that meets this constraint. N_{min} is defined in Section 2.3.1 on page 75.

Adaptation of the hopping sequence is achieved through two additions to the basic channel hopping sequence according to Figure 2.16 on page 86:

- *Unused* RF channels are re-mapped uniformly onto *used* RF channels. That is, if the hop selection kernel of the basic system generates an *unused* RF channel, an alternative RF channel out of the set of *used* RF channels is selected pseudo-randomly.
- The *used* RF channel generated for the master-to-slave packet is also used for the immediately following slave-to-master packet (see Section 2.6.1 on page 82).

2.6.3.1 Channel re-mapping function

When the adapted hop selection kernel is selected, the basic hop selection kernel according to Figure 2.16 on page 86 is initially used to determine an RF channel. If this RF channel is *unused* according to the *AFH_channel_map*, the *unused* RF channel is re-mapped by the re-mapping function to one of the *used* RF channels. If the RF channel determined by the basic hop selection kernel is already in the set of *used* RF channels, no adjustment is made. The hop sequence of the (non-adapted) basic hop equals the sequence of the adapted selection kernel on all locations where *used* RF channels are generated by the basic hop. This property facilitates non-AFH slaves remaining synchronized while other slaves in the piconet are using the adapted hopping sequence.

A block diagram of the re-mapping mechanism is shown in Figure 2.20 on page 90. The re-mapping function is a post-processing step to the selection kernel from Figure 2.16 on page 86, denoted as ‘Hop selection of the basic hop’. The output f_k of the basic hop selection kernel is an RF channel number that ranges between 0 and 78. This RF channel will either be in the set of *used* RF channels or in the set of *unused* RF channels.

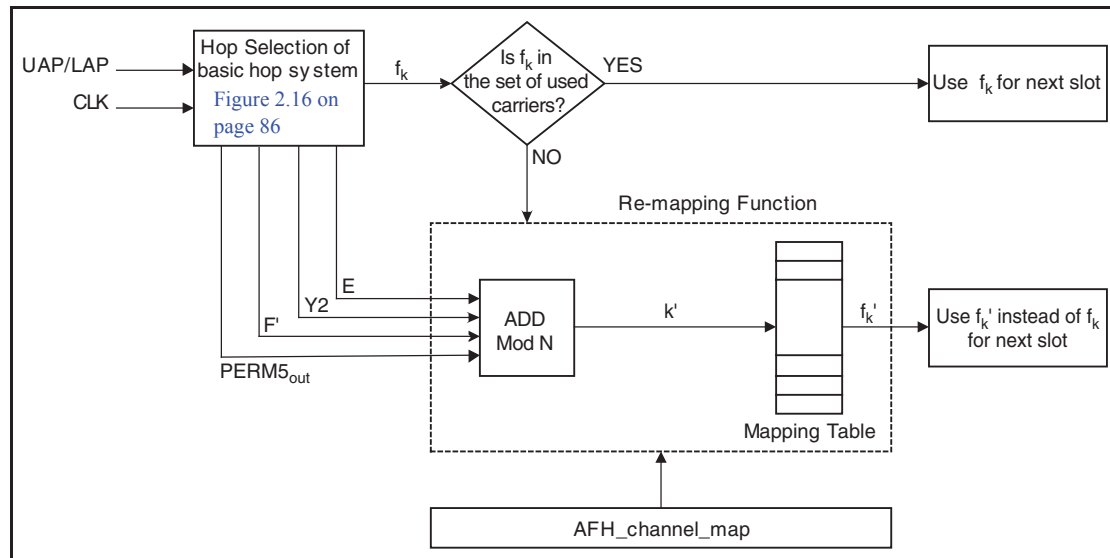


Figure 2.20: Block diagram of adaptive hop selection mechanism

When an unused RF channel is generated by the basic hop selection mechanism, it is re-mapped to the set of *used* RF channels as follows. A new index $k' \in \{0, 1, \dots, N-1\}$ is calculated using some of the parameters from the basic hop selection kernel:

$$k' = (\text{PERM5}_{\text{out}} + E + F' + Y2) \bmod N$$

where F' is defined in Table 2.2 on page 91. The index k' is then used to select the re-mapped channel from a mapping table that contains all of the even *used* RF channels in ascending order followed by all the odd *used* RF channels in ascending order (i.e., the mapping table of Figure 2.16 on page 86 with all the *unused* RF channels removed).

2.6.4 Control word

In the following section X_{j-i} , $i < j$, will denote bits $i, i+1, \dots, j$ of the bit vector X . By convention, X_0 is the least significant bit of the vector X .

The control word of the kernel is controlled by the overall control signals X , $Y1$, $Y2$, A to F , and F' as illustrated in Figure 2.16 on page 86 and Figure 2.20 on page 90. During paging and inquiry, the inputs A to E use the address values as given in the corresponding columns of Table 2.2 on page 91. In addition, the inputs X , $Y1$ and $Y2$ are used. The F and F' inputs are unused. The clock bits CLK_{6-2} (i.e., input X) specifies the phase within the length 32 sequence. CLK_1 (i.e., inputs $Y1$ and $Y2$) is used to select between TX and RX. The address inputs determine the sequence order within segments. The final mapping onto the hop frequencies is determined by the register contents.

During the **CONNECTION** state (see Section 8.5 on page 167), the inputs A , C and D shall be derived from the address bits being bit-wise XORed with the

clock bits as shown in the “Connection state” column of [Table 2.2 on page 91](#) (the two most significant bits, MSBs, are XORED together, the two second MSBs are XORED together, etc.).

| | Page scan / Interlaced Page Scan / Inquiry scan / Interlaced Inquiry Scan | Page/Inquiry | Master/Slave page response and Inquiry response | Connection state |
|----|---|--|---|------------------------------------|
| X | $CLKN_{16-12} /$ $(CLKN_{16-12} + 16) \bmod 32 /$ $Xir_{4-0} /$ $Xir_{4-0} + 16) \bmod 32$ | Xp_{4-0} / Xi_{4-0} | $Xprm_{4-0} /$ $Xprs_{4-0} /$ Xir_{4-0} | CLK_{6-2} |
| Y1 | 0 | $CLKE_1 / CLKN_1$ | $CLKE_1 / CLKN_1 / 1$ | CLK_1 |
| Y2 | 0 | $32 \times CLKE_1 /$ $32 \times CLKN_1$ | $32 \times CLKE_1 /$ $32 \times CLKN_1 /$ 32×1 | $32 \times CLK_1$ |
| A | A_{27-23} | A_{27-23} | A_{27-23} | $A_{27-23} \oplus CLK_{25-21}$ |
| B | A_{22-19} | A_{22-19} | A_{22-19} | A_{22-19} |
| C | $A_{8,6,4,2,0}$ | $A_{8,6,4,2,0}$ | $A_{8,6,4,2,0}$ | $A_{8,6,4,2,0} \oplus CLK_{20-16}$ |
| D | A_{18-10} | A_{18-10} | A_{18-10} | $A_{18-10} \oplus CLK_{15-7}$ |
| E | $A_{13,11,9,7,5,3,1}$ | $A_{13,11,9,7,5,3,1}$ | $A_{13,11,9,7,5,3,1}$ | $A_{13,11,9,7,5,3,1}$ |
| F | 0 | 0 | 0 | $16 \times CLK_{27-7} \bmod 79$ |
| F' | n/a | n/a | n/a | $16 \times CLK_{27-7} \bmod N$ |

Table 2.2: Control for hop system.

The five X input bits vary depending on the current state of the device. In the **page scan** and **inquiry scan** substates, the native clock (CLKN) shall be used. In **CONNECTION** state the master clock (CLK) shall be used as input. The situation is somewhat more complicated for the other states.

2.6.4.1 Page scan and inquiry scan hopping sequences

When the sequence selection input is set to page scan, the Bluetooth device address of the scanning device shall be used as address input. When the sequence selection input is set to inquiry scan, the GIAC LAP and the four LSBs of the DCI (as A_{27-24}), shall be used as address input for the hopping sequence. For the transmitted access code and in the receiver correlator, the appropriate GIAC or DIAC shall be used. The application decides which inquiry access code to use depending on the purpose of the inquiry.

2.6.4.2 Page hopping sequence

When the sequence selection input is set to page, the paging device shall start using the **A**-train, i.e., $\{f(k-8), \dots, f(k), \dots, f(k+7)\}$, where $f(k)$ is the source's estimate of the current receiver frequency in the paged device. The index k is a function of all the inputs in Figure 2.16. There are 32 possible paging frequencies within each 1.28 second interval. Half of these frequencies belong to the **A**-train, the rest (i.e., $\{f(k+8), \dots, f(k+15), f(k-16), \dots, f(k-9)\}$) belong to the **B**-train. In order to achieve the -8 offset of the **A**-train, a constant of 24 shall be added to the clock bits (which is equivalent to -8 due to the modulo 32 operation). The **B**-train is obtained by setting the offset to 8. A cyclic shift of the order within the trains is also necessary in order to avoid a possible repetitive mismatch between the paging and scanning devices. Thus,

$$Xp = [\text{CLKE}_{16-12} + k_{\text{offset}} + (\text{CLKE}_{4-2,0} - \text{CLKE}_{16-12}) \bmod 16] \bmod 32, \quad (\text{EQ } 2)$$

where

$$k_{\text{offset}} = \begin{cases} 24 & \text{A-train,} \\ 8 & \text{B-train.} \end{cases} \quad (\text{EQ } 3)$$

Alternatively, each switch between the **A**- and **B**-trains may be accomplished by adding 16 to the current value of k_{offset} (originally initialized with 24).

2.6.4.3 Slave page response hopping sequence

When the sequence selection input is set to *slave page response*, in order to eliminate the possibility of losing the link due to discrepancies of the native clock CLKN and the master's clock estimate CLKE, the four bits CLKN_{16-12} shall be frozen at their current value. The value shall be frozen at the content it has in the slot where the recipient's access code is detected. The native clock shall *not* be stopped; it is merely the values of the bits used for creating the X-input that are kept fixed for a while. A frozen value is denoted by an asterisk (*) in the discussion below.

For each response slot the paged device shall use an X-input value one larger (modulo 32) than in the preceding response slot. However, the first response shall be made with the X-input kept at the same value as it was when the access code was recognized. Let N be a counter starting at zero. Then, the X-input in the $(N+1)$ -th response slot (the first response slot being the one immediately following the page slot now responding to) of the **slave response** sub-state is:

$$Xprs = [\text{CLKN}^*_{16-12} + N] \bmod 32, \quad (\text{EQ } 4)$$



The counter N shall be set to zero in the slot where the slave acknowledges the page (see [Figure 8.3 on page 160](#) and [Figure 8.4 on page 160](#)). Then, the value of N shall be increased by one each time $CLKN_1$ is set to zero, which corresponds to the start of a master TX slot. The X-input shall be constructed this way until the first **FHS** packet is received *and* the immediately following response packet has been transmitted. After this the slave shall enter the **CONNECTION** state using the parameters received in the **FHS** packet.

2.6.4.4 Master page response hopping sequence

When the sequence selection input is set to *master page response*, the master shall freeze its estimated slave clock to the value that triggered a response from the paged device. It is equivalent to using the values of the clock estimate when receiving the slave response (since only $CLKE_1$ will differ from the corresponding page transmission). Thus, the values are frozen when the slave **ID** packet is received. In addition to the clock bits used, the current value of k_{offset} shall also be frozen. The master shall adjust its X-input in the same way the paged device does, i.e., by incrementing this value by one for each time $CLKE_1$ is set to zero. The first increment shall be done before sending the **FHS** packet to the paged device. Let N be a counter starting at one. The rule for forming the X-input is:

$$X_{prm} = [CLKE^*_{16-12} + k_{offset}^* + (CLKE^*_{4-2,0} - CLKE^*_{16-12}) \bmod 16 + N] \bmod 32, \quad (\text{EQ } 5)$$

The value of N shall be increased each time $CLKE_1$ is set to zero, which corresponds to the start of a master TX slot.

2.6.4.5 Inquiry hopping sequence

When the sequence selection input is set to *inquiry*, the X-input is similar to that used in the *page hopping sequence*. Since no particular device is addressed, the native clock $CLKN$ of the inquirer shall be used. Moreover, which of the two train offsets to start with is of no real concern in this state. Consequently,

$$X_i = [CLKN_{16-12} + k_{offset} + (CLKN_{4-2,0} - CLKN_{16-12}) \bmod 16] \bmod 32, \quad (\text{EQ } 6)$$

where k_{offset} is defined by [\(EQ 3\) on page 92](#). The initial choice of the offset is arbitrary.

The GIAC LAP and the four LSBs of the DCI (as A_{27-24}) shall be used as address input for the hopping sequence generator.



2.6.4.6 Inquiry response hopping sequence

The *inquiry response* hopping sequence is similar to the *slave page response* hopping sequence with respect to the X-input. The clock input shall not be frozen, thus the following equation apply:

$$X_{ir} = [\text{CLKN}_{16-12} + N] \bmod 32, \quad (\text{EQ } 7)$$

Furthermore, the counter N is increased not on CLKN_1 basis, but rather after each **FHS** packet has been transmitted in response to the inquiry. There is no restriction on the initial value of N as it is independent of the corresponding value in the inquiring unit.

The GIAC LAP and the four LSBs of the DCI (as A_{27-24}) shall be used as address input for the hopping sequence generator. The other input bits to the generator shall be the same as for page response.

2.6.4.7 Basic and adapted channel hopping sequence

In the *basic* and *adapted channel hopping sequences*, the clock bits to use in the basic or adapted hopping sequence generation shall always be derived from the master clock, CLK. The address bits shall be derived from the Bluetooth device address of the master.

3 PHYSICAL LINKS

A physical link represents a baseband connection between devices. A physical link is always associated with exactly one physical channel. Physical links have common properties that apply to all logical transports on the physical link.

The common properties of physical links are:

- Power control (see Link Manager Protocol [Section 4.1.3 on page 235](#))
- Link supervision (see [Section 3.1 on page 95](#) and Link Manager Protocol [Section 4.1.6 on page 242](#))
- Encryption (see Security [Part H] [Section 4 on page 787](#) and Link Manager Protocol [Part C] [Section 4.2.5 on page 257](#))
- Channel quality-driven data rate change (see Link Manager Protocol [Section 4.1.7 on page 243](#))
- Multi-slot packet control (see Link Manager Protocol [Section 4.1.10 on page 247](#))

3.1 LINK SUPERVISION

A connection can break down due to various reasons such as a device moving out of range, encountering severe interference or a power failure condition. Since this may happen without any prior warning, it is important to monitor the link on both the master and the slave side to avoid possible collisions when the logical transport address (see [Section 4.2 on page 97](#)) or parked member address (see [Section 4.7.1 on page 105](#)) is reassigned to another slave.

To be able to detect link loss, both the master and the slave shall use a link supervision timer, $T_{\text{supervision}}$. Upon reception of a valid packet header with one of the slave's addresses (see [Section 4.2 on page 97](#)) on the physical link, the timer shall be reset. If at any time in **CONNECTION** state, the timer reaches the *supervisionTO* value, the connection shall be considered disconnected. The same link supervision timer shall be used for SCO, eSCO, and ACL logical transports.

The timeout period, *supervisionTO*, is negotiated by the Link Manager. Its value shall be chosen so that the supervision timeout will be longer than hold and sniff periods. Link supervision of a parked slave shall be done by unparking and re-parking the slave.



4 LOGICAL TRANSPORTS

4.1 GENERAL

Between master and slave(s), different types of logical transports may be established. Five logical transports have been defined:

- Synchronous Connection-Oriented (SCO) logical transport
- Extended Synchronous Connection-Oriented (eSCO) logical transport
- Asynchronous Connection-Oriented (ACL) logical transport
- Active Slave Broadcast (ASB) logical transport
- Parked Slave Broadcast (PSB) logical transport

The synchronous logical transports are point-to-point logical transports between a master and a single slave in the piconet. The synchronous logical transports typically support time-bounded information like voice or general synchronous data. The master maintains the synchronous logical transports by using reserved slots at regular intervals. In addition to the reserved slots the eSCO logical transport may have a retransmission window after the reserved slots.

The ACL logical transport is also a point-to-point logical transport between the master and a slave. In the slots not reserved for synchronous logical transport(s), the master can establish an ACL logical transport on a per-slot basis to any slave, including the slave(s) already engaged in a synchronous logical transport.

The ASB logical transport is used by a master to communicate with active slaves. The PSB logical transport is used by a master to communicate with parked slaves.

4.2 LOGICAL TRANSPORT ADDRESS (LT_ADDR)

Each slave active in a piconet is assigned a primary 3-bit logical transport address (LT_ADDR). The all-zero LT_ADDR is reserved for broadcast messages. The master does not have an LT_ADDR. A master's timing relative to the slaves distinguishes it from the slaves. A secondary LT_ADDR is assigned to the slave for each eSCO logical transport in use in the piconet. Only eSCO traffic (i.e. NULL, POLL, and one of the EV packet types as negotiated at eSCO logical transport setup) may be sent on these LT_ADDRs. ACL traffic (including LMP) shall always be sent on the primary LT_ADDR. A slave shall only accept packets with matching primary or secondary LT_ADDR and broadcast packets. The LT_ADDR is carried in the packet header (see [Section 6.4 on page 116](#)). The LT_ADDR shall only be valid for as long as a slave is in the active mode. As soon as it is disconnected or parked, the slave shall lose all of its LT_ADDRs.



The primary LT_ADDR shall be assigned by the master to the slave when the slave is activated. This is either at connection establishment, at role switch, or when the slave is unpaired. At connection establishment and at role switch, the primary LT_ADDR is carried in the **FHS** payload. When unpairing, the primary LT_ADDR is carried in the unpair message.

4.3 SYNCHRONOUS LOGICAL TRANSPORTS

The first type of synchronous logical transport, the SCO logical transport is a symmetric, point-to-point link between the master and a specific slave. The SCO logical transport reserves slots and can therefore be considered as a circuit-switched connection between the master and the slave. The master may support up to three SCO links to the same slave or to different slaves. A slave may support up to three SCO links from the same master, or two SCO links if the links originate from different masters. SCO packets are never retransmitted.

The second type of synchronous logical transport, the eSCO logical transport, is a point-to-point logical transport between the master and a specific slave. eSCO logical transports may be symmetric or asymmetric. Similar to SCO, eSCO reserves slots and can therefore be considered a circuit-switched connection between the master and the slave. In addition to the reserved slots, eSCO supports a retransmission window immediately following the reserved slots. Together, the reserved slots and the retransmission window form the complete eSCO window.

4.4 ASYNCHRONOUS LOGICAL TRANSPORT

In the slots not reserved for synchronous logical transports, the master may exchange packets with any slave on a per-slot basis. The ACL logical transport provides a packet-switched connection between the master and all active slaves participating in the piconet. Both asynchronous and isochronous services are supported. Between a master and a slave only a single ACL logical transport shall exist. For most ACL packets, packet retransmission is applied to assure data integrity.

ACL packets not addressed to a specific slave are considered as broadcast packets and should be read by every slave. If there is no data to be sent on the ACL logical transport and no polling is required, no transmission is required.

4.5 TRANSMIT/RECEIVE ROUTINES

This section describes the way to use the packets as defined in [Section 6 on page 109](#) in order to support the traffic on the ACL, SCO and eSCO logical transports. Both single-slave and multi-slave configurations are considered. In addition, the use of buffers for the TX and RX routines are described.

The TX and RX routines described in sections 4.5.1 and 4.5.2 are informative only.

4.5.1 TX Routine

The TX routine is carried out separately for each asynchronous and synchronous link. [Figure 4.1 on page 99](#) shows the asynchronous and synchronous buffers as used in the TX routine. In this figure, only a single TX asynchronous buffer and a single TX synchronous buffer are shown. In the master, there is a separate TX asynchronous buffer for each slave. In addition there may be one or more TX synchronous buffers for each synchronous slave (different SCO or eSCO logical transports may either reuse the same TX synchronous buffer, or each have their own TX synchronous buffer). Each TX buffer consists of two FIFO registers: one **current** register which can be accessed and read by the Link Controller in order to compose the packets, and one **next** register that can be accessed by the Baseband Resource Manager to load new information. The positions of the switches S1 and S2 determine which register is current and which register is next; the switches are controlled by the Link Controller. The switches at the input and the output of the FIFO registers can never be connected to the same register simultaneously.

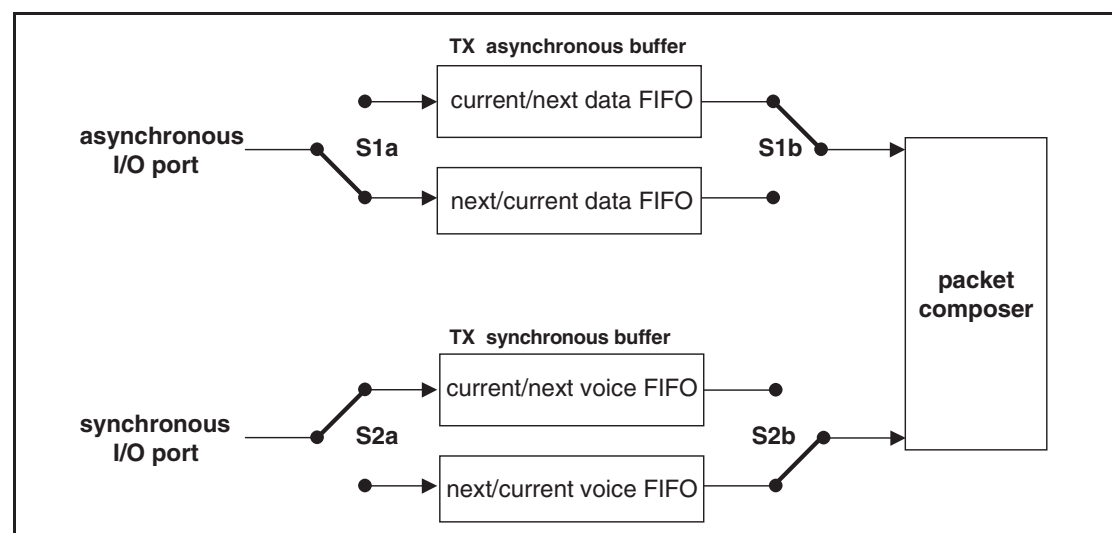


Figure 4.1: Functional diagram of TX buffering.

Of the packets common on the ACL and SCO logical transports (**NULL**, **POLL** and **DM1**) only the **DM1** packet carries a payload that is exchanged between the Link Controller and the Link Manager; this common packet makes use of the asynchronous buffer. All ACL packets make use of the asynchronous



buffer. All SCO and eSCO packets make use of the synchronous buffer except for the **DV** packet where the synchronous data part is handled by the synchronous buffer and the data part is handled by the asynchronous buffer. In the next sections, the operation for ACL traffic, SCO traffic, eSCO traffic, and combined data-voice traffic on the SCO logical transport are described.

4.5.1.1 ACL traffic

In the case of asynchronous data only the TX ACL buffer in [Figure 4.1 on page 99](#) has to be considered. In this case, only packet types **DM** or **DH** are used, and these can have different lengths. The length is indicated in the payload header. The selection of **DM** or **DH** packets should depend on the quality of the link. See [\[Part C\] Section 4.1.7 on page 243](#).

The default packet type in pure data traffic is **NULL** (see [Section 6.5.1.2 on page 120](#)). This means that, if there is no data to be sent (the data traffic is asynchronous, and therefore pauses occur in which no data is available) or no slaves need to be polled, **NULL** packets are sent instead – in order to send link control information to the other device (e.g. ACK/STOP information for received data). When no link control information is available (either no need to acknowledge and/or no need to stop the RX flow) no packet is sent at all.

The TX routine works as follows. The Baseband Resource Manager loads new data information in the register to which the switch S1a points. Next, it gives a command to the Link Controller, which forces the switch S1 to change (both S1a and S1b switch synchronously). When the payload needs to be sent, the packet composer reads the current register and, depending on the packet type, builds a payload which is appended to the channel access code and the header and is subsequently transmitted. In the response packet (which arrives in the following RX slot if it concerned a master transmission, or may be postponed until some later RX slot if it concerned a slave transmission), the result of the transmission is reported back. In case of an ACK, the switch S1 changes position; if a NAK (explicit or implicit) is received instead, the switch S1 will not change position. In that case, the same payload is retransmitted at the next TX occasion.

As long as the Baseband Resource Manager keeps loading the registers with new information, the Link Controller will automatically transmit the payload; in addition, retransmissions are performed automatically in case of errors. The Link Controller will send **NULL** or nothing when no new data is loaded. If no new data has been loaded in the **next** register, during the last transmission, the packet composer will be pointing to an empty register after the last transmission has been acknowledged and the **next** register becomes the **current** register. If new data is loaded in the **next** register, a **flush** command is required to switch the S1 switch to the proper register. As long as the Baseband Resource Manager keeps loading the data and type registers before each TX slot, the data is automatically processed by the Link Controller since the S1 switch is controlled by the ACK information received in response. However, if the traffic from the Baseband Resource Manager is interrupted once and a default packet is sent instead, a **flush** command is necessary to continue the flow in the Link Controller.



The **flush** command can also be used in case of time-bounded (isochronous) data. In case of a bad link, many retransmissions are necessary. In certain applications, the data is time-bounded: if a payload is retransmitted all the time because of link errors, it may become outdated, and the system might decide to continue with more recent data instead and skip the payload that does not come through. This is accomplished by the **flush** command as well. With the **flush**, the switch S1 is forced to change and the Link Controller is forced to consider the next data payload and overrules the ACK control. Any ACL type of packet can be used to send data or link control information to any other ACL slave.

4.5.1.2 SCO traffic

On the SCO logical transport only **HV** and **DV** packet types are used, See [Section 6.5.2 on page 123](#). The synchronous port may continuously load the **next** register in the synchronous buffer. The S2 switches are changed according to the T_{SCO} interval. This T_{SCO} interval is negotiated between the master and the slave at the time the SCO logical transport is established.

For each new SCO slot, the packet composer reads the **current** register after which the S2 switch is changed. If the SCO slot has to be used to send control information with high priority concerning a control packet between the master and the SCO slave, or a control packet between the master and any other slave, the packet composer will discard the SCO information and use the control information instead. This control information shall be sent in a DM1 packet. Data or link control information may also be exchanged between the master and the SCO slave by using the **DV** or **DM1** packets.

4.5.1.3 Mixed data/voice traffic

In [Section 6.5.2 on page 123](#), a **DV** packet has been defined that can support both data and voice simultaneously on a single SCO logical transport. When the TYPE is **DV**, the Link Controller reads the data register to fill the data field and the voice register to fill the voice field. Thereafter, the switch S2 is changed. However, the position of S1 depends on the result of the transmission as on the ACL logical transport: only if an ACK has been received will the S1 switch change its position. In each **DV** packet, the voice information is new, but the data information might be retransmitted if the previous transmission failed. If there is no data to be sent, the SCO logical transport will automatically change from **DV** packet type to the current **HV** packet type used before the mixed data/voice transmission. Note that a **flush** command is necessary when the data stream has been interrupted and new data has arrived.

Combined data-voice transmission can also be accomplished by using a separate ACL logical transport in addition to the SCO logical transport(s) if channel capacity permits this.

4.5.1.4 eSCO Traffic

On the eSCO logical transport only **EV**, **POLL** and **NULL** packet types are used, see [Section 6.5.3 on page 124](#). The synchronous port may continuously load the next register in the synchronous buffer. The S2 switches are changed according to the T_{eSCO} interval. This T_{eSCO} interval is negotiated between the master and the slave at the time the eSCO logical transport is established.

For each new eSCO slot, the packet composer reads the current register after which the S2 switch is changed. If the eSCO slot has to be used to send control information with high priority concerning a control packet between the master and the eSCO slave, or an ACL packet between the master and any other slave, the packet composer will discard the eSCO information and use the control information instead. Control information to the eSCO slave is sent in a DM1 packet on the primary LT_ADDR.

4.5.1.5 Default packet types

On the ACL links, the default type is always **NULL** both for the master and the slave. This means that if no user information needs to be sent, either a **NULL** packet is sent if there is **ACK** or **STOP** information, or no packet is sent at all. The **NULL** packet can be used by the master to allocate the next slave-to-master slot to a certain slave (namely the one addressed). However, the slave is not forced to respond to the **NULL** packet from the master. If the master requires a response, it sends a **POLL** packet.

The SCO and eSCO packet types are negotiated at the LM level when the SCO or eSCO logical transport is established. The agreed packet type is also the default packet type for the reserved SCO or eSCO slots.

4.5.2 RX routine

The RX routine is carried out separately for the ACL logical transport and the synchronous logical transports. However, in contrast to the master TX asynchronous buffer, a single RX buffer is shared among all slaves. For the synchronous buffer, how the different synchronous logical transports are distinguished depends on whether extra synchronous buffers are required or not. [Figure 4.2 on page 103](#) shows the asynchronous and synchronous buffers as used in the RX routine. The RX asynchronous buffer consists of two FIFO registers: one register that can be accessed and loaded by the Link Controller with the payload of the latest RX packet, and one register that can be accessed by the Baseband Resource Manager to read the previous payload. The RX synchronous buffer also consists of two FIFO registers: one register which is filled with newly arrived voice information, and one register which can be read by the voice processing unit.

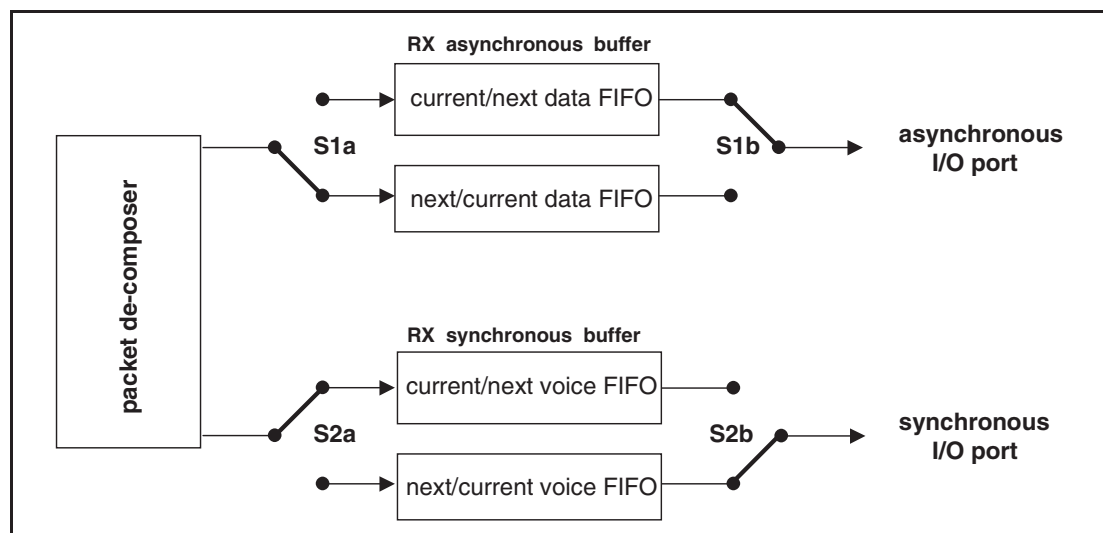


Figure 4.2: Functional diagram of RX buffering

Since the TYPE indication in the header (see [Section 6.4.2 on page 116](#)) of the received packet indicates whether the payload contains data and/or voice, the packet de-composer can automatically direct the traffic to the proper buffers. The switch S1 changes every time the Baseband Resource Manager reads the old register. If the next payload arrives before the RX register is emptied, a STOP indication is included in the packet header of the next TX packet that is returned. The STOP indication is removed again as soon as the RX register is emptied. The SEQN field is checked before a new ACL payload is stored into the asynchronous register (flush indication in LLID and broadcast messages influence the interpretation of the SEQN field see [Section 7.6 on page 144](#)).

The S2 switch is changed every T_{SCO} or T_{eSCO} for SCO and eSCO respectively. If, due to errors in the header, no new synchronous payload arrives, the switch still changes. The synchronous data processing unit then processes the synchronous data to account for the missing parts.

4.5.3 Flow control

Since the RX ACL buffer can be full while a new payload arrives, flow control is required. The header field FLOW in the return TX packet may use STOP or GO in order to control the transmission of new data.

4.5.3.1 Destination control

As long as data can not be received, a STOP indication shall be transmitted which is automatically inserted by the Link Controller into the header of the return packet. STOP shall be returned as long as the RX ACL buffer is not emptied by the Baseband Resource Manager. When new data can be accepted again, the GO indication shall be returned. GO shall be the default value. All packet types not including data can still be received. Voice communication for example is not affected by the flow control. Although a device can not receive new information, it may still continue to transmit information: the flow control shall be separate for each direction.

4.5.3.2 Source control

On the reception of a STOP signal, the Link Controller shall automatically switch to the default packet type. The ACL packet transmitted just before the reception of the STOP indication shall be kept until a GO signal is received. It may be retransmitted as soon as a GO indication is received. Only default packets shall be sent as long as the STOP indication is received. When no packet is received, GO shall be assumed implicitly. Note that the default packets contain link control information (in the header) for the receive direction (which may still be open) and may contain synchronous data (**HV** or **EV** packets). When a GO indication is received, the Link Controller may resume transmitting the data that is present in the TX ACL buffers.

In a multi-slave configuration, only the transmission to the slave that issued the STOP signal shall be stalled. This means that the master shall only stop transmission from the TX ACL buffer corresponding to the slave that momentarily cannot accept data.

4.6 ACTIVE SLAVE BROADCAST TRANSPORT

The active slave broadcast logical transport is used to transport L2CAP user traffic to all devices in the piconet that are currently connected to the piconet physical channel that is used by the ASB. There is no acknowledgement protocol and the traffic is uni-directional from the piconet master to the slaves. The ASB logical transport may only be used for L2CAP group traffic and shall never be used for L2CAP connection-oriented channels, L2CAP control signalling or LMP control signalling.

The ASB logical transport is unreliable. To improve reliability somewhat each packet is transmitted a number of times. An identical sequence number is used to assist with filtering retransmissions at the slave device.

The ASB logical transport is identified by the reserved, all-zero, LT_ADDR. Packets on the ASB logical transport may be sent by the master at any time.

4.7 PARKED SLAVE BROADCAST TRANSPORT

The parked slave broadcast logical transport is used for communication from the master to the slaves that are parked. The PSB logical transport is more complex than the other logical transports as it consists of a number of phases, each having a different purpose. These phases are the control information phase (used to carry the LMP logical link), the user information phase (used to carry the L2CAP logical link), and the access phase (carrying baseband signaling).

The PSB logical transport is identified by the reserved, all-zero, LT_ADDR.

4.7.1 Parked member address (PM_ADDR)

A slave in the **PARK** state can be identified by its BD_ADDR or by a dedicated parked member address (PM_ADDR). This latter address is an 8-bit member address that separates the parked slaves. The PM_ADDR shall only be valid as long as the slave is parked. When the slave is activated it shall be assigned an LT_ADDR but shall lose the PM_ADDR. The PM_ADDR is assigned to the slave by the master during the parking procedure (see [\[Part C\] Section 4.5.2 on page 272](#)).

The all-zero PM_ADDR shall be reserved for parked slaves that only use their BD_ADDR to be unparked.

4.7.2 Access request address (AR_ADDR)

The access request address (AR_ADDR) is used by the parked slave to determine the slave-to-master half slot in the access window where it is allowed to send access request messages, see also [Section 8.9.6 on page 192](#). The AR_ADDR shall be assigned to the slave when it enters the **PARK** state and shall only be valid as long as the slave is parked. The AR_ADDR is not necessarily unique; i.e. different parked slaves may have the same AR_ADDR.



5 LOGICAL LINKS

Five logical links are defined:

- Link Control (LC)
- ACL Control (ACL-C)
- User Asynchronous/Isochronous (ACL-U)
- User Synchronous (SCO-S)
- User Extended Synchronous (eSCO-S)

The control logical links LC and ACL-C are used at the link control level and link manager level, respectively. The ACL-U logical link is used to carry either asynchronous or isochronous user information. The SCO-S, and eSCO-S logical links are used to carry synchronous user information. The LC logical link is carried in the packet header, all other logical links are carried in the packet payload. The ACL-C and ACL-U logical links are indicated in the logical link ID, LLID, field in the payload header. The SCO-S and eSCO-S logical links are carried by the synchronous logical transports only; the ACL-U link is normally carried by the ACL logical transport; however, they may also be carried by the data in the DV packet on the SCO logical transport. The ACL-C link may be carried either by the SCO or the ACL logical transport.

5.1 LINK CONTROL LOGICAL LINK (LC)

The LC control logical link shall be mapped onto the packet header. This logical link carries low level link control information like ARQ, flow control, and payload characterization. The LC logical link is carried in every packet except in the **ID** packet which does not have packet header.

5.2 ACL CONTROL LOGICAL LINK (ACL-C)

The ACL-C logical link shall carry control information exchanged between the link managers of the master and the slave(s). The ACL-C logical link shall use DM1 packets. The ACL-C logical link is indicated by the LLID code 11 in the payload header.

5.3 USER ASYNCHRONOUS/ISOCHRONOUS LOGICAL LINK (ACL-U)

The ACL-U logical link shall carry L2CAP asynchronous and isochronous user data. These messages may be transmitted in one or more baseband packets. For fragmented messages, the start packet shall use an LLID code of 10 in the payload header. Remaining continuation packets shall use LLID code 01. If there is no fragmentation, all packets shall use the LLID start code 10.

5.3.1 Pausing the ACL-U logical link

When paused by LM, the Link Controller transmits the current packet with ACL-U information, if any, until an ACK is received or, optionally, until an explicit NACK is received. While the ACL-U logical link is paused, the Link Controller shall not transmit any packets with ACL-U logical link information.

If the ACL-U was paused after an ACK, the next sequence number shall be used on the next packet. If the ACL-U was paused after a NAK, the same sequence number shall be used on the next packet and the un-acknowledged packet shall be transmitted once the ACL-U logical link is un-paused.

When the ACL-U logical link is un-paused by LM, the Link Controller may resume transmitting packets with ACL-U information.

5.4 USER SYNCHRONOUS DATA LOGICAL LINK (SCO-S)

The SCO-S logical link carries transparent synchronous user data. This logical link is carried over the synchronous logical transport SCO.

5.5 USER EXTENDED SYNCHRONOUS DATA LOGICAL LINK (eSCO-S)

The eSCO-S logical link also carries transparent synchronous user data. This logical link is carried over the extended synchronous logical transport eSCO.

5.6 LOGICAL LINK PRIORITIES

The ACL-C logical link shall have a higher priority than the ACL-U logical link when scheduling traffic on the shared ACL logical transport, except in the case when retransmissions of unacknowledged ACL packets shall be given priority over traffic on the ACL-C logical link. The ACL-C logical link should also have priority over traffic on the SCO-S and eSCO-S logical links but opportunities for interleaving the logical links should be taken.

6 PACKETS

Bluetooth devices shall use the packets as defined in the following sections.

6.1 GENERAL FORMAT

6.1.1 Basic Rate

The general packet format of Basic Rate packets is shown in [Figure 6.1 on page 109](#). Each packet consists of 3 entities: the access code, the header, and the payload. In the figure, the number of bits per entity is indicated.

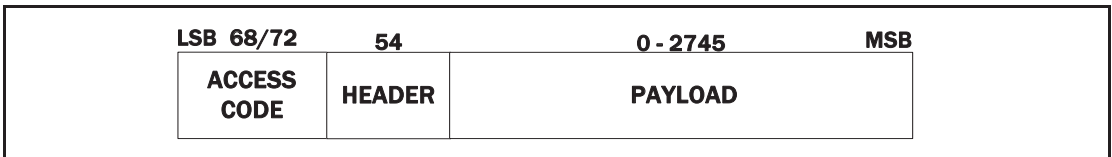


Figure 6.1: General Basic Rate packet format.

The access code is 72 or 68 bits and the header is 54 bits. The payload ranges from zero to a maximum of 2745 bits. Different packet types have been defined. Packet may consist of:

- the shortened access code only (see ID packet on page 116)
- the access code and the packet header
- the access code, the packet header and the payload.

6.1.2 Enhanced Data Rate

The general format of Enhanced Data Rate packets is shown in General enhanced data rate packet format. The access code and packet header are identical in format and modulation to Basic Rate packets. Enhanced Data Rate packets have a guard time and synchronization sequence following the packet header. Following the payload are two trailer symbols. The guard time, synchronization sequence and trailer are defined in section 6.6.

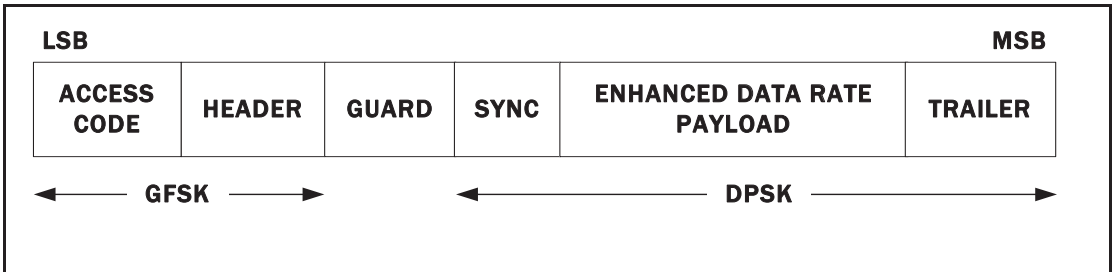


Figure 6.2: General enhanced data rate packet format

6.2 BIT ORDERING

The bit ordering when defining packets and messages in the *Baseband Specification*, follows the *Little Endian* format. The following rules apply:

- The *least significant bit* (LSB) corresponds to b_0 ;
- The LSB is the first bit sent over the air;
- In illustrations, the LSB is shown on the left side;

Furthermore, data fields generated internally at baseband level, such as the packet header fields and payload header length, shall be transmitted with the LSB first. For instance, a 3-bit parameter $X=3$ is sent as:

$$b_0b_1b_2 = 110$$

over the air where 1 is sent first and 0 is sent last.

6.3 ACCESS CODE

Every packet starts with an access code. If a packet header follows, the access code is 72 bits long, otherwise the access code is 68 bits long and is known as a shortened access code. The shortened access code does not contain a trailer. This access code is used for synchronization, DC offset compensation and identification. The access code identifies all packets exchanged on a physical channel: all packets sent in the same physical channel are preceded by the same access code. In the receiver of the device, a sliding correlator correlates against the access code and triggers when a threshold is exceeded. This trigger signal is used to determine the receive timing.

The shortened access code is used in paging, inquiry, and park. In this case, the access code itself is used as a signalling message and neither a header nor a payload is present.

The access code consists of a preamble, a sync word, and possibly a trailer, see [Figure 6.3 on page 111](#). For details see [Section 6.3.1 on page 111](#).

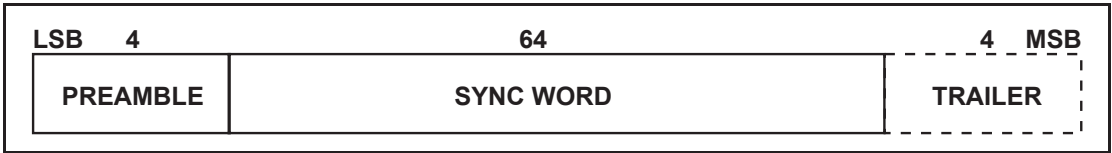


Figure 6.3: Access code format

6.3.1 Access code types

The different access code types use different Lower Address Parts (LAPs) to construct the sync word. The LAP field of the BD_ADDR is explained in [Section 1.2 on page 66](#). A summary of the different access code types is in [Table 6.1 on page 111](#).

| Code type | LAP | Code length | Comments |
|-----------|--------------|--------------------|---|
| CAC | Master | 72 | See also Section 1.3 on page 67 |
| DAC | Paged device | 68/72 ¹ | |
| GIAC | Reserved | 68/72* | |
| DIAC | Dedicated | 68/72* | |

Table 6.1: Summary of access code types.

1. length 72 is only used in combination with FHS packets

The CAC consists of a **preamble**, **sync word**, and **trailer** and its total length is 72 bits. When used as self-contained messages without a header, the DAC and IAC do not include the trailer bits and are of length 68 bits.



6.3.2 Preamble

The preamble is a fixed zero-one pattern of 4 symbols used to facilitate DC compensation. The sequence is either 1010 or 0101, depending on whether the LSB of the following sync word is 1 or 0, respectively. The preamble is shown in [Figure 6.4 on page 112](#).

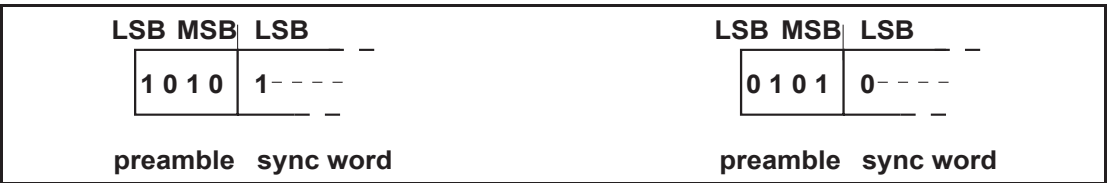


Figure 6.4: Preamble

6.3.3 Sync word

The sync word is a 64-bit code word derived from a 24 bit address (LAP); for the CAC the master’s LAP is used; for the GIAC and the DIAC, reserved, dedicated LAPs are used; for the DAC, the slave LAP is used. The construction guarantees large Hamming distance between sync words based on different LAPs. In addition, the good auto correlation properties of the sync word improve timing acquisition.

6.3.3.1 Synchronization word definition

The sync words are based on a (64,30) expurgated block code with an overlay (bit-wise XOR) of a 64 bit full length pseudo-random noise (PN) sequence. The expurgated code guarantees large Hamming distance ($d_{min} = 14$) between sync words based on different addresses. The PN sequence improves the auto correlation properties of the access code. The following steps describe how the sync word shall be generated:

- 1. Generate information sequence;
- 2. XOR this with the “information covering” part of the PN overlay sequence;
- 3. Generate the codeword;
- 4. XOR the codeword with all 64 bits of the PN overlay sequence;

The information sequence is generated by appending 6 bits to the 24 bit LAP (step 1). The appended bits are 001101 if the MSB of the LAP equals 0. If the MSB of the LAP is 1 the appended bits are 110010. The LAP MSB together with the appended bits constitute a length-seven Barker sequence. The purpose of including a Barker sequence is to further improve the auto correlation properties. In step 2 the information is pre-scrambled by XORing it with the bits $p_{34} \dots p_{63}$ of the PN sequence (defined in [section 6.3.3.2 on page 115](#)). After generating the codeword (step 3), the complete PN sequence is XORed to the



codeword (step 4). This step de-scrambles the information part of the codeword. At the same time the parity bits of the codeword are scrambled. Consequently, the original LAP and Barker sequence are ensured a role as a part of the access code sync word, and the cyclic properties of the underlying code is removed. The principle is depicted in [Figure 6.5 on page 113](#)

In the following discussion, binary sequences will be denoted by their corresponding D-transform (in which D^i represents a delay of i time units). Let $p'(D) = p'_0 + p'_1D + \dots + p'_{62}D^{62}$ be the 63 bit PN sequence, where p'_0 is the first bit (LSB) leaving the PRNG (see [Figure 6.6 on page 115](#)), and, p'_{62} is the last bit (MSB). To obtain 64 bits, an extra zero is appended at the *end* of this sequence (thus, $p'(D)$ is unchanged). For notational convenience, the reciprocal of this extended polynomial, $p(D) = D^{63}p'(1/D)$, will be used in the following discussion. This is the sequence $p'(D)$ in reverse order. We denote the 24 bit lower address part (LAP) of the Bluetooth device address by $a(D) = a_0 + a_1D + \dots + a_{23}D^{23}$ (a_0 is the LSB of the Bluetooth device address).

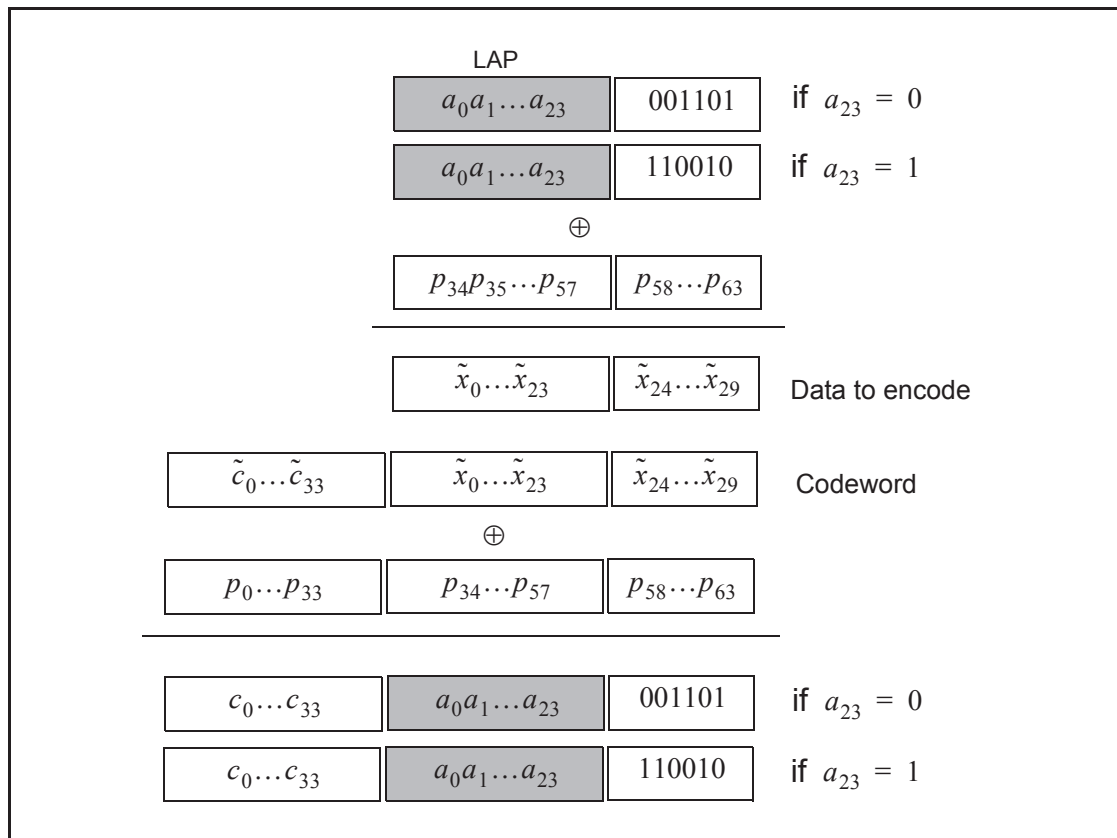


Figure 6.5: Construction of the sync word.

The (64,30) block code generator polynomial is denoted $g(D) = (1 + D)g'(D)$, where $g'(D)$ is the generator polynomial 157464165547 (octal notation) of a primitive binary (63,30) BCH code. Thus, in octal notation $g(D)$ is



$$g(D) = 260534236651, \quad (\text{EQ 8})$$

the left-most bit corresponds to the high-order (g_{34}) coefficient. The DC-free four bit sequences 0101 and 1010 can be written

$$\begin{cases} F_0(D) = D + D^3, \\ F_1(D) = 1 + D^2, \end{cases} \quad (\text{EQ 9})$$

respectively. Furthermore,

$$\begin{cases} B_0(D) = D^2 + D^3 + D^5, \\ B_1(D) = 1 + D + D^4, \end{cases} \quad (\text{EQ 10})$$

which are used to create the length seven Barker sequences. Then, the access code shall be generated by the following procedure:

1. Format the 30 information bits to encode:

$$x(D) = a(D) + D^{24}B_{a_{23}}(D).$$

2. Add the information covering part of the PN overlay sequence:

$$\tilde{x}(D) = x(D) + p_{34} + p_{35}D + \dots + p_{63}D^{29}.$$

3. Generate parity bits of the (64,30) expurgated block code:¹

$$\tilde{c}(D) = D^{34}\tilde{x}(D) \bmod g(D).$$

4. Create the codeword:

$$\tilde{s}(D) = D^{34}\tilde{x}(D) + \tilde{c}(D).$$

5. Add the PN sequence:

$$s(D) = \tilde{s}(D) + p(D).$$

6. Append the (DC-free) preamble and trailer:

$$y(D) = F_{c_0}(D) + D^4s(D) + D^{68}F_{a_{23}}(D).$$

1. $x(D) \bmod y(D)$ denotes the remainder when $x(D)$ is divided by $y(D)$.

6.3.3.2 Pseudo-random noise sequence generation

To generate the PN sequence the primitive polynomial $h(D) = 1 + D + D^3 + D^4 + D^6$ shall be used. The LFSR and its starting state are shown in [Figure 6.6 on page 115](#). The PN sequence generated (including the extra terminating zero) becomes (hexadecimal notation) 83848D96BBCC54FC. The LFSR output starts with the left-most bit of this PN sequence. This corresponds to $p'(D)$ of the previous section. Thus, using the reciprocal $p(D)$ as overlay gives the 64 bit sequence:

$$p = 3F2A33DD69B121C1,$$

(EQ 11)

where the left-most bit is $p_0 = 0$ (there are two initial zeros in the binary representation of the hexadecimal digit 3), and $p_{63} = 1$ is the right-most bit.

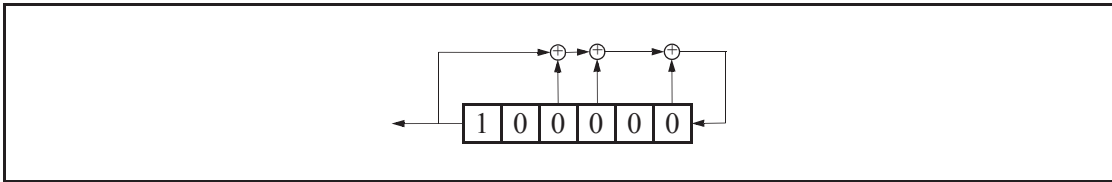


Figure 6.6: LFSR and the starting state to generate $p'(D)$.

6.3.4 Trailer

The trailer is appended to the sync word as soon as the packet header follows the access code. This is typically the case with the CAC, but the trailer is also used in the DAC and IAC when these codes are used in FHS packets exchanged during page response and inquiry response.

The trailer is a fixed zero-one pattern of four symbols. The trailer together with the three MSBs of the syncword form a 7-bit pattern of alternating ones and zeroes which may be used for extended DC compensation. The trailer sequence is either 1010 or 0101 depending on whether the MSB of the sync word is 0 or 1, respectively. The choice of trailer is illustrated in [Figure 6.7 on page 115](#).



Figure 6.7: Trailer in CAC when MSB of sync word is 0 (a), and when MSB of sync word is 1 (b).



6.4 PACKET HEADER

The header contains link control (LC) information and consists of 6 fields:

- LT_ADDR: 3- bit logical transport address
- TYPE: 4-bit type code
- FLOW: 1-bit flow control
- ARQN: 1-bit acknowledge indication
- SEQN: 1-bit sequence number
- HEC: 8-bit header error check

The total header, including the HEC, consists of 18 bits, see [Figure 6.8 on page 116](#), and is encoded with a rate 1/3 FEC (not shown but described in [Section 7.4 on page 142](#)) resulting in a 54-bit header. The LT_ADDR and TYPE fields shall be sent LSB first.

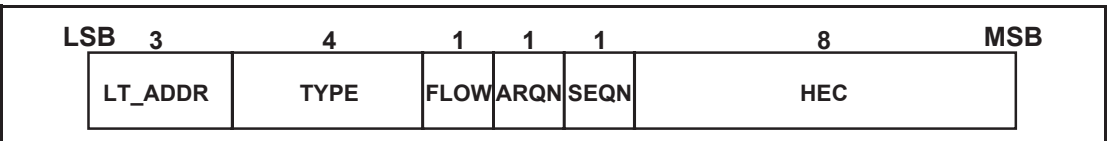


Figure 6.8: Header format.

6.4.1 LT_ADDR

The 3-bit LT_ADDR field contains the logical transport address for the packet (see [Section 4.2 on page 97](#)). This field indicates the destination slave for a packet in a master-to-slave transmission slot and indicates the source slave for a slave-to-master transmission slot.

6.4.2 TYPE

Sixteen different types of packets can be distinguished. The 4-bit TYPE code specifies which packet type is used. The interpretation of the TYPE code depends on the logical transport address in the packet. First, it shall be determined whether the packet is sent on an SCO logical transport, an eSCO logical transport, or an ACL logical transport. Second, it shall be determined whether Enhanced Data Rate has been enabled for the logical transport (ACL or eSCO) indicated by LT_ADDR. It can then be determined which type of SCO packet, eSCO packet, or ACL packet has been received. The TYPE code determines how many slots the current packet will occupy (see the slot occupancy column in [Table 6.2 on page 119](#)). This allows the non-addressed receivers to refrain from listening to the channel for the duration of the remaining slots. In [Section 6.5 on page 118](#), each packet type is described in more detail.



6.4.3 FLOW

The FLOW bit is used for flow control of packets over the ACL logical transport. When the RX buffer for the ACL logical transport in the recipient is full, a STOP indication (FLOW=0) shall be returned to stop the other device from transmitting data temporarily. The STOP signal only affects ACL packets. Packets including only link control information (ID, POLL, and NULL packets), SCO packets or eSCO packets can still be received. When the RX buffer can accept data, a GO indication (FLOW=1) shall be returned. When no packet is received, or the received header is in error, a GO shall be assumed implicitly. In this case, the slave can receive a new packet with CRC although its RX buffer is still not emptied. The slave shall then return a NAK in response to this packet even if the packet passed the CRC check.

The FLOW bit is not used on the eSCO logical transport or the ACL-C logical link and shall be set to one on transmission and ignored upon receipt.

6.4.4 ARQN

The 1-bit acknowledgment indication ARQN is used to inform the source of a successful transfer of payload data with CRC, and can be positive acknowledge ACK or negative acknowledge NAK. See [Section 7.6 on page 144](#) for initialization and usage of this bit.

6.4.5 SEQN

The SEQN bit provides a sequential numbering scheme to order the data packet stream. See [section 7.6.2 on page 147](#) for initialization and usage of the SEQN bit. For broadcast packets, a modified sequencing method is used, see [Section 7.6.5 on page 150](#).

6.4.6 HEC

Each header has a header-error-check to check the header integrity. The HEC is an 8-bit word (generation of the HEC is specified in [Section 7.1.1 on page 138](#)). Before generating the HEC, the HEC generator is initialized with an 8-bit value. For FHS packets sent in **master response** substate, the slave upper address part (UAP) shall be used. For FHS packets sent in **inquiry response**, the default check initialization (DCI, see [Section 1.2.1 on page 66](#)) shall be used. In all other cases, the UAP of the master device shall be used.

After the initialization, a HEC shall be calculated for the 10 header bits. Before checking the HEC, the receiver shall initialize the HEC check circuitry with the proper 8-bit UAP (or DCI). If the HEC does not check, the entire packet shall be discarded. More information can be found in [Section 7.1 on page 138](#).

6.5 PACKET TYPES

The packets used on the piconet are related to the logical transports they are used in. Three logical transports with distinct packet types are defined (see [Section 4 on page 97](#)): the SCO logical transport, the eSCO logical transport, and the ACL logical transport. For each of these logical transports, 15 different packet types can be defined.

To indicate the different packets on a logical transport, the 4-bit TYPE code is used. The packet types are divided into four segments. The first segment is reserved for control packets. All control packets occupy a single time slot. The second segment is reserved for packets occupying a single time slot. The third segment is reserved for packets occupying three time slots. The fourth segment is reserved for packets occupying five time slots. The slot occupancy is reflected in the segmentation and can directly be derived from the type code. [Table 6.2 on page 119](#) summarizes the packets defined for the SCO, eSCO, and ACL logical transport types.

All packet types with a payload shall use GFSK modulation unless specified otherwise in the following sections.

ACL logical transports Enhanced Data Rate packet types are explicitly selected via LMP using the *packet_type_table* (ptt) parameter. eSCO Enhanced Data Rate packet types are selected when the eSCO logical transport is established.

| Segment | TYPE code $b_3b_2b_1b_0$ | Slot occupancy | SCO logical transport (1 Mbps) | eSCO logical transport (1 Mbps) | eSCO logical transport (2-3 Mbps) | ACL logical transport (1 Mbps) ptt=0 | ACL logical transport (2-3 Mbps) ptt=1 |
|---------|-----------------------------|----------------|--------------------------------|---------------------------------|-----------------------------------|---|---|
| 1 | 0000 | 1 | NULL | NULL | NULL | NULL | NULL |
| | 0001 | 1 | POLL | POLL | POLL | POLL | POLL |
| | 0010 | 1 | FHS | reserved | reserved | FHS | FHS |
| | 0011 | 1 | DM1 | reserved | reserved | DM1 | DM1 |
| 2 | 0100 | 1 | undefined | undefined | undefined | DH1 | 2-DH1 |
| | 0101 | 1 | HV1 | undefined | undefined | undefined | undefined |
| | 0110 | 1 | HV2 | undefined | 2-EV3 | undefined | undefined |
| | 0111 | 1 | HV3 | EV3 | 3-EV3 | undefined | undefined |
| | 1000 | 1 | DV | undefined | undefined | undefined | 3-DH1 |
| | 1001 | 1 | undefined | undefined | undefined | AUX1 | AUX1 |
| 3 | 1010 | 3 | undefined | undefined | undefined | DM3 | 2-DH3 |
| | 1011 | 3 | undefined | undefined | undefined | DH3 | 3-DH3 |
| | 1100 | 3 | undefined | EV4 | 2-EV5 | undefined | undefined |
| | 1101 | 3 | undefined | EV5 | 3-EV5 | undefined | undefined |
| 4 | 1110 | 5 | undefined | undefined | undefined | DM5 | 2-DH5 |
| | 1111 | 5 | undefined | undefined | undefined | DH5 | 3-DH5 |

Table 6.2: Packets defined for synchronous and asynchronous logical transport types.

6.5.1 Common packet types

There are five common kinds of packets. In addition to the types listed in segment 1 of the previous table, the ID packet is also a common packet type but is not listed in segment 1 because it does not have a packet header.

6.5.1.1 ID packet

The identity or ID packet consists of the device access code (DAC) or inquiry access code (IAC). It has a fixed length of 68 bits. It is a very robust packet since the receiver uses a bit correlator to match the received packet to the known bit sequence of the ID packet.



6.5.1.2 NULL packet

The NULL packet has no payload and consists of the channel access code and packet header only. Its total (fixed) length is 126 bits. The NULL packet may be used to return link information to the source regarding the success of the previous transmission (ARQN), or the status of the RX buffer (FLOW). The NULL packet may not have to be acknowledged.

6.5.1.3 POLL packet

The POLL packet is very similar to the NULL packet. It does not have a payload. In contrast to the NULL packet, it requires a confirmation from the recipient. It is not a part of the ARQ scheme. The POLL packet does not affect the ARQN and SEQN fields. Upon reception of a POLL packet the slave shall respond with a packet even when the slave does not have any information to send unless the slave has scatternet commitments in that timeslot. This return packet is an implicit acknowledgement of the POLL packet. This packet can be used by the master in a piconet to poll the slaves. Slaves shall not transmit the POLL packet.

6.5.1.4 FHS packet

The FHS packet is a special control packet containing, among other things, the Bluetooth device address and the clock of the sender. The payload contains 144 information bits plus a 16-bit CRC code. The payload is coded with a rate 2/3 FEC with a gross payload length of 240 bits.

Figure 6.9 on page 120 illustrates the format and contents of the FHS payload. The payload consists of eleven fields. The FHS packet is used in page master response, inquiry response and in role switch.

The FHS packet contains real-time clock information. This clock information shall be updated before each retransmission. The retransmission of the FHS payload is different than retransmissions of ordinary data payloads where the same payload is used for each retransmission. The FHS packet is used for frequency hop synchronization before the piconet channel has been established, or when an existing piconet changes to a new piconet.

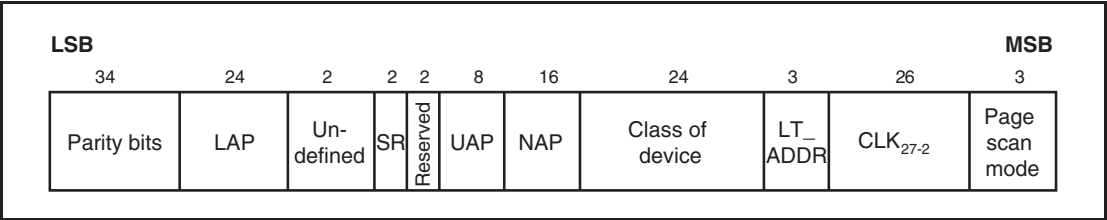


Figure 6.9: Format of the FHS payload.

Each field is described in more detail below:

| | |
|---------------------------|--|
| Parity bits | This 34-bit field contains the parity bits that form the first part of the sync word of the access code of the device that sends the FHS packet. These bits are derived from the LAP as described in Section 1.2 on page 66 . |
| LAP | This 24-bit field shall contain the lower address part of the device that sends the FHS packet. |
| Undefined | This 2-bit field is reserved for future use and shall be set to zero. |
| SR | This 2-bit field is the scan repetition field and indicates the interval between two consecutive page scan windows, see also Table 6.4 and Table 8.1 on page 155 |
| Reserved | This 2-bit field shall be set to 10. |
| UAP | This 8-bit field shall contain the upper address part of the device that sends the FHS packet. |
| NAP | This 16-bit field shall contain the non-significant address part of the device that sends the FHS packet (see also Section 1.2 on page 66 for LAP, UAP, and NAP). |
| Class of device | This 24-bit field shall contain the class of device of the device that sends the FHS packet. The field is defined in Bluetooth Assigned Numbers (https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers). |
| LT_ADDR | This 3-bit field shall contain the logical transport address the recipient shall use if the FHS packet is used at connection setup or role switch. A slave responding to a master or a device responding to an inquiry request message shall include an all-zero LT_ADDR field if it sends the FHS packet. |
| CLK₂₇₋₂ | This 26-bit field shall contain the value of the native clock of the device that sends the FHS packet, sampled at the beginning of the transmission of the access code of this FHS packet. This clock value has a resolution of 1.25ms (two-slot interval). For each new transmission, this field is updated so that it accurately reflects the real-time clock value. |
| Page scan mode | This 3-bit field shall indicate which scan mode is used by default by the sender of the FHS packet. The interpretation of the page scan mode is illustrated in Table 6.5 . |

Table 6.3: Description of the FHS payload

The device sending the FHS shall set the SR bits according to [Table 6.4](#).

| SR bit format b_1b_0 | SR mode |
|------------------------|----------|
| 00 | R0 |
| 01 | R1 |
| 10 | R2 |
| 11 | reserved |

Table 6.4: Contents of SR field

The device sending the FHS shall set the page scan mode bits according to [Table 6.5](#).

| Bit format $b_2b_1b_0$ | Page scan mode |
|------------------------|-------------------------|
| 000 | Mandatory scan mode |
| 001 | Reserved for future use |
| 010 | Reserved for future use |
| 011 | Reserved for future use |
| 100 | Reserved for future use |
| 101 | Reserved for future use |
| 110 | Reserved for future use |
| 111 | Reserved for future use |

Table 6.5: Contents of page scan mode field

The LAP, UAP, and NAP together form the 48-bit Bluetooth Device Address of the device that sends the FHS packet. Using the parity bits and the LAP, the recipient can directly construct the channel access code of the sender of the FHS packet.

When initializing the HEC and CRC for the FHS packet of inquiry response, the UAP shall be the DCI.

6.5.1.5 DM1 packet

DM1 is part of segment 1 in order to support control messages in any logical transport that allows the DM1 packet (see [Table 6.2 on page 119](#)). However, it may also carry regular user data. Since the DM1 packet can be regarded as an ACL packet, it will be discussed in [Section 6.5.4 on page 126](#).

6.5.2 SCO packets

HV and DV packets are used on the synchronous SCO logical transport. The HV packets do not include a CRC and shall not be retransmitted. DV packets include a CRC on the data section, but not on the synchronous data section. The data section of DV packets shall be retransmitted. SCO packets may be routed to the synchronous I/O port. Four packets are allowed on the SCO logical transport: HV1, HV2, HV3 and DV. These packets are typically used for 64kb/s speech transmission but may be used for transparent synchronous data.

6.5.2.1 HV1 packet

The **HV1** packet has 10 information bytes. The bytes are protected with a rate 1/3 FEC. No CRC is present. The payload length is fixed at 240 bits. There is no payload header present.

6.5.2.2 HV2 packet

The **HV2** packet has 20 information bytes. The bytes are protected with a rate 2/3 FEC. No CRC is present. The payload length is fixed at 240 bits. There is no payload header present.

6.5.2.3 HV3 packet

The **HV3** packet has 30 information bytes. The bytes are not protected by FEC. No CRC is present. The payload length is fixed at 240 bits. There is no payload header present.

6.5.2.4 DV packet

The **DV** packet is a combined data - voice packet. The DV packet shall only be used in place of an HV1 packet. The payload is divided into a voice field of 80 bits and a data field containing up to 150 bits, see [Figure 6.10](#). The voice field is not protected by FEC. The data field has between 1 and 10 information bytes (including the 1-byte payload header) and includes a 16-bit CRC. The data field is encoded with a rate 2/3 FEC. Since the **DV** packet has to be sent at regular intervals due to its synchronous contents, it is listed under the SCO packet types. The voice and data fields shall be treated separately. The voice field shall be handled in the same way as normal SCO data and shall never be retransmitted; that is, the voice field is always new. The data field is checked for errors and shall be retransmitted if necessary. When the asynchronous data field in the DV packet has not been acknowledged before the SCO logical transport is terminated, the asynchronous data field shall be retransmitted in a DM1 packet.

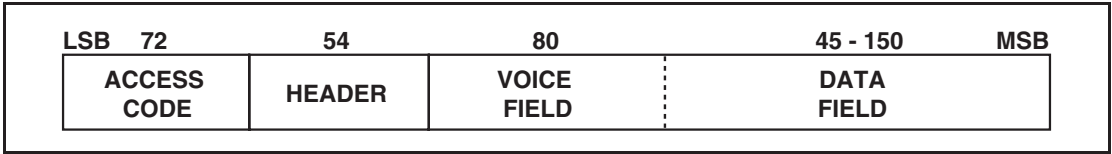


Figure 6.10: DV packet format

6.5.3 eSCO packets

EV packets are used on the synchronous eSCO logical transport. The packets include a CRC and retransmission may be applied if no acknowledgement of proper reception is received within the retransmission window. eSCO packets may be routed to the synchronous I/O port. Three eSCO packet types (EV3, EV4, EV5) are defined for Basic Rate operation and four additional eSCO packet types (2-EV3, 3-EV3, 2-EV5, 3-EV5) for Enhanced Data Rate operation. The eSCO packets may be used for 64kb/s speech transmission as well as transparent data at 64kb/s and other rates.

6.5.3.1 EV3 packet

The **EV3** packet has between 1 and 30 information bytes plus a 16-bit CRC code. The bytes are not protected by FEC. The EV3 packet may cover up to a single time slot. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.

6.5.3.2 EV4 packet

The **EV4** packet has between 1 and 120 information bytes plus a 16-bit CRC code. The EV4 packet may cover up to three time slots. The information plus CRC bits are coded with a rate 2/3 FEC. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.

6.5.3.3 EV5 packet

The **EV5** packet has between 1 and 180 information bytes plus a 16-bit CRC code. The bytes are not protected by FEC. The EV5 packet may cover up to three time slots. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.

6.5.3.4 2-EV3 packet

The **2-EV3** packet is similar to the EV3 packet except that the payload is modulated using $\pi/4$ -DQPSK. It has between 1 and 60 information bytes plus a 16-bit CRC code. The bytes are not protected by FEC. The 2-EV3 packet covers a single time slot. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.



6.5.3.5 2-EV5 packet

The **2-EV5** packet is similar to the EV5 packet except that the payload is modulated using $\pi/4$ -DQPSK. It has between 1 and 360 information bytes plus a 16-bit CRC code. The bytes are not protected by FEC. The 2-EV5 packet may cover up to three time slots. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.

6.5.3.6 3-EV3 packet

The **3-EV3** packet is similar to the EV3 packet except that the payload is modulated using 8DPSK. It has between 1 and 90 information bytes plus a 16-bit CRC code. The bytes are not protected by FEC. The 3-EV3 packet covers a single time slot. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.

6.5.3.7 3-EV5 packet

The **3-EV5** packet is similar to the EV5 packet except that the payload is modulated using 8DPSK. It has between 1 and 540 information bytes plus a 16-bit CRC code. The bytes are not protected by FEC. The 3-EV5 packet may cover up to three time slots. There is no payload header present. The payload length is set during the LMP eSCO setup and remains fixed until the link is removed or re-negotiated.



6.5.4 ACL packets

ACL packets are used on the asynchronous logical transport. The information carried may be user data or control data.

Seven packet types are defined for Basic Rate operation: DM1, DH1, DM3, DH3, DM5, DH5 and AUX1. Six additional packets are defined for Enhanced Data Rate operation: 2-DH1, 3-DH1, 2-DH3, 3-DH3, 2-DH5 and 3-DH5.

6.5.4.1 DM1 packet

The DM1 packet carries data information only. The payload has between 1 and 18 information bytes (including the 1-byte payload header) plus a 16-bit CRC code. The DM1 packet occupies a single time slot. The information plus CRC bits are coded with a rate 2/3 FEC. The payload header in the DM1 packet is 1 byte long, see [Figure 6.12 on page 130](#). The length indicator in the payload header specifies the number of user bytes (excluding payload header and the CRC code).

6.5.4.2 DH1 packet

This packet is similar to the DM1 packet, except that the information in the payload is not FEC encoded. As a result, the DH1 packet has between 1 and 28 information bytes (including the 1-byte payload header) plus a 16-bit CRC code. The DH1 packet occupies a single time slot.

6.5.4.3 DM3 packet

The DM3 packet may occupy up to three time slots. The payload has between 2 and 123 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The information plus CRC bits are coded with a rate 2/3 FEC. The payload header in the DM3 packet is 2 bytes long, see [Figure 6.13 on page 131](#). The length indicator in the payload header specifies the number of user bytes (excluding payload header and the CRC code).

6.5.4.4 DH3 packet

This packet is similar to the DM3 packet, except that the information in the payload is not FEC encoded. As a result, the DH3 packet has between 2 and 185 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The DH3 packet may occupy up to three time slots.

6.5.4.5 DM5 packet

The DM5 packet may occupy up to five time slots. The payload has between 2 and 226 information bytes (including the 2-byte payload header) plus a 16-bit



CRC code. The payload header in the DM5 packet is 2 bytes long. The information plus CRC bits are coded with a rate 2/3 FEC. The length indicator in the payload header specifies the number of user bytes (excluding payload header and the CRC code).

6.5.4.6 DH5 packet

This packet is similar to the DM5 packet, except that the information in the payload is not FEC encoded. As a result, the DH5 packet has between 2 and 341 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The DH5 packet may occupy up to five time slots.

6.5.4.7 AUX1 packet

This packet resembles a DH1 packet but has no CRC code. The AUX1 packet has between 1 and 30 information bytes (including the 1-byte payload header). The AUX1 packet occupies a single time slot. The AUX1 packet shall not be used for the ACL-U or ACL-C logical links. An AUX1 packet may be discarded.

6.5.4.8 2-DH1 packet

This packet is similar to the DH1 packet except that the payload is modulated using $\pi/4$ -DQPSK. The 2-DH1 packet has between 2 and 56 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The 2-DH1 packet occupies a single time slot.

6.5.4.9 2-DH3 packet

This packet is similar to the DH3 packet except that the payload is modulated using $\pi/4$ -DQPSK. The 2-DH3 packet has between 2 and 369 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The 2-DH3 packet may occupy up to three time slots.

6.5.4.10 2-DH5 packet

This packet is similar to the DH5 packet except that the payload is modulated using $\pi/4$ -DQPSK. The 2-DH5 packet has between 2 and 681 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The 2-DH5 packet may occupy up to five time slots.

6.5.4.11 3-DH1 packet

This packet is similar to the DH1 packet except that the payload is modulated using 8DPSK. The 3-DH1 packet has between 2 and 85 information bytes



(including the 2-byte payload header) plus a 16-bit CRC code. The 3-DH1 packet occupies a single time slot.

6.5.4.12 3-DH3 packet

This packet is similar to the DH3 packet except that the payload is modulated using 8DPSK. The 3-DH3 packet has between 2 and 554 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The 3-DH3 packet may occupy up to three time slots.

6.5.4.13 3-DH5 packet

This packet is similar to the DH5 packet except that the payload is modulated using 8DPSK. The 3-DH5 packet has between 2 and 1023 information bytes (including the 2-byte payload header) plus a 16-bit CRC code. The 3-DH5 packet may occupy up to five time slots.

6.6 PAYLOAD FORMAT

In the payload, two fields are distinguished: the synchronous data field and the asynchronous data field. The ACL packets only have the asynchronous data field and the SCO and eSCO packets only have the synchronous data field – with the exception of the DV packets which have both.

6.6.1 Synchronous data field

In SCO, which is only supported in Basic Rate mode, the synchronous data field has a fixed length and consists only of the synchronous data body portion. No payload header is present.

In Basic Rate eSCO, the synchronous data field consists of two segments: a synchronous data body and a CRC code. No payload header is present.

In Enhanced Data Rate eSCO, the synchronous data field consists of five segments: a guard time, a synchronization sequence, a synchronous data body, a CRC code and a trailer. No payload header is present.

1. Enhanced Data Rate Guard Time

For Enhanced Data Rate packets the guard time is defined as the period starting at the end of the last GFSK symbol of the header and ending at the start of the reference symbol of the synchronization sequence. The length of the guard time shall be between 4.75 μ sec and 5.25 μ sec.

2. Enhanced Data Rate Synchronization Sequence

For Enhanced Data Rate packets the symbol timing at the start of the synchronization sequence shall be within $\pm\frac{1}{4}$ μsec of the symbol timing of the last GFSK symbol of the packet header. The length of the synchronization sequence is 11 μsec (11 DPSK symbols) and consists of a reference symbol (with arbitrary phase) followed by ten DPSK symbols.

The phase changes between the DPSK symbols (shown in Synchronization sequence) shall be

$$\{\phi_1, \phi_2, \phi_3, \phi_4, \phi_5, \phi_6, \phi_7, \phi_8, \phi_9, \phi_{10}\} = \{3\pi/4, -3\pi/4, 3\pi/4, -3\pi/4, 3\pi/4, -3\pi/4, -3\pi/4, 3\pi/4, 3\pi/4, 3\pi/4\} \quad (\text{EQ 12})$$

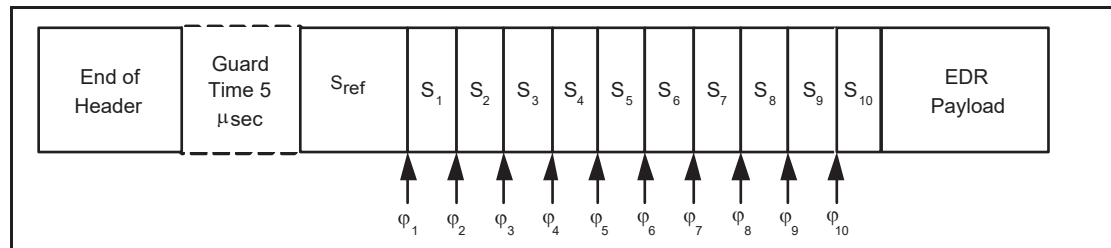


Figure 6.11: Synchronization sequence

S_{ref} is the reference symbol. ϕ_1 is the phase change between the reference symbol and the first DPSK symbol S_1 . ϕ_k is the phase change between the $k-1^{\text{th}}$ symbol S_{k-1} and the k^{th} symbol S_k .

Note: the synchronization sequence may be generated using the modulator by pre-pending the data with bits that generate the synchronization sequence.

For $\pi/4$ -DQPSK, the bit sequence used to generate the synchronization sequence is 0,1,1,1,0,1,1,1,0,1,1,1,1,0,1,0,1,0,1.

For 8DPSK, the bit sequence used to generate the synchronization sequence is 0,1,0,1,1,1,0,1,0,1,1,1,0,1,0,1,1,1,1,0,1,0,0,1,0,0,1,0.

3. Synchronous data body

For HV and DV packets, the synchronous data body length is fixed. For EV packets, the synchronous data body length is negotiated during the LMP eSCO setup. Once negotiated, the synchronous data body length remains constant unless re-negotiated. The synchronous data body length may be different for each direction of the eSCO logical transport.

4. CRC code

The 16-bit CRC in the payload is generated as specified in [Section 7.1 on page 138](#). The 8-bit UAP of the master is used to initialize the CRC generator.

Only the Synchronous data body segment is used to generate the CRC code.



5. Enhanced Data Rate Trailer

For Enhanced Data Rate packets, two trailer symbols shall be added to the end of the payload. The trailer bits shall be all zero, i.e. {00, 00} for the $\pi/4$ -DQPSK and {000, 000} for the 8DPSK.

6.6.2 Asynchronous data field

Basic rate ACL packets have an asynchronous data field consisting of two or three segments: a payload header, a payload body, and possibly a CRC code (the AUX1 packet does not carry a CRC code).

Enhanced Data Rate ACL packets have an asynchronous data field consisting of six segments: a guard time, a synchronization sequence, a payload header, a payload body, a CRC and a trailer.

1. Enhanced Data Rate Guard time

This is the same as defined for the Synchronous data field in section 6.6.1.

2. Enhanced Data Rate Synchronization sequence

This is the same as defined for the Synchronous data field in section 6.6.1.

3. Payload header

The payload header is one or two bytes long. Basic rate packets in segments one and two have a 1-byte payload header; Basic Rate packets in segments three and four and all Enhanced Data Rate packets have a 2-byte payload header. The payload header specifies the logical link (2-bit LLID indication), controls the flow on the logical channels (1-bit FLOW indication), and has a payload length indicator (5 bits and 10 bits for 1-byte and 2-byte payload headers, respectively). In the case of a 2-byte payload header, the length indicator is extended by five bits into the next byte. The remaining three bits of the second byte are reserved for future use and shall be set to zero. The formats of the 1-byte and 2-byte payload headers are shown in [Figure 6.12 on page 130](#) and [Figure 6.13 on page 131](#).

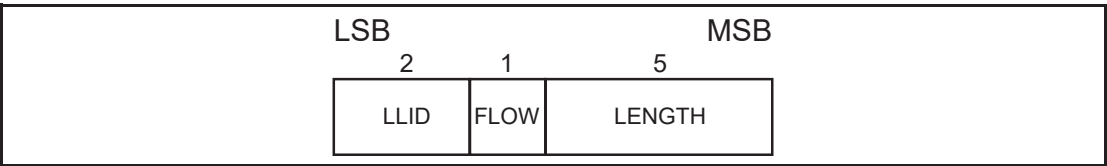


Figure 6.12: Payload header format for Basic Rate single-slot ACL packets.

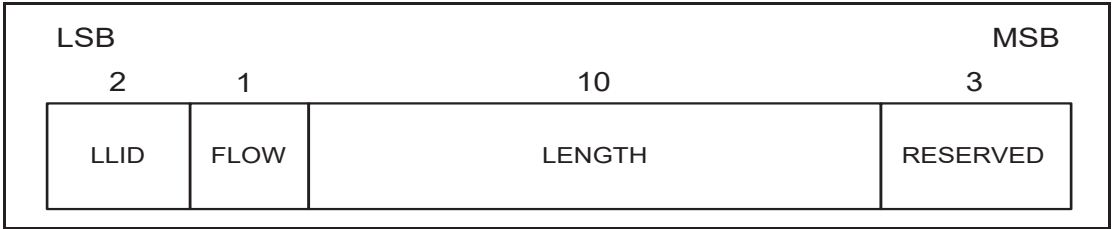


Figure 6.13: Payload header format for multi-slot ACL packets and all EDR ACL packets.

The LLID field shall be transmitted first, the length field last. In [Table 6.6 on page 132](#), more details about the contents of the LLID field are listed.

| LLID code b_1b_0 | Logical Link | Information |
|-----------------------|--------------|---|
| 00 | NA | undefined |
| 01 | ACL-U | Continuation fragment of an L2CAP message |
| 10 | ACL-U | Start of an L2CAP message or no fragmentation |
| 11 | ACL-C | LMP message |

Table 6.6: Logical link LLID field contents

An L2CAP message may be fragmented into several packets. Code 10 shall be used for an ACL-U packet carrying the first fragment of such a message; code 01 shall be used for continuing fragments. If there is no fragmentation, code 10 shall be used for every packet. Code 11 shall be used for LMP messages. Code 00 is reserved for future use.

The flow indicator in the payload is used to control the flow at the L2CAP level. It is used to control the flow per logical link. FLOW=1 means flow-on (GO) and FLOW=0 means flow-off (STOP). After a new connection has been established the flow indicator shall be set to GO. When a device receives a payload header with the flow bit set to STOP, it shall stop the transmission of ACL packets before an additional amount of payload data is sent. This amount is defined as the flow control lag, expressed as a number of bytes. The shorter the flow control lag, the less buffering the other device must dedicate to this function. The flow control lag shall not exceed 1792 bytes (7×256 bytes). In order to allow devices to optimize the selection of packet length and buffer space, the flow control lag of a given implementation shall be provided in the LMP_features_res message.

If a packet containing the payload flow bit of STOP is received, with a valid packet header but bad payload, the payload flow control bit shall be ignored. The baseband ACK contained in the packet header will be received and a further ACL packet may be transmitted. Each occurrence of this situation allows a further ACL packet to be sent in spite of the flow control request being sent via the payload header flow control bit. It is recommended that devices that use the payload header flow bit should ensure that no further ACL packets are sent until the payload flow bit has been correctly received. This can be accomplished by simultaneously turning on the flow bit in the packet header and keeping it on until an ACK is received back (ARQN=1). This will typically be only one round trip time. Since they lack a payload CRC, AUX1 packets should not be used with a payload flow bit of STOP.

The Baseband Resource Manager is responsible for setting and processing the flow bit in the payload header. Real-time flow control shall be carried out at the packet level by the link controller via the flow bit in the packet header (see [Section 6.4.3 on page 117](#)). With the payload flow bit, traffic from the remote end can be controlled. It is allowed to generate and send an ACL packet with payload length zero irrespective of flow status. L2CAP start-fragment and continue-fragment indications (LLID=10 and LLID=01) also retain their meaning when the payload length is equal to zero (i.e. an empty start-fragment shall not be sent in the middle of an on-going ACL-U packet transmission). It is always safe to send an ACL packet with length=0 and LLID=01. The payload flow bit has its own meaning for each logical link (ACL-U or ACL-C), [Table 6.7 on page 133](#). On the ACL-C logical link, no flow control is applied and the payload FLOW bit shall always be set to one.

| LLID code b ₁ b ₀ | Usage and semantics of the ACL payload header FLOW bit |
|--|---|
| 00 | Not defined, reserved for future use. |
| 01 or 10 | Flow control of the ACL-U channel (L2CAP messages) |
| 11 | Always set FLOW=1 on transmission and ignore the bit on reception |

Table 6.7: Use of payload header flow bit on the logical links.

The length indicator shall be set to the number of bytes (i.e. 8-bit words) in the payload excluding the payload header and the CRC code; i.e. the payload body only. With reference to [Figure 6.12](#) and [Figure 6.13](#), the MSB of the length field in a 1-byte header is the last (right-most) bit in the payload header; the MSB of the length field in a 2-byte header is the fourth bit (from left) of the second byte in the payload header.

4. Payload body

The payload body includes the user information and determines the effective user throughput. The length of the payload body is indicated in the length field of the payload header.

5. CRC code generation

The 16-bit cyclic redundancy check code in the payload is generated as specified in [Section 7.1 on page 138](#). Before determining the CRC code, an 8-bit value is used to initialize the CRC generator. For the CRC code in the FHS packets sent in **master response** substate, the UAP of the slave is used. For the FHS packet sent in **inquiry response** substate, the DCI (see [Section 1.2.1 on page 66](#)) is used. For all other packets, the UAP of the master is used.

Only the Payload header and Payload body segments are used to generate the CRC code.

6. Enhanced Data Rate Trailer

This is the same as defined for the Synchronous data field in section 6.6.1.

6.7 PACKET SUMMARY

A summary of the packets and their characteristics is shown in [Table 6.8](#), [Table 6.9](#) and [Table 6.10](#). The payload represents the packet payload excluding FEC, CRC, and payload header.

| Type | Payload (bytes) | FEC | CRC | Symmetric Max. Rate | Asymmetric Max. Rate |
|------|-----------------|-----|-----|---------------------|----------------------|
| ID | na | na | na | na | na |
| NULL | na | na | na | na | na |
| POLL | na | na | na | na | na |
| FHS | 18 | 2/3 | yes | na | na |

Table 6.8: Link control packets

| Type | Payload Header (bytes) | User Payload (bytes) | FEC | CRC | Symmetric Max. Rate (kb/s) | Asymmetric Max. Rate (kb/s) | |
|-------|------------------------|----------------------|-----|-----|----------------------------|-----------------------------|---------|
| | | | | | | Forward | Reverse |
| DM1 | 1 | 0-17 | 2/3 | yes | 108.8 | 108.8 | 108.8 |
| DH1 | 1 | 0-27 | no | yes | 172.8 | 172.8 | 172.8 |
| DM3 | 2 | 0-121 | 2/3 | yes | 258.1 | 387.2 | 54.4 |
| DH3 | 2 | 0-183 | no | yes | 390.4 | 585.6 | 86.4 |
| DM5 | 2 | 0-224 | 2/3 | yes | 286.7 | 477.8 | 36.3 |
| DH5 | 2 | 0-339 | no | yes | 433.9 | 723.2 | 57.6 |
| AUX1 | 1 | 0-29 | no | no | 185.6 | 185.6 | 185.6 |
| 2-DH1 | 2 | 0-54 | no | yes | 345.6 | 345.6 | 345.6 |
| 2-DH3 | 2 | 0-367 | no | yes | 782.9 | 1174.4 | 172.8 |
| 2-DH5 | 2 | 0-679 | no | yes | 869.7 | 1448.5 | 115.2 |
| 3-DH1 | 2 | 0-83 | no | yes | 531.2 | 531.2 | 531.2 |
| 3-DH3 | 2 | 0-552 | no | yes | 1177.6 | 1766.4 | 235.6 |
| 3-DH5 | 2 | 0-1021 | no | yes | 1306.9 | 2178.1 | 177.1 |

Table 6.9: ACL packets

| Type | Payload Header (bytes) | User Payload (bytes) | FEC | CRC | Symmetric Max. Rate (kb/s) |
|-----------------|------------------------|----------------------|-------|-------|----------------------------|
| HV1 | na | 10 | 1/3 | no | 64.0 |
| HV2 | na | 20 | 2/3 | no | 64.0 |
| HV3 | na | 30 | no | no | 64.0 |
| DV ¹ | 1 D | 10+(0-9) D | 2/3 D | yes D | 64.0+57.6 D |
| EV3 | na | 1-30 | No | Yes | 96 |
| EV4 | na | 1-120 | 2/3 | Yes | 192 |
| EV5 | na | 1-180 | No | Yes | 288 |
| 2-EV3 | na | 1-60 | No | Yes | 192 |
| 2-EV5 | na | 1-360 | No | Yes | 576 |
| 3-EV3 | na | 1-90 | No | Yes | 288 |
| 3-EV5 | na | 1-540 | No | Yes | 864 |

Table 6.10: Synchronous packets

1. Items followed by 'D' relate to data field only.



7 BITSTREAM PROCESSING

Bluetooth devices shall use the bitstream processing schemes as defined in the following sections.

Before the payload is sent over the air interface, several bit manipulations are performed in the transmitter to increase reliability and security. An HEC is added to the packet header, the header bits are scrambled with a whitening word, and FEC coding is applied. In the receiver, the inverse processes are carried out. [Figure 7.1 on page 137](#) shows the processes carried out for the packet header both at the transmit and the receive side. All header bit processes are mandatory.

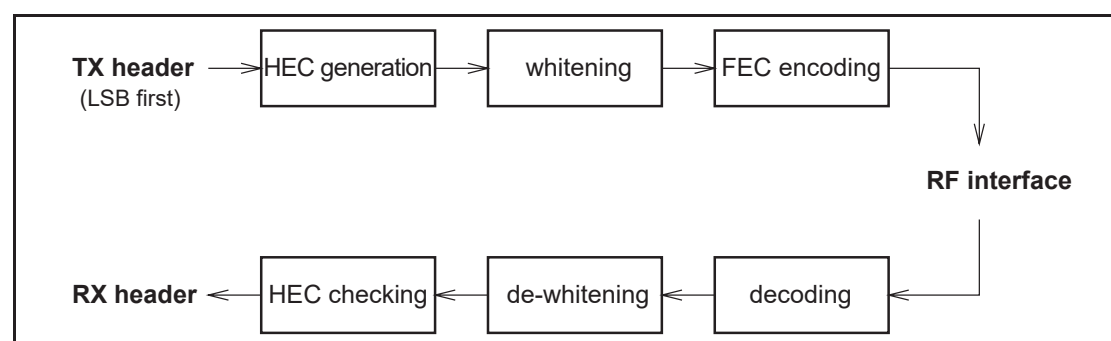


Figure 7.1: Header bit processes.

[Figure 7.2 on page 137](#) shows the processes that may be carried out on the payload. In addition to the processes defined for the packet header, encryption can be applied on the payload. Only whitening and de-whitening, as explained in [Section 7.2 on page 141](#), are mandatory for every payload; all other processes are optional and depend on the packet type (see [Section 6.6 on page 128](#)) and whether encryption is enabled. In [Figure 7.2 on page 137](#), optional processes are indicated by dashed blocks.

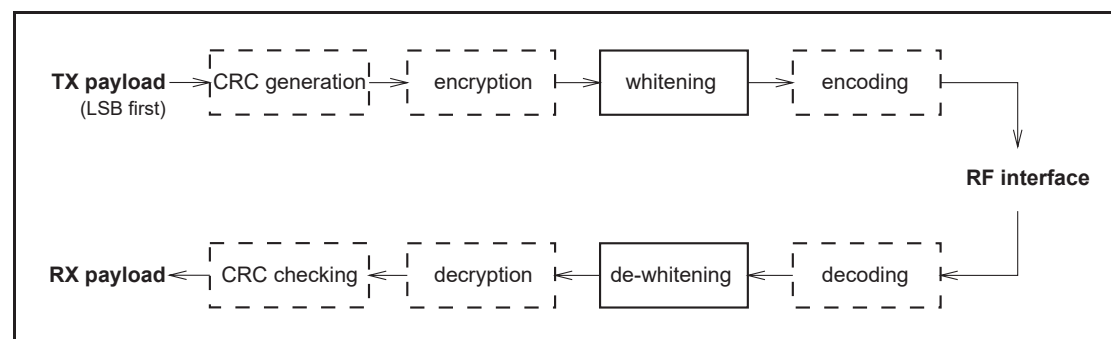


Figure 7.2: Payload bit processes.

7.1 ERROR CHECKING

The packet can be checked for errors or wrong delivery using the channel access code, the HEC in the header, and the CRC in the payload. At packet reception, the access code is checked first. Since the 64-bit sync word in the channel access code is derived from the 24-bit master LAP, this checks if the LAP is correct, and prevents the receiver from accepting a packet of another piconet (provided the LAP field of the master's BD_ADDR is different).

The HEC and CRC computations are normally initialized with the UAP of the master. Even though the access code may be the same for two piconets the different UAP values will typically cause the HEC and CRC to fail. However, there is an exception where no common UAP is available in the transmitter and receiver. This is the case when the HEC and CRC are generated for the FHS packet in **inquiry response** substate. In this case the DCI value shall be used.

The generation and check of the HEC and CRC are summarized in [Figure 7.5 on page 139](#) and [Figure 7.8 on page 140](#). Before calculating the HEC or CRC, the shift registers in the HEC/CRC generators shall be initialized with the 8-bit UAP (or DCI) value. Then the header and payload information shall be shifted into the HEC and CRC generators, respectively (with the LSB first).

7.1.1 HEC generation

The HEC generating LFSR is depicted in [Figure 7.3 on page 138](#). The generator polynomial is

$g(D) = (D + 1)(D^7 + D^4 + D^3 + D^2 + 1) = D^8 + D^7 + D^5 + D^2 + D + 1$. Initially this circuit shall be pre-loaded with the 8-bit UAP such that the LSB of the UAP (denoted UAP_0) goes to the left-most shift register element, and, UAP_7 goes to the right-most element. The initial state of the HEC LFSR is depicted in [Figure 7.4 on page 139](#). Then the data shall be shifted in with the switch S set in position 1. When the last data bit has been clocked into the LFSR, the switch S shall be set in position 2, and, the HEC can be read out from the register. The LFSR bits shall be read out from right to left (i.e., the bit in position 7 is the first to be transmitted, followed by the bit in position 6, etc.).

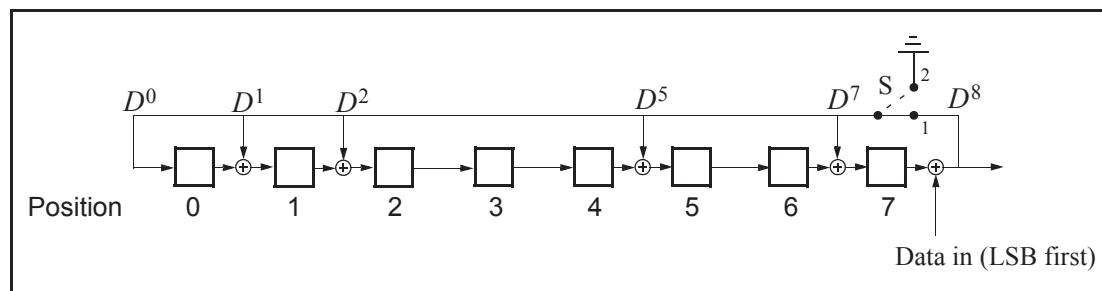


Figure 7.3: The LFSR circuit generating the HEC.

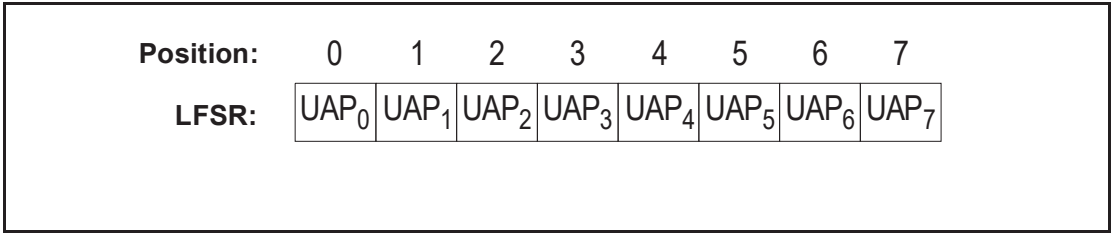


Figure 7.4: Initial state of the HEC generating circuit.

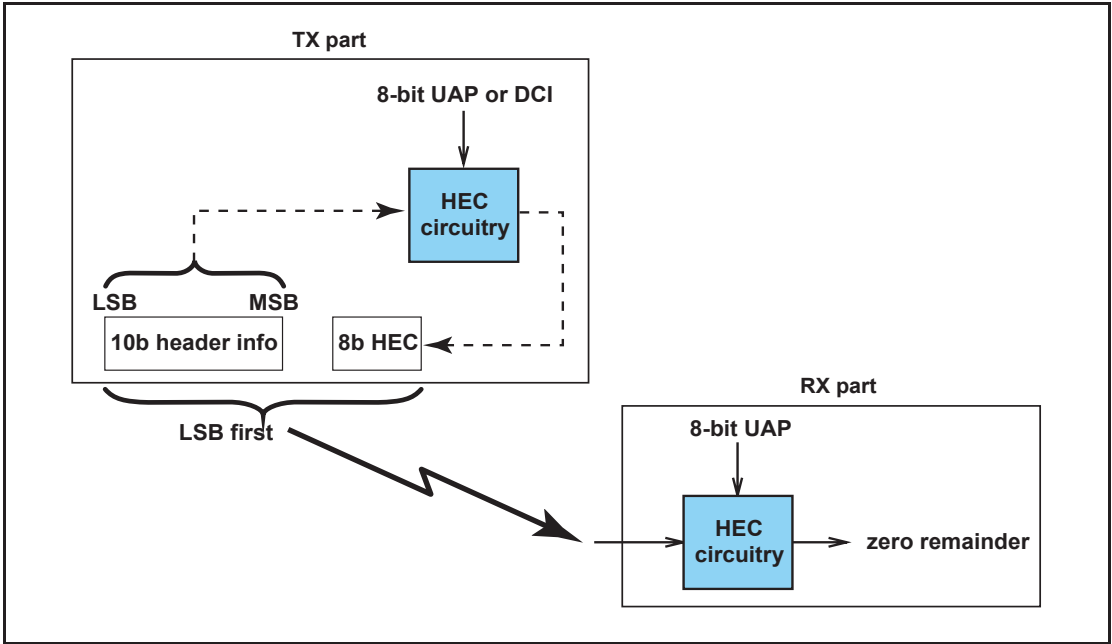


Figure 7.5: HEC generation and checking.

7.1.2 CRC generation

The 16 bit LFSR for the CRC is constructed similarly to the HEC using the CRC-CCITT generator polynomial $g(D) = D^{16} + D^{12} + D^5 + 1$ (i.e. 210041 in octal representation) (see [Figure 7.6 on page 140](#)). For this case, the 8 left-most bits shall be initially loaded with the 8-bit UAP (UAP₀ to the left and UAP₇ to the right) while the 8 right-most bits shall be reset to zero. The initial state of the 16 bit LFSR is specified in [Figure 7.7 on page 140](#). The switch S shall be set in position 1 while the data is shifted in. After the last bit has entered the LFSR, the switch shall be set in position 2, and, the register’s contents shall be transmitted, from right to left (i.e., starting with position 15, then position 14, etc.).

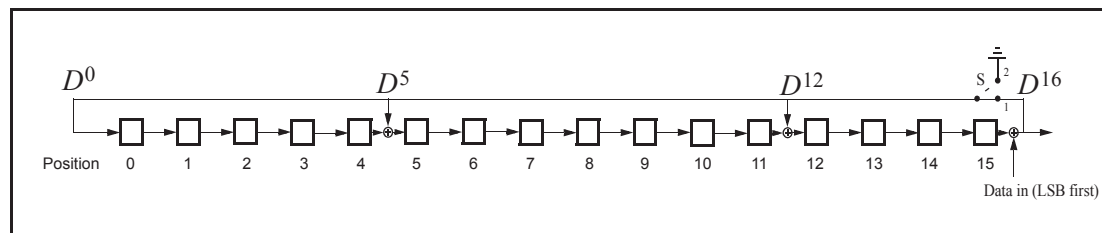


Figure 7.6: The LFSR circuit generating the CRC.

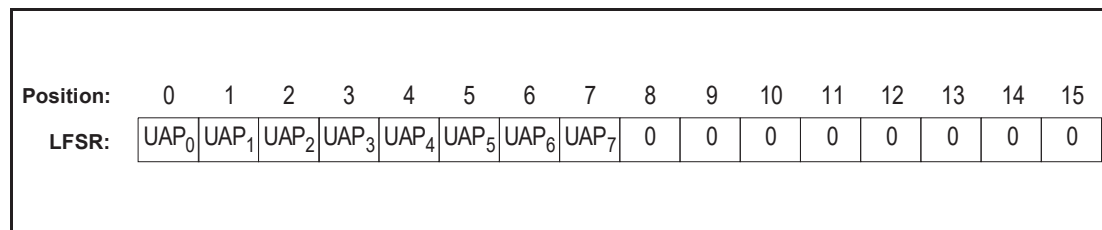


Figure 7.7: Initial state of the CRC generating circuit.

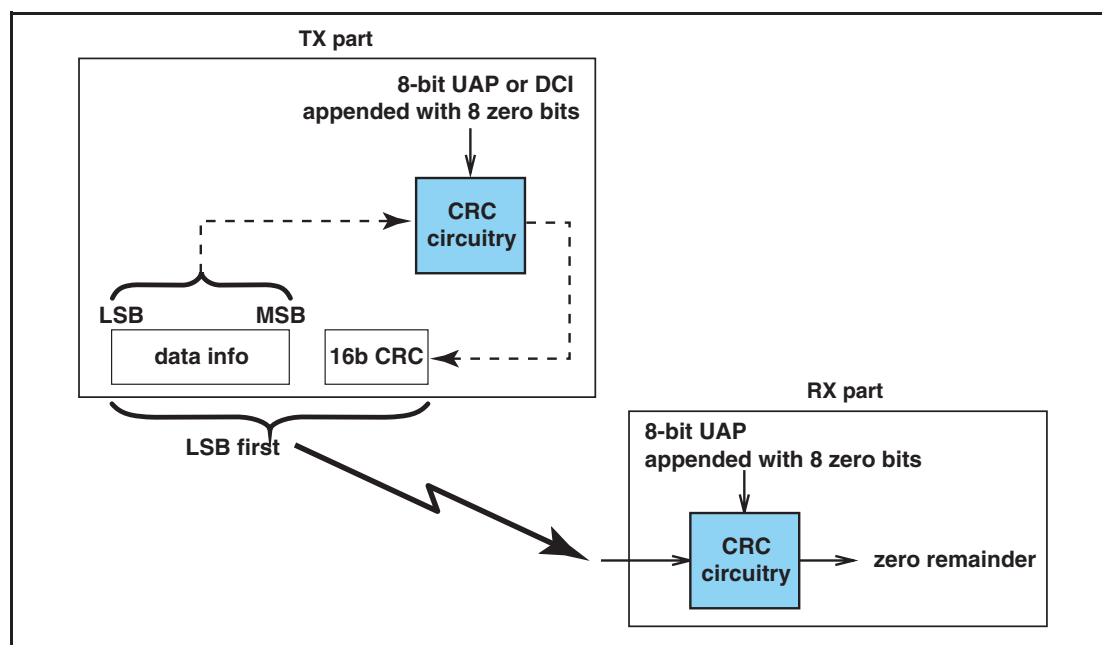


Figure 7.8: CRC generation and checking.

7.2 DATA WHITENING

Before transmission, both the header and the payload shall be scrambled with a data whitening word in order to randomize the data from highly redundant patterns and to minimize DC bias in the packet. The scrambling shall be performed prior to the FEC encoding.

At the receiver, the received data shall be descrambled using the same whitening word generated in the recipient. The descrambling shall be performed after FEC decoding.

The whitening word is generated with the polynomial $g(D) = D^7 + D^4 + 1$ (i.e., 221 in octal representation) and shall be subsequently XORed with the header and the payload. The whitening word is generated with the linear feedback shift register shown in [Figure 7.9 on page 141](#). Before each transmission, the shift register shall be initialized with a portion of the master Bluetooth clock, CLK_{6-1} , extended with an MSB of value one. This initialization shall be carried out with CLK_1 written to position 0, CLK_2 written to position 1, etc. An exception is the FHS packet sent during page response or inquiry, where initialization of the whitening register shall be carried out differently. Instead of the master clock, the X-input used in the **inquiry** or **page response** (depending on current state) routine shall be used, see [Table 2.2](#). The 5-bit value shall be extended with two MSBs of value 1. During register initialization, the LSB of X (i.e., X_0) shall be written to position 0, X_1 shall be written to position 1, etc.

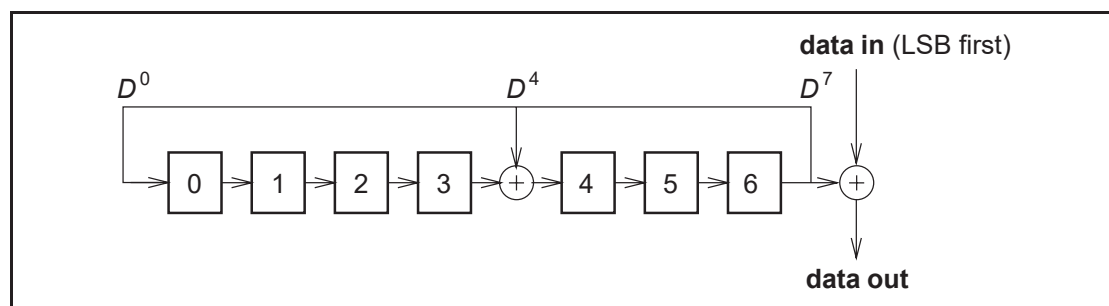


Figure 7.9: Data whitening LFSR.

After initialization, the packet header and the payload (including the CRC) are whitened. The payload whitening shall continue from the state the whitening LFSR had at the end of HEC. There shall be no re-initialization of the shift register between packet header and payload. The first bit of the “data in” sequence shall be the LSB of the packet header.

For Enhanced Data Rate packets, whitening shall not be applied to the guard, synchronization and trailer portions of the Enhanced Data Rate packets. During the periods where whitening is not applied the LFSR shall be paused.



7.3 ERROR CORRECTION

There are three error correction schemes defined for Bluetooth:

- 1/3 rate FEC
- 2/3 rate FEC
- ARQ scheme for the data

The purpose of the FEC scheme on the data payload is to reduce the number of retransmissions. However, in a reasonable error-free environment, FEC gives unnecessary overhead that reduces the throughput. Therefore, the packet definitions given in [Section 6 on page 109](#) have been kept flexible to use FEC in the payload or not, resulting in the **DM** and **DH** packets for the ACL logical transport, **HV** packets for the SCO logical transport, and **EV** packets for the eSCO logical transport. The packet header is always protected by a 1/3 rate FEC since it contains valuable link information and is designed to withstand more bit errors.

Correction measures to mask errors in the voice decoder are not included in this section. This matter is discussed in [Section 9.3 on page 198](#).

7.4 FEC CODE: RATE 1/3

A simple 3-times repetition FEC code is used for the header. The repetition code is implemented by repeating each bit three times, see the illustration in [Figure 7.10 on page 142](#). The 3-times repetition code is used for the entire header, as well as for the synchronous data field in the **HV1** packet.

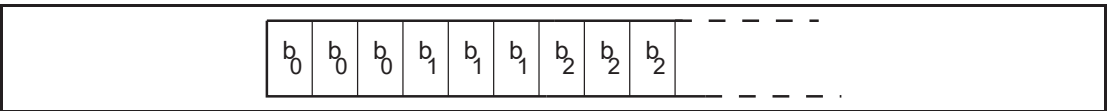


Figure 7.10: Bit-repetition encoding scheme.

7.5 FEC CODE: RATE 2/3

The other FEC scheme is a (15,10) shortened Hamming code. The generator polynomial is $g(D) = (D + 1)(D^4 + D + 1)$. This corresponds to 65 in octal notation. The LFSR generating this code is depicted in [Figure 7.11 on page 143](#). Initially all register elements are set to zero. The 10 information bits are sequentially fed into the LFSR with the switches S1 and S2 set in position 1. Then, after the final input bit, the switches S1 and S2 are set in position 2, and the five parity bits are shifted out. The parity bits are appended to the information bits. Subsequently, each block of 10 information bits is encoded into a 15 bit codeword. This code can correct all single errors and detect all double errors in each codeword. This 2/3 rate FEC is used in the **DM** packets, in the data field of the **DV** packet, in the **FHS** packet, in the **HV2** packet, and in the **EV4** packet. Since the encoder operates with information segments of length 10, tail bits with value zero shall be appended after the CRC bits to bring the total number of bits equal to a multiple of 10. The number of tail bits to append shall be the least possible that achieves this (i.e., in the interval 0...9). These tail bits are not included in the payload length indicator for ACL packets or in the payload length field of the eSCO setup LMP command.

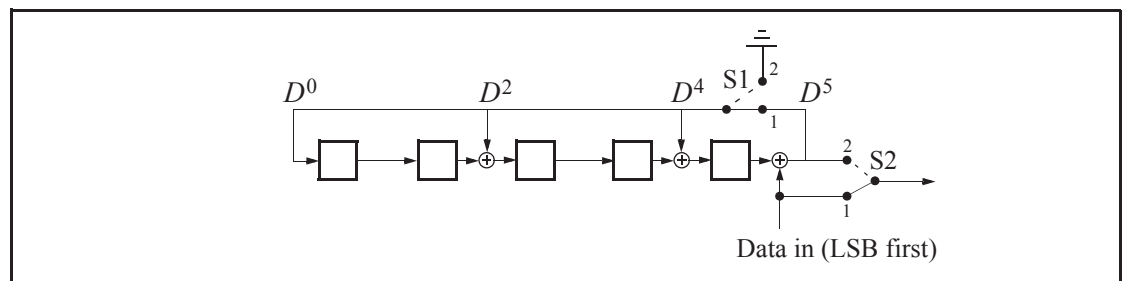


Figure 7.11: LFSR generating the (15,10) shortened Hamming code.

7.6 ARQ SCHEME

With an automatic repeat request scheme, **DM**, **DH** the data field of **DV** packets, and **EV** packets shall be transmitted until acknowledgement of a successful reception is returned by the destination (or timeout is exceeded). The acknowledgement information shall be included in the header of the return packet. The ARQ scheme is only used on the payload in the packet and only on packets that have a CRC. The packet header and the synchronous data payload of HV and DV packets are not protected by the ARQ scheme.

7.6.1 Unnumbered ARQ

Bluetooth uses a fast, unnumbered acknowledgment scheme. An ACK (ARQN=1) or a NAK (ARQN=0) is returned in response to the receipt of previously received packet. The slave shall respond in the slave-to-master slot directly following the master-to-slave slot unless the slave has scatternet commitments in that timeslot; the master shall respond at the next event addressing the same slave (the master may have addressed other slaves between the last received packet from the considered slave and the master response to this packet). For a packet reception to be successful, at least the HEC must pass. In addition, the CRC must pass if present.

In the first POLL packet at the start of a new connection (as a result of a page, page scan, role switch or unpair) the master shall initialize the ARQN bit to NAK. The response packet sent by the slave shall also have the ARQN bit set to NAK. The subsequent packets shall use the following rules. The initial value of the master's eSCO ARQN at link set-up shall be NAK.

The ARQ bit shall only be affected by data packets containing CRC and empty slots. As shown in [Figure 7.12 on page 145](#), upon successful reception of a CRC packet, the ARQN bit shall be set to ACK. If, in any receive slot in the slave, or, in a receive slot in the master following transmission of a packet, one of these events applies:

1. no access code is detected,
2. the HEC fails,
3. the CRC fails,

then the ARQN bit shall be set to NAK. In eSCO the ARQN bit may be set to ACK even when the CRC on an EV packet has failed thus enabling delivery of erroneous packets.

Packets that have correct HEC but that are addressed to other slaves, or packets other than DH, DM, DV or EV packets, shall not affect the ARQN bit, except as noted in [Section 7.6.2.2 on page 148](#). In these cases the ARQN bit shall be left as it was prior to reception of the packet. For ACL packets, if a CRC packet with a correct header has the same SEQN as the previously received CRC packet, the ARQN bit shall be set to ACK and the payload shall be ignored without checking the CRC. For eSCO packets, the SEQN shall not be used

when determining the ARQN. If an eSCO packet has been received successfully within the eSCO window subsequent receptions within the eSCO window shall be ignored. At the end of the eSCO window, the master's ARQN shall be retained for the first master-to-slave transmission in the next eSCO window.

The ARQ bit in the FHS packet is not meaningful. Contents of the ARQN bit in the FHS packet shall not be checked.

Broadcast packets shall be checked on errors using the CRC, but no ARQ scheme shall be applied. Broadcast packets shall never be acknowledged.

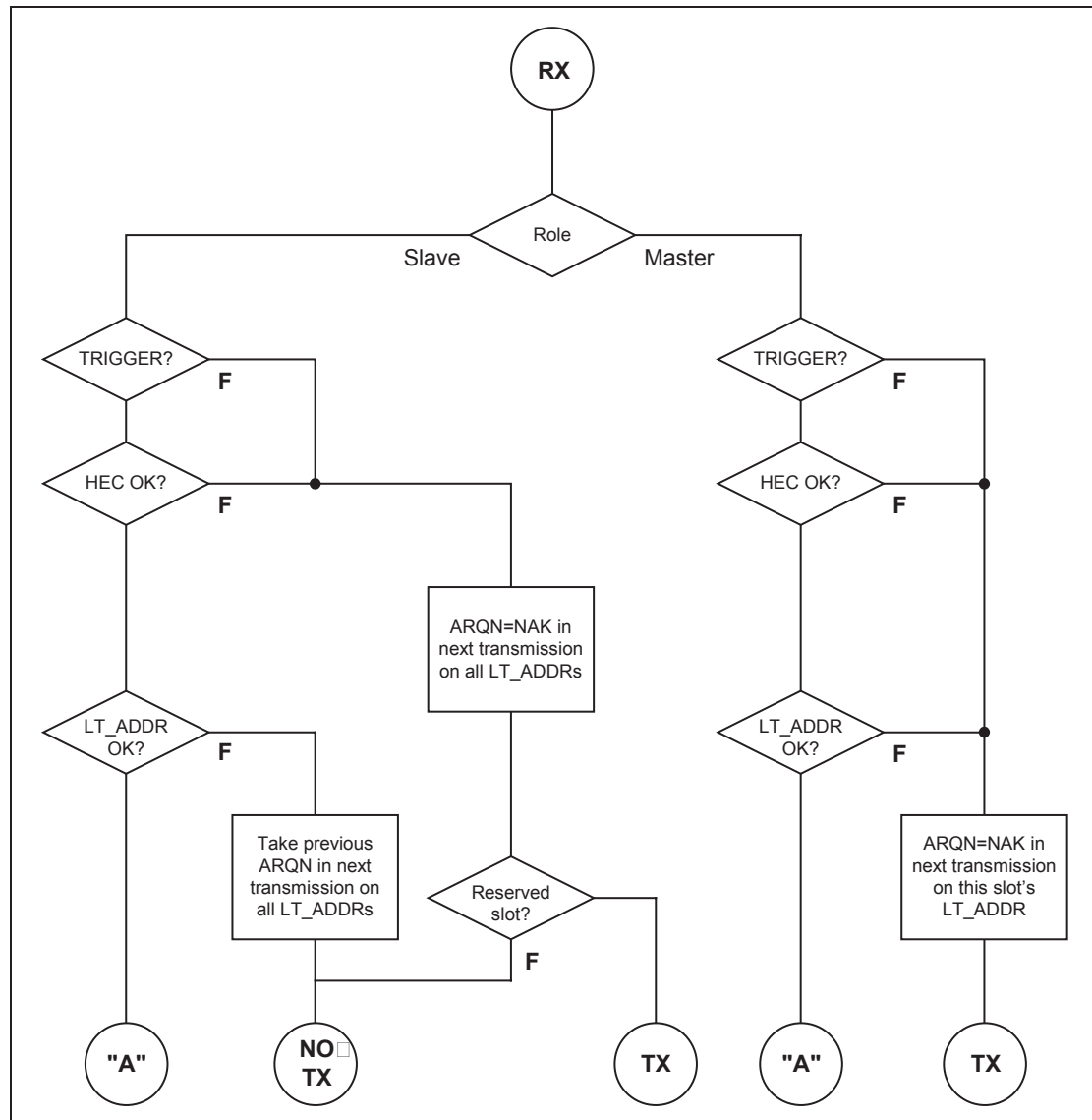


Figure 7.12: Stage 1 of the receive protocol for determining the ARQN bit.

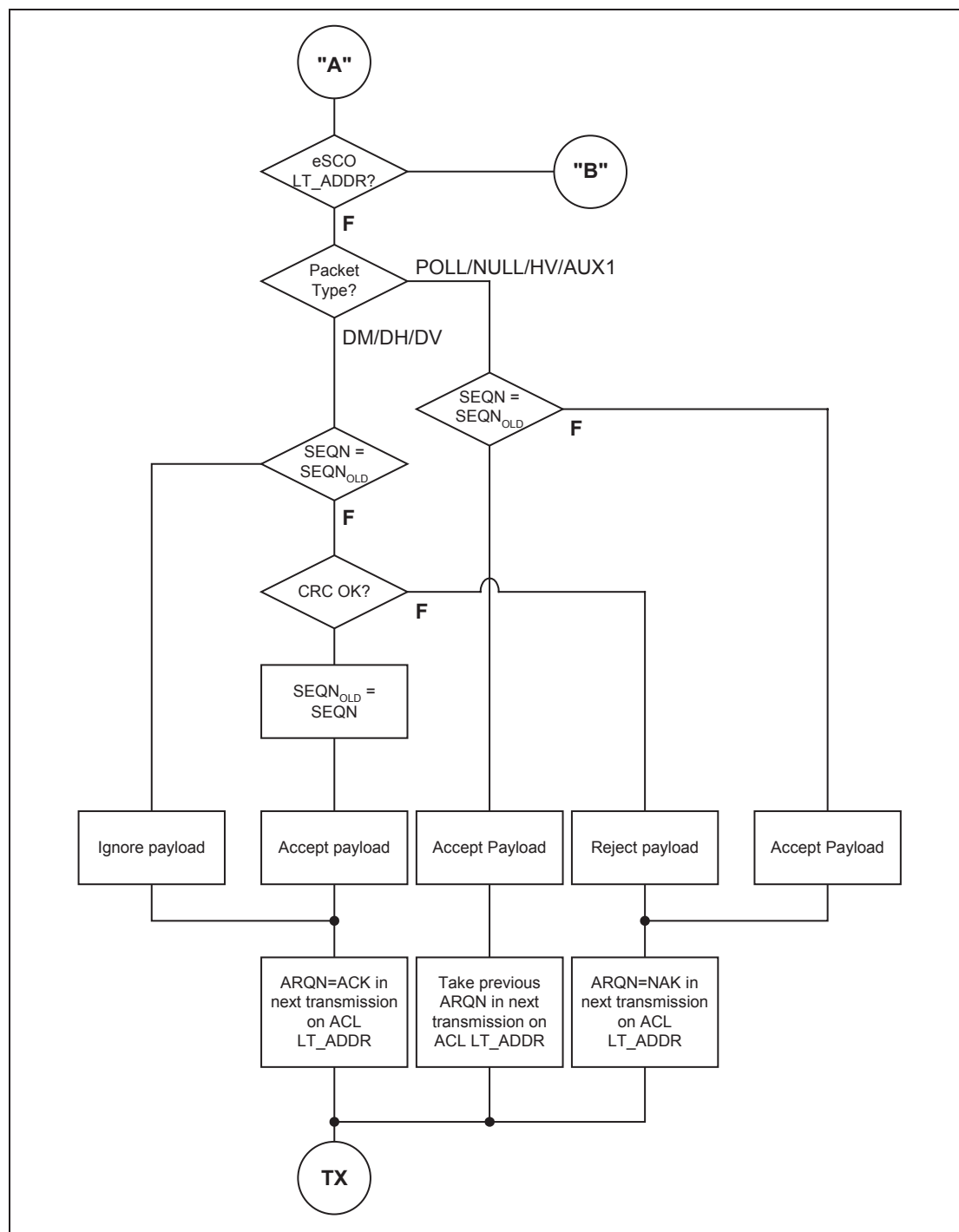


Figure 7.13: Stage 2 (ACL) of the receive protocol for determining the ARQN bit.

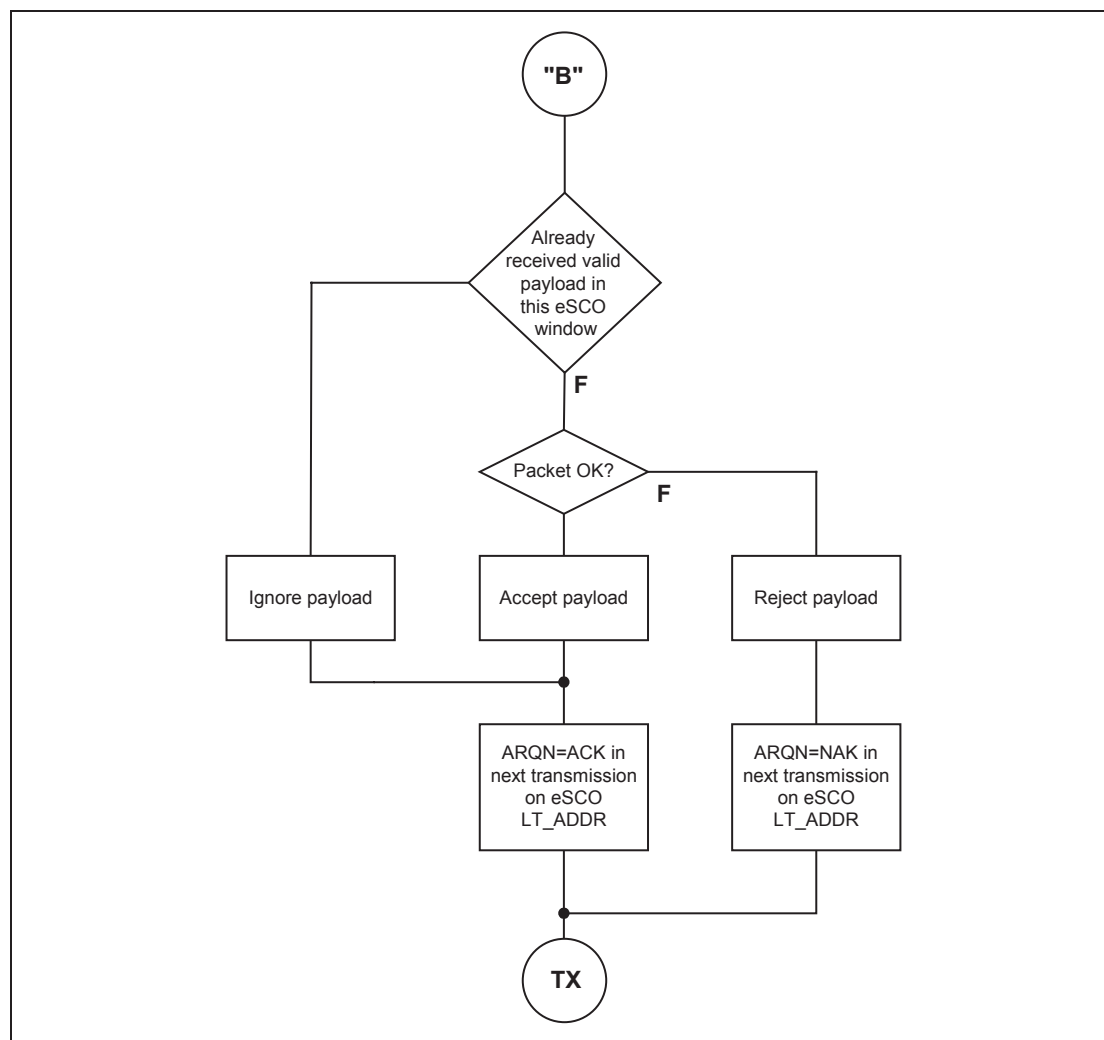


Figure 7.14: Stage 2 (eSCO) of the receive protocol for determining the ARQN bit.

7.6.2 Retransmit filtering

The data payload shall be transmitted until a positive acknowledgment is received or a timeout is exceeded. A retransmission shall be carried out either because the packet transmission itself failed, or because the acknowledgment transmitted in the return packet failed (note that the latter has a lower failure probability since the header is more heavily coded). In the latter case, the destination keeps receiving the same payload over and over again. In order to filter out the retransmissions in the destination, the SEQN bit is present in the header. Normally, this bit is alternated for every new CRC data payload transmission. In case of a retransmission, this bit shall not be changed so the destination can compare the SEQN bit with the previous SEQN value. If different, a new data payload has arrived; otherwise it is the same data payload and may be ignored. Only new data payloads shall be transferred to the Baseband Resource Manager. Note that CRC data payloads can be carried only by **DM**, **DH**, **DV** or **EV** packets.

7.6.2.1 Initialization of SEQN at start of new connection

The SEQN bit of the first CRC data packet at the start of a connection (as a result of page, page scan, role switch or unpair) on both the master and the slave sides shall be set to 1. The subsequent packets shall use the rules in the following sections.

7.6.2.2 ACL and SCO retransmit filtering

The SEQN bit shall only be affected by the CRC data packets as shown in [Figure 7.15](#). It shall be inverted every time a new CRC data packet is sent. The CRC data packet shall be retransmitted with the same SEQN number until an ACK is received or the packet is flushed. When an ACK is received, a new payload may be sent and on that transmission the SEQN bit shall be inverted. If a device decides to flush (see [Section 7.6.3 on page 150](#)), and it has not received an acknowledgement for the current packet, it shall replace the current packet with an ACL-U continuation packet with the same sequence number as the current packet and length zero. If it replaces the current packet in this way it shall not move on to transmit the next packet until it has received an ack.

If the slave receives a packet other than DH, DM, DV or EV with the SEQN bit inverted from that in the last header successfully received on the same LT_ADDR, it shall set the ARQN bit to NAK until a DH, DM, DV or EV packet is successfully received.

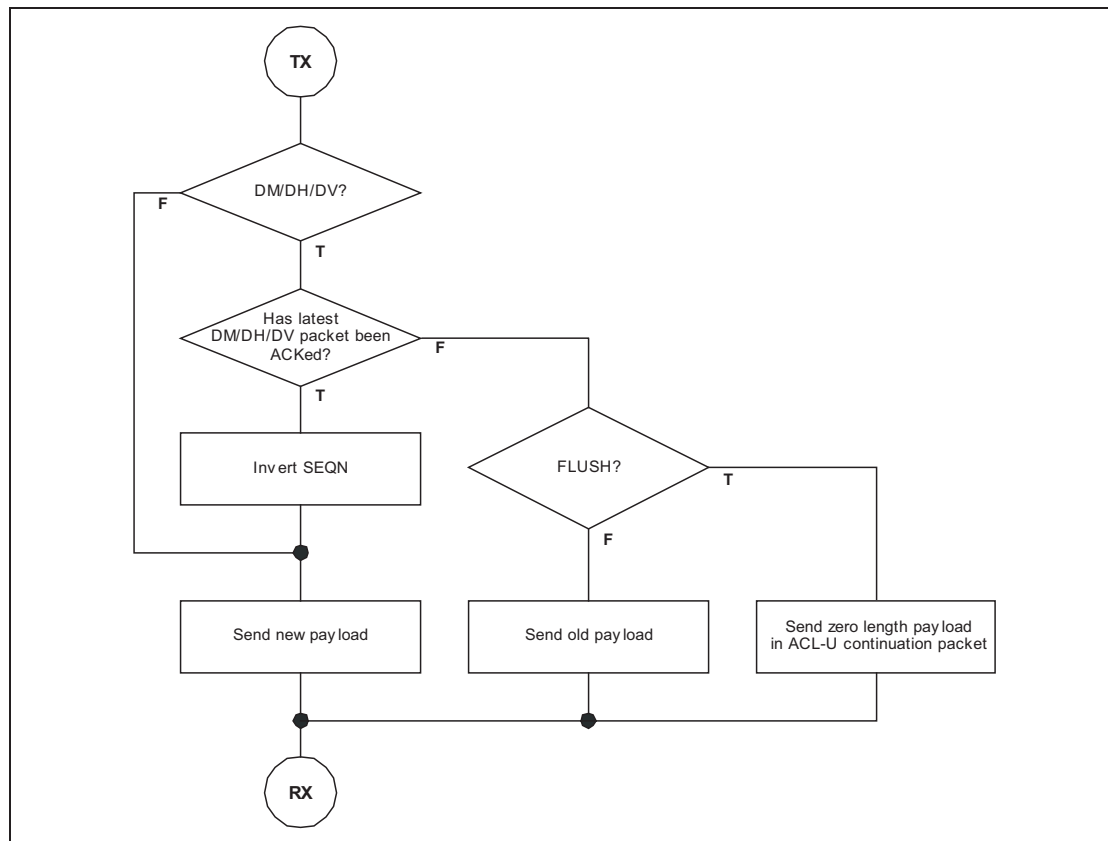


Figure 7.15: Transmit filtering for packets with CRC.



7.6.2.3 eSCO retransmit filtering

In eSCO, the SEQN bit shall be toggled every eSCO window. The value shall be constant for the duration of the eSCO window. The initial value of SEQN shall be zero.

For a given eSCO window the SEQN value shall be constant.

7.6.2.4 FHS retransmit filtering

The SEQN bit in the FHS packet is not meaningful. This bit may be set to any value. Contents of the SEQN bit in the FHS packet shall not be checked.

7.6.2.5 Packets without CRC retransmit filtering

During transmission of packets without a CRC the SEQN bit shall remain the same as it was in the previous packet.

7.6.3 Flushing payloads

In ACL, the ARQ scheme can cause variable delay in the traffic flow since retransmissions are inserted to assure error-free data transfer. For certain communication links, only a limited amount of delay is allowed: retransmissions are allowed up to a certain limit at which the current payload shall be ignored. This data transfer is indicated as **isochronous traffic**. This means that the retransmit process must be overruled in order to continue with the next data payload. Aborting the retransmit scheme is accomplished by *flushing* the old data and forcing the link controller to take the next data instead.

Flushing results in loss of remaining portions of an L2CAP message. Therefore, the packet following the flush shall have a start packet indication of LLID = 10 in the payload header for the next L2CAP message. This informs the destination of the flush. (see [Section 6.6 on page 128](#)). Flushing will not necessarily result in a change in the SEQN bit value, see the previous section.

The Flush Timeout defines a maximum period after which all segments of the ACL-U packet are flushed from the Controller buffer. The Flush Timeout shall start when the First segment of the ACL-U packet is stored in the Controller buffer. After the Flush timeout has expired the Link Controller may continue transmissions according to the procedure described in [Section 7.6.2.2 on page 148](#), however the Baseband Resource Manager shall not continue the transmission of the ACL-U packet to the Link Controller. If the Baseband Resource Manager has further segments of the packet queued for transmission to the Link Controller it shall delete the remaining segments of the ACL-U packet from the queue. In case the complete ACL-U packet was not stored in the Controller buffer yet, any Continuation segments, received for the ACL logical transport, shall be flushed, until a First segment is received. When the complete ACL-U packet has been flushed, the Link Manager shall continue transmission of the next ACL-U packet for the ACL logical transport. The default Flush Timeout shall be infinite, i.e. re-transmissions are carried out until physical link loss occurs. This is also referred to as a 'reliable channel'. All devices shall support the default Flush Timeout.

In eSCO, packets shall be automatically flushed at the end of the eSCO window.

7.6.4 Multi-slave considerations

In a piconet with multiple logical transports, the master shall carry out the ARQ protocol independently on each logical transport.

7.6.5 Broadcast packets

Broadcast packets are packets transmitted by the master to all the slaves simultaneously. (see paragraph 8.6.4) If multiple hop sequences are being used each transmission may only be received by some of the slaves. In this case the master shall repeat the transmission on each hop sequence. A broad-



cast packet shall be indicated by the all-zero LT_ADDR (note; the FHS packet is the only packet which may have an all-zero LT_ADDR but is not a broadcast packet). Broadcast packets shall not be acknowledged (at least not at the LC level).

Since broadcast messages are not acknowledged, each broadcast packet is transmitted at least a fixed number of times. A broadcast packet should be transmitted N_{BC} times before the next broadcast packet of the same broadcast message is transmitted, see [Figure 7.16 on page 152](#). Optionally, a broadcast packet may be transmitted $N_{BC} + 1$ times. Note: $N_{BC}=1$ means that each broadcast packet should be sent only once, but optionally may be sent twice. However, time-critical broadcast information may abort the ongoing broadcast train. For instance, unpark messages sent at beacon instances may do this, see [Section 8.9.5 on page 192](#).

If multiple hop sequences are being used then the master may transmit on the different hop sequences in any order, providing that transmission of a new broadcast packet shall not be started until all transmissions of any previous broadcast packet have completed on all hop sequences. The transmission of a single broadcast packet may be interleaved among the hop sequences to minimize the total time to broadcast a packet. The master has the option of transmitting only N_{BC} times on channels common to all hop sequences.

Broadcast packets with a CRC shall have their own sequence number. The SEQN of the first broadcast packet with a CRC shall be set to SEQN = 1 by the master and shall be inverted for each new broadcast packet with CRC thereafter. Broadcast packets without a CRC have no influence on the sequence number. The slave shall accept the SEQN of the first broadcast packet it receives in a connection and shall check for change in SEQN for subsequent broadcast packets. Since there is no acknowledgement of broadcast messages and there is no end packet indication, it is important to receive the start packets correctly. To ensure this, repetitions of the broadcast packets that are L2CAP start packets and LMP packets shall not be filtered out. These packets shall be indicated by LLID=1X in the payload header as explained in [section 6.6 on page 128](#). Only repetitions of the L2CAP continuation packets shall be filtered out.

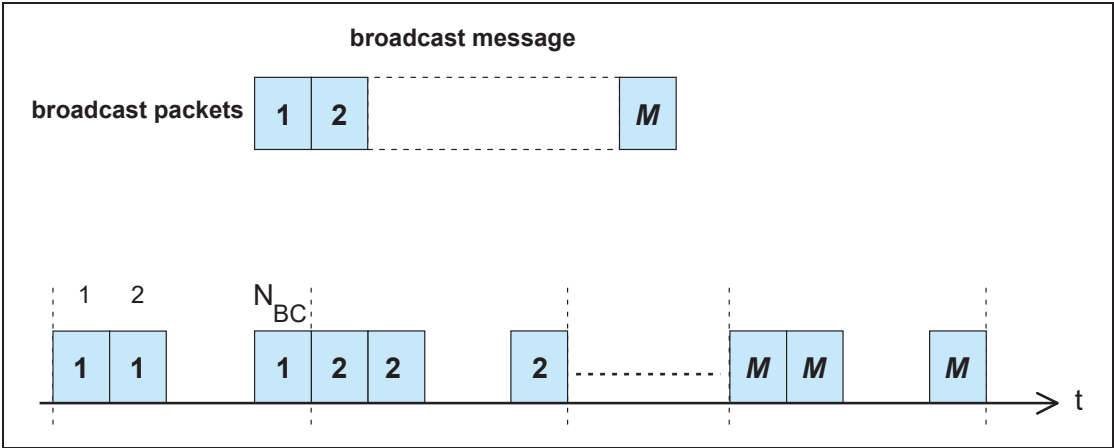


Figure 7.16: Broadcast repetition scheme

8 LINK CONTROLLER OPERATION

This section describes how a piconet is established and how devices can be added to and released from the piconet. Several states of operation of the devices are defined to support these functions. In addition, the operation of several piconets with one or more common members, the scatternet, is discussed.

8.1 OVERVIEW OF STATES

Figure 8.1 on page 153 shows a state diagram illustrating the different states used in the link controller. There are three major states: **STANDBY**, **CONNECTION**, and **PARK**; in addition, there are seven substates, **page**, **page scan**, **inquiry**, **inquiry scan**, **master response**, **slave response**, and **inquiry response**. The substates are interim states that are used to establish connections and enable device discovery. To move from one state or substate to another, either commands from the link manager are used, or internal signals in the link controller are used (such as the trigger signal from the correlator and the timeout signals).

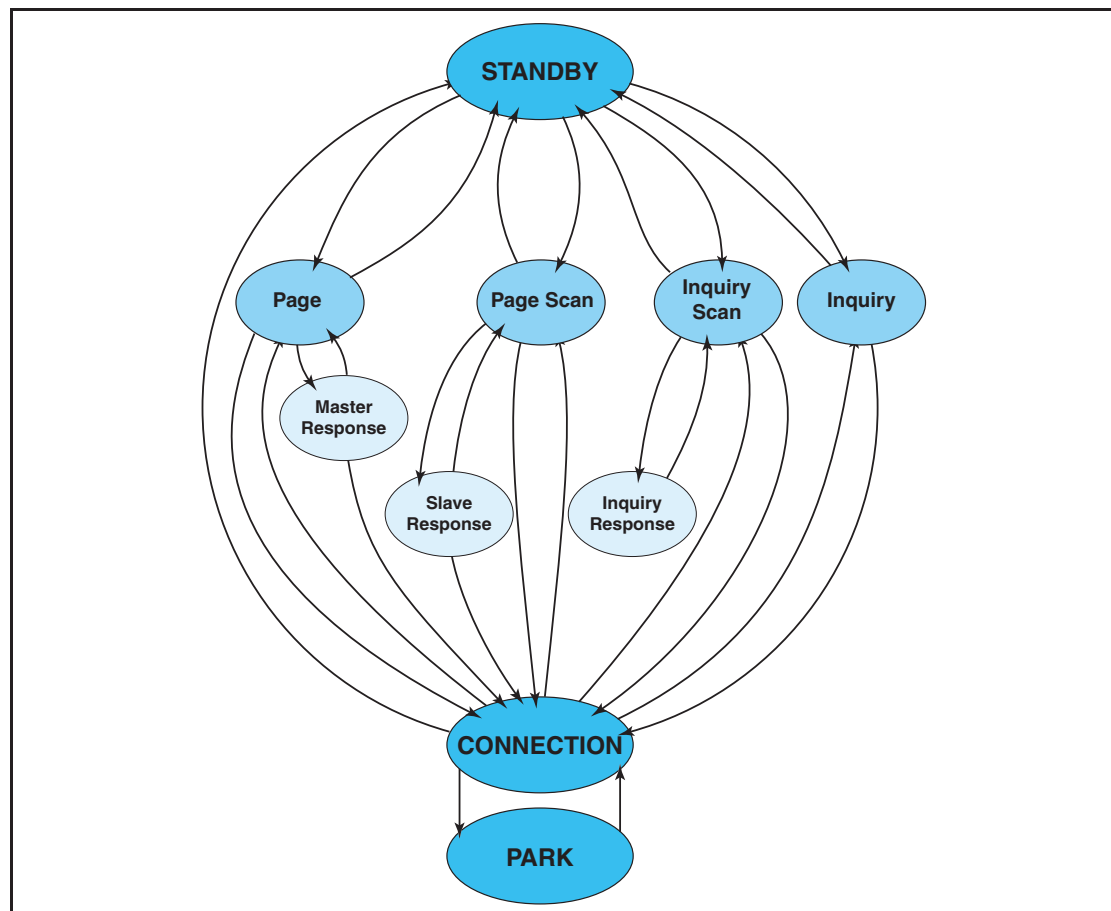


Figure 8.1: State diagram of link controller.



8.2 STANDBY STATE

The **STANDBY** state is the default state in the device. In this state, the device may be in a low-power mode. Only the native clock is running at the accuracy of the LPO (or better).

The controller may leave the **STANDBY** state to scan for page or inquiry messages, or to page or inquiry itself.

8.3 CONNECTION ESTABLISHMENT SUBSTATES

In order to establish new connections the paging procedure is used. Only the Bluetooth device address is required to set up a connection. Knowledge about the clock, obtained from the inquiry procedure (see [Section 8.4 on page 163](#)) or from a previous connection with this device, and the page scanning mode of the other device will accelerate the setup procedure. A device that establishes a connection carries out a page procedure and will automatically become the master of the connection.

8.3.1 Page scan substate

In the **page scan** substate, a device may be configured to use either the standard or interlaced scanning procedure. During a standard scan, a device listens for the duration of the scan window $T_{w_page_scan}$ (11.25ms default, see [HCI \[Part E\] Section 7.3.20 on page 494](#)), while the interlaced scan is performed as two back to back scans of $T_{w_page_scan}$. If the scan interval is not at least twice the scan window, then interlaced scan shall not be used. During each scan window, the device shall listen at a single hop frequency, its correlator matched to its device access code (DAC). The scan window shall be long enough to completely scan 16 page frequencies.

When a device enters the **page scan** substate, it shall select the scan frequency according to the page hopping sequence determined by the device's Bluetooth device address, see [Section 2.6.4.1 on page 91](#). The phase in the sequence shall be determined by $CLKN_{16-12}$ of the device's native clock; that is, every 1.28s a different frequency is selected.

In the case of a standard scan, if the correlator exceeds the trigger threshold during the **page scan**, the device shall enter the **slave response** substate described in [Section 8.3.3.1 on page 160](#). The scanning device may also use interlaced scan. In this case, if the correlator does not exceed the trigger threshold during the first scan it shall scan a second time using the phase in the sequence determined by $[CLKN_{16-12} + 16] \bmod 32$. If on this second scan the correlator exceeds the trigger threshold the device shall enter the **slave response** substate using $[CLKN_{16-12} + 16] \bmod 32$ as the frozen $CLKN^*$ in the calculation for $X_{prs}^{(79)}$, see [Section 2.6.4.3 on page 92](#) for details. If the correlator does not exceed the trigger threshold during a scan in normal mode or



during the second scan in interlaced scan mode it shall return to either the **STANDBY** or **CONNECTION** state.

The **page scan** substate can be entered from the **STANDBY** state or the **CONNECTION** state. In the **STANDBY** state, no connection has been established and the device can use all the capacity to carry out the **page scan**. Before entering the **page scan** substate from the **CONNECTION** state, the device should reserve as much capacity as possible for scanning. If desired, the device may place ACL connections in Hold, Park or Sniff, see [Section 8.8 on page 185](#) and [Section 8.9 on page 185](#). Synchronous connections should not be interrupted by the page scan, although eSCO retransmissions should be paused during the scan. The page scan may be interrupted by the reserved synchronous slots which should have higher priority than the **page scan**. SCO packets should be used requiring the least amount of capacity (**HV3** packets). The scan window shall be increased to minimize the setup delay. If one SCO logical transport is present using **HV3** packets and $T_{SCO}=6$ slots or one eSCO logical transport is present using **EV3** packets and $T_{ESCO}=6$ slots, a total scan window $T_{w \text{ page scan}}$ of at least 36 slots (22.5ms) is recommended; if two SCO links are present using **HV3** packets and $T_{SCO}=6$ slots or two eSCO links are present using **EV3** packets and $T_{ESCO}=6$ slots, a total scan window of at least 54 slots (33.75ms) is recommended.

The scan interval $T_{\text{page scan}}$ is defined as the interval between the beginnings of two consecutive page scans. A distinction is made between the case where the scan interval is equal to the scan window $T_{w \text{ page scan}}$ (continuous scan), the scan interval is maximal 1.28s, or the scan interval is maximal 2.56s. These three cases shall determine the behavior of the paging device; that is, whether the paging device shall use R0, R1 or R2, see also [Section 8.3.2 on page 156](#). [Table 8.1](#) illustrates the relationship between $T_{\text{page scan}}$ and modes R0, R1 and R2. Although scanning in the R0 mode is continuous, the scanning may be interrupted for example by reserved synchronous slots. The scan interval information is included in the SR field in the FHS packet.

| SR mode | $T_{\text{page scan}}$ |
|----------|---|
| R0 | $\leq 1.28\text{s}$ and $= T_{w \text{ page scan}}$ |
| R1 | $\leq 1.28\text{s}$ |
| R2 | $\leq 2.56\text{s}$ |
| Reserved | - |

Table 8.1: Relationship between scan interval, and paging modes R0, R1 and R2.



8.3.2 Page substate

The **page** substate is used by the master (source) to activate and connect to a slave (destination) in the **page scan** substate. The master tries to coincide with the slave's scan activity by repeatedly transmitting the paging message consisting of the slave's device access code (DAC) in different hop channels. Since the Bluetooth clocks of the master and the slave are not synchronized, the master does not know exactly when the slave wakes up and on which hop frequency. Therefore, it transmits a train of identical page scan messages at different hop frequencies and listens in between the transmit intervals until it receives a response from the slave.

The page procedure in the master consists of a number of steps. First, the Host communicates the BD_ADDR of the slave to the Controller. This BD_ADDR shall be used by the master to determine the page hopping sequence, see [Section 2.6.4.2 on page 92](#). The slave's BD_ADDR shall be used to determine the page hopping sequence, see [Section 2.6.4.2 on page 92](#). For the phase in the sequence, the master shall use an estimate of the slave's clock. For example, this estimate can be derived from timing information that was exchanged during the last encounter with this particular device (which could have acted as a master at that time), or from an inquiry procedure. With this estimate CLKE of the slave's Bluetooth clock, the master can predict on which hop channel the slave starts page scanning.

The estimate of the Bluetooth clock in the slave can be completely wrong. Although the master and the slave use the same hopping sequence, they use different phases in the sequence and might never select the same frequency. To compensate for the clock drifts, the master shall send its page message during a short time interval on a number of wake-up frequencies. It shall transmit also on hop frequencies just before and after the current, predicted hop frequency. During each TX slot, the master shall sequentially transmit on two different hop frequencies. In the following RX slot, the receiver shall listen sequentially to two corresponding RX hops for ID packet. The RX hops shall be selected according to the page response hopping sequence. The page response hopping sequence is strictly related to the page hopping sequence: for each page hop there is a corresponding page response hop. The RX/TX timing in the **page** substate is described in [Section 2.2.5 on page 72](#), see also [Figure 2.7 on page 77](#). In the next TX slot, it shall transmit on two hop frequencies different from the former ones. Note: The hop rate is increased to 3200 hops/s.

With the increased hopping rate as described above, the transmitter can cover 16 different hop frequencies in 16 slots or 10 ms. The page hopping sequence is divided over two paging trains **A** and **B** of 16 frequencies. Train **A** includes the 16 hop frequencies surrounding the current, predicted hop frequency $f(k)$, where k is determined by the clock estimate $CLKE_{16-12}$. The first train consists of hops

$f(k-8), f(k-7), \dots, f(k), \dots, f(k+7)$



When the difference between the Bluetooth clocks of the master and the slave is between -8×1.28 s and $+7 \times 1.28$ s, one of the frequencies used by the master will be the hop frequency the slave will listen to. Since the master does not know when the slave will enter the **page scan** substate, the master has to repeat this train **A** N_{page} times or until a response is obtained, whichever is shorter. If the slave scan interval corresponds to R1, the repetition number is at least 128; if the slave scan interval corresponds to R2 or if the master has not previously read the slave's SR mode, the repetition number is at least 256. If the master has not previously read the slave's SR mode it shall use $N_{\text{page}} \geq 256$. Note that CLKE_{16-12} changes every 1.28 s; therefore, every 1.28 s, the trains will include different frequencies of the page hopping set.

When the difference between the Bluetooth clocks of the master and the slave is less than -8×1.28 s or larger than $+7 \times 1.28$ s, the remaining 16 hops are used to form the new 10 ms train **B**. The second train consists of hops

$f(k-16), f(k-15), \dots, f(k-9), f(k+8), \dots, f(k+15)$

Train **B** shall be repeated for N_{page} times. If no response is obtained, train **A** shall be tried again N_{page} times. Alternate use of train A and train B shall be continued until a response is received or the timeout *pageTO* is exceeded. If a response is returned by the slave, the master device enters the **master response** substate.

The **page** substate may be entered from the **STANDBY** state or the **CONNECTION** state. In the **STANDBY** state, no connection has been established and the device can use all the capacity to carry out the page. Before entering the **page** substate from the **CONNECTION** state, the device should free as much capacity as possible for scanning. To ensure this, it is recommended that the ACL connections are put on hold or park. However, the synchronous connections shall not be disturbed by the page. This means that the page will be interrupted by the reserved SCO and eSCO slots which have higher priority than the page. In order to obtain as much capacity for paging, it is recommended to use the SCO packets which use the least amount of capacity (**HV3** packets). If SCO or eSCO links are present, the repetition number N_{page} of a single train shall be increased, see [Table 8.2](#). Here it has been assumed that the **HV3** packet are used with an interval $T_{\text{SCO}}=6$ slots or **EV3** packets are used with an interval of $T_{\text{ESCO}}=6$ slots, which would correspond to a 64 kb/s synchronous link.



| SR mode | no synchronous link | one synchronous link (HV3) | two synchronous links (HV3) |
|---------|----------------------------|----------------------------|-----------------------------|
| R0 | $N_{\text{page}} \geq 1$ | $N_{\text{page}} \geq 2$ | $N_{\text{page}} \geq 3$ |
| R1 | $N_{\text{page}} \geq 128$ | $N_{\text{page}} \geq 256$ | $N_{\text{page}} \geq 384$ |
| R2 | $N_{\text{page}} \geq 256$ | $N_{\text{page}} \geq 512$ | $N_{\text{page}} \geq 768$ |

Table 8.2: Relationship between train repetition, and paging modes R0, R1 and R2 when synchronous links are present.

The construction of the page train shall be independent of the presence of synchronous links; that is, synchronous packets are sent on the reserved slots but shall not affect the hop frequencies used in the unreserved slots, see [Figure 8.2 on page 158](#).

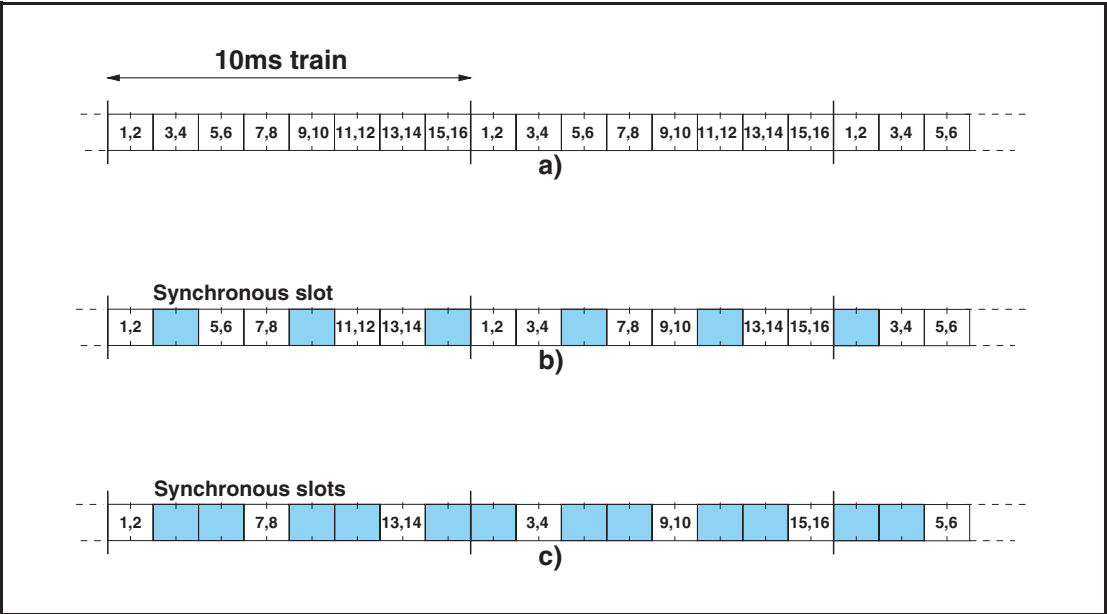


Figure 8.2: Conventional page (a), page while one synchronous link present (b), page while two synchronous links present (c).

8.3.3 Page response substates

When a page message is successfully received by the slave, there is a coarse FH synchronization between the master and the slave. Both the master and the slave enter a response substate to exchange vital information to continue the connection setup. It is important for the piconet connection that both devices shall use the same channel access code, use the same channel hopping sequence, and their clocks are synchronized. These parameters shall be derived from the master device. The device that initializes the connection (starts paging) is defined as the master device (which is thus only valid during the time the piconet exists). The channel access code and channel hopping sequence shall be derived from the Bluetooth device address (BD_ADDR) of the master. The timing shall be determined by the master clock. An offset shall be added to the slave's native clock to temporarily synchronize the slave clock to the master clock. At start-up, the master parameters are transmitted from the master to the slave. The messaging between the master and the slave at start-up is specified in this section.

The initial messaging between master and slave is shown in [Table 8.3 on page 159](#) and in [Figure 8.3 on page 160](#) and [Figure 8.4 on page 160](#). In those two figures frequencies $f(k)$, $f(k+1)$, etc. are the frequencies of the page hopping sequence determined by the slave's BD_ADDR. The frequencies $f'(k)$, $f'(k+1)$, etc. are the corresponding page_response frequencies (slave-to-master). The frequencies $g(m)$ belong to the basic channel hopping sequence.

| Step | Message | Packet Type | Direction | Hopping Sequence | Access Code and Clock |
|------|----------------------------|-------------|-----------------|------------------|-----------------------|
| 1 | Page | ID | Master to slave | Page | Slave |
| 2 | First slave page response | ID | Slave to master | Page response | Slave |
| 3 | Master page response | FHS | Master to slave | Page | Slave |
| 4 | Second slave page response | ID | Slave to master | Page response | Slave |
| 5 | 1st packet master | POLL | Master to slave | Channel | Master |
| 6 | 1st packet slave | Any type | Slave to master | Channel | Master |

Table 8.3: Initial messaging during start-up.

In step 1 (see [Table 8.3 on page 159](#)), the master device is in **page** substate and the slave device in the **page scan** substate. Assume in this step that the page message sent by the master reaches the slave. On receiving the page message, the slave enters the **slave response** in step 2. The master waits for a reply from the slave and when this arrives in step 2, it will enter the **master response** in step 3. Note that during the initial message exchange, all parame-



ters are derived from the slave's device address, and that only the page hopping and page response hopping sequences are used (are also derived from the slave's device address). Note that when the master and slave enter the response states, their clock input to the page and page response hop selection is frozen as is described in [Section 2.6.4.3 on page 92](#).

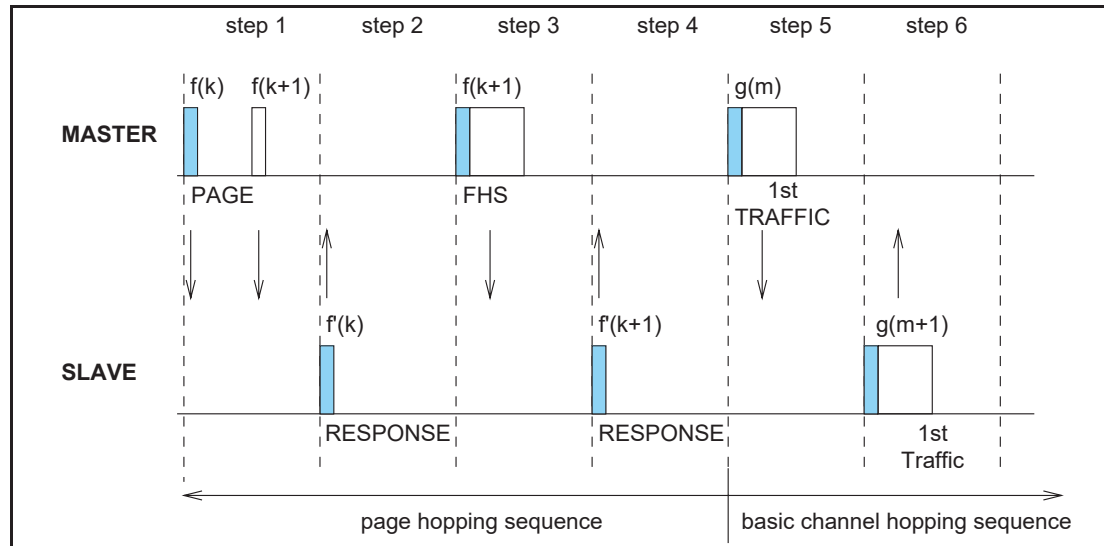


Figure 8.3: Messaging at initial connection when slave responds to first page message.

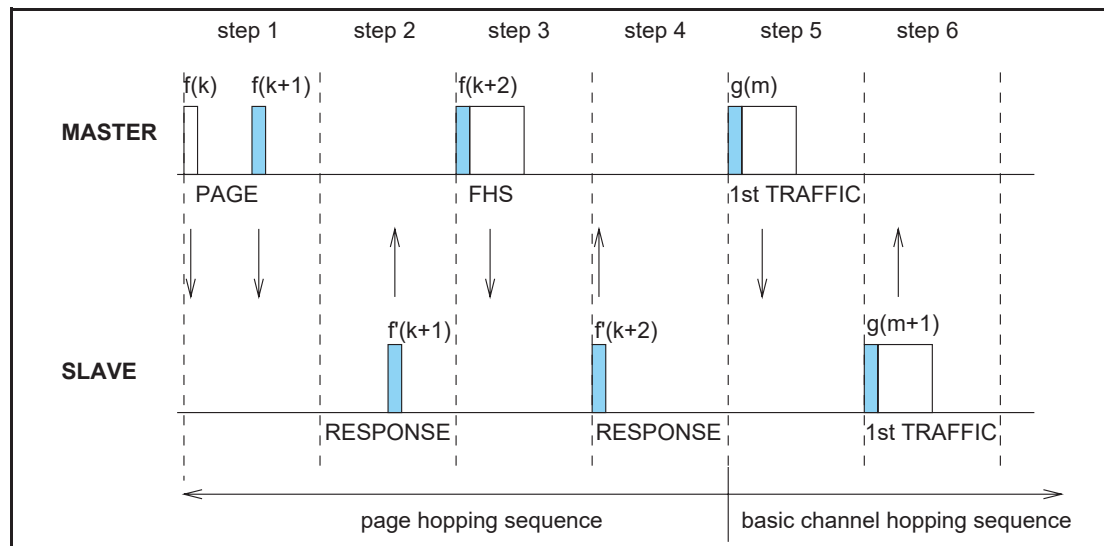


Figure 8.4: Messaging at initial connection when slave responds to second page message.

8.3.3.1 Slave response substate

After having received the page message in step 1, the slave device shall transmit a slave page response message (the slave's device access code) in step 2. This response message shall be the slave's device access code. The slave shall transmit this response 625 μ s after the beginning of the received page message and at the response hop frequency that corresponds to the hop fre-



quency in which the page message was received. The slave transmission is therefore time aligned to the master transmission. During initial messaging, the slave shall still use the page response hopping sequence to return information to the master. The clock input $CLKN_{16-12}$ shall be frozen at the value it had at the time the page message was received.

After having sent the response message, the slave's receiver shall be activated 312.5 μ s after the start of the response message and shall await the arrival of an **FHS** packet. Note that an **FHS** packet can arrive 312.5 μ s after the arrival of the page message as shown in [Figure 8.4 on page 160](#), and not after 625 μ s as is usually the case in the piconet physical channel RX/TX timing. More details about the timing can be found in [Section 2.4.4 on page 78](#).

If the setup fails before the **CONNECTION** state has been reached, the following procedure shall be carried out. The slave shall listen as long as no **FHS** packet is received until *pagerespTO* is exceeded. Every 1.25 ms, however, it shall select the next master-to-slave hop frequency according to the page hop sequence. If nothing is received after *pagerespTO*, the slave shall return back to the **page scan** substate for one scan period. Length of the scan period depends on the synchronous reserved slots present. If no page message is received during this additional scan period, the slave shall resume scanning at its regular scan interval and return to the state it was in prior to the first page scan state.

If an **FHS** packet is received by the slave in the **slave response** substate, the slave shall return a slave page response message in step 4 to acknowledge reception of the **FHS** packet. This response shall use the page response hopping sequence. The transmission of the slave page response packet is based on the reception of the **FHS** packet. Then the slave shall change to the master's channel access code and clock as received from the **FHS** packet. Only the 26 MSBs of the master clock are transferred: the timing shall be such that CLK_1 and CLK_0 are both zero at the time the **FHS** packet was received as the master transmits in even slots only. The offset between the master's clock and the slave's clock shall be determined from the master's clock in the **FHS** packet and reported to the slave's Baseband Resource Manager.

Finally, the slave enters the **CONNECTION** state in step 5. From then on, the slave shall use the master's clock and the master's BD_ADDR to determine the basic channel hopping sequence and the channel access code. The slave shall use the LT_ADDR in the **FHS** payload as the primary LT_ADDR in the **CONNECTION** state. The connection mode shall start with a POLL packet transmitted by the master. The slave may respond with any type of packet. If the POLL packet is not received by the slave, or the response packet is not received by the master, within *newconnectionTO* number of slots after FHS packet acknowledgement, the master and the slave shall return to **page** and **page scan** substates, respectively. See [Section 8.5 on page 167](#)



8.3.3.2 Master response substate

When the master has received a slave page response message in step 2, it shall enter the **master response** routine. It shall freeze the current clock input to the page hop selection scheme. The master shall then transmit an **FHS** packet in step 3 containing the master's real-time Bluetooth clock, the master's BD_ADDR, the BCH parity bits, and the class of device. The **FHS** packet contains all information to construct the channel access code without requiring a mathematical derivation from the master's Bluetooth device address. The LT_ADDR field in the packet header of FHS packets in the master response substate shall be set to all-zeros. The **FHS** packet shall be transmitted at the beginning of the master-to-slave slot following the slot in which the slave responded. The FHS packet shall carry the all-zero LT_ADDR. The TX timing of the **FHS** is not based on the reception of the response packet from the slave. The **FHS** packet may therefore be sent 312.5 μ s after the reception of the response packet like shown in [Figure 8.4 on page 160](#) and not 625 μ s after the received packet as is usual in the piconet physical channel RX/TX timing, see also [Section 2.4.4 on page 78](#).

After the master has sent its **FHS** packet, it shall wait for a second slave page response message in step 4 acknowledging the reception of the **FHS** packet. This response shall be the slave's device access code. If no response is received, the master shall retransmit the **FHS** packet with an updated clock and still using the slave's parameters. It shall retransmit the FHS packet with the clock updated each time until a second slave page response message is received, or the timeout of *pagerespTO* is exceeded. In the latter case, the master shall return to the **page** substate and send an error message to the Baseband Resource Manager. During the retransmissions of the **FHS** packet, the master shall use the page hopping sequence.

If the slave's response is received, the master shall change to using the master parameters, so it shall use the channel access code and the master clock. The lower clock bits CLK₀ and CLK₁ shall be reset to zero at the start of the **FHS** packet transmission and are not included in the **FHS** packet. Finally, the master enters the **CONNECTION** state in step 5. The master BD_ADDR shall be used to change to a new hopping sequence, the *basic channel hopping sequence*. The basic channel hopping sequence uses all 79 hop channels in a pseudo-random fashion, see also [Section 2.6.4.7 on page 94](#). The master shall now send its first traffic packet in a hop determined with the new (master) parameters. This first packet shall be a POLL packet. See [Section 8.5 on page 167](#). This packet shall be sent within *newconnectionTO* number of slots after reception of the FHS packet acknowledgement. The slave may respond with any type of packet. If the POLL packet is not received by the slave or the POLL packet response is not received by the master within *newconnectionTO* number of slots, the master and the slave shall return to **page** and **page scan** substates, respectively.

8.4 DEVICE DISCOVERY SUBSTATES

In order to discover other devices a device shall enter **inquiry** substate. In this substate, it shall repeatedly transmit the inquiry message (ID packet, see [Section 6.5.1.1 on page 119](#)) at different hop frequencies. The **inquiry** hop sequence is derived from the LAP of the GIAC. Thus, even when DIACs are used, the applied hopping sequence is generated from the GIAC LAP. A device that allows itself to be discovered, shall regularly enter the **inquiry scan** substate to respond to inquiry messages. The following sections describe the message exchange and contention resolution during inquiry response. The inquiry response is optional: a device is not forced to respond to an inquiry message.

During the **inquiry** substate, the discovering device collects the Bluetooth device addresses and clocks of all devices that respond to the inquiry message. It can then, if desired, make a connection to any one of them by means of the previously described page procedure.

The inquiry message broadcast by the source does not contain any information about the source. However, it may indicate which class of devices should respond. There is one general inquiry access code (GIAC) to inquire for any device, and a number of dedicated inquiry access codes (DIAC) that only inquire for a certain type of device. The inquiry access codes are derived from reserved Bluetooth device addresses and are further described in [Section 6.3.1 on page 111](#).



8.4.1 Inquiry scan substate

The **inquiry scan** substate is very similar to the **page scan** substate. However, instead of scanning for the device's device access code, the receiver shall scan for the inquiry access code long enough to completely scan for 16 inquiry frequencies. Two types of scans are defined: standard and interlaced. In the case of a standard scan the length of this scan period is denoted $T_{w_inquiry_scan}$ (11.25ms default, see HCI [Part E] Section 7.3.22 on page 496). The standard scan is performed at a single hop frequency as defined by Xir_{4-0} (see Section 2.6.4.6 on page 94). The interlaced scan is performed as two back to back scans of $T_{w_inquiry_scan}$ where the first scan is on the normal hop frequency and the second scan is defined by $[Xir_{4-0} + 16] \bmod 32$. If the scan interval is not at least twice the scan window then interlaced scan shall not be used. The inquiry procedure uses 32 dedicated inquiry hop frequencies according to the inquiry hopping sequence. These frequencies are determined by the general inquiry address. The phase is determined by the native clock of the device carrying out the **inquiry scan**; the phase changes every 1.28s.

Instead of, or in addition to, the general inquiry access code, the device may scan for one or more dedicated inquiry access codes. However, the scanning shall follow the inquiry scan hopping sequence determined by the general inquiry address. If an inquiry message is received during an inquiry wake-up period, the device shall enter the **inquiry response** substate.

The **inquiry scan** substate can be entered from the **STANDBY** state or the **CONNECTION** state. In the **STANDBY** state, no connection has been established and the device can use all the capacity to carry out the **inquiry scan**. Before entering the **inquiry scan** substate from the **CONNECTION** state, the device should reserve as much capacity as possible for scanning. If desired, the device may place ACL logical transports in Sniff, Hold, or Park. Synchronous logical transports are preferably not interrupted by the **inquiry scan**, although eSCO retransmissions should be paused during the scan. In this case, the **inquiry scan** may be interrupted by the reserved synchronous slots. SCO packets should be used requiring the least amount of capacity (**HV3** packets). The scan window, $T_{w_inquiry_scan}$, shall be increased to increase the probability to respond to an inquiry message. If one SCO logical transport is present using HV3 packets and $T_{SCO}=6$ slots or one eSCO logical transport is present using EV3 packets and $T_{ESCO}=6$ slots, a total scan window of at least 36 slots (22.5ms) is recommended; if two SCO links are present using HV3 packets and $T_{SCO}=6$ slots or two eSCO links are present using EV3 packets and $T_{ESCO}=6$ slots, a total scan window of at least 54 slots (33.75ms) is recommended.

The scan interval $T_{inquiry_scan}$ is defined as the interval between two consecutive inquiry scans. The **inquiry scan** interval shall be less than or equal to 2.56 s.



8.4.2 Inquiry substate

The **inquiry** substate is used to discover new devices. This substate is very similar to the **page** substate; the TX/RX timing shall be the same as in paging, see [Section 2.4.4 on page 78](#) and [Figure 2.7 on page 77](#). The TX and RX frequencies shall follow the inquiry hopping sequence and the inquiry response hopping sequence, and are determined by the general inquiry access code and the native clock of the discovering device. In between inquiry transmissions, the receiver shall scan for inquiry response messages. When a response is received, the entire packet (an **FHS** packet) is read, after which the device shall continue with inquiry transmissions. The device in an **inquiry** substate shall not acknowledge the inquiry response messages. If enabled by the Host (see HCI [\[Part E\] Section 7.3.54 on page 533](#)), the RSSI value of the inquiry response message shall be measured. It shall keep probing at different hop channels and in between listening for response packets. As in the **page** substate, two 10 ms trains **A** and **B** are defined, splitting the 32 frequencies of the inquiry hopping sequence into two 16-hop parts. A single train shall be repeated for at least $N_{\text{inquiry}}=256$ times before a new train is used. In order to collect all responses in an error-free environment, at least three train switches must have taken place. As a result, the **inquiry** substate may have to last for 10.24 s unless the inquirer collects enough responses and aborts the **inquiry** substate earlier. If desired, the inquirer may also prolong the **inquiry** substate to increase the probability of receiving all responses in an error-prone environment. If an inquiry procedure is automatically initiated periodically (say a 10 s period every minute), then the interval between two inquiry instances shall be determined randomly. This is done to avoid two devices synchronizing their inquiry procedures.

The **inquiry** substate is continued until stopped by the Baseband Resource Manager (when it decides that it has sufficient number of responses), when a timeout has been reached (*inquiryTO*), or by a command from the host to cancel the inquiry procedure.

The **inquiry** substate can be entered from the **STANDBY** state or the **CONNECTION** state. In the **STANDBY** state, no connection has been established and the device can use all the capacity to carry out the inquiry. Before entering the **inquiry** substate from the **CONNECTION** state, the device should free as much capacity as possible for scanning. To ensure this, it is recommended that the ACL logical transports are placed in Sniff, Hold, or Park. However, the reserved slots of synchronous logical transports shall not be disturbed by the inquiry. This means that the inquiry will be interrupted by the reserved SCO and eSCO slots which have higher priority than the inquiry. In order to obtain as much capacity as possible for inquiry, it is recommended to use the SCO packets which use the least amount of capacity (**HV3** packets). If SCO or eSCO links are present, the repetition number N_{inquiry} shall be increased, see [Table 8.4 on page 166](#).

Here it has been assumed that **HV3** packets are used with an interval $T_{\text{SCO}}=6$

slots or **EV3** packets are used with an interval of $T_{ESCO}=6$ slots, which would correspond to a 64 kb/s synchronous link.

| | No synchronous links | One synchronous link (HV3) | Two synchronous links (HV3) |
|----------------------|----------------------|----------------------------|-----------------------------|
| N_{inquiry} | ≥ 256 | ≥ 512 | ≥ 768 |

Table 8.4: Increase of train repetition when synchronous links are present.

8.4.3 Inquiry response substate

The slave response substate for inquiries differs completely from the slave response substate applied for pages. When the inquiry message is received in the **inquiry scan** substate, the recipient shall return an inquiry response (FHS) packet containing the recipient's device address (BD_ADDR) and other parameters.

The following protocol in the slave's **inquiry response** shall be used. On the first inquiry message received in this substate the slave shall enter the **inquiry response** substate and shall return an **FHS** response packet to the master 625 μ s after the inquiry message was received. A contention problem may arise when several devices are in close proximity to the inquiring device and all respond to an inquiry message at the same time. However, because every device has a free running clock it is highly unlikely that they all use the same phase of the inquiry hopping sequence. In order to avoid repeated collisions between devices that wake up in the same inquiry hop channel simultaneously, a device shall back-off for a random period of time. Thus, if the device receives an inquiry message and returns an FHS packet, it shall generate a random number, RAND, between 0 and MAX_RANDOM. For scanning intervals ≥ 1.28 s MAX_RANDOM shall be 1023, however, for scanning intervals < 1.28 s MAX_RANDOM may be as small as 127. A profile that uses a special DIAC may choose to use a smaller MAX_RANDOM than 1023 even when the scanning interval is ≥ 1.28 s. The slave shall return to the **CONNECTION** or **STANDBY** state for the duration of at least RAND time slots. Before returning to the **CONNECTION** and **STANDBY** state, the device may go through the **page scan** substate. After at least RAND slots, the device shall add an offset of 1 to the phase in the inquiry hop sequence (the phase has a 1.28 s resolution) and return to the **inquiry scan** substate again. If the slave is triggered again, it shall repeat the procedure using a new RAND. The offset to the clock accumulates each time an **FHS** packet is returned. During a probing window, a slave may respond multiple times, but on different frequencies and at different times. Reserved synchronous slots should have priority over response packets; that is, if a response packet overlaps with a reserved synchronous slot, it shall not be sent but the next inquiry message is awaited.

The messaging during the inquiry routines is summarized in [Table 8.5 on page 167](#). In step 1, the master transmits an inquiry message using the inquiry access code and its own clock. The slave responds with the **FHS** packet containing the slave's Bluetooth device address, native clock and other slave information. This **FHS** packet is returned at times that tend to be random. The **FHS**

packet is not acknowledged in the inquiry routine, but it is retransmitted at other times and frequencies as long as the master is probing with inquiry messages.

| Step | Message | Packet Type | Direction | Hopping Sequence | Access Code and Clock |
|------|------------------|-------------|-----------------|------------------|-----------------------|
| 1 | Inquiry | ID | master to slave | inquiry | inquiry |
| 2 | Inquiry response | FHS | slave to master | inquiry response | inquiry |

Table 8.5: Messaging during inquiry routines.

8.5 CONNECTION STATE

In the **CONNECTION** state, the connection has been established and packets can be sent back and forth. In both devices, the channel (master) access code, the master's Bluetooth clock, and the AFH_channel_map are used. **CONNECTION** state uses the *basic* or *adapted channel hopping sequence*.

The **CONNECTION** state starts with a POLL packet sent by the master to verify the switch to the master's timing and channel frequency hopping. The slave may respond with any type of packet. If the slave does not receive the POLL packet or the master does not receive the response packet for *newconnecti-onTO* number of slots, both devices shall return to **page/page scan** substates.

The first information packets in the **CONNECTION** state contain control messages that characterize the link and give more details regarding the devices. These messages are exchanged between the link managers of the devices. For example, they may define the SCO logical transport and the sniff parameters. Then the transfer of user information can start by alternately transmitting and receiving packets.

The **CONNECTION** state is left through a **detach** or **reset** command. The **detach** command is used if the link has been disconnected in the normal way; all configuration data in the link controller shall remain valid. The **reset** command is a soft reset of the link controller. The functionality of the soft reset is described in [\[Part E\] Section 7.3.2 on page 469](#).

In the **CONNECTION** state, if a device is not going to be nominally present on the channel at all times it may describe its unavailability by using sniff mode or hold mode (see [Figure 8.5 on page 168](#)).

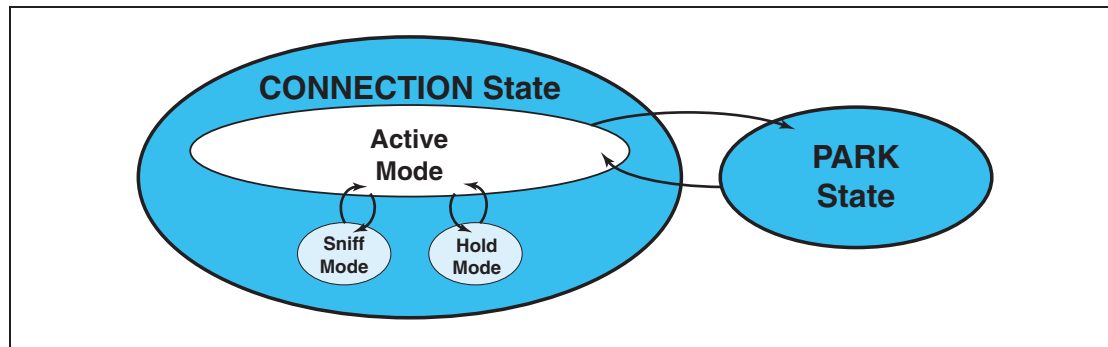


Figure 8.5: Connection state.

8.6 ACTIVE MODE

In the active mode, both master and slave actively participate on the channel. Up to seven slaves may be in the active mode at any given time. The master schedules the transmission based on traffic demands to and from the different slaves. In addition, it supports regular transmissions to keep slaves synchronized to the channel. Slaves in the active mode listen in the master-to-slave slots for packets. These devices are known as *active slaves*. If an active slave is not addressed, it may sleep until the next new master transmission. Slaves can derive the number of slots the master has reserved for transmission from TYPE field in the packet header; during this time, the non-addressed slaves do not have to listen on the master-to-slave slots. When a device is participating in multiple piconets it should listen in the master-to-slave slot for the current piconet. It is recommended that a device not be away from each piconet in which it is participating for more than T_{poll} slots. A periodic master transmission is required to keep the slaves synchronized to the channel. Since the slaves only need the channel access code to synchronize, any packet type can be used for this purpose.

Only the slave that is addressed by one of its LT_ADDRs (primary or secondary) may return a packet in the next slave-to-master slot. If no valid packet header is received, the slave may only respond in its reserved SCO or eSCO slave-to-master slot. In the case of a broadcast message, no slave shall return a packet (an exception is the access window for access requests in the **PARK** state, see [Section 8.9 on page 185](#)).

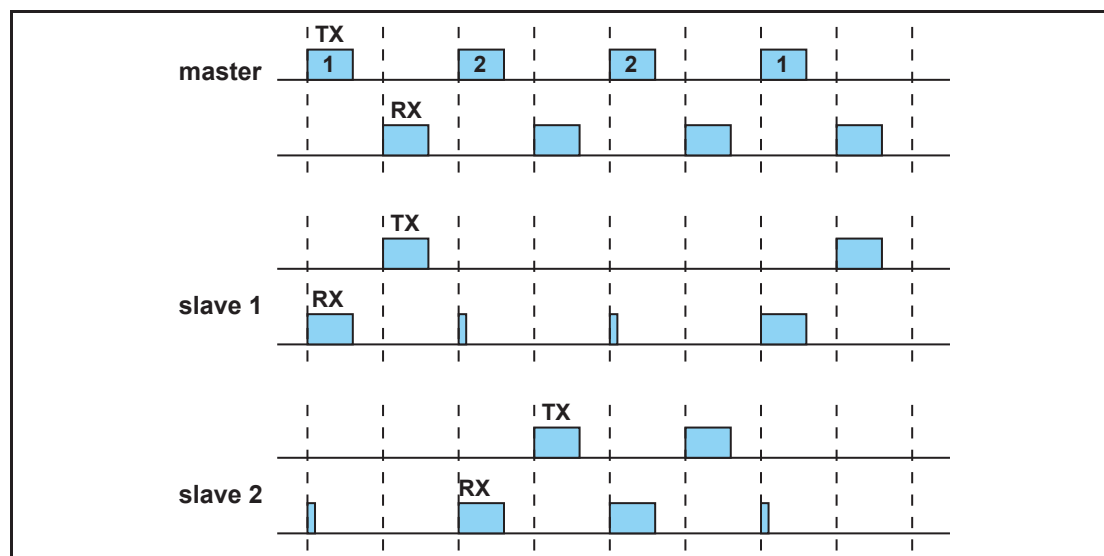


Figure 8.6: RX/TX timing in multi-slave configuration

For ACL logical transports the mode selection may be left to real time packet type selections. The packet type table (ptt) in section 6.5 allows the selection of Basic Rate or Enhanced Data Rate for each of the packet type codes, however; the DM1 packet is available in all packet type tables. ACL traffic over this given physical or logical link shall utilize the packet types in the given column of Packets defined for synchronous and asynchronous logical transport types.

8.6.1 Polling in the active mode

The master always has full control over the piconet. Due to the TDD scheme, slaves can only communicate with the master and not other slaves. In order to avoid collisions on the ACL logical transport, a slave is only allowed to transmit in the slave-to-master slot when addressed by the LT_ADDR in the packet header in the preceding master-to-slave slot. If the LT_ADDR in the preceding slot does not match, or a valid packet header was not received, the slave shall not transmit.

The master normally attempts to poll a slave's ACL logical transport no less often than once every T_{poll} slots. T_{poll} is set by the Link Manager (see [\[Part C\] Section 4.1.8 on page 244](#)).

The slave's ACL logical transport may be polled with any packet type except for FHS and ID. For example, polling during SCO may use HV packets, since the slave may respond to an HV packet with a DM1 packet (see [Section 8.6.2 on page 169](#)).

8.6.2 SCO

The SCO logical transport shall be established by the master sending an SCO setup message via the LM protocol. This message contains timing parameters



including the SCO interval T_{SCO} and the offset D_{SCO} to specify the reserved slots.

In order to prevent clock wrap-around problems, an initialization flag in the LMP setup message indicates whether initialization procedure 1 or 2 is being used. The slave shall apply the initialization method as indicated by the initialization flag. The master shall use initialization 1 when the MSB of the current master clock (CLK_{27}) is 0; it shall use initialization 2 when the MSB of the current master clock (CLK_{27}) is 1. The master-to-slave SCO slots reserved by the master and the slave shall be initialized on the slots for which the clock satisfies the applicable equation:

$$CLK_{27-1} \bmod T_{SCO} = D_{SCO} \quad \text{for initialization 1}$$

$$(\overline{CLK_{27}}, CLK_{26-1}) \bmod T_{SCO} = D_{SCO} \quad \text{for initialization 2}$$

The slave-to-master SCO slots shall directly follow the reserved master-to-slave SCO slots. After initialization, the clock value $CLK(k+1)$ for the next master-to-slave SCO slot shall be derived by adding the fixed interval T_{SCO} to the clock value of the current master-to-slave SCO slot:

$$CLK(k+1) = CLK(k) + T_{SCO}$$

The master will send SCO packets to the slave at regular intervals (the SCO interval T_{SCO} counted in slots) in the reserved master-to-slave slots. An HV1 packet can carry 1.25ms of speech at a 64 kb/s rate. An HV1 packet shall therefore be sent every two time slots ($T_{SCO}=2$). An HV2 packet can carry 2.5ms of speech at a 64 kb/s rate. An HV2 packet shall therefore be sent every four time slots ($T_{SCO}=4$). An HV3 packet can carry 3.75ms of speech at a 64 kb/s rate. An HV3 packet shall therefore be sent every six time slots ($T_{SCO}=6$).

The slave is allowed to transmit in the slot reserved for its SCO logical transport unless the (valid) LT_ADDR in the preceding slot indicates a different slave. If no valid LT_ADDR can be derived in the preceding slot, the slave may still transmit in the reserved SCO slot.

Since the DM1 packet is recognized on the SCO logical transport, it may be sent during the SCO reserved slots if a valid packet header with the primary LT_ADDR is received in the preceding slot. DM1 packets sent during SCO reserved slots shall only be used to send ACL-C data.

The slave shall not transmit anything other than an HV packet in a reserved SCO slot unless it decodes its own slave address in the packet header of the packet in the preceding master-to-slave transmission slot.



8.6.3 eSCO

The eSCO logical transport is established by the master sending an eSCO setup message via the LM protocol. This message contains timing parameters including the eSCO interval T_{ESCO} and the offset D_{ESCO} to specify the reserved slots.

To enter eSCO, the master or slave shall send an eSCO setup command via the LM protocol. This message shall contain the eSCO interval T_{ESCO} and an offset D_{ESCO} . In order to prevent clock wrap-around problems, an initialization flag in the LMP setup message indicates whether initialization procedure 1 or 2 shall be used. The initiating device shall use initialization 1 when the MSB of the current master clock (CLK_{27}) is 0; it shall use initialization 2 when the MSB of the current master clock (CLK_{27}) is 1. The responding device shall apply the initialization method as indicated by the initialization flag. The master-to-slave eSCO slots reserved by the master and the slave shall be initialized on the slots for which the clock satisfies the applicable equation:

$$\text{CLK}_{27-1} \bmod T_{\text{ESCO}} = D_{\text{ESCO}} \quad \text{for initialization 1}$$

$$(\overline{\text{CLK}}_{27}, \text{CLK}_{26-1}) \bmod T_{\text{ESCO}} = D_{\text{ESCO}} \quad \text{for initialization 2}$$

The slave-to-master eSCO slots shall directly follow the reserved master-to-slave eSCO slots. After initialization, the clock value $\text{CLK}(k+1)$ for the next master-to-slave eSCO slot shall be found by adding the fixed interval T_{ESCO} to the clock value of the current master-to-slave eSCO slot:

$$\text{CLK}(k+1) = \text{CLK}(k) + T_{\text{ESCO}}$$

When an eSCO logical transport is established, the master shall assign an additional LT_ADDR to the slave. This provides the eSCO logical transport with an ARQ scheme that is separate from that of the ACL logical transport. All traffic on a particular eSCO logical transport, and only that eSCO traffic, is carried on the eSCO LT_ADDR. The eSCO ARQ scheme uses the ARQN bit in the packet header, and operates similarly to the ARQ scheme on ACL links.

There are two different polling rules in eSCO. In the eSCO reserved slots, the polling rule is the same as to the SCO reserved slots. The master may send a packet in the master slot. The slave may transmit on the eSCO LT_ADDR in the following slot either if it received a packet on the eSCO LT_ADDR in the previous slot, or if it did not receive a valid packet header in the previous slot. When the master-to-slave packet type is a three-slot packet, the slave's transmit slot is the fourth slot of the eSCO reserved slots. A master shall transmit in an eSCO retransmission window on a given eSCO LT_ADDR only if it addressed that eSCO LT_ADDR in the immediately preceding eSCO reserved slots. A slave may transmit on an eSCO LT_ADDR in the eSCO reserved slots only if the slave did not received a valid packet header with a different LT_ADDR in the eSCO reserved slots. Inside retransmission windows, the

same polling rule as for ACL traffic is used: the slave shall transmit on the eSCO channel only if it received a valid packet header and correct LT_ADDR on the eSCO channel in the previous master-to-slave transmission slot. The master may transmit on any non-eSCO LT_ADDR in any master-to-slave transmission slot inside the eSCO retransmission window. The master shall only transmit on an eSCO LT_ADDR in the retransmission window if there are enough slots left for both the master and slave packets to complete in the retransmission window. The master may refrain from transmitting in any slot during the eSCO retransmission window. When there is no data to transmit from master to slave, either due to the traffic being unidirectional or due to the master-to-slave packet having been ACK'ed, the master shall use the POLL packet. When the master-to-slave packet has been ACK'ed, and the slave-to-master packet has been correctly received, the master shall not address the slave on the eSCO LT_ADDR until the next eSCO reserved slot, with the exception that the master may transmit a NULL packet with ARQN=ACK on the eSCO LT_ADDR. When there is no data to transmit from slave to master, either due to the traffic being unidirectional or due to the slave-to-master packet having been ACK'ed, the slave shall use NULL packets. eSCO traffic should be given priority over ACL traffic in the retransmission window.

Figure 8.7 on page 172 shows the eSCO window when single slot packets are used.

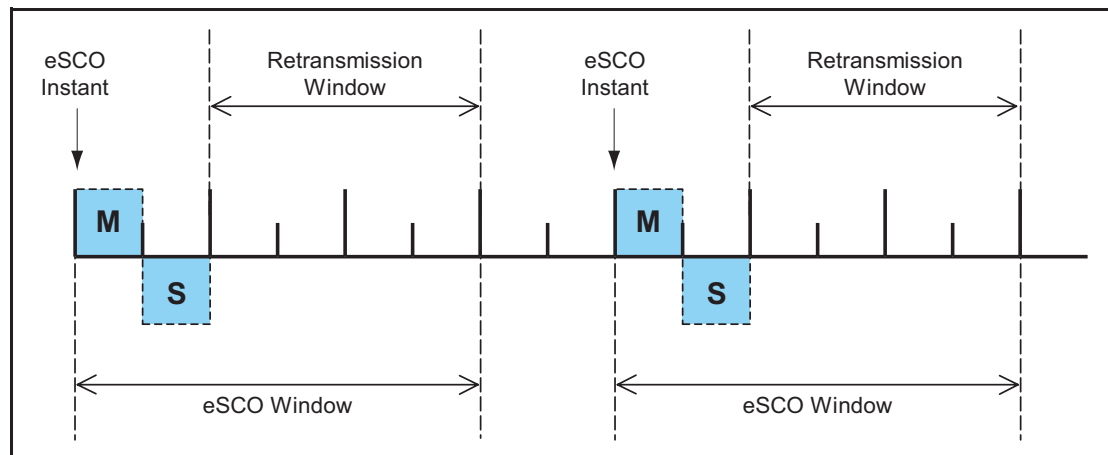


Figure 8.7: eSCO Window Details for Single-Slot Packets

When multi-slot packets are used in either direction of the eSCO logical transport, the first transmission continues into the following slots. The retransmission window in this case starts the slot after the end of the slave-to-master packet, i.e. two, four or six slots immediately following the eSCO instant are reserved and should not be used for other traffic. Figure 8.8 on page 173 shows the eSCO window when multi-slot packets are used in one direction and single-slot packets are used in the other direction.

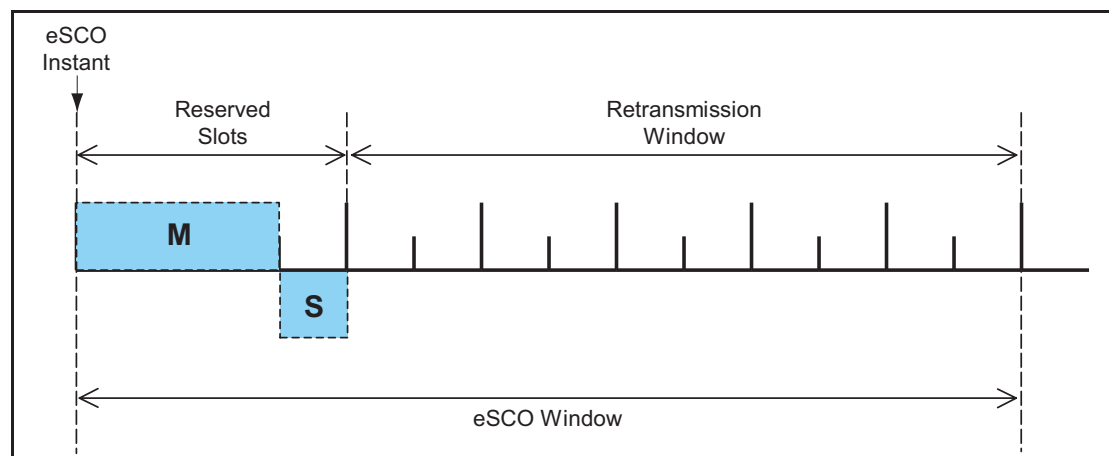


Figure 8.8: eSCO Window Details for Asymmetric Traffic

eSCO windows may overlap on the master, but shall not overlap on an individual slave.

In the reserved slots both master and slave shall only listen and transmit at their allocated slots at the first transmission time of each eSCO window. Intermittent lapses due to, for instance, time-critical signaling during connection establishment are allowed. Both master and slave may refrain from sending data and may use instead POLL and NULL packets respectively. When the master transmits a POLL packet instead of an EV4 or EV5 packet the slave shall transmit starting in the same slot as if the master transmitted an EV4 or EV5 packet. If the slave does not receive anything in the reserved master-to-slave transmission slot it shall transmit in the same slot as if the master had transmitted the negotiated packet type. For example, if the master had negotiated an EV5 packet the slave would transmit three slots later. [If the master does not receive a slave transmission in response to an eSCO packet it causes an implicit NAK of the packet in question. The listening requirements for the slave during the retransmission window are the same as for an active ACL logical transport.

8.6.4 Broadcast scheme

The master of the piconet can broadcast messages to all slaves on the ASB-U, PSB-C, and PSB-U logical transports. A broadcast packet shall have an LT_ADDR set to all zero. Each new broadcast message (which may be carried by a number of packets) shall start with the start of L2CAP message indication (LLID=10).

The Broadcast LT_ADDR shall use a ptt=0.

A broadcast packet shall never be acknowledged. In an error-prone environment, the master may carry out a number of retransmissions to increase the probability for error-free delivery, see also [Section 7.6.5 on page 150](#).



In order to support the **PARK** state (as described in [Section 8.9 on page 185](#)), a master transmission shall take place at fixed intervals. This master transmission will act as a beacon to which slaves can synchronize. If no traffic takes place at the beacon event, broadcast packets shall be sent. More information is given in [Section 8.9 on page 185](#).



8.6.5 Role switch

There are several occasions when a role switch is used.

- a role switch is necessary when joining an existing piconet by paging, since by definition, the paging device is initially master of a "small" piconet only involving the pager (master) and the paged (slave) device.
- a role switch is necessary in order for a slave in an existing piconet to set up a new piconet with itself as master and the original piconet master as slave. If the original piconet had more than one slave, then this implies a double role for the original piconet master; it becomes a slave in the new piconet while still maintaining the original piconet as master.

Prior to the role switch, encryption if present, shall be stopped in the old piconet. A role switch shall not be performed if the physical link is in Sniff or Hold mode, in the **PARK** state, or has any synchronous logical transports.

For the master and slave involved in the role switch, the switch results in a reversal of their TX and RX timing: a TDD switch. Additionally, since the piconet parameters are derived from the Bluetooth device address and clock of the master, a role switch inherently involves a redefinition of the piconet as well: a piconet switch. The new piconet's parameters shall be derived from the former slave's device address and clock.

Assume device A is to become master; device B was the former master. Then there are two alternatives: either the slave initiates the role switch or the master initiates the role switch. These alternatives are described in Link Manager Protocol, [\[Part C\] Section 4.4.2 on page 268](#). The baseband procedure is the same regardless of which alternative is used.

In step 1, the slave A and master B shall perform a TDD switch using the former hopping scheme (still using the Bluetooth device address and clock of device B), so there is no piconet switch yet. The slot offset information sent by slave A shall not be used yet but shall be used in step 3. Device A now becomes the master, device B the slave. The LT_ADDR formerly used by device A in its slave role, shall now be used by slave B.

At the moment of the TDD switch, both devices A and B shall start a timer with a time out of *newconnectionTO*. The timer shall be stopped in slave B as soon as it receives an FHS packet from master A on the TDD-switched channel. The timer shall be stopped in master A as soon as it receives an ID packet from slave B. If the *newconnectionTO* expires, the master and slave shall return to the old piconet timing and AFH state, taking their old roles of master and slave. The FHS packet shall be sent by master A using the "old" piconet parameters. The LT_ADDR in the FHS packet header shall be the former LT_ADDR used by device A. The LT_ADDR carried in the FHS payload shall be the new LT_ADDR intended for device B when operating on the new piconet. After the FHS acknowledgment, which is the ID packet and shall be sent by the slave on the old hopping sequence, both master A and slave B shall use the new channel parameters of the new piconet as indicated by the FHS with the sequence selection set to *basic channel hopping sequence*. If the new master has physi-



cal links that are *AFH enabled*, following the piconet switch the new master is responsible for controlling the AFH operational mode of its new slave.

Since the old and new masters' clocks are synchronized, the clock information sent in the FHS payload shall indicate the new master's clock at the beginning of the FHS packet transmission. Furthermore, the 1.25 ms resolution of the clock information given in the FHS packet is not sufficient for aligning the slot boundaries of the two piconets. The slot-offset information in the LMP message previously sent by device A shall be used to provide more accurate timing information. The slot offset indicates the delay between the start of the master-to-slave slots of the old and new piconet channels. This timing information ranges from 0 to 1249 μs with a resolution of 1 μs . It shall be used together with the clock information in the FHS packet to accurately position the correlation window when switching to the new master's timing after acknowledgment of the FHS packet.

After reception of the FHS packet acknowledgment, the new master A shall switch to its own timing with the sequence selection set to the *basic channel hopping sequence* and shall send a POLL packet to verify the switch. Both the master and the slave shall start a new timer with a time out of *newconnectionTO* on FHS packet acknowledgment. The start of this timer shall be aligned with the beginning of the first master TX slot boundary of the new piconet, following the FHS packet acknowledgment. The slave shall stop the timer when the POLL packet is received; the master shall stop the timer when the POLL packet is acknowledged. The slave shall respond with any type of packet to acknowledge the POLL. Any pending AFH_Instant shall be cancelled once the POLL packet has been received by the slave. If no response is received, the master shall re-send the POLL packet until *newconnectionTO* is reached. If this timer expires, both the slave and the master shall return to the old piconet timing with the old master and slave roles. Expiry of the timer shall also restore the state associated with AFH (including any pending AFH_Instant), Channel Quality Driven Data Rate (CQDDR, Link Manager Protocol [\[Part C\] Section 4.1.7 on page 243](#)) and power control (Link Manager Protocol [\[Part C\] Section 4.1.3 on page 235](#)). The procedure may then start again beginning at step 1. Aligning the timer with TX boundaries of the new piconet ensures that no device returns to the old piconet timing in the middle of a master RX slot.

After the role switch the ACL logical transport is reinitialized as if it were a new connection. For example, the SEQN of the first data packet containing a CRC on the new piconet channel shall be set according to the rules in [section 7.6.2 on page 147](#).

A parked slave must be unparked before it can participate in a role switch.

8.6.6 Scatternet

Multiple piconets may cover the same area. Since each piconet has a different master, the piconets hop independently, each with their own hopping sequence and phase as determined by the respective master. In addition, the packets carried on the channels are preceded by different channel access codes as determined by the master device addresses. As more piconets are added, the probability of collisions increases; a graceful degradation of performance results as is common in frequency-hopping spread spectrum systems.

If multiple piconets cover the same area, a device can participate in two or more overlaying piconets by applying time multiplexing. To participate on the proper channel, it shall use the associated master device address and proper clock offset to obtain the correct phase. A device can act as a slave in several piconets, but only as a master in a single piconet: since two piconets with the same master are synchronized and use the same hopping sequence, they are one and the same piconet. A group of piconets in which connections exist between different piconets is called a *scatternet*.

A master or slave can become a slave in another piconet by being paged by the master of this other piconet. On the other hand, a device participating in one piconet can page the master or slave of another piconet. Since the paging device always starts out as master, a master-slave role switch is required if a slave role is desired. This is described in the [Section 8.6.5 on page 175](#).

8.6.6.1 Inter-piconet communications

Time multiplexing must be used to switch between piconets. Devices may achieve the time multiplexing necessary to implement scatternet by using sniff mode or by remaining in an active ACL connection. For an ACL connection in piconets where the device is a slave in the **CONNECTION** state, it may choose not to listen in every master slot. In this case it should be recognized that the quality of service on this link may degrade abruptly if the slave is not present enough to match up with the master polling that slave. Similarly, in piconets where the device is master it may choose not to transmit in every master slot. In this case it is important to honor T_{poll} as much as possible. Devices in sniff mode may have sufficient time to visit another piconet in between sniff slots. When the device is a slave using sniff mode and there are not sufficient idle slots, the device may choose to not listen to all master transmission slots in the sniff_attempts period or during the subsequent sniff_timeout period. A master is not required to transmit during sniff slots and therefore has flexibility for scatternet. If SCO or eSCO links are established, other piconets shall only be visited in the non-reserved slots in between reserved slots. This is only possible if there is a single SCO logical transport using HV3 packets or eSCO links where at least four slots remain in between the reserved slots. Since the multiple piconets are not synchronized, guard time must be left to account for misalignment. This means that only 2 slots can effectively be used to visit another piconet in between the HV3 packets.



Since the clocks of two masters of different piconets are not synchronized, a slave device participating in two piconets shall maintain two offsets that, added to its own native clock, create the two master clocks. Since the two master clocks drift independently, the slave must regularly update the offsets in order to keep synchronization to both masters.

8.6.7 Hop sequence switching

Hop sequence adaptation is controlled by the master and can be set to either *enabled* or *disabled*. Once enabled, hop sequence adaptation shall apply to all logical transports on a physical link. Once enabled, the master may periodically update the set of *used* and *unused* channels as well as disable hop sequence adaptation on a physical link. When a master has multiple physical links the state of each link is independent of all other physical links.

When hop sequence adaptation is enabled, the *sequence selection* hop selection kernel input is set to *adapted channel hopping sequence* and the *AFH_channel_map* input is set to the appropriate set of *used* and *unused* channels. Additionally, the *same channel* mechanism shall be used. When hop sequence adaptation is enabled with all channels *used* this is known as AHS(79).

When hop sequence adaptation is disabled, the *sequence selection* input of the hop selection kernel is set to *basic channel hopping sequence* (the *AFH_channel_map* input is unused in this case) and the *same channel* mechanism shall not be used.

The hop sequence adaptation state shall be changed when the master sends the LMP_set_AFH PDU and a baseband acknowledgement is received. When the baseband acknowledgement is received prior to the hop sequence switch instant, *AFH_Instant*, (See Link Manager Protocol [Part C] Section 4.1.4 on page 237) the hop sequence proceeds as shown in Figure 8.9 on page 178.

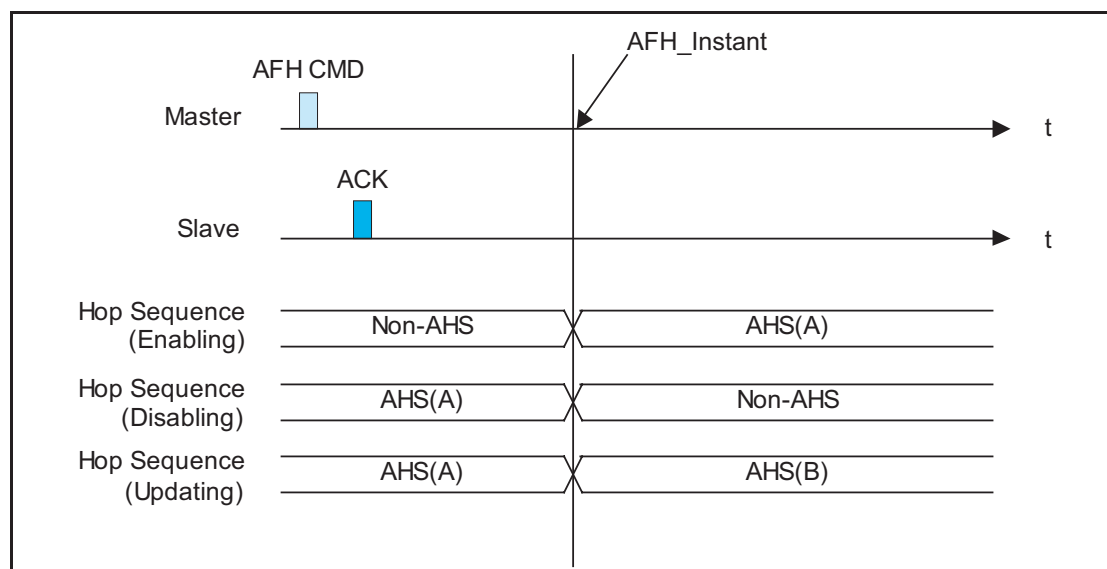


Figure 8.9: Successful hop sequence switching

When the baseband acknowledgement is not received prior to the *AFH_Instant* the master shall use a recovery hop sequence for the slave(s) that did not respond with an acknowledgement (this may be because the slave did not hear the master's transmission or the master did not hear the slave's transmission). When hop sequence adaptation is being enabled or disabled the recovery sequence shall be the *AFH_channel_map* specified in the LMP_set_AFH PDU. When the *AFH_channel_map* is being updated the master shall choose a recovery sequence that includes all of the RF channels marked as *used* in either the old or new *AFH_channel_map*, e.g. AHS(79). Once the baseband acknowledgement is received the master shall use the *AFH_channel_map* in the LMP_set_AFH PDU starting with the next transmission to the slave. See [Figure 8.10 on page 179](#).

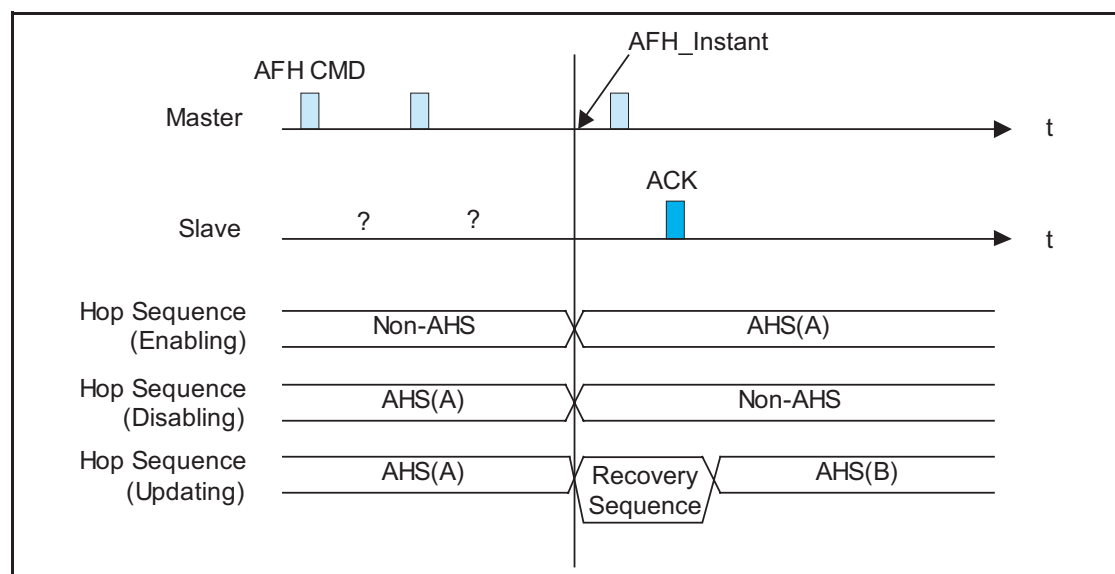


Figure 8.10: Recovery hop sequences

When the *AFH_Instant* occurs during a multi-slot packet transmitted by the master, the slave shall use the same hopping sequence parameters as the master used at the start of the multi-slot packet. An example of this is shown in [Figure 8.11 on page 180](#). In this figure the *basic channel hopping sequence* is designated *f*. The first *adapted channel hopping sequence* is designated with *f'*, and the second *adapted channel hopping sequence* is designated *f''*.

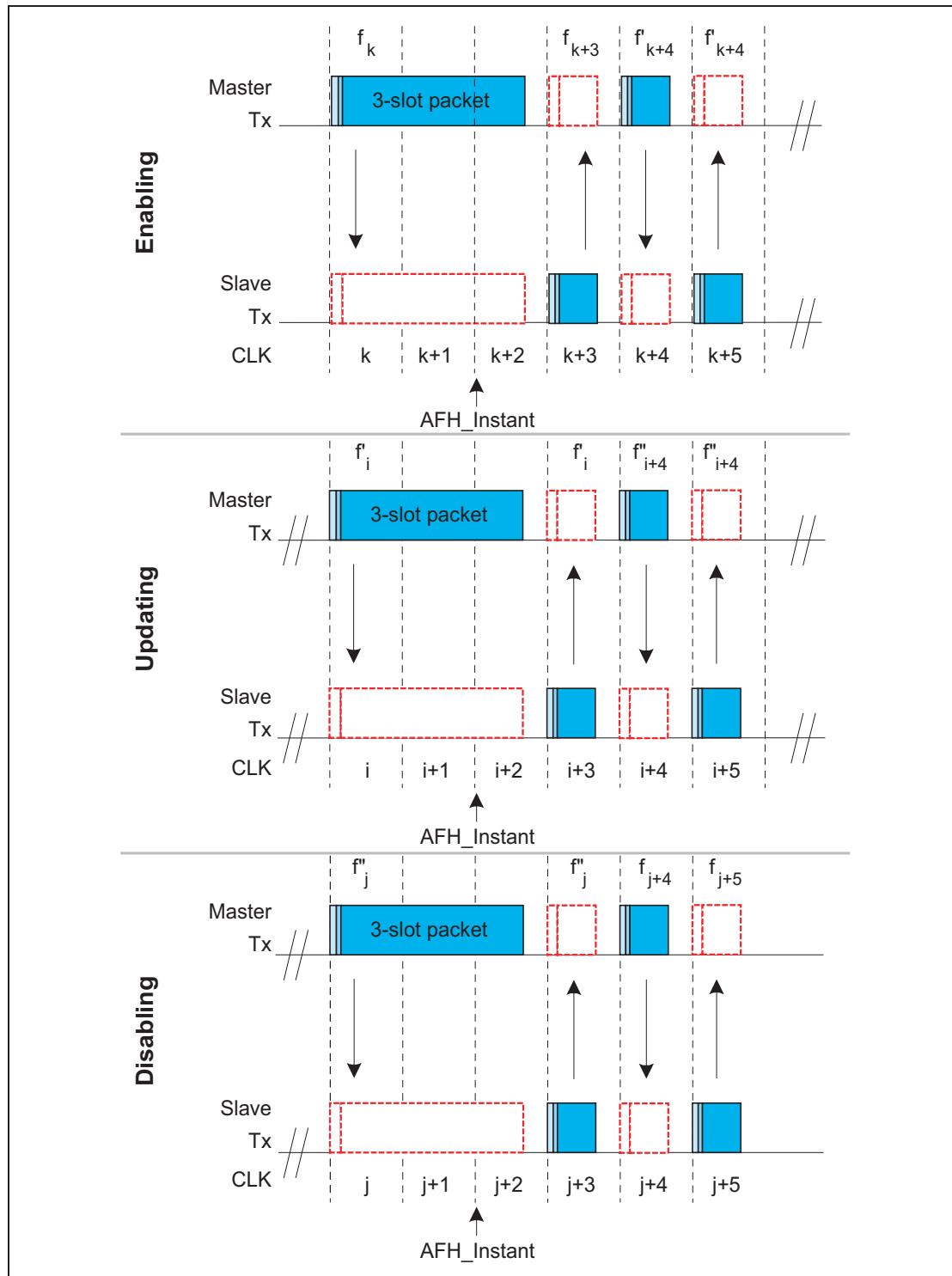


Figure 8.11: AFH_Instant changes during multi-slot packets transmitted by the master.

8.6.8 Channel classification and channel map selection

RF channels are classified as being *unknown*, *bad* or *good*. These classifications are determined individually by the master and slaves based on local information (e.g. active or passive channel assessment methods or from the Host via HCI). Information received from other devices via LMP (e.g. an *AFH_channel_map* from a master or a channel classification report from a slave) shall not be included in a device's channel classification.

The three possible channel classifications shall be as defined in [Table 8.6 on page 181](#).

| Classification | Definition |
|----------------|--|
| <i>unknown</i> | A channel shall be classified as <i>unknown</i> if the channel assessment measurements are insufficient to reliably classify the channel, and the channel is not marked as <i>bad</i> in the most recent HCI <i>Set_AFH_Channel_Classification</i> . |
| <i>bad</i> | <p>A channel may be classified as <i>bad</i> if an ACL or synchronous throughput failure measure associated with it has exceeded a threshold (defined by the particular channel assessment algorithm employed).</p> <p>A channel may also be classified as <i>bad</i> if an interference-level measure associated with it, determining the interference level that the link poses upon other systems in the vicinity, has exceeded a threshold (defined by the particular channel assessment algorithm employed).</p> <p>A channel shall be classified as <i>bad</i> when it is marked as <i>bad</i> in the most recent HCI <i>Set_AFH_Channel_Classification</i> command.</p> |
| <i>good</i> | A channel shall be classified as <i>good</i> if it is not either <i>unknown</i> or <i>bad</i> . |

Table 8.6: Channel classification descriptions

A master with AFH enabled physical links shall determine an *AFH_channel_map* based on any combination of the following information:

- Channel classification from local measurements (e.g. active or passive channel assessment in the Controller), if supported and enabled. The Host may enable or disable local measurements using the HCI *Write_AFH_Channel_Classification_Mode* command, defined in the HCI Functional Specification [\[Part E\] Section 7.3.58 on page 537](#) if HCI is present.
- Channel classification information from the Host using the HCI *Set_AFH_channel_classification* command, defined in the HCI Functional Specification [\[Part E\] Section 7.3.58 on page 537](#) if HCI is present. Channels classified as *bad* in the most recent *AFH_Host_Channel_Classification* shall be marked as *unused* in the *AFH_channel_map*.
- Channel classification reports received from slaves in *LMP_channel_classification* PDUs, defined in the LMP Specification [\[Part C\] Section 4.1.5 on page 240](#).



The algorithm used by the master to combine these information sources and generate the *AFH_channel_map* is not defined in the specification and will be implementation specific. At no time shall the number of channels used be less than N_{min} , defined in [Section 2.3.1 on page 75](#).

If a master that determines that all channels should be *used* it may keep AFH operation enabled using an *AFH_channel_map* of 79 *used* channels, i.e. AHS(79).

8.6.9 Power Management

Features are provided to allow low-power operation. These features are both at the microscopic level when handling the packets, and at the macroscopic level when using certain operation modes.

8.6.9.1 Packet handling

In order to minimize power consumption, packet handling is minimized both at TX and RX sides. At the TX side, power is minimized by only sending useful data. This means that if only link control information needs to be exchanged, **NULL** packets may be used. No transmission is required if there is no link control information to be sent, or if the transmission would only involve a NAK (NAK is implicit on no reply). If there is data to be sent, the payload length shall be adapted in order to send only the valid data bytes. At the RX side, packet processing takes place in different steps. If no valid access code is found in the search window, the transceiver may return to sleep. If an access code is found, the receiver device shall start to process the packet header. If the HEC fails, the device may return to sleep after the packet header. A valid header indicates if a payload will follow and how many slots are involved.

8.6.9.2 Slot occupancy

As was described in [Section 6.5 on page 118](#), the packet type indicates how many slots a packet may occupy. A slave not addressed in the packet header may go to sleep for the remaining slots the packet occupies. This can be read from the TYPE code.

8.6.9.3 Recommendations for low-power operation

The most common and flexible methods for reducing power consumption are the use of sniff and park. Hold can also be used by repeated negotiation of hold periods.

8.6.9.4 Enhanced Data Rate

Enhanced Data Rate provides power saving because of the ability to send a given amount of data in either fewer packets or with the same (or similar) number of packets but with shorter payloads.

8.7 SNIFF MODE

In sniff mode, the duty cycle of the slave's activity in the piconet may be reduced. If a slave is in active mode on an ACL logical transport, it shall listen in every ACL slot to the master traffic, unless that link is being treated as a scatternet link or is absent due to hold mode. With sniff mode, the time slots when a slave is listening are reduced, so the master shall only transmit to a slave in specified time slots. The sniff anchor points are spaced regularly with an interval of T_{sniff} .

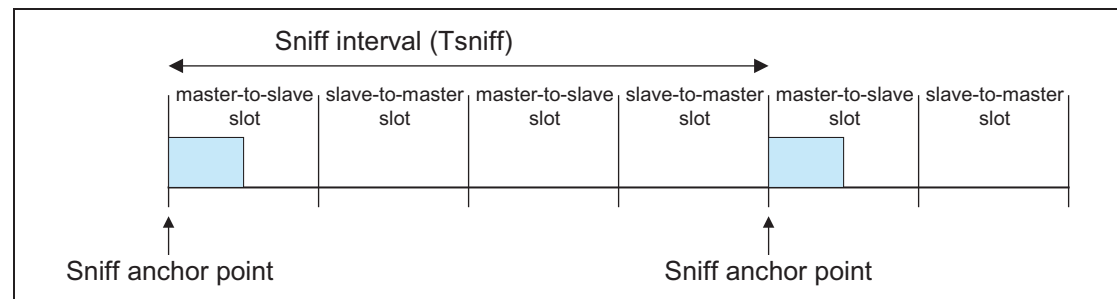


Figure 8.12: Sniff anchor points

The slave listens in master-to-slave transmission slots starting at the sniff anchor point. It shall use the following rules to determine whether to continue listening:

- If fewer than $N_{\text{sniff attempt}}$ master-to-slave transmission slots have elapsed since the sniff anchor point then the slave shall continue listening.
- If the slave has received a packet with a matching LT_ADDR that contains ACL data (DM, DH, DV, or AUX1 packets) in the preceding $N_{\text{sniff timeout}}$ master-to-slave transmission slots then it shall continue listening.
- If the slave has transmitted a packet containing ACL data (DM, DH, DV, or AUX1 packets) in the preceding $N_{\text{sniff timeout}}$ slave-to-master transmission slots then it shall continue listening.
- If the slave has received any packet with a matching LT_ADDR in the preceding $N_{\text{sniff timeout}}$ master-to-slave transmission slots then it may continue listening.
- A device may override the rules above and stop listening prior to $N_{\text{sniff timeout}}$ or the remaining $N_{\text{sniff attempt}}$ slots if it has activity in another piconet.

It is possible that activity from one sniff timeout may extend to the next sniff anchor point. Any activity from a previous sniff timeout shall not affect activity



after the next sniff anchor point. So in the above rules, only the slots since the last sniff anchor point are considered.

Note that $N_{\text{sniff attempt}} = 1$ and $N_{\text{sniff timeout}} = 0$ cause the slave to listen only at the slot beginning at the sniff anchor point, irrespective of packets received from the master.

$N_{\text{sniff attempt}} = 0$ shall not be used.

Sniff mode only applies to asynchronous logical transports and their associated LT_ADDR. sniff mode shall not apply to synchronous logical transports, therefore, both masters and slaves shall still respect the reserved slots and retransmission windows of synchronous links.

To enter sniff mode, the master or slave shall issue a sniff command via the LM protocol. This message includes the sniff interval T_{sniff} and an offset D_{sniff} . In addition, an initialization flag indicates whether initialization procedure 1 or 2 shall be used. The device shall use initialization 1 when the MSB of the current master clock (CLK_{27}) is 0; it shall use initialization 2 when the MSB of the current master clock (CLK_{27}) is 1. The slave shall apply the initialization method as indicated by the initialization flag irrespective of its clock bit value CLK_{27} . The sniff anchor point determined by the master and the slave shall be initialized on the slots for which the clock satisfies the applicable equation:

$$\begin{aligned} \text{CLK}_{27-1} \bmod T_{\text{sniff}} &= D_{\text{sniff}} && \text{for initialization 1} \\ (\overline{\text{CLK}_{27}}, \text{CLK}_{26-1}) \bmod T_{\text{sniff}} &= D_{\text{sniff}} && \text{for initialization 2} \end{aligned}$$

this implies that D_{sniff} must be even

After initialization, the clock value $\text{CLK}(k+1)$ for the next sniff anchor point shall be derived by adding the fixed interval T_{sniff} to the clock value of the current sniff anchor point:

$$\text{CLK}(k+1) = \text{CLK}(k) + T_{\text{sniff}}$$

8.7.1 Sniff Transition Mode

Sniff transition mode is a special mode which is used during the transition between sniff and active mode. It is required because during this transition it is unclear which mode (Sniff or Active) the slave is in and it is necessary to ensure that the slave is polled correctly regardless of which mode it is in.

In sniff transition mode the master shall maintain the active mode poll interval in case the slave is in active mode. In addition the master shall poll the slave at least once in the sniff attempt transmit slots starting at each sniff instant: note that this transmission counts for the active mode polling as well. The master must use its high power accurate clock when in Sniff Transition Mode.



The precise circumstances under which the master enters Sniff Transition Mode are defined in [\[Part C\] Section 4.5.3.1 on page 279](#).

8.8 HOLD MODE

During the **CONNECTION** state, the ACL logical transport to a slave can be put in a **hold** mode. In **hold** mode the slave temporarily shall not support ACL packets on the channel. Any synchronous packet during reserved synchronous slots (from SCO and eSCO links) shall be supported. With the **hold** mode, capacity can be made free to do other things like scanning, paging, inquiring, or attending another piconet. The device in **hold** mode can also enter a low-power sleep mode. During **hold** mode, the slave device keeps its logical transport address(es) (LT_ADDR).

Prior to entering hold mode, master and slave agree on the time duration the slave remains in hold mode. A timer shall be initialized with the *holdTO* value. When the timer is expired, the slave shall wake up, synchronize to the traffic on the channel and will wait for further master transmissions.

8.9 PARK STATE

When a slave does not need to participate on the piconet channel, but still needs to remain synchronized to the channel, it can enter **PARK** state. **PARK** state is a state with very little activity in the slave. In the **PARK** state, the slave shall give up its logical transport address LT_ADDR. Instead, it shall receive two new addresses to be used in the **PARK** state

- PM_ADDR: 8-bit Parked Member Address
- AR_ADDR: 8-bit Access Request Address

The PM_ADDR distinguishes a parked slave from the other parked slaves. This address may be used in the master-initiated unpark procedure. In addition to the PM_ADDR, a parked slave may also be unparked by its 48-bit BD_ADDR. The all-zero PM_ADDR is a reserved address: if a parked device has the all-zero PM_ADDR it can only be unparked by the BD_ADDR. In that case, the PM_ADDR has no meaning. The AR_ADDR shall be used by the slave in the slave-initiated unpark procedure. All messages sent to the parked slaves are carried by broadcast packets.

The parked slave wakes up at regular intervals to listen to the channel in order to re-synchronize and to check for broadcast messages. To support the synchronization and channel access of the parked slaves, the master supports a beacon train described in the next section. The beacon structure is communicated to the slave when it is parked. When the beacon structure changes, the parked slaves are updated through broadcast messages.

The master shall maintain separate non-overlapping park beacon structures for each hop sequence. The beacon structures shall not overlap either their beacon slots or access windows.



In addition for using it for low power consumption, park is used to connect more than seven slaves to a single master. At any one time, only seven slaves can be in the **CONNECTION** state. However, by swapping active and parked slaves out respectively in the piconet, the number of slaves can be much larger (255 if the PM_ADDR is used, and an arbitrarily large number if the BD_ADDR is used).

8.9.1 Beacon train

To support parked slaves, the master establishes a beacon train when one or more slaves are parked. The beacon train consists of one beacon slot or a train of equidistant beacon slots which is transmitted periodically with a constant time interval. The beacon train is illustrated in [Figure 8.13 on page 188](#). A train of N_B ($N_B \geq 1$) beacon slots is defined with an interval of T_B slots. The beacon slots in the train are separated by Δ_B . The start of the first beacon slot is referred to as the **beacon instant** and serves as the beacon timing reference. The beacon parameters N_B and T_B are chosen such that there are sufficient beacon slots for a parked slave to synchronize to during a certain time window in an error-prone environment.

When parked, the slave shall receive the beacon parameters through an LMP command. In addition, the timing of the beacon instant is indicated through the offset D_B . As with the SCO logical transport (see [Section 8.6.2 on page 169](#)), two initialization procedures 1 or 2 are used. The master shall use initialization 1 when the MSB of the current master clock (CLK_{27}) is 0; it shall use initialization 2 when the MSB of the current master clock (CLK_{27}) is 1. The chosen initialization procedure shall also be carried by an initialization flag in the LMP command. The slave shall apply the initialization method as indicated by the initialization flag irrespective of its clock bit CLK_{27} . The master-to-slave slot positioned at the beacon instant shall be initialized on the slots for which the clock satisfies the applicable equation:

$$\text{CLK}_{27-1} \bmod T_B = D_B \quad \text{for initialization 1}$$

$$(\overline{\text{CLK}}_{27}, \text{CLK}_{26-1}) \bmod T_B = D_B \quad \text{for initialization 2}$$

this implies that D_B will be even

After initialization, the clock value $\text{CLK}(k+1)$ for the next beacon instant shall be derived by adding the fixed interval T_B to the clock value of the current beacon instant:

$$\text{CLK}(k+1) = \text{CLK}(k) + T_B$$

The beacon train serves four purposes:

1. transmission of master-to-slave packets which the parked slaves can use for re-synchronization
2. carrying messages to the parked slaves to change the beacon parameters



3. carrying general broadcast messages to the parked slaves
4. unparking of one or more parked slaves

Since a slave can synchronize to any packet which is preceded by the proper channel access code, the packets carried on the beacon slots do not have to contain specific broadcast packets for parked slaves to be able to synchronize; any packet may be used. The only requirement placed on the beacon slots is that there is a master-to-slave transmission present on the hopping sequence associated with the park structure. If there is no information to be sent, **NULL** packets may be transmitted by the master. If there is indeed broadcast information to be sent to the parked slaves, the first packet of the broadcast message shall be repeated in every beacon slot of the beacon train. However, synchronous traffic in the synchronous reserved slots may interrupt the beacon transmission if it is on the same hopping sequence as the parked slaves. The master shall configure its park beacon structure so that reserved slots of synchronous logical transports do not cause slaves to miss synchronization on a beacon slot. For example, a master that has active slaves using AHS, and parked slaves using Non-AHS shall ensure that the Park beacons cannot be interrupted by AHS synchronous reserved slots.

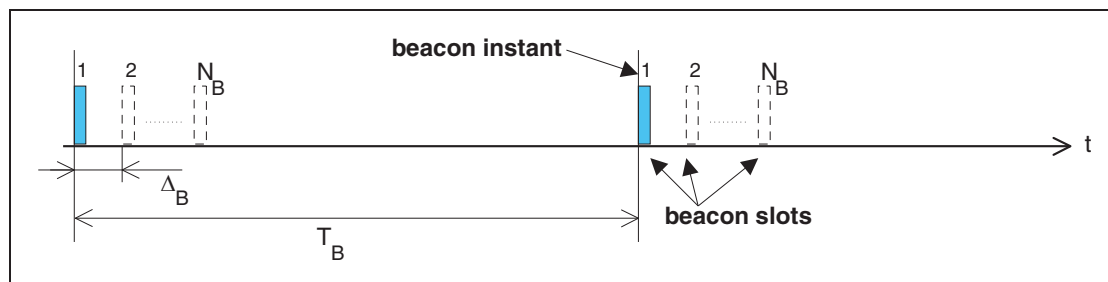


Figure 8.13: General beacon train format

The master can place parked slaves in any of the AFH operating modes, but shall ensure that all parked slaves use the same hop sequence. Masters should use AHS(79) or AHS when all the slaves in the Piconet are AFH capable.

A master that switches a slave between AFH enabled, AFH disabled or AHS(79) operation shall ensure that the AFH_Instant occurs before transmission of the beacon train using this hop sequence.

The master communicates with parked slaves using broadcast messages. Since these messages can be time - critical, an ongoing repetition train of broadcast message may be prematurely aborted by broadcast information destined to parked slaves in beacon slots and in access windows (see [Section 8.9.2 on page 189](#)).

8.9.2 Beacon access window

In addition to the beacon slots, an access window is defined where the parked slaves can send requests to be unparked. To increase reliability, the access window may be repeated M_{access} times ($M_{\text{access}} \geq 1$), see [Figure 8.14 on page 189](#). The access window starts a fixed delay D_{access} after the beacon instant. The width of the access window is T_{access} .

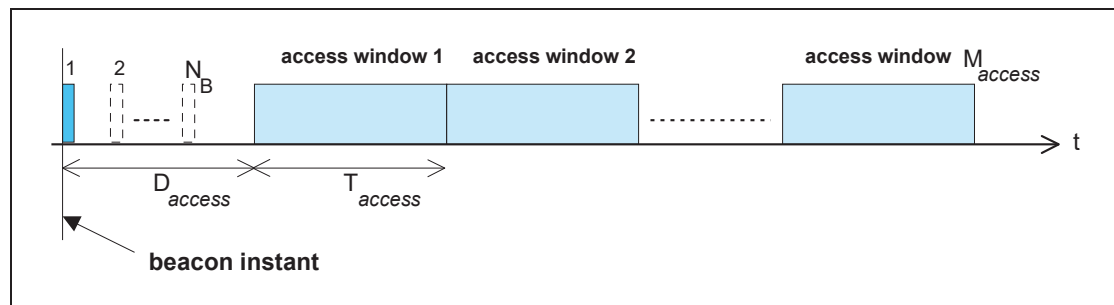


Figure 8.14: Definition of access window

The access window supports a polling slave access technique. The format of the polling technique is shown in [Figure 8.15 on page 189](#). The same TDD structure is used as on the piconet channel, i.e. master-to-slave transmission is alternated with slave-to-master transmission. The slave-to-master slot is divided into two half slots of 312.5 μs each. The half slot a parked slave is allowed to respond in corresponds to its access request address (AR_ADDR), see also [section 8.9.6 on page 192](#). For counting the half slots to determine the access request slot, the start of the access window is used, see [Figure 8.15 on page 189](#). The slave shall only send an access request in the proper slave-to-master half slot if a broadcast packet has been received in the preceding master-to-slave slot. In this way, the master polls the parked slaves.

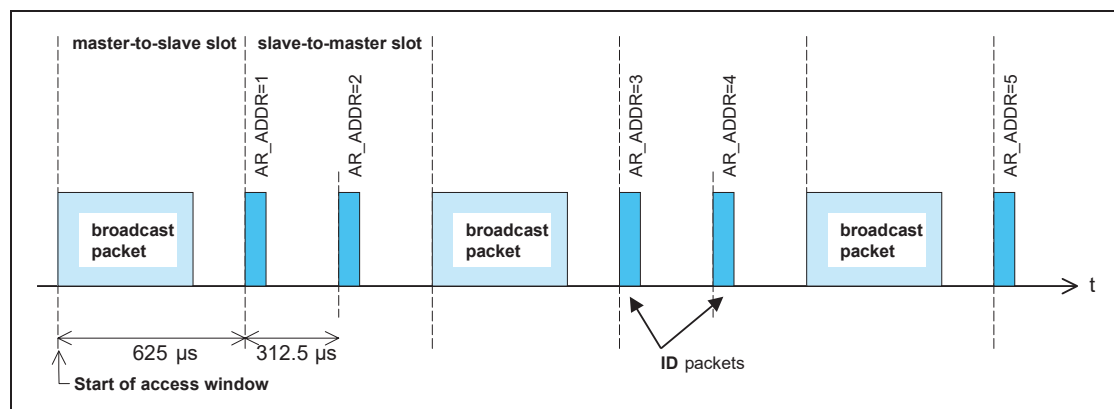


Figure 8.15: Access procedure applying the polling technique.

The slots of the access window may also be used for traffic on the piconet if required. For example, if a synchronous connection has to be supported, the slots reserved for the synchronous link may carry synchronous information

instead of being used for access requests, i.e. if the master-to-slave slot in the access window contains a packet different from a broadcast packet, the following slave-to-master slot shall not be used for slave access requests. If the master transmits a broadcast packet in the access window then it shall use the hop sequence associated with the park structure. Slots in the access window not affected by piconet traffic may still be used according to the defined access structure, (an example is shown in [Figure 8.16 on page 190](#)) the access procedure shall be continued as if no interruption had taken place.

When the slave is parked, the master shall indicate what type of access scheme will be used. For the polling scheme, the number of slave-to-master access slots $N_{\text{acc_slot}}$ is indicated.

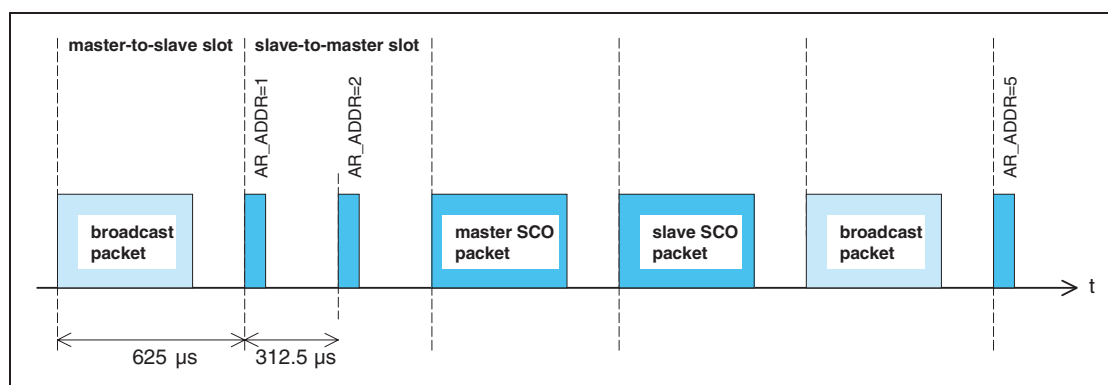


Figure 8.16: Disturbance of access window by SCO traffic

By default, the access window is always present. However, its activation depends on the master sending broadcast messages to the slave at the appropriate slots in the access window. A flag in a broadcast LMP message within the beacon slots may indicate that the access window(s) belonging to this instant will not be activated. This prevents unnecessary scanning of parked slaves that want to request access.

8.9.3 Parked slave synchronization

Parked slaves wake up periodically to re-synchronize to the channel. Any packet exchanged on the channel can be used for synchronization. Since master transmission is mandatory on the beacon slots, parked slaves will use the beacon train to re-synchronize. A parked slave may wake-up at the beacon instant to read the packet sent on the first beacon slot. If this fails, it may retry on the next beacon slot in the beacon train; in total, there are N_B opportunities per beacon instant to re-synchronize. During the search, the slave may increase its search window, see also [Section 2.2.5.2 on page 74](#). The separation between the beacon slots in the beacon train Δ_B shall be chosen such that consecutive search windows will not overlap.

The parked slave may not wake up at every beacon instant. Instead, a sleep interval may be applied which is longer than the beacon interval T_B , see [Figure 8.17 on page 191](#). The slave sleep window shall be a multiple N_{B_sleep} of T_B .



The precise beacon instant the slave may wake up on shall be indicated by the master with D_{B_sleep} which indicates the offset (in multiples of T_B) with respect to the beacon instant ($0 < D_{B_sleep} < N_{B_sleep} - 1$). To initialize the wake-up period, the applicable equation shall be used:

$$\text{CLK}_{27-1} \bmod (N_{B_sleep} \cdot T_B) = D_B + D_{B_sleep} \cdot T_B \quad \text{for initialization 1}$$

$$(\overline{\text{CLK}_{27}}, \text{CLK}_{26-1}) \bmod (N_{B_sleep} \cdot T_B) = D_B + D_{B_sleep} \cdot T_B \quad \text{for initialization 2}$$

where initialization 1 shall be chosen by the master if the MSB in the current master clock is 0 and initialization 2 shall be chosen by the master if the MSB in the current master clock is 1.

When the master needs to send broadcast messages to the parked slaves, it may use the beacon slots for these broadcast messages. However, if $N_B < N_{BC}$, the slots following the last beacon slot in the beacon train shall be used for the remaining $N_{BC} - N_B$ broadcast packets. If $N_B > N_{BC}$, the broadcast message shall be repeated on all N_B beacon slots.

A parked slave shall read the broadcast messages sent in the beacon slot(s) it wakes up in. If the parked slave wakes up, the minimum wake-up activity shall be to read the channel access code for re-synchronization and the packet header to check for broadcast messages.

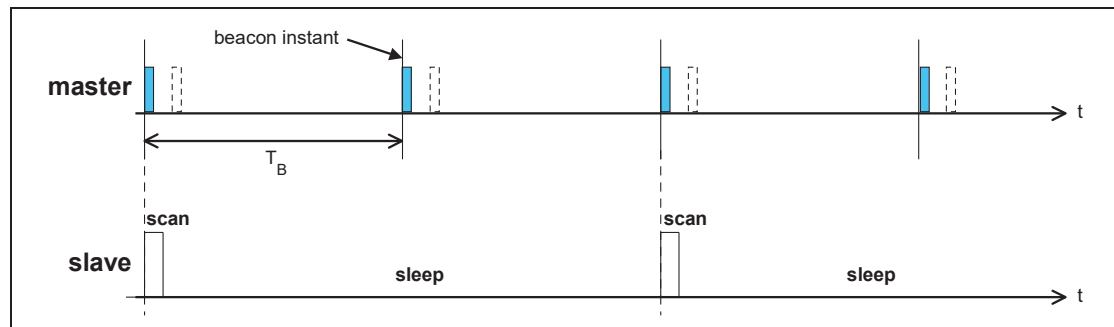


Figure 8.17: Extended sleep interval of parked slaves.

8.9.4 Parking

A master can park an active slave through the exchange of LMP commands. Before being put into park, the slave shall be assigned a PM_ADDR and an AR_ADDR. Every parked slave shall have a unique PM_ADDR or a PM_ADDR of 0. The AR_ADDR is not necessarily unique. The beacon parameters shall be given by the master when the slave is parked. The slave shall then give up its LT_ADDR and shall enter **PARK** state. A master can park only a single slave at a time. The park message is carried with a normal data packet and addresses the slave through its LT_ADDR.

8.9.5 Master-initiated unparking

The master can unpark a parked slave by sending a dedicated LMP unpark command including the parked slave's address. This message shall be sent in a broadcast packet on the beacon slots. The master shall use either the slave's PM_ADDR, or its BD_ADDR. The message also includes the logical transport address LT_ADDR the slave shall use after it has re-entered the piconet. The unpark message may include a number of slave addresses so that multiple slaves may be unparked simultaneously. For each slave, a different LT_ADDR shall be assigned.

After having received the unpark message, the parked slave matching the PM_ADDR or BD_ADDR shall leave the **PARK** state and enter the **CONNECTION** state. It shall keep listening to the master until it is addressed by the master through its LT_ADDR. The first packet sent by the master shall be a POLL packet. The return packet in response to the POLL packet confirms that the slave has been unparked. If no response packets from the slave is received for *newconnectionTO* number of slots after the end of beacon repetition period, the master shall unpark the slave again. The master shall use the same LT_ADDR on each unpark attempt until it has received a link supervision timeout for that slave or the unpark has completed successfully. If the slave does not receive the POLL packet for *newconnectionTO* number of slots after the end of beacon repetition period, it shall return to park, with the same beacon parameters. After confirming that the slave is in the **CONNECTION** state, the master decides in which mode the slave will continue.

When a device is unparked, the SEQN bit for the link shall be reset to 1 on both the master and the slave (see [Section 7.6.2.1 on page 148](#)).

8.9.6 Slave-initiated unparking

A slave can request access to the channel through the access window defined in [section 8.9.2 on page 189](#). As shown in [Figure 8.15 on page 189](#), the access window includes several slave-to-master half slots where the slave may send an access request message. The specific half slot the slave is allowed to respond in, corresponds to its access request address (AR_ADDR) which it received when it was parked. The order of the half slots (in [Figure 8.15](#) the AR_ADDR numbers linearly increase from 1 to 5) is not fixed: an LMP command sent in the beacon slots may reconfigure the access window. When a slave desires access to the channel, it shall send an access request message in the proper slave-to-master half slot. The access request message of the slave is the **ID** packet containing the device access code (DAC) of the master (which is the channel access code without the trailer). The parked slave shall only transmit an access request message in the half slot, when in the preceding master-to-slave slot a broadcast packet has been received. This broadcast message may contain any kind of broadcast information not necessarily related to the parked slave(s). If no broadcast information is available, a broadcast **NULL** or broadcast **POLL** packet shall be sent.



After having sent an access request, the parked slave shall listen for an unpark message from the master. As long as no unpark message is received, the slave shall repeat the access requests in the subsequent access windows. After the last access window (there are M_{access} windows in total, see [Section 8.9.2 on page 189](#)), the parked slave shall listen for an additional N_{poll} time slots for an unpark message. If no unpark message is received within N_{poll} slots after the end of the last access window, the slave may return to sleep and retry an access attempt after the next beacon instant.

After having received the unpark message, the parked slave matching the PM_ADDR or BD_ADDR shall leave the **PARK** state and enter the **CONNECTION** state. It shall keep listening to the master until it is addressed by the master through its LT_ADDR. The first packet sent by the master shall be a POLL packet. The return packet in response to the POLL packet confirms that the slave has been unparked. After confirming that the slave is in the **CONNECTION** state, the master decides in which mode the slave will continue. If no response packet from the slave is received for *newconnectionTO* number of slots after N_{poll} slots after the end of the last access window, the master shall send the unpark message to the slave again. If the slave does not receive the POLL packet for *newconnectionTO* number of slots after N_{poll} slots after the end of the last access window, it shall return to park, with the same beacon parameters.

When a device is unparked, the SEQN bit for the link shall be reset to 1 on both the master and the slave (see [Section 7.6.2.1 on page 148](#)).

8.9.7 Broadcast scan window

In the beacon train, the master can support broadcast messages to the parked slaves. However, it may extend its broadcast capacity by indicating to the parked slaves that more broadcast information is following after the beacon train. This is achieved by an LMP command ordering the parked slaves (as well as the active slaves) to listen to the channel for broadcast messages during a limited time window. This time window starts at the beacon instant and continues for the period indicated in the LMP command sent in the beacon train.

8.9.8 Polling in the park state

In the **PARK** state, parked slaves may send access requests in the access window provided a broadcast packet is received in the preceding master-to-slave slot. Slaves in the **CONNECTION** state shall not send in the slave-to-master slots following the broadcast packet, since they are only allowed to send if addressed specifically.



9 AUDIO

On the air-interface, either a 64 kb/s log PCM (Pulse Code Modulation) format (A-law or μ -law) may be used, or a 64 kb/s CVSD (Continuous Variable Slope Delta Modulation) may be used. The latter format applies an adaptive delta modulation algorithm with syllabic companding.

The voice coding on the line interface is designed to have a quality equal to or better than the quality of 64 kb/s log PCM.

[Table 9.1 on page 195](#) summarizes the voice coding schemes supported on the air interface. The appropriate voice coding scheme is selected after negotiations between the Link Managers.

| Voice Codecs | |
|-------------------|------------|
| linear | CVSD |
| 8-bit logarithmic | A-law |
| | μ -law |

Table 9.1: Voice coding schemes supported on the air interface.

9.1 LOG PCM CODEC

Since the synchronous logical transports on the air-interface can support a 64 kb/s information stream, a 64 kb/s log PCM traffic can be used for transmission. Either A-law or μ -law compression may be applied. In the event that the line interface uses A-law and the air interface uses μ -law or vice versa, a conversion from A-law to μ -law shall be performed. The compression method shall follow ITU-T recommendations G. 711.

9.2 CVSD CODEC

A more robust format for voice over the air interface is delta modulation. This modulation scheme follows the waveform where the output bits indicate whether the prediction value is smaller or larger then the input waveform. To reduce slope overload effects, syllabic companding is applied: the step size is adapted according to the average signal slope. The input to the CVSD encoder shall be 64 ksamples/s linear PCM (typically 16 bits, but actual value is implementation specific). Block diagrams of the CVSD encoder and CVSD decoder are shown in [Figure 9.1 on page 196](#), [Figure 9.2 on page 196](#) and [Figure 9.3 on page 196](#). The system shall be clocked at 64 kHz.

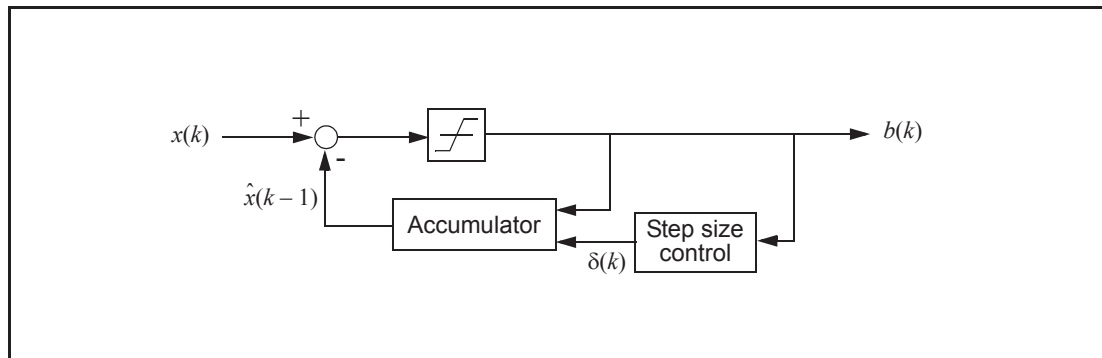


Figure 9.1: Block diagram of CVSD encoder with syllabic companding.

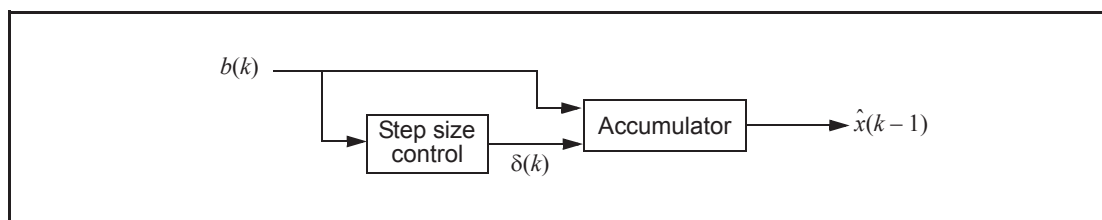


Figure 9.2: Block diagram of CVSD decoder with syllabic companding.

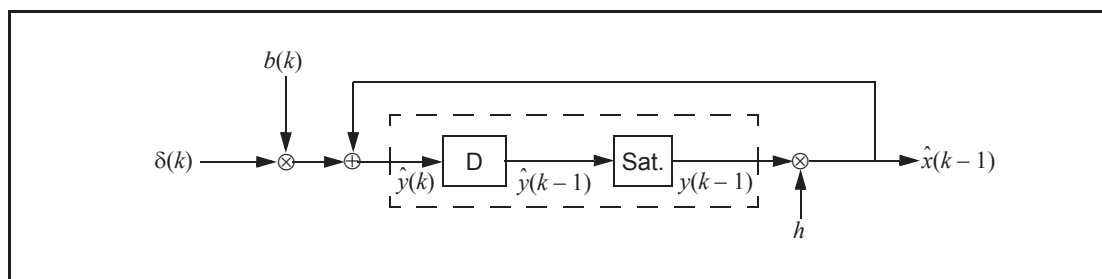


Figure 9.3: Accumulator procedure.

Let $\text{sgn}(x) = 1$ for $x \geq 0$, otherwise $\text{sgn}(x) = -1$. On air these numbers shall be represented by the sign bit; i.e. negative numbers are mapped on “1” and positive numbers are mapped on “0”.

Denote the CVSD encoder output bit $b(k)$, the encoder input $x(k)$, the accumulator contents $y(k)$, and the step size $\delta(k)$. Furthermore, let h be the decay factor for the accumulator, let β denote the decay factor for the step size, and, let α be the syllabic companding parameter. The latter parameter monitors the slope by considering the K most recent output bits

Let

$$\hat{x}(k) = h y(k). \quad (\text{EQ 13})$$

Then, the CVSD encoder internal state shall be updated according to the following set of equations:

$$b(k) = \text{sgn}\{x(k) - \hat{x}(k-1)\}, \quad (\text{EQ 14})$$

$$\alpha = \begin{cases} 1, & \text{if } J \text{ bits in the last } K \text{ output bits are equal,} \\ 0, & \text{otherwise,} \end{cases} \quad (\text{EQ 15})$$

$$\delta(k) = \begin{cases} \min\{\delta(k-1) + \delta_{\min}, \delta_{\max}\}, & \alpha = 1, \\ \max\{\beta\delta(k-1), \delta_{\min}\}, & \alpha = 0, \end{cases} \quad (\text{EQ 16})$$

$$y(k) = \begin{cases} \min\{\hat{y}(k), y_{\max}\}, & \hat{y}(k) \geq 0. \\ \max\{\hat{y}(k), y_{\min}\}, & \hat{y}(k) < 0. \end{cases} \quad (\text{EQ 17})$$

where

$$\hat{y}(k) = \hat{x}(k-1) + b(k)\delta(k). \quad (\text{EQ 18})$$

In these equations, δ_{\min} and δ_{\max} are the minimum and maximum step sizes, and, y_{\min} and y_{\max} are the accumulator's negative and positive saturation values, respectively. Over air, the bits shall be sent in the same order they are generated by the CVSD encoder.

For a 64 kb/s CVSD, the parameters as shown in [Table 9.2](#) shall be used. The numbers are based on a 16 bit signed number output from the accumulator. These values result in a time constant of 0.5 ms for the accumulator decay, and a time constant of 16 ms for the step size decay

| Parameter | Value |
|-----------------|----------------------------|
| h | $1 - \frac{1}{32}$ |
| β | $1 - \frac{1}{1024}$ |
| J | 4 |
| K | 4 |
| δ_{\min} | 10 |
| δ_{\max} | 1280 |
| y_{\min} | -2^{15} or $-2^{15} + 1$ |
| y_{\max} | $2^{15} - 1$ |

Table 9.2: CVSD parameter values. The values are based on a 16 bit signed number output from the accumulator.



9.3 ERROR HANDLING

In the DV, HV3, EV3, EV5, 2-EV3, 3-EV3, 2-EV5 and 3-EV5 packets, the voice is not protected by FEC. The quality of the voice in an error-prone environment then depends on the robustness of the voice coding scheme and, in the case of eSCO, the retransmission scheme. CVSD, in particular, is rather insensitive to random bit errors, which are experienced as white background noise. However, when a packet is rejected because either the channel access code, the HEC test was unsuccessful, or the CRC has failed, measures have to be taken to “fill” in the lost speech segment.

The voice payload in the **HV2** and **EV4** packets are protected by a 2/3 rate FEC. For errors that are detected but cannot be corrected, the receiver should try to minimize the audible effects. For instance, from the 15-bit FEC segment with uncorrected errors, the 10-bit information part as found before the FEC decoder should be used. The **HV1** packet is protected by a 3 bit repetition FEC. For this code, the decoding scheme will always assume zero or one-bit errors. Thus, there exist no detectable but uncorrectable error events for **HV1** packets.

9.4 GENERAL AUDIO REQUIREMENTS

9.4.1 Signal levels

For A-law and μ -law log-PCM encoded signals the requirements on signal levels shall follow the ITU-T recommendation G.711.

Full swing at the 16 bit linear PCM interface to the CVSD encoder is defined to be 3 dBm0.

9.4.2 CVSD audio quality

For Bluetooth audio quality the requirements are put on the transmitter side. The 64 ksamples/s linear PCM input signal should have negligible spectral power density above 4 kHz. The power spectral density in the 4-32 kHz band of the decoded signal at the 64 ksample/s linear PCM output, should be more than 20 dB below the maximum in the 0-4 kHz range.

10 LIST OF FIGURES

| | | |
|--------------|---|-----|
| Figure 1.1: | Piconets with a single slave operation (a), a multi-slave operation (b) and a scatternet operation (c). | 61 |
| Figure 1.2: | Standard Basic Rate packet format. | 62 |
| Figure 1.3: | Standard Enhanced Data Rate packet format | 62 |
| Figure 1.4: | Bluetooth clock. | 63 |
| Figure 1.5: | Format of BD_ADDR. | 64 |
| Figure 2.1: | Multi-slot packets | 69 |
| Figure 2.2: | Derivation of CLK in master (a) and in slave (b). | 70 |
| Figure 2.3: | RX/TX cycle of master transceiver in normal mode for single-slot packets. | 71 |
| Figure 2.4: | RX/TX cycle of slave transceiver in normal mode for single-slot packets. | 72 |
| Figure 2.5: | RX timing of slave returning from hold mode. | 73 |
| Figure 2.6: | Derivation of CLKE. | 74 |
| Figure 2.7: | RX/TX cycle of transceiver in PAGE mode. | 75 |
| Figure 2.8: | Timing of page response packets on successful page in first half slot | 76 |
| Figure 2.9: | Timing of page response packets on successful page in second half slot | 77 |
| Figure 2.10: | Timing of inquiry response packet on successful inquiry in first half slot | 79 |
| Figure 2.11: | Timing of inquiry response packet on successful inquiry in second half slot | 79 |
| Figure 2.12: | General block diagram of hop selection scheme. | 81 |
| Figure 2.13: | Hop selection scheme in CONNECTION state. | 82 |
| Figure 2.14: | Single- and multi-slot packets. | 83 |
| Figure 2.15: | Example of the same channel mechanism. | 83 |
| Figure 2.16: | Block diagram of the basic hop selection kernel for the hop system. | 84 |
| Figure 2.17: | XOR operation for the hop system. | 85 |
| Figure 2.18: | Permutation operation for the hop system. | 86 |
| Figure 2.19: | Butterfly implementation. | 86 |
| Figure 2.20: | Block diagram of adaptive hop selection mechanism | 88 |
| Figure 4.1: | Functional diagram of TX buffering. | 97 |
| Figure 4.2: | Functional diagram of RX buffering | 101 |
| Figure 6.1: | General Basic Rate packet format. | 107 |
| Figure 6.2: | General enhanced data rate packet format | 107 |
| Figure 6.3: | Access code format | 109 |
| Figure 6.4: | Preamble | 110 |
| Figure 6.5: | Construction of the sync word. | 111 |
| Figure 6.6: | LFSR and the starting state to generate | 113 |



| | | |
|--------------|---|-----|
| Figure 6.7: | Trailer in CAC when MSB of sync word is 0 (a), and when MSB of sync word is 1 (b). | 113 |
| Figure 6.8: | Header format. | 114 |
| Figure 6.9: | Format of the FHS payload. | 118 |
| Figure 6.10: | DV packet format | 121 |
| Figure 6.11: | Synchronization sequence | 127 |
| Figure 6.12: | Payload header format for Basic Rate single-slot ACL packets. | 128 |
| Figure 6.13: | Payload header format for multi-slot ACL packets and all EDR ACL packets. | 129 |
| Figure 7.1: | Header bit processes. | 135 |
| Figure 7.2: | Payload bit processes. | 135 |
| Figure 7.3: | The LFSR circuit generating the HEC. | 136 |
| Figure 7.4: | Initial state of the HEC generating circuit. | 137 |
| Figure 7.5: | HEC generation and checking. | 137 |
| Figure 7.6: | The LFSR circuit generating the CRC. | 138 |
| Figure 7.7: | Initial state of the CRC generating circuit. | 138 |
| Figure 7.8: | CRC generation and checking. | 138 |
| Figure 7.9: | Data whitening LFSR. | 139 |
| Figure 7.10: | Bit-repetition encoding scheme. | 140 |
| Figure 7.11: | LFSR generating the (15,10) shortened Hamming code. | 141 |
| Figure 7.12: | Stage 1 of the receive protocol for determining the ARQN bit. | 143 |
| Figure 7.13: | Stage 2 (ACL) of the receive protocol for determining the ARQN bit. | 144 |
| Figure 7.14: | Stage 2 (eSCO) of the receive protocol for determining the ARQN bit. | 145 |
| Figure 7.15: | Transmit filtering for packets with CRC. | 146 |
| Figure 7.16: | Broadcast repetition scheme | 150 |
| Figure 8.1: | State diagram of link controller. | 151 |
| Figure 8.2: | Conventional page (a), page while one synchronous link present (b), page while two synchronous links present (c). | 156 |
| Figure 8.3: | Messaging at initial connection when slave responds to first page message. | 158 |
| Figure 8.4: | Messaging at initial connection when slave responds to second page message. | 158 |
| Figure 8.5: | Connection state. | 166 |
| Figure 8.6: | RX/TX timing in multi-slave configuration | 167 |
| Figure 8.7: | eSCO Window Details for Single-Slot Packets | 170 |
| Figure 8.8: | eSCO Window Details for Asymmetric Traffic | 171 |
| Figure 8.9: | Successful hop sequence switching | 176 |
| Figure 8.10: | Recovery hop sequences | 177 |
| Figure 8.11: | AFH_Instant changes during multi-slot packets transmitted by the master. | 178 |



| | |
|---|-----|
| Figure 8.12: Sniff anchor points | 181 |
| Figure 8.13: General beacon train format | 186 |
| Figure 8.14: Definition of access window | 187 |
| Figure 8.15: Access procedure applying the polling technique. | 187 |
| Figure 8.16: Disturbance of access window by SCO traffic | 188 |
| Figure 8.17: Extended sleep interval of parked slaves. | 189 |
| Figure 9.1: Block diagram of CVSD encoder with syllabic companding. ... | 194 |
| Figure 9.2: Block diagram of CVSD decoder with syllabic companding. ... | 194 |
| Figure 9.3: Accumulator procedure. | 194 |
| Figure 12.1: SLR measurement set-up. | 203 |
| Figure 12.2: RLR measurement set-up. | 203 |
| Figure 12.3: Plot of recommended frequency mask for Bluetooth. The GSM send frequency mask is given for comparison (dotted line) ... | 204 |
| Figure 12.4: Timing constraint on AFH_Instant with slaves in park, hold and sniff | 208 |



11 LIST OF TABLES

| | | |
|-------------|--|-----|
| Table 2.1: | Control of the butterflies for the hop system | 85 |
| Table 2.2: | Control for hop system | 89 |
| Table 6.1: | Summary of access code types | 109 |
| Table 6.2: | Packets defined for synchronous and asynchronous logical transport types | 117 |
| Table 6.3: | Description of the FHS payload | 119 |
| Table 6.4: | Contents of SR field | 120 |
| Table 6.5: | Contents of page scan mode field | 120 |
| Table 6.6: | Logical link LLID field contents | 130 |
| Table 6.7: | Use of payload header flow bit on the logical links | 131 |
| Table 6.8: | Link control packets | 132 |
| Table 6.9: | ACL packets | 132 |
| Table 6.10: | Synchronous packets | 133 |
| Table 8.1: | Relationship between scan interval, and paging modes R0, R1 and R2 | 153 |
| Table 8.2: | Relationship between train repetition, and paging modes R0, R1 and R2 when synchronous links are present | 156 |
| Table 8.3: | Initial messaging during start-up | 157 |
| Table 8.4: | Increase of train repetition when synchronous links are present | 164 |
| Table 8.5: | Messaging during inquiry routines | 165 |
| Table 8.6: | Channel classification descriptions | 179 |
| Table 9.1: | Voice coding schemes supported on the air interface | 193 |
| Table 9.2: | CVSD parameter values. The values are based on a 16 bit signed number output from the accumulator | 195 |
| Table 12.1: | Recommended Frequency Mask for Bluetooth | 204 |

APPENDIX A: GENERAL AUDIO RECOMMENDATIONS

MAXIMUM SOUND PRESSURE

It is the sole responsibility of each manufacturer to design their audio products in a safe way with regards to injury to the human ear. The Bluetooth Specification doesn't specify maximum sound pressure from an audio device.

OTHER TELEPHONY NETWORK REQUIREMENTS

It is the sole responsibility of each manufacturer to design the Bluetooth audio product so that it meets the regulatory requirements of all telephony networks that it may be connected to.

AUDIO LEVELS FOR BLUETOOTH

Audio levels shall be calculated as Send Loudness Rating, SLR, and Receive Loudness Rating, RLR. The calculation methods are specified in ITU-T Recommendation P.79.

The physical test set-up for Handsets and Headsets is described in ITU-T Recommendation P.51 and P.57

The physical test set-up for speakerphones and "Vehicle handsfree systems" is specified in ITU-T Recommendation P.34.

A general equation for computation of loudness rating (LR) for telephone sets is given by ITU-T recommendations P.79 and is given by

$$LR = -\frac{10}{m} \log_{10} \left(\sum_{i=N_1}^{N_2} 10^{m(s_i - w_i)/10} \right), \quad (\text{EQ 19})$$

where

m is a constant (~ 0.2).

w_i = weighting coefficient (different for the various LRs).

S_i = the sensitivity at frequency F_i , of the electro-acoustic path

N_1, N_2 , consecutive filter bank numbers (Art. Index: 200-4000 Hz)

(EQ 19) on page 204 is used for calculating the (SLR) according to Figure 12.1 on page 205, and (RLR) according to Figure 12.2 on page 205. When calculating LRs one must only include those parts of the frequency band where an actual signal transmission can occur in order to ensure that the additive property of LRs is retained. Therefore ITU-T P.79 uses only the frequency band 200-4000 Hz in LR computations.

MICROPHONE PATH

SLR measurement model

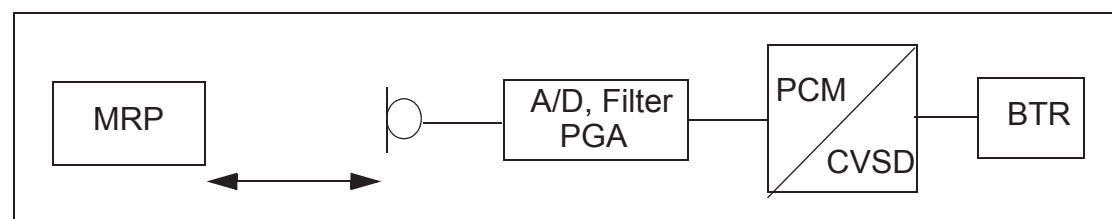


Figure 12.1: SLR measurement set-up.

LOUDSPEAKER PATH

RLR measurement model

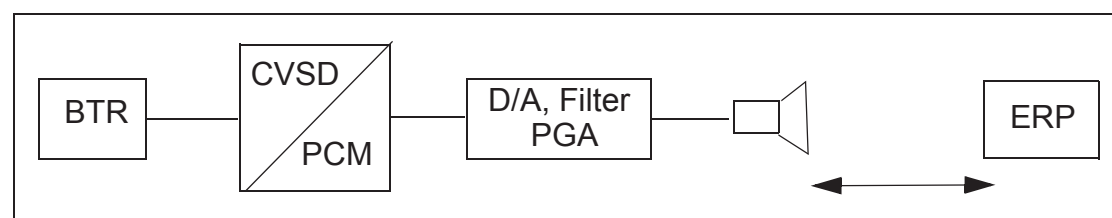


Figure 12.2: RLR measurement set-up.

BLUETOOTH VOICE INTERFACE

The specification for the Bluetooth voice interface should follow in the first place the *ITU-T Recommendations P.79*, which specifies the loudness ratings for telephone sets. These recommendations give general guidelines and specific algorithms used for calculating the loudness ratings of the audio signal with respect to Ear Reference Point (ERP).

For Bluetooth voice interface to the different cellular system terminals, loudness and frequency recommendations based on the cellular standards should be used. For example, GSM 03.50 gives recommendation for both the loudness ratings and frequency mask for a GSM terminal interconnection with Bluetooth.

1- The output of the CVSD decoder are 16-bit linear PCM digital samples, at a sampling frequency of 8 ksample/second. Bluetooth also supports 8-bit log PCM samples of A-law and μ -law type. The sound pressure at the ear reference point for a given 16-bit CVSD sample, should follow the sound pressure level given in the cellular standard specification.

2- A maximum sound pressure which can be represented by a 16-bit linear PCM sample at the output of the CVSD decoder should be specified according to the loudness rating, in ITU P.79 and at PGA value of 0 dB. Programmable Gain Amplifiers (PGAs) are used to control the audio level at the terminals by the user. For conversion between various PCM representations: A-law, μ -law and linear PCM, ITU-T G.711, G.712, G.714 give guidelines and PCM value relationships. Zero-code suppression based on ITU-T G.711 is also recommended to avoid network mismatches.

FREQUENCY MASK

For interfacing a Bluetooth terminal to a digital cellular mobile terminal, a compliance of the CVSD decoder signal to the frequency mask given in the cellular standard, is recommended to guarantee correct function of the speech coders. A recommendation for a frequency mask is given in the Table 12.1 below. The [Figure 12.3](#) below shows a plot of the frequency mask for Bluetooth (solid line). The GSM frequency mask (dotted line) is shown in [Figure 12.3](#) for comparison.

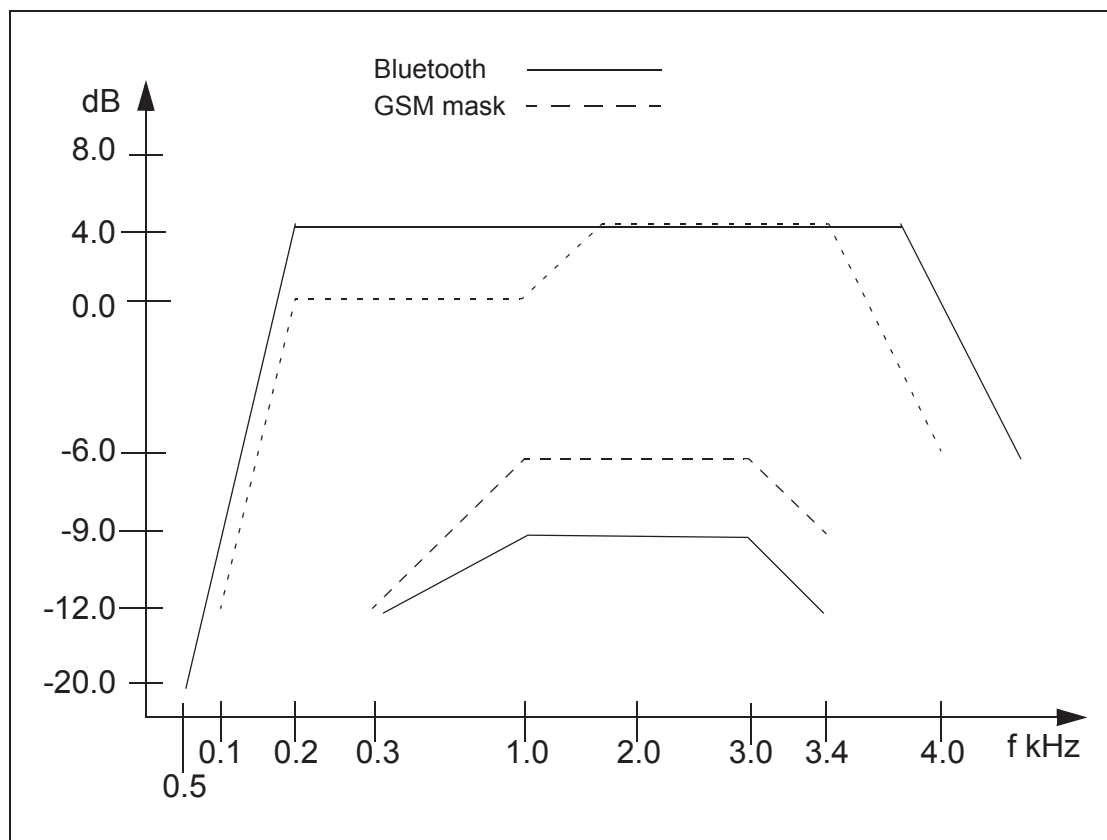


Figure 12.3: Plot of recommended frequency mask for Bluetooth. The GSM send frequency mask is given for comparison (dotted line)

| Frequency (Hz) | Upper Limit (dB) | Lower Limit (dB) |
|----------------|------------------|------------------|
| 50 | -20 | - |
| 300 | 4 | -12 |
| 1000 | 4 | -9 |
| 2000 | 4 | -9 |
| 3000 | 4 | -9 |
| 3400 | 4 | -12 |
| 4000 | 0 | - |

Table 12.1: Recommended Frequency Mask for Bluetooth

APPENDIX B: TIMERS

This appendix contains a list of Baseband timers related to inactivity timeout defined in this specification. Definitions and default values of the timers are listed below

All timer values are given in slots.

LIST OF TIMERS

inquiryTO

The *inquiryTO* defines the number of slots the **inquiry** substate will last. The timer value may be changed by the host. HCI provides a command to change the timer value.

pageTO

The *pageTO* defines the number of slots the **page** substate can last before a response is received. The timer value may be changed by the host. HCI provides a command to change the timer value.

pagerespTO

In the slave, it defines the number of slots the slave awaits the master's response, FHS packet, after sending the page acknowledgment ID packet. In the master, *pagerespTO* defines the number of slots the master should wait for the FHS packet acknowledgment before returning to **page** substate. Both master and slave units should use the same value for this timeout, to ensure common page/scan intervals after reaching *pagerespTO*.

The *pagerespTO* value is 8 slots.

newconnectionTO

Every time a new connection is started through paging, scanning, role switch or unpairing, the master sends a POLL packet as the first packet in the new connection. Transmission and acknowledgment of this POLL packet is used to confirm the new connection. If the POLL packet is not received by the slave or the response packet is not received by the master for *newconnectionTO* number of slots, both the master and the slave will return to the previous substate.

newconnectionTO value is 32 slots.



supervisionTO

The *supervisionTO* is used by both the master and slave to monitor link loss. If a device does not receive any packets that pass the HEC check and have the proper LT_ADDR for a period of *supervisionTO*, it will reset the link. The supervision timer keeps running in hold mode, sniff mode and park state.

The *supervisionTO* value may be changed by the host. HCI provides a command to change the timer value. At the baseband level a default value that is equivalent to 20 seconds will be used.

APPENDIX C: RECOMMENDATIONS FOR AFH OPERATION IN PARK, HOLD AND SNIFF

The three possible AFH operation modes for an AFH capable slave in park, hold and sniff are the same three AFH operation modes used during **CONNECTION** state:

- *Enabled* (using the same AHS as slaves in the **CONNECTION** state)
- *Enabled* (using AHS(79))
- *Disabled*

The master may place an AFH capable slave in any of the three AFH operating modes.

Operation at the Master

A master that has one or more slaves in park, hold or sniff and decides to update them simultaneously shall schedule an *AFH_Instant* for a time that allows it to update all these slaves (as well as its active slaves) with the new adaptation.

A master that has multiple slaves with non-overlapping “wake” times (e.g. slaves in sniff mode with different timing parameters) may keep them *enabled* on the same adaptation provided that its scheduling of the *AFH_Instant* allows enough time to update them all.

This timing is summarized in the figure below. In this example the master decides that a hop sequence adaptation is required. However it cannot schedule an *AFH_Instant* until it has informed its active slave, its slave in hold, its slave in sniff, and had time to un-park its parked slaves.

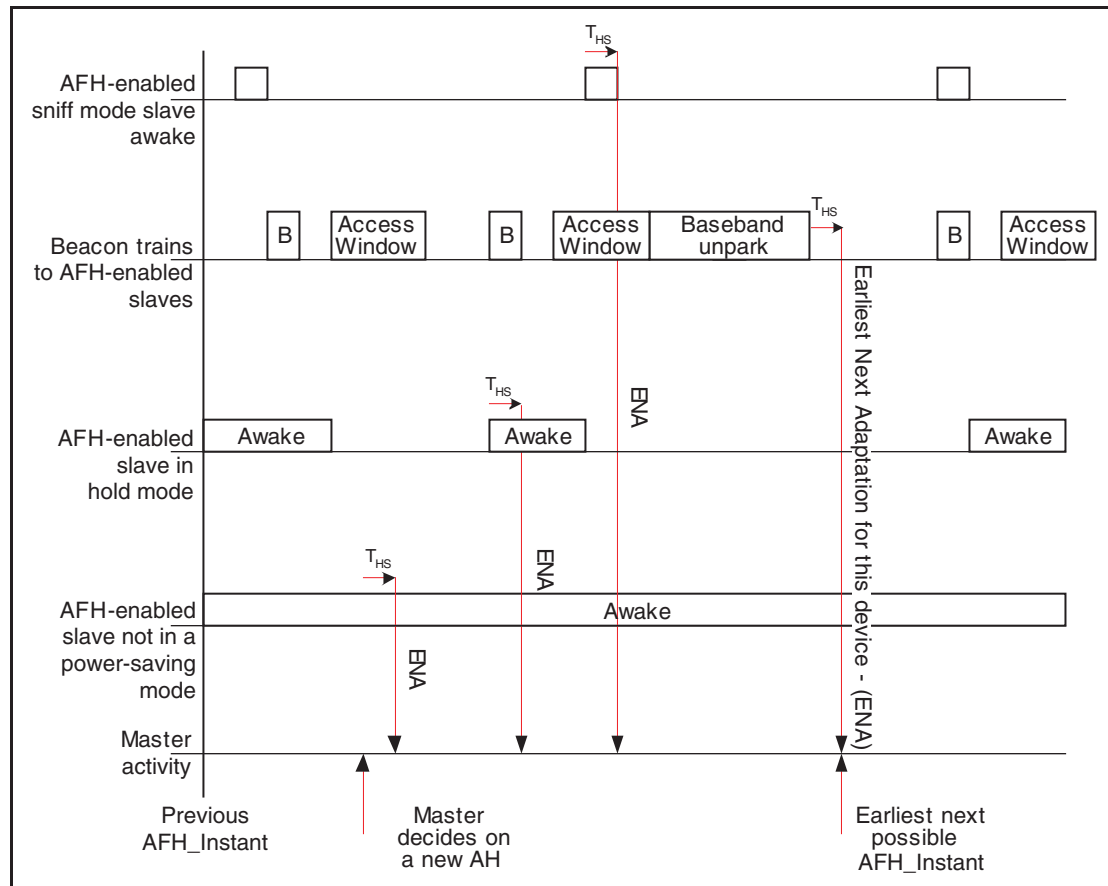


Figure 12.4: Timing constraint on AFH_Instant with slaves in park, hold and sniff

Operation in park

A slave that is in the Park state cannot send or receive any AFH LMP messages. Once the slave has left the Park state the master may subsequently update the slave's adaptation.


AFH Operation in Sniff

Once a slave has been placed in sniff mode, the master may periodically change its AHS without taking the slave out of sniff mode.

AFH Operation in Hold

A slave that is in hold mode cannot send or receive any LMP messages. Once the slave has left hold mode the master may subsequently update the slave's adaptation.

LINK MANAGER PROTOCOL



This specification describes the Link Manager Protocol (LMP) which is used for link set-up and control. The signals are interpreted and filtered out by the Link Manager on the receiving side and are not propagated to higher layers.



CONTENTS

| | | |
|----------|---|------------|
| 1 | Introduction | 217 |
| 2 | General Rules | 219 |
| 2.1 | Message Transport | 219 |
| 2.2 | Synchronization | 219 |
| 2.3 | Packet Format..... | 220 |
| 2.4 | Transactions..... | 221 |
| 2.4.1 | LMP Response Timeout..... | 222 |
| 2.5 | Error Handling | 222 |
| 2.5.1 | Transaction collision resolution | 223 |
| 2.6 | Procedure Rules | 223 |
| 2.7 | General Response Messages..... | 224 |
| 2.8 | LMP Message Constraints | 224 |
| 3 | Device Features..... | 225 |
| 3.1 | General Description | 225 |
| 3.2 | Feature Definitions | 225 |
| 3.3 | Feature Mask Definition | 230 |
| 3.4 | Link Manager Interoperability policy..... | 232 |
| 4 | Procedure Rules..... | 233 |
| 4.1 | Connection Control | 233 |
| 4.1.1 | Connection establishment..... | 233 |
| 4.1.2 | Detach | 234 |
| 4.1.3 | Power control | 235 |
| 4.1.4 | Adaptive frequency hopping..... | 237 |
| 4.1.4.1 | Master enables AFH | 238 |
| 4.1.4.2 | Master disables AFH..... | 238 |
| 4.1.4.3 | Master updates AFH..... | 239 |
| 4.1.4.4 | AFH operation in park, hold and sniff modes..... | 239 |
| 4.1.5 | Channel classification..... | 240 |
| 4.1.5.1 | Channel classification reporting enabling and disabling..... | 241 |
| 4.1.6 | Link supervision..... | 242 |
| 4.1.7 | Channel quality driven data rate change (CQDDR) | 243 |
| 4.1.8 | Quality of service (QoS) | 244 |
| 4.1.8.1 | Master notifies slave of the quality of service | 244 |
| 4.1.8.2 | Device requests new quality of service | 245 |
| 4.1.9 | Paging scheme parameters | 246 |
| 4.1.9.1 | Page mode | 246 |
| 4.1.9.2 | Page scan mode | 246 |



| | | |
|---------|---|-----|
| 4.1.10 | Control of multi-slot packets | 247 |
| 4.1.11 | Enhanced Data Rate | 247 |
| 4.2 | Security | 249 |
| 4.2.1 | Authentication | 249 |
| 4.2.1.1 | Claimant has link key | 249 |
| 4.2.1.2 | Claimant has no link key | 250 |
| 4.2.1.3 | Repeated attempts | 250 |
| 4.2.2 | Pairing | 251 |
| 4.2.2.1 | Responder accepts pairing | 251 |
| 4.2.2.2 | Responder has a fixed PIN | 252 |
| 4.2.2.3 | Responder rejects pairing | 252 |
| 4.2.2.4 | Creation of the link key | 253 |
| 4.2.2.5 | Repeated attempts | 253 |
| 4.2.3 | Change link key | 254 |
| 4.2.4 | Change current link key type | 255 |
| 4.2.4.1 | Change to a temporary link key | 255 |
| 4.2.4.2 | Make the semi-permanent link key the current link key | 256 |
| 4.2.5 | Encryption | 257 |
| 4.2.5.1 | Encryption mode | 257 |
| 4.2.5.2 | Encryption key size | 258 |
| 4.2.5.3 | Start encryption | 259 |
| 4.2.5.4 | Stop encryption | 260 |
| 4.2.5.5 | Change encryption mode, key or random number | 260 |
| 4.2.6 | Request supported encryption key size | 261 |
| 4.3 | Informational Requests | 262 |
| 4.3.1 | Timing accuracy | 262 |
| 4.3.2 | Clock offset | 263 |
| 4.3.3 | LMP version | 263 |
| 4.3.4 | Supported features | 264 |
| 4.3.5 | Name request | 266 |
| 4.4 | Role Switch | 267 |
| 4.4.1 | Slot offset | 267 |
| 4.4.2 | Role switch | 268 |
| 4.5 | Modes of Operation | 270 |
| 4.5.1 | Hold mode | 270 |
| 4.5.1.1 | Master forces hold mode | 270 |
| 4.5.1.2 | Slave forces hold mode | 271 |
| 4.5.1.3 | Master or slave requests hold mode | 271 |
| 4.5.2 | Park state | 272 |
| 4.5.2.1 | Master requests slave to enter park state | 274 |



| | | |
|----------|--|------------|
| 4.5.2.2 | Slave requests to enter park state | 275 |
| 4.5.2.3 | Master sets up broadcast scan window | 276 |
| 4.5.2.4 | Master modifies beacon parameters..... | 277 |
| 4.5.2.5 | Unparking slaves | 277 |
| 4.5.3 | Sniff mode | 278 |
| 4.5.3.1 | Master or slave requests sniff mode | 279 |
| 4.5.3.2 | Moving a slave from sniff mode to active mode..... | 280 |
| 4.6 | Logical Transports..... | 281 |
| 4.6.1 | SCO logical transport | 281 |
| 4.6.1.1 | Master initiates an SCO link..... | 281 |
| 4.6.1.2 | Slave initiates an SCO link..... | 282 |
| 4.6.1.3 | Master requests change of SCO parameters..... | 283 |
| 4.6.1.4 | Slave requests change of SCO parameters | 283 |
| 4.6.1.5 | Remove an SCO link | 283 |
| 4.6.2 | eSCO logical transport | 284 |
| 4.6.2.1 | Master initiates an eSCO link..... | 284 |
| 4.6.2.2 | Slave initiates an eSCO link..... | 285 |
| 4.6.2.3 | Master or slave requests change of eSCO parameters..... | 286 |
| 4.6.2.4 | Remove an eSCO link | 286 |
| 4.6.2.5 | Rules for the LMP negotiation and renegotiation | 287 |
| 4.6.2.6 | Negotiation state definitions..... | 288 |
| 4.7 | Test Mode | 289 |
| 4.7.1 | Activation and deactivation of test mode..... | 289 |
| 4.7.2 | Control of test mode | 290 |
| 4.7.3 | Summary of test mode PDUs..... | 291 |
| 5 | Summary | 295 |
| 5.1 | PDU Summary | 295 |
| 5.2 | Parameter Definitions | 303 |
| 5.3 | Default Values | 311 |
| 6 | List of Figures..... | 313 |
| 7 | List of Tables | 317 |



1 INTRODUCTION

The Link Manager Protocol (LMP) is used to control and negotiate all aspects of the operation of the Bluetooth connection between two devices. This includes the set-up and control of logical transports and logical links, and for control of physical links.

The Link Manager Protocol is used to communicate between the Link Managers (LM) on the two devices which are connected by the ACL logical transport. All LMP messages shall apply solely to the physical link and associated logical links and logical transports between the sending and receiving devices.

The protocol is made up of a series of messages which shall be transferred over the ACL-C logical link on the default ACL logical transport between two devices. LMP messages shall be interpreted and acted-upon by the LM and shall not be directly propagated to higher protocol layers.

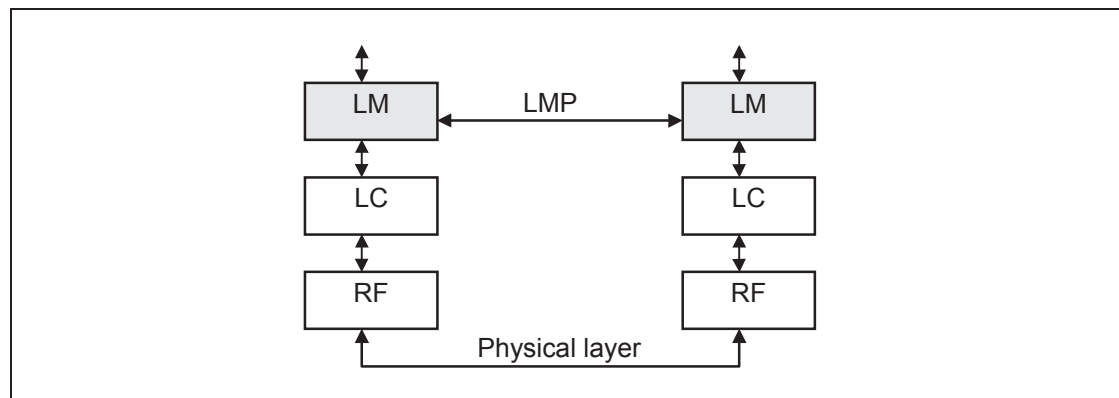


Figure 1.1: Link Manager Protocol signalling layer.



2 GENERAL RULES

2.1 MESSAGE TRANSPORT

LMP messages shall be exchanged over the ACL-C logical link that is carried on the default ACL logical transport ([Baseband Specification, Section 4.4, on page 98](#)). The ACL-C logical link is distinguished from the ACL-U (which carries L2CAP and user data) by the Logical Link Identifier (LLID) field carried in the payload header of variable-length packets ([Baseband Specification, Section 6.6.2, on page 130](#)).

The ACL-C has a higher priority than other traffic - see [Baseband Specification, Section 5.6, on page 108](#).

The error detection and correction capabilities of the baseband ACL logical transport are generally sufficient for the requirements of the LMP. Therefore LMP messages do not contain any additional error detection information beyond what can be realized by means of sanity checks performed on the contents of LMP messages. Any such checks and protections to overcome undetected errors in LMP messages is an implementation matter.

2.2 SYNCHRONIZATION

This section is informative and explains why many of the LMP message sequences are defined as they are.

LMP messages are carried on the ACL-C logical link, which does not guarantee a time to deliver or acknowledge packets. LMP procedures take account of this when synchronizing state changes in the two devices. For example, criteria are defined that specify when a logical transport address (LT_ADDR) may be re-used after it becomes available due to a device leaving the piconet or entering the park state. Other LMP procedures, such as hold or role switch include the Bluetooth clock as a parameter in order to define a fixed synchronization point. The transitions into and out of sniff mode are protected with a transition mode.

The LC normally attempts to communicate with each slave no less often than every T_{poll} slots (see [Section 4.1.8 on page 244](#)) based on the T_{poll} for that slave.

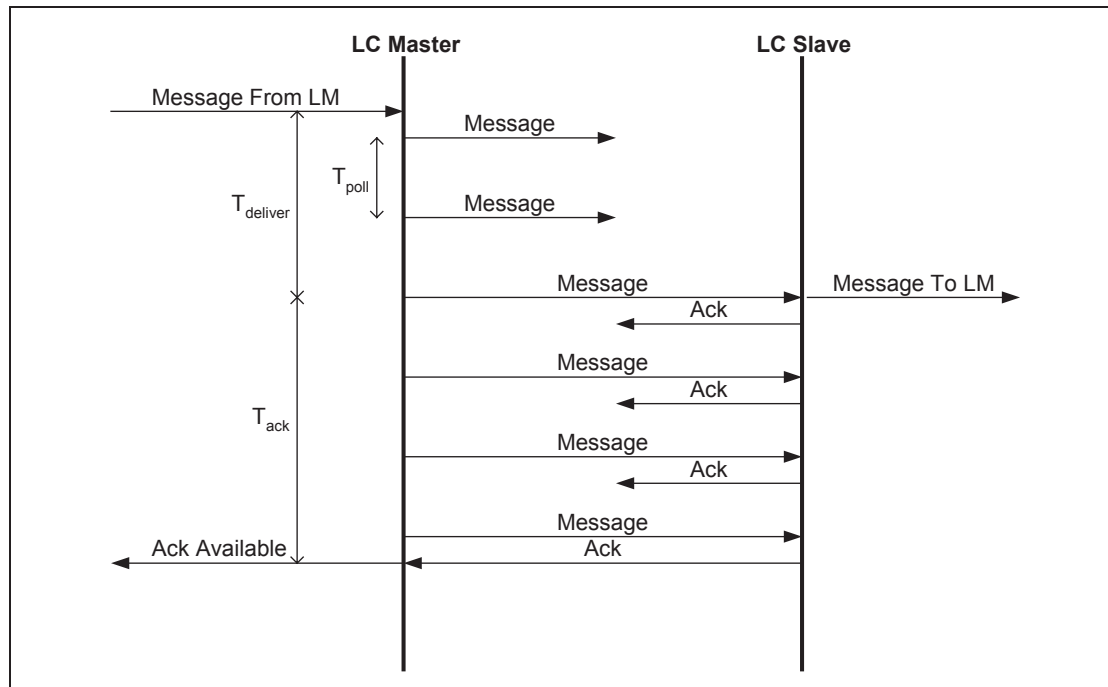


Figure 2.1: Transmission of a message from master to slave¹.

Figure 2.1 on page 220 illustrates the fundamental problem. It shows the transmission of a packet from the master to the slave in conditions of heavy interference for illustrative purposes. It is obvious that neither side can determine the value of either $T_{deliver}$ or T_{ack} . It is therefore not possible to use simple messages to identify uniquely the instant at which a state change occurs in the other device.

2.3 PACKET FORMAT

Each PDU is assigned either a 7 or a 15 bit opcode used to uniquely identify different types of PDUs, see Table 5.1 on page 295. The first 7 bits of the opcode and a transaction ID are located in the first byte of the payload body. If the initial 7 bits of the opcode have one of the special escape values 124-127 then an additional byte of opcode is located in the second byte of the payload and the combination uniquely identifies the PDU.

The FLOW bit in the packet header is always 1 and is ignored on reception.

If the PDU contains one or more parameters these are placed in the payload starting immediately after the opcode, i.e. at byte 2 if the PDU has a 7 bit opcode or byte 3 if the PDU has a 15 bit opcode. The number of bytes used

1. Note the diagram shows the limiting case where the master transmits the message at intervals of T_{poll} . In the case of heavy interference improved performance is gained by transmitting more often.

depends on the length of the parameters. All parameters have a little-endian format, i.e. the least significant byte is transferred first.

LMP messages shall be transmitted using DM1 packets, however if an HV1 SCO link is in use and the length of the payload is less than 9 bytes then DV packets may be used.

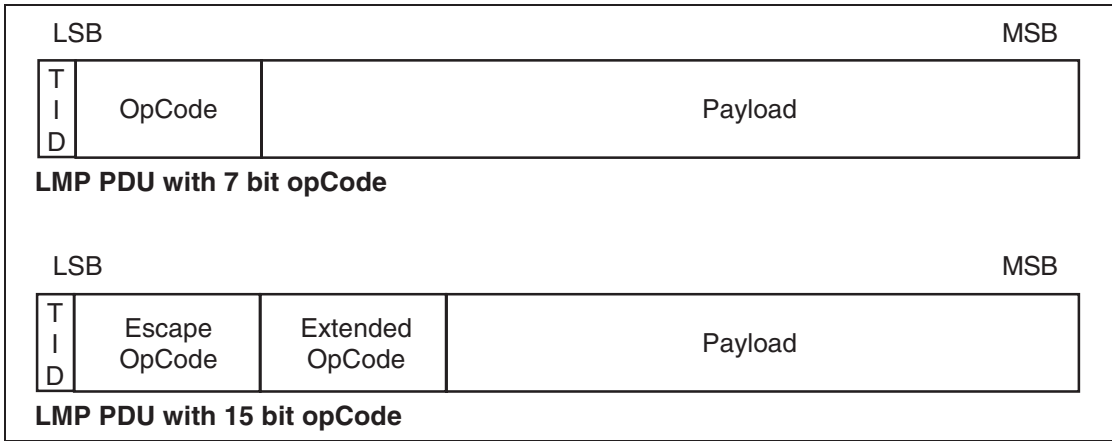


Figure 2.2: Payload body when LMP PDUs are sent.

2.4 TRANSACTIONS

The LMP operates in terms of transactions. A transaction is a connected set of message exchanges which achieve a particular purpose. All PDUs which form part of the same transaction shall have the same value for the transaction ID which is stored as part of the first byte of the opCode (see [Section 2.3 on page 220](#)).

The transaction ID is in the least significant bit. It shall be 0 if the PDU forms part of a transaction that was initiated by the master and 1 if the transaction was initiated by the slave.

Each sequence described in [Section 4 on page 233](#) shall be defined as a transaction. For pairing, see [Section 4.2.2 on page 251](#), and encryption, see [Section 4.2.5 on page 257](#), all sequences belonging to each section shall be counted as one transaction and shall use the same transaction ID. For connection establishment, see [Section 4.1.1 on page 233](#), LMP_host_connection_req and the response with LMP_accepted or LMP_not_accepted shall form one transaction and have the transaction ID of 0. LMP_setup_complete is a stand-alone PDU, which forms a transaction by itself.

For error handling, see [Section 2.5 on page 222](#), the PDU to be rejected and LMP_not_accepted or LMP_not_accepted_ext shall form a single transaction.



2.4.1 LMP Response Timeout

The time between receiving a baseband packet carrying an LMP PDU and sending a baseband packet carrying a valid response PDU, according to the procedure rules in [Section 4 on page 233](#), shall be less than the LMP Response Timeout. The value of this timeout is 30 seconds. Note that the LMP Response Timeout is applied not only to sequences described in [Section 4 on page 233](#), but also to the series of the sequences defined as the transactions in [Section 4 on page 233](#). It shall also be applied to the series of LMP transactions that take place during a period when traffic on the ACL-U logical link is disabled for the duration of the series of LMP transactions, for example during the enabling of encryption.

The LMP Response Timeout shall restart each time an LMP PDU which requires a reply is queued for transmission by the baseband.

2.5 ERROR HANDLING

If the LM receives a PDU with unrecognized opcode, it shall respond with LMP_not_accepted or LMP_not_accepted_ext with the error code *unknown LMP PDU*. The opcode parameter that is echoed back is the unrecognized opcode.

If the LM receives a PDU with invalid parameters, it shall respond with LMP_not_accepted or LMP_not_accepted_ext with the error code *invalid LMP parameters*.

If the maximum response time, see [Section 2.4 on page 221](#), is exceeded or if a link loss is detected (see [Baseband Specification, Section 3.1, on page 95](#)), the party that waits for the response shall conclude that the procedure has terminated unsuccessfully.

Erroneous LMP messages can be caused by errors on the channel or systematic errors at the transmit side. To detect the latter case, the LM should monitor the number of erroneous messages and disconnect if it exceeds a threshold, which is implementation-dependent.

When the LM receives a PDU that is not allowed, and the PDU normally expects a PDU reply, for example LMP_host_connection_req or LMP_unit_key, the LM shall return PDU LMP_not_accepted or LMP_not_accepted_ext with the error code *PDU not allowed*. If the PDU normally doesn't expect a reply, for example LMP_sres or LMP_temp_key, the PDU will be ignored.

The reception of an optional PDU which is not supported shall be handled in one of two ways: if the LM simply does not know the opcode (e.g. it was added at a later version of the specification) it shall respond with LMP_not_accepted or LMP_not_accepted_ext with the error code *unknown LMP PDU*. If the LM recognizes the PDU as optional but unsupported then it shall reply with LMP_not_accepted or LMP_not_accepted_ext with the error code *unsupported LMP feature* if the PDU would normally generate a reply otherwise no reply is generated.

2.5.1 Transaction collision resolution

Since LMP PDUs are not interpreted in real time, collision situations can occur where both LMs initiate the same procedure and both cannot be completed. In this situation, the master shall reject the slave-initiated procedure by sending LMP_not_accepted or LMP_not_accepted_ext with the error code *LMP error transaction collision*. The master-initiated procedure shall then be completed.

Collision situations can also occur where both LMs initiate different procedures and both cannot be completed. In this situation, the master shall reject the slave-initiated procedure by sending LMP_not_accepted or LMP_not_accepted_ext with the error code *LMP error different transaction collision*. The master-initiated procedure shall then be completed.

2.6 PROCEDURE RULES

Each procedure is described and depicted with a sequence diagram. The following symbols are used in the sequence diagrams:

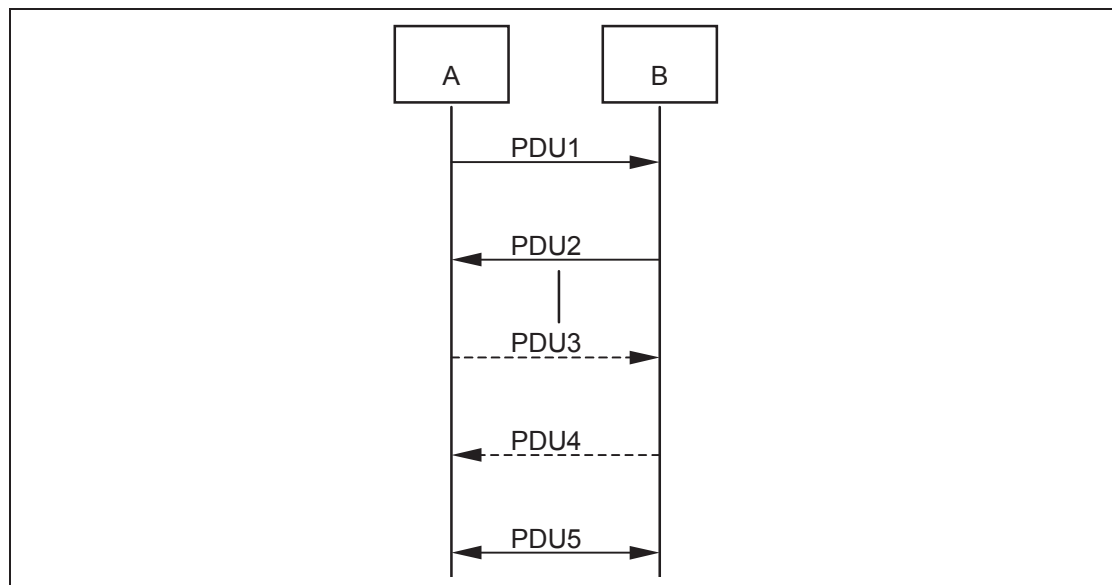


Figure 2.3: Symbols used in sequence diagrams.

PDU1 is a PDU sent from A to B. PDU2 is a PDU sent from B to A. PDU3 is a PDU that is optionally sent from A to B. PDU4 is a PDU that is optionally sent from B to A. PDU5 is a PDU sent from either A or B. A vertical line indicates that more PDUs can optionally be sent.



2.7 GENERAL RESPONSE MESSAGES

The PDUs LMP_accepted, LMP_accepted_ext, LMP_not_accepted and LMP_not_accepted_ext are used as response messages to other PDUs in a number of different procedures. LMP_accepted or LMP_accepted_ext includes the opcode of the message which is accepted. LMP_not_accepted or LMP_not_accepted_ext includes the opcode of the message which is not accepted and the error code why it is not accepted.

LMP_accepted_ext and LMP_not_accepted_ext shall be used when the opcode is 15 bits in length. LMP_accepted and LMP_not_accepted shall be used when the opcode is 7 bits in length.

| M/O | PDU | Contents |
|-----|----------------------|--|
| M | LMP_accepted | op code |
| M | LMP_not_accepted | op code error code |
| O | LMP_accepted_ext | escape op code extended op code |
| O | LMP_not_accepted_ext | escape op code extended op code error code |

Table 2.1: General response messages.

2.8 LMP MESSAGE CONSTRAINTS

This section is informative.

- No LMP message shall exceed the maximum payload length of a single DM1 packet i.e. 17 bytes in length ([Baseband Specification, Section 6.5.4.1, on page 126](#)).
- All LM messages are of fixed length apart from those sent using broadcast in park state.
- The LMP version number shall not be used to indicate the presence or absence of functionality.

3 DEVICE FEATURES

3.1 GENERAL DESCRIPTION

Each PDU is either Mandatory or Optional as defined by the M/O field in the tables of [Section 4 on page 233](#). An M in this field shall indicate that support for the feature is mandatory. An O in this field shall indicate that support for the PDU is optional and it shall be followed by the number(s) of the feature(s) involved in brackets.

All features added after the 1.1 specification have associated LMP feature bits. Support of these features may be made “mandatory” by the qualification process but the LM still considers them to be optional since it must interoperate with older devices which do not support them.

The LM does not need to be able to transmit a PDU which is optional. Support of optional PDUs is indicated by a device's features mask. The features mask can be read (see [Section 4.3.4 on page 264](#)). An LM shall not send or be sent any PDU which is incompatible with the features signalled in its or its peer's features mask, as detailed in [Section 3.2](#).

3.2 FEATURE DEFINITIONS

| Feature | Definition |
|-------------------------|--|
| Extended features | This feature indicates whether the device is able to support the extended features mask using the LMP sequences defined in Section 4.3.4 on page 264 . |
| Timing accuracy | This feature indicates whether the LM supports requests for timing accuracy using the sequence defined in Section 4.3.1 on page 262 . |
| Enhanced inquiry scan | This feature indicates whether the device is capable of supporting the enhanced inquiry scan mechanism as defined in Baseband Specification, Section 8.4.1, on page 164 . The presence of this feature has only local meaning and does not imply support for any additional LMP PDUs or sequences. |
| Interlaced inquiry scan | This feature indicates whether the device is capable of supporting the interlaced inquiry scan mechanism as defined in Baseband Specification, Section 8.4.1, on page 164 . The presence of this feature has only local meaning and does not imply support for any additional LMP PDUs or sequences. |
| Interlaced page scan | This feature indicates whether the device is capable of supporting the interlaced page scan mechanism as defined in Baseband Specification, Section 8.3.1, on page 154 . The presence of this feature has only local meaning and does not imply support for any additional LMP PDUs or sequences. |

Table 3.1: Feature definitions.

| Feature | Definition |
|------------------------------|---|
| RSSI with inquiry results | This feature indicates whether the device is capable of reporting the RSSI with inquiry results as defined in Baseband Specification, Section 8.4.2, on page 165 . The presence of this feature has only local meaning and does not imply support for any additional LMP PDUs or sequences. |
| Paging parameter negotiation | This feature indicates whether the LM is capable of supporting the signaling of changes in the paging scheme as defined in Section 4.1.9 on page 246 . |
| 3 slot packets | This feature indicates whether the device supports the transmission and reception of both DM3 and DH3 packets for the transport of traffic on the ACL-U logical link. |
| 5 slot packets | This feature indicates whether the device supports the transmission and reception of both DM5 and DH5 packets for the transport of traffic on the ACL-U logical link. |
| Flow control lag | This is defined as the total amount of ACL-U data that can be sent following the receipt of a valid payload header with the payload header flow bit set to 0 and is in units of 256 bytes. See further in Baseband Specification, Section 6.6.2, on page 130 . |
| AFH capable slave | This feature indicates whether the device is able to support the Adaptive Frequency Hopping mechanism as a slave as defined in Baseband Specification, Section 2.3, on page 75 using the LMP sequences defined in Section 4.1.4 on page 237 . |
| AFH classification slave | This feature indicates whether the device is able to support the AFH classification mechanism as a slave as defined in Baseband Specification, Section 8.6.8, on page 181 using the LMP sequences defined Section 4.1.5 on page 240 . |
| AFH capable master | This indicates whether the device is able to support the Adaptive Frequency Hopping mechanism as a master as defined in Baseband Specification, Section 2.3, on page 75 using the LMP sequences defined in Section 4.1.4 on page 237 . |
| AFH classification master | This feature indicate whether the device is able to support the AFH classification mechanism as a master as defined in Baseband Specification, Section 8.6.8, on page 181 using the LMP sequences defined Section 4.1.5 on page 240 . |
| Power control | This feature indicates whether the device is capable of adjusting its transmission power. This feature indicates the ability to receive the LMP_incr_power and LMP_decr_power PDUs and transmit the LMP_max_power and LMP_min_power PDUs, using the sequences defined in Section 4.1.3 on page 235 . These sequences may be used even if the remote device does not support the power control feature, as long as it supports the Power control requests feature. |

Table 3.1: Feature definitions.

| Feature | Definition |
|----------------------------------|---|
| Power control requests | This feature indicates whether the device is capable of determining if the transmit power level of the other device should be adjusted and will send the LMP_incr_power and LMP_decr_power PDUs to request the adjustments. It indicates the ability to receive the LMP_max_power and LMP_min_power PDUs, using the sequences in Section 4.1.3 on page 235 . These sequences may be used even if the remote device does not support the RSSI feature, as long as it supports the power control feature. |
| Channel Quality Driven Data Rate | This feature indicates whether the LM is capable of recommending a packet type (or types) depending on the channel quality using the LMP sequences defined in section 4.1.7 on page 243 . |
| Broadcast encryption | This feature indicates whether the device is capable of supporting broadcast encryption as defined in [Part H] Section 4.2 on page 788 and also the sequences defined in Section 4.2.6 on page 261 and Section 4.2.4 on page 255 . Note: Devices compliant to versions of this specification 1.1 and earlier may support broadcast encryption even though this feature bit is not set. |
| Encryption | This feature indicates whether the device supports the encryption of packet contents using the sequence defined in Section 4.2.5 on page 257 . |
| Slot offset | This feature indicates whether the LM supports the transfer of the slot offset using the sequence defined in Section 4.4.1 on page 267 . |
| Role switch | This feature indicates whether the device supports the change of master and slave roles as defined by baseband Section 8.6.5 on page 175 using the sequence defined in Section 4.4.2 on page 268 . |
| Hold mode | This feature indicates whether the device is able to support Hold mode as defined in baseband Section 8.8 on page 185 using the LMP sequences defined in Section 4.5.1 on page 270 . |
| Sniff mode | This feature indicates whether the device is able to support sniff mode as defined in baseband Section 8.7 on page 183 using the LMP sequences defined in Section 4.5.3 on page 278 . |
| Park state | This feature indicates whether the device is able to support Park state as defined in baseband Section 8.9 on page 185 using the LMP sequences defined in Section 4.5.2 on page 272 . |
| SCO link | This feature shall indicate whether the device is able to support the SCO logical transport as defined in Baseband Specification, Section 4.3, on page 98 , the HV1 packet defined in Baseband Specification, Section 6.5.2.1, on page 123 and receiving the DV packet defined in Baseband Specification, Section 6.5.2.4, on page 123 using the LMP sequence in Section 4.6.1 on page 281 . |
| HV2 packets | This feature indicates whether the device is capable of supporting the HV2 packet type as defined in baseband Section 6.5.2.2 on page 123 on the SCO logical transport. |

Table 3.1: Feature definitions.

| Feature | Definition |
|---------------------------------------|---|
| HV3 packets | This feature indicates whether the device is capable of supporting the HV3 packet type as defined in baseband Section 6.5.2.3 on page 123 on the SCO logical transport. |
| μ -law log synchronous data | This feature indicates whether the device is capable of supporting μ -Law Log format data as defined in Baseband Specification, Section 9.1, on page 195 on the SCO and eSCO logical transports. |
| A-law log synchronous data | This feature indicates whether the device is capable of supporting A-Law Log format data as defined in Baseband Specification, Section 9.1, on page 195 on the SCO and eSCO logical transports. |
| CVSD synchronous data | This feature indicates whether the device is capable of supporting CVSD format data as defined in Baseband Specification, Section 9.2, on page 195 on the SCO and eSCO logical transports. |
| Transparent synchronous data | This feature indicates whether the device is capable of supporting transparent synchronous data as defined in Baseband Specification, Section 6.4.3, on page 117 on the SCO and eSCO logical transports. |
| Extended SCO link | This feature indicates whether the device is able to support the eSCO logical transport as defined Baseband Specification, Section 5.5, on page 108 and the EV3 packet defined in Baseband Specification, Section 6.5.3.1, on page 124 using the LMP sequences defined in Section 4.6.2 on page 284 . |
| EV4 packets | This feature indicates whether the device is capable of supporting the EV4 packet type defined in Baseband Specification, Section 6.5.3.2, on page 124 on the eSCO logical transport. |
| EV5 packets | This feature indicates whether the device is capable of supporting the EV5 packet type defined in Baseband Specification, Section 6.5.3.3, on page 124 on the eSCO logical transport. |
| Enhanced Data Rate ACL 2 Mbps mode | This feature indicates whether the device supports the transmission and reception of 2-DH1 packets for the transport of traffic on the ACL-U logical link. |
| Enhanced Data Rate ACL 3 Mbps mode | <p>This feature indicates whether the device supports the transmission and reception of 3-DH1 packets for the transport of traffic on the ACL-U logical link.</p> <p>This feature bit shall only be set if the “Enhanced Data Rate ACL 2 Mbps mode” feature bit is set.</p> |
| 3-slot Enhanced Data Rate ACL packets | <p>This feature indicates whether the device supports the transmission and reception of three-slot Enhanced Data Rate packets on the ACL-U logical link.</p> <p>This feature bit shall only be set if the “Enhanced Data Rate ACL 2 Mbps mode” feature bit is set.</p> |
| 5-slot Enhanced Data Rate ACL packets | <p>This feature indicates whether the device supports the transmission and reception of 5-slot Enhanced Data Rate packets for the transport of traffic on the ACL-U logical link.</p> <p>This feature bit shall only be set if the “Enhanced Data Rate ACL 2 Mbps mode” feature bit is set.</p> |

Table 3.1: Feature definitions.

| Feature | Definition |
|--|--|
| Enhanced Data Rate eSCO 2 Mbps mode | This feature indicates whether the device supports the transmission and reception of 2-EV3 packets for the transport of traffic on the eSCO logical transport. |
| Enhanced Data Rate eSCO 3 Mbps mode | <p>This feature indicates whether the device supports the transmission and reception of 3-EV3 packets for the transport of traffic on the eSCO logical transport.</p> <p>This feature bit shall only be set if the “Enhanced Data Rate eSCO 2 Mbps mode” feature bit is set.</p> |
| 3-slot Enhanced Data Rate eSCO packets | <p>This feature indicates whether the device supports the transmission and reception of 3-slot Enhanced Data Rate packets for the transport of traffic on the eSCO logical transport.</p> <p>This feature bit shall only be set if the “Enhanced Data Rate eSCO 2 Mbps mode” feature bit is set.</p> |

Table 3.1: Feature definitions.

3.3 FEATURE MASK DEFINITION

The features are represented as a bit mask when they are transferred in LMP messages. For each feature a single bit is specified which shall be set to 1 if the feature is supported and set to 0 otherwise. The single exception is the flow control lag which is coded as a 3 bit field with the least significant bit in byte 2 bit 4 and the most significant bit in byte 2 bit 6. All unknown or unassigned feature bits shall be set to 0.

| No. | Supported feature | Byte | Bit |
|-----|--|------|-----|
| 0 | 3 slot packets | 0 | 0 |
| 1 | 5 slot packets | 0 | 1 |
| 2 | Encryption | 0 | 2 |
| 3 | Slot offset | 0 | 3 |
| 4 | Timing accuracy | 0 | 4 |
| 5 | Role switch | 0 | 5 |
| 6 | Hold mode | 0 | 6 |
| 7 | Sniff mode | 0 | 7 |
| 8 | Park state | 1 | 0 |
| 9 | Power control requests | 1 | 1 |
| 10 | Channel quality driven data rate (CQDDR) | 1 | 2 |
| 11 | SCO link | 1 | 3 |
| 12 | HV2 packets | 1 | 4 |
| 13 | HV3 packets | 1 | 5 |
| 14 | μ-law log synchronous data | 1 | 6 |
| 15 | A-law log synchronous data | 1 | 7 |
| 16 | CVSD synchronous data | 2 | 0 |
| 17 | Paging parameter negotiation | 2 | 1 |
| 18 | Power control | 2 | 2 |
| 19 | Transparent synchronous data | 2 | 3 |
| 20 | Flow control lag (least significant bit) | 2 | 4 |
| 21 | Flow control lag (middle bit) | 2 | 5 |
| 22 | Flow control lag (most significant bit) | 2 | 6 |
| 23 | Broadcast encryption | 2 | 7 |
| 24 | Reserved | 3 | 0 |
| 25 | Enhanced Data Rate ACL 2 Mbps mode | 3 | 1 |

Table 3.2: Feature mask definition

| No. | Supported feature | Byte | Bit |
|-----|--|------|-----|
| 26 | Enhanced Data Rate ACL 3Mbps mode | 3 | 2 |
| 27 | Enhanced inquiry scan | 3 | 3 |
| 28 | Interlaced inquiry scan | 3 | 4 |
| 29 | Interlaced page scan | 3 | 5 |
| 30 | RSSI with inquiry results | 3 | 6 |
| 31 | Extended SCO link (EV3 packets) | 3 | 7 |
| 32 | EV4 packets | 4 | 0 |
| 33 | EV5 packets | 4 | 1 |
| 34 | Reserved | 4 | 2 |
| 35 | AFH capable slave | 4 | 3 |
| 36 | AFH classification slave | 4 | 4 |
| 37 | Reserved | 4 | 5 |
| 38 | Reserved | 4 | 6 |
| 39 | 3-slot Enhanced Data Rate ACL packets | 4 | 7 |
| 40 | 5-slot Enhanced Data Rate ACL packets | 5 | 6 |
| 41 | reserved | 5 | 1 |
| 42 | reserved | 5 | 2 |
| 43 | AFH capable master | 5 | 3 |
| 44 | AFH classification master | 5 | 4 |
| 45 | Enhanced Data Rate eSCO 2 Mbps mode | 5 | 5 |
| 46 | Enhanced Data Rate eSCO 3 Mbps mode | 5 | 6 |
| 47 | 3-slot Enhanced Data Rate eSCO packets | 5 | 7 |
| 48 | Reserved | 6 | 0 |
| 63 | Extended features | 7 | 7 |

Table 3.2: Feature mask definition

3.4 LINK MANAGER INTEROPERABILITY POLICY

Link managers of any version will interoperate using the lowest common subset of functionality by reading the LMP features mask (defined in [Table 3.2 on page 230](#)).

An optional LMP PDU shall only be sent to a device if the corresponding feature bit is set in its feature mask. The exception to this are certain PDUs (see [Section 4.1.1 on page 233](#)) which can be sent before the features mask is requested. Note: a later version device with a restricted feature set is indistinguishable from an earlier version device with the same features.

4 PROCEDURE RULES

4.1 CONNECTION CONTROL

4.1.1 Connection establishment

After the paging procedure, LMP procedures with for clock offset request, LMP version, supported features, name request and detach may then be initiated.

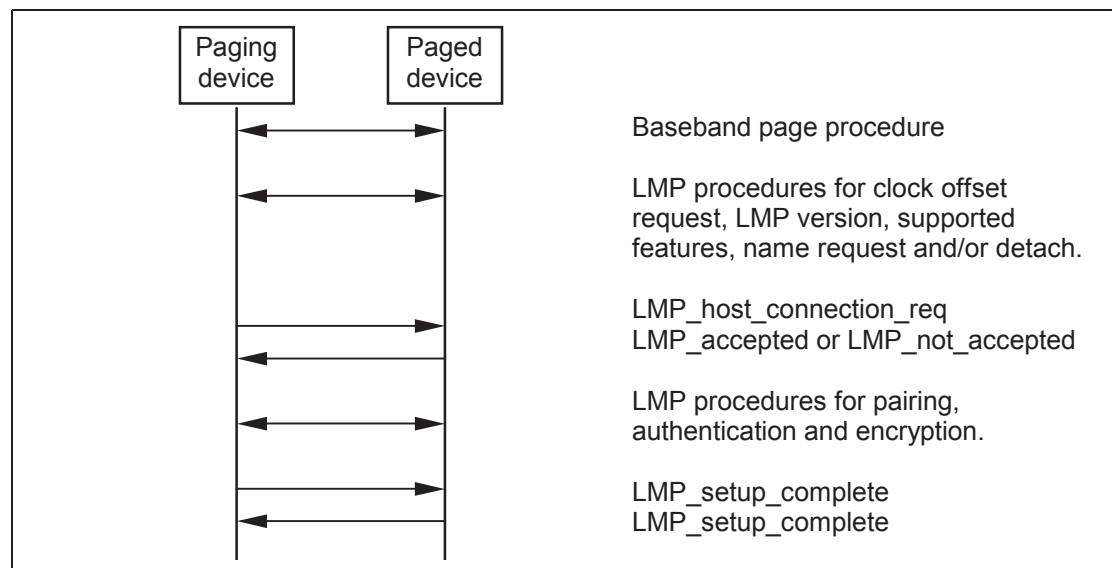


Figure 4.1: Connection establishment.

When the paging device wishes to create a connection involving layers above LM, it sends an LMP_host_connection_req PDU. When the other side receives this message, the host is informed about the incoming connection. The remote device can accept or reject the connection request by sending an LMP_accepted PDU or an LMP_not_accepted PDU. Alternatively, if the slave needs a role switch, see [Section 4.4.2 on page 268](#), it sends an LMP_slot_offset PDU and LMP_switch_req PDU after it has received an LMP_host_connection_req PDU. If the role switch fails the LM shall continue with the creation of the connection unless this cannot be supported due to limited resources in which case the connection shall be terminated with an LMP_detach PDU with error code *other end terminated connection: low resources*. When the role switch has been successfully completed, the old slave will reply with an LMP_accepted PDU or an LMP_not_accepted PDU to the LMP_host_connection_req PDU (with the transaction ID set to 0).

If the paging device receives an LMP_not_accepted PDU in response to LMP_host_connection_req it shall immediately disconnect the link using the mechanism described in [Section 4.1.2 on page 234](#).



If the LMP_host_connection_req PDU is accepted, LMP security procedures (pairing, authentication and encryption) may be invoked. When a device is not going to initiate any more security procedures during connection establishment it sends an LMP_setup_complete PDU. When both devices have sent LMP_setup_complete PDUs the traffic can be transferred on the ACL-U logical transport.

| M/O | PDU | Contents |
|-----|-------------------------|----------|
| M | LMP_host_connection_req | - |
| M | LMP_setup_complete | - |

Table 4.1: PDUs used for connection establishment.

4.1.2 Detach

The connection between two Bluetooth devices may be detached anytime by the master or the slave. An error code parameter is included in the message to inform the other party of why the connection is detached.

| M/O | PDU | Contents |
|-----|------------|------------|
| M | LMP_detach | error code |

Table 4.2: PDU used for detach.

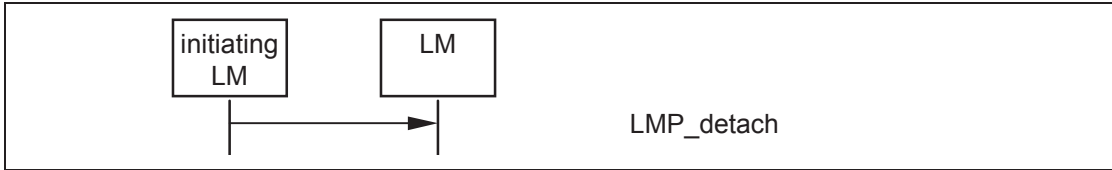
The initiating LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). The initiating LM then queues the LMP_detach for transmission and it shall start a timer for $6 \cdot T_{\text{poll}}$ slots where T_{poll} is the poll interval for the connection. If the initiating LM receives the baseband acknowledgement before the timer expires it starts a timer for $3 \cdot T_{\text{poll}}$ slots. When this timer expires, and if the initiating LM is the master, the LT_ADDR(s) may be re-used immediately. If the initial timer expires then the initiating LM drops the link and starts a timer for $T_{\text{link supervision timeout}}$ slots after which the LT_ADDR(s) may be re-used if the initiating LM is the master.

When the receiving LM receives the LMP_detach, it shall start a timer for $6 \cdot T_{\text{poll}}$ slots if it is the master and $3 \cdot T_{\text{poll}}$ if it is the slave. On timer expiration, the link shall be detached and, if the receiving LM is the master, the LT_ADDR(s) may be re-used immediately. If the receiver never receives the LMP_detach then a link supervision timeout will occur, the link will be detached, and the LT_ADDR may be re-used immediately.

If at any time during this or any other LMP sequence the Link supervision timeout expires then the link shall be terminated immediately and the LT_ADDR(S) may be re-used immediately.

If the connection is in hold mode, the initiating LM shall wait for hold mode to end before initiating the procedure defined above. If the connection is in sniff mode or park state, the initiating LM shall perform the procedure to exit sniff

mode or park state before initiating the procedure defined above. If the procedure to exit sniff mode or park state does not complete within the LMP response timeout (30 seconds) the procedure defined above shall be initiated anyway.



Sequence 1: Connection closed by sending LMP_detach.

4.1.3 Power control

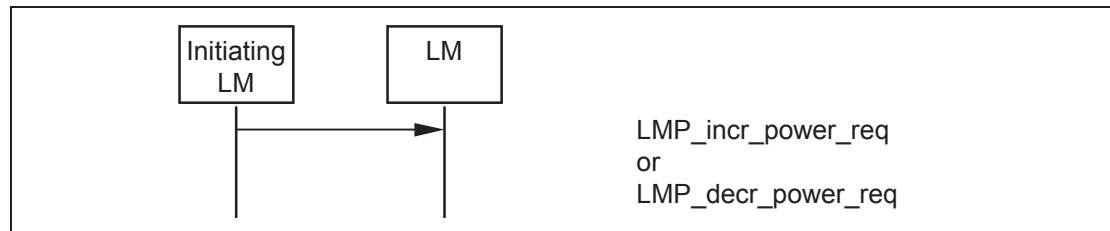
If the received signal characteristics differs too much from the preferred value of a Bluetooth device, it may request an increase or a decrease of the other device’s TX power. The power adjustment requests may be made at anytime following a successful baseband paging procedure.

If a device does not support power control requests this is indicated in the supported features list and thus no power control requests shall be sent after the supported features response has been processed. Prior to this time, a power control adjustment might be sent and if the recipient does not support power control it is allowed to send LMP_max_power in response to LMP_incr_power_req and LMP_min_power in response to LMP_decr_power_req. Another possibility is to send LMP_not_accepted with the error code *unsupported LMP feature*.

Upon receipt of an LMP_incr_power_req PDU or LMP_decr_power_req PDU the output power shall be increased or decreased one step. See [Radio Specification Section 3, on page 31](#) for the definition of the step size. The TX power is a property of the physical link, and affects all logical transports carried over the physical link. Power control requests carried over the default ACL-C logical link shall only affect the physical link associated with the default ACL-C logical link: they shall not affect the power level used on the physical links to other slaves.

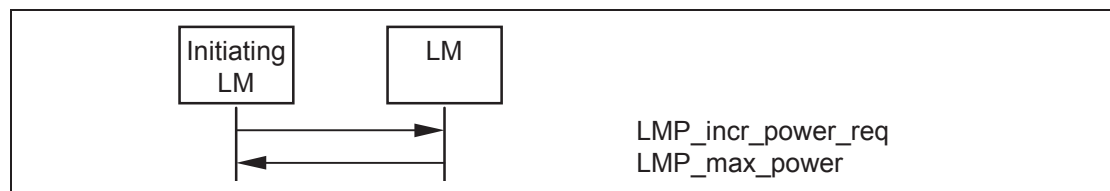
| M/O | PDU | Contents |
|-------|--------------------|-------------------------|
| O(9) | LMP_incr_power_req | for future use (1 Byte) |
| O(9) | LMP_decr_power_req | for future use (1 Byte) |
| O(18) | LMP_max_power | - |
| O(18) | LMP_min_power | - |

Table 4.3: PDUs used for power control.

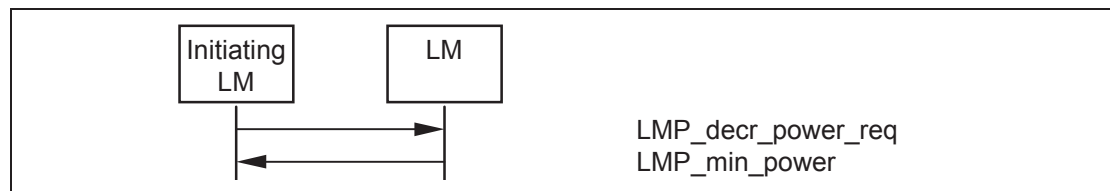


Sequence 2: A device requests a change of the other device's TX power.

If the receiver of `LMP_incr_power_req` is at maximum power `LMP_max_power` shall be returned. The device shall only request an increase again after having requested a decrease at least once. If the receiver of `LMP_decr_power_req` is at minimum power then `LMP_min_power` shall be returned and the device shall only request a decrease after having requested an increase at least once.



Sequence 3: The TX power cannot be increased.



Sequence 4: The TX power cannot be decreased.

One byte is reserved in `LMP_incr/decr_power_req` for future use. The parameter value shall be 0x00 and ignored upon receipt.

4.1.4 Adaptive frequency hopping

AFH is used to improve the performance of physical links in the presence of interference as well as reducing the interference caused by physical links on other devices in the ISM band. AFH shall only be used during the connection state.

| M/O | PDU | Contents |
|----------------------|-------------|--|
| O(35) Rx O(43) Tx | LMP_set_AFH | AFH_Instant, AFH_Mode, AFH_Channel_Map |

Table 4.4: PDUs used for AFH

The LMP_set_AFH PDU contains three parameters: AFH_Instant, AFH_Mode, and AFH_Channel_Map. The parameter, AFH_Instant, specifies the instant at which the hopset switch will become effective. This is specified as a Bluetooth Clock value of the master’s clock, that is available to both devices. The AFH instant is chosen by the master and shall be an even value at least $6 \cdot T_{poll}$ or 96 slots (whichever is greater) in the future, where T_{poll} is at least the longest poll interval for all AFH enabled physical links. The AFH_instant shall be within 12 hours of the current clock value. The parameter AFH_Mode, specifies whether AFH shall be enabled or disabled. The parameter AFH_Channel_Map, specifies the set of channels that shall be used if AFH is enabled.

When the LMP_set_AFH PDU is received the AFH instant shall be compared with the current Bluetooth clock value. If it is in the past then the AFH_instant has passed and the slave shall immediately configure the hop selection kernel (see [Baseband Specification, Section 2.6.3, on page 89](#)) with the new AFH_mode and AFH_channel_map specified in the LMP_set_AFH PDU. If it is in the future then a timer shall be started to expire at the AFH instant. When this timer expires it shall configure the hop selection kernel with the new AFH_mode and AFH_channel_map.

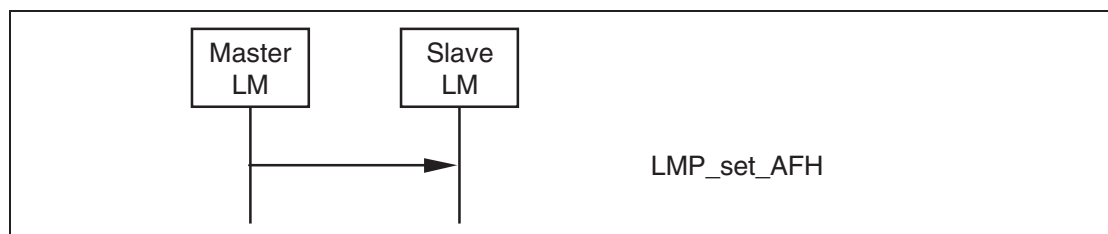
The master shall not send a new LMP_set_AFH PDU to a slave until it has received the baseband acknowledgement for any previous LMP_set_AFH addressed to that slave and the instant has passed.

Role switch while AFH is enabled shall follow the procedures define by [Baseband Specification, Section 8.6.5, on page 175](#).



4.1.4.1 Master enables AFH

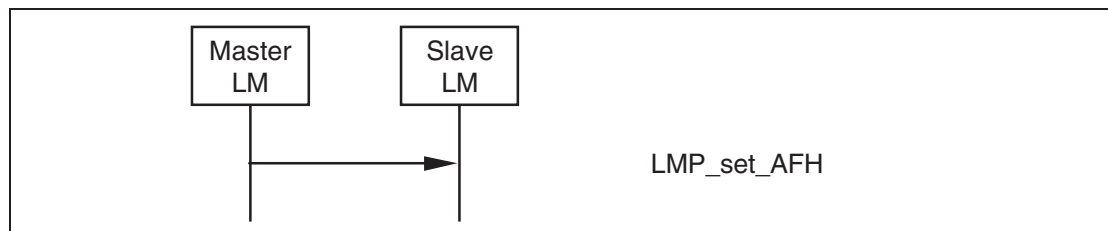
Prior to enabling AFH the master LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). The master shall then enable AFH on a physical link by sending the LMP_set_AFH PDU with AFH_mode set to AFH_enabled, the AFH_channel_map parameter containing the set of used and unused channels, and an AFH_instant. The LM shall not calculate the AFH instant until after traffic on the ACL-U logical link has been stopped. The master considers the physical link to be AFH_enabled once the baseband acknowledgement has been received and the AFH_instant has passed. Once the baseband acknowledgement has been received the master shall restart transmission on the ACL-U logical link.



Sequence 5: Master Enables AFH.

4.1.4.2 Master disables AFH

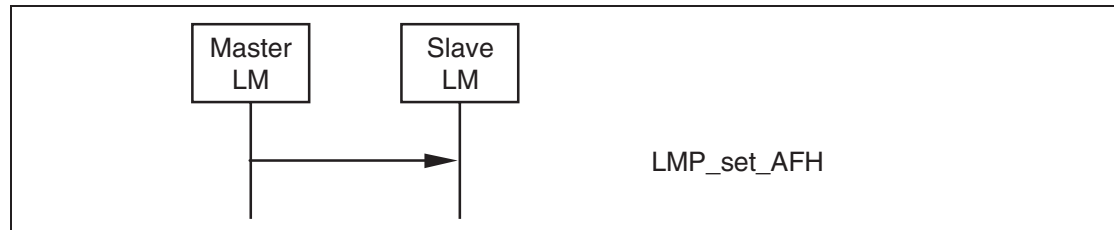
Prior to disabling AFH the master LM shall pause traffic on the ACL-U logical link ([Baseband Specification, Section 5.3.1, on page 108](#)). The master shall then disable AFH operation on a physical link by sending the LMP_set_AFH PDU with AFH_mode set to AFH_disabled and an AFH_instant. The AFH_channel_map parameter is not valid when AFH_mode is AFH_disabled. The LM shall not calculate the AFH instant until after traffic on the ACL-U logical link has been stopped. The master considers the physical link to have entered AFH_disabled operation once the baseband acknowledgement has been received and the AFH_instant has passed. Once the baseband acknowledgement has been received the master shall restart transmission on the ACL-U logical link.



Sequence 6: Master disables AFH.

4.1.4.3 Master updates AFH

A master shall update the AFH parameters on a physical link by sending the LMP_set_AFH PDU with AFH_mode set to AFH_enabled, an AFH_instant and a new AFH_channel_map. The master shall consider the slave to have the updated AFH parameters once the baseband acknowledgement has been received and the AFH_instant has passed.



Sequence 7: Master Updates AFH.

4.1.4.4 AFH operation in park, hold and sniff modes

A slave in Park, Hold or Sniff shall retain the AFH_mode and AFH_channel_map prior to entering those modes. A master may change the AFH_mode while a slave is in sniff.

A master that receives a request from an AFH_enabled slave to enter Park, Hold or Sniff and decides to operate the slave using a different hop sequence shall respond with an LMP_set_AFH PDU specifying the new hop sequence.

The master continues with the LMP signalling, for Park, Hold or Sniff initiation, once the baseband acknowledgement for the LMP_set_AFH PDU has been received. Optionally, the master may delay the continuation of this LMP signalling until after the instant. An AFH_capable_slave device shall support both of these cases.

A master that receives a request from an AFH_enabled slave to enter Park, Hold or Sniff and decides not to change the slave's hop sequence shall respond exactly as it would do without AFH. In this case, AFH operation has no effect on the LMP signalling.



4.1.5 Channel classification

A master may request channel classification information from a slave that is AFH_enabled.

A slave that supports the AFH_classification_slave feature shall perform channel classification and reporting according to its AFH_reporting_mode. The master shall control the AFH_reporting_mode using the LMP_channel_classification_req PDU. The slave shall report its channel classification using the LMP_channel_classification PDU.

The slave shall report pairs of channels as *good*, *bad* or *unknown*. See [Table 5.2 on page 303](#) for the detailed format of the AFH_Channel_Classification parameter. When one channel in the n^{th} channel pair is good and the other channel is unknown the n^{th} channel pair shall be reported as good. When one channel in the n^{th} channel pair is bad and the other is unknown the n^{th} channel pair shall be reported as bad. It is implementation dependent what to report when one channel in a channel pair is good and the other is bad.

| M/O | PDU | Contents |
|----------------------|--------------------------------|--|
| O(36) Rx O(44) Tx | LMP_channel_classification_req | AFH_Reporting_Mode, AFH_Min_Interval, AFH_Max_Interval |
| O(36) Tx O(44) Rx | LMP_channel_classification | AFH_Channel_Classification |

Table 4.5: PDUs used for Channel Classification Reporting.

The LMP_channel_classification_req PDU contains three parameters: AFH_Reporting_Mode, AFH_Min_Interval, and AFH_Max_Interval. In the AFH_reporting_disabled state, the slave shall not generate any channel classification reports. The parameter AFH_min_interval, defines the minimum amount of time from the last LMP_channel_classification command that was sent before the next LMP_channel_classification PDU may be sent. The parameter AFH_max_interval, defines the maximum amount of time between the change in the radio environment being detected by a slave and its generation of an LMP_channel_classification PDU. The AFH_max_interval shall be equal to or larger than AFH_min_interval.

The AFH_reporting_mode parameter shall determine if the slave is in the AFH_reporting_enabled or AFH_reporting_disabled state. The default state, prior to receipt of any LMP_channel_classification_req PDUs, shall be AFH_reporting_disabled.

AFH_reporting_mode is implicitly set to the AFH_reporting_disabled state when any of the following occur:

- Establishment of a connection at the baseband level
- Master-slave role switch



- Entry to park state operation
- Entry to hold mode operation

AFH_reporting_mode is implicitly restored to its former value when any of the following occur:

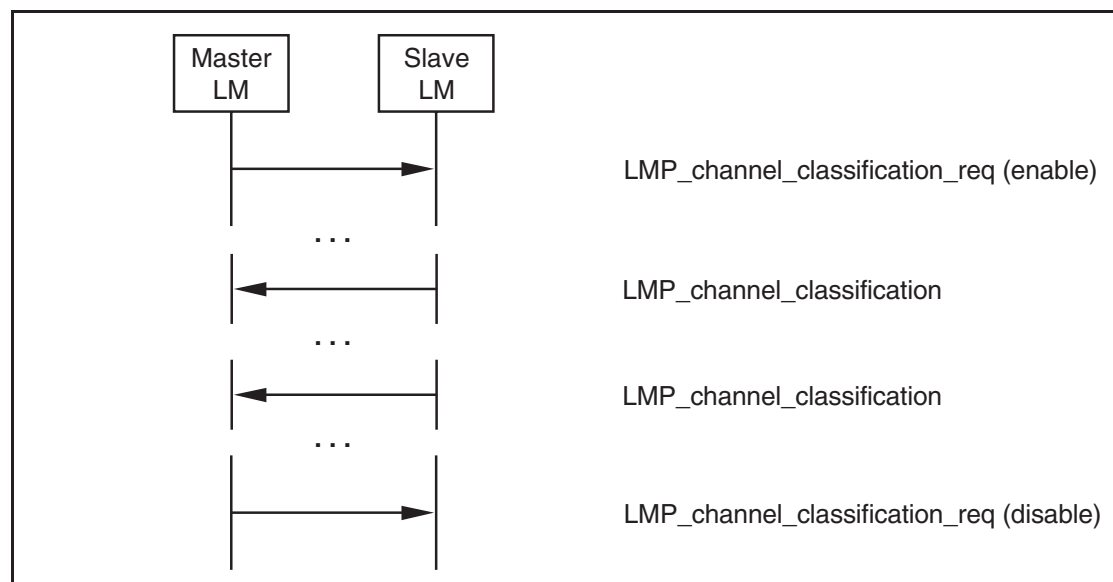
- Exit from park state operation
- Exit from hold mode
- Failure of Master-slave role switch

4.1.5.1 Channel classification reporting enabling and disabling

A master enables slave channel classification reporting by sending the LMP_channel_classification_req PDU with the AFH_reporting_mode parameter set to AFH_reporting_enabled.

When a slave has had classification reporting enabled by the master it shall send the LMP_channel_classification PDU according to the information in the latest LMP_channel_classification_req PDU. The LMP_channel_classification PDU shall not be sent if there has been no change in the slave's channel classification.

A master disables slave channel classification reporting by sending the LMP_channel_classification_req PDU with the AFH_reporting_mode parameter set to AFH_reporting_disabled.



Sequence 8: Channel classification reporting.

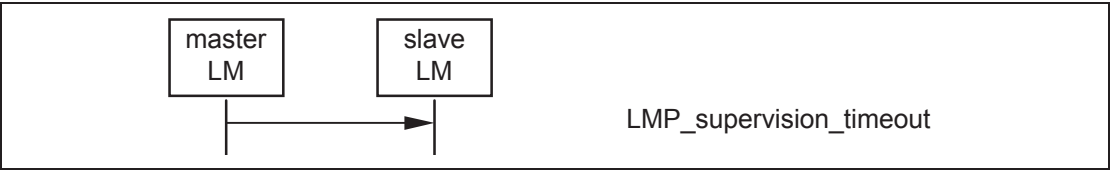


4.1.6 Link supervision

Each physical link has a timer that is used for link supervision. This timer is used to detect physical link loss caused by devices moving out of range, or being blocked by interference, a device’s power-down, or other similar failure cases. Link supervision is specified in [Baseband Specification, Section 3.1, on page 95](#).

| M/O | PDU | Contents |
|-----|-------------------------|---------------------|
| M | LMP_supervision_timeout | supervision timeout |

Table 4.6: PDU used to set the supervision timeout.



Sequence 9: Setting the link supervision timeout.

4.1.7 Channel quality driven data rate change (CQDDR)

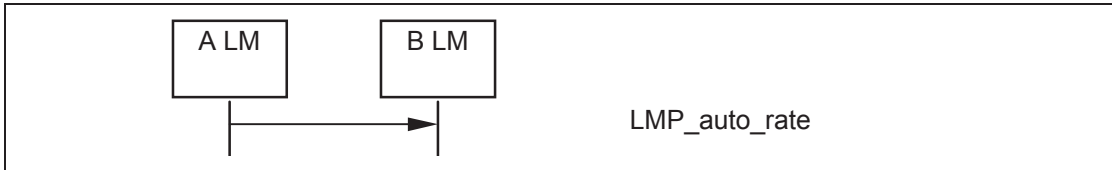
The data throughput for a given packet type depends on the quality of the RF channel. Quality measurements in the receiver of one device can be used to dynamically control the packet type transmitted from the remote device for optimization of the data throughput. Device A sends the LMP_auto_rate PDU once to notify device B to enable this feature. Once enabled, device B may change the packet type(s) that A transmits by sending the LMP_preferred_rate PDU. This PDU has a parameter which determines the preferred coding (with or without 2/3FEC) and optionally the preferred size in slots of the packets. Device A is not required to change to the packet type specified by this parameter. Device A shall not send a packet that is larger than max slots (see [Section 4.1.10 on page 247](#)) even if the preferred size is greater than this value.

The data rate parameter includes the preferred rate for Basic Rate and Enhanced Data Rate modes. When operating in Basic Rate mode, the device shall use bits 0-2 to determine the preferred data rate. When operating in Enhanced Data Rate mode, the device shall use bits 3-6 to determine the preferred data rate. For devices that support Enhanced Data Rate, the preferred rates for both Basic Rate and Enhanced Data Rate modes shall be valid at all times.

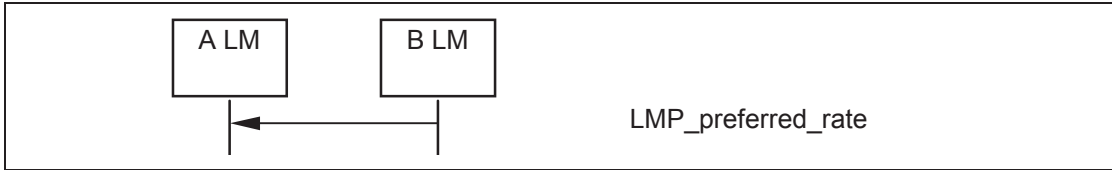
These PDUs may be sent at any time after connection setup is completed.

| M/O | PDU | Contents |
|-------|--------------------|-----------|
| O(10) | LMP_auto_rate | - |
| O(10) | LMP_preferred_rate | data rate |

Table 4.7: PDUs used for quality driven change of the data rate.



Sequence 10: A notifies B to enable CQDDR



Sequence 11: B sends A a preferred packet type



4.1.8 Quality of service (QoS)

The LM provides QoS capabilities. A poll interval, T_{poll} , that is defined as the maximum time between transmissions from the master to a particular slave on the ACL logical transport, is used to support bandwidth allocation and latency control - see [Baseband Specification, Section 8.6.1, on page 169](#) for details. The poll interval is guaranteed in the active and sniff modes except when there are collisions with page, page scan, inquiry and inquiry scan, during time critical LMP sequences in the current piconet and any other piconets in which the Bluetooth device is a member, and during critical baseband sequences (such as the page response, initial connection state until the first POLL, and master slave switch). These PDUs maybe sent at anytime after connection setup is completed.

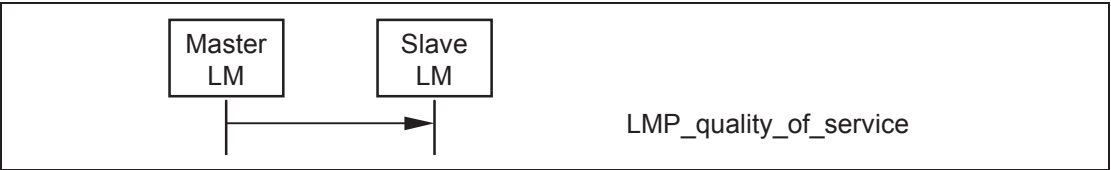
Master and slave negotiate the number of repetitions for broadcast packets (N_{BC}), see [Baseband Specification, Section 7.6.5, on page 150](#).

| M/O | PDU | Contents |
|-----|----------------------------|---------------------------|
| M | LMP_quality_of_service | poll interval N_{BC} |
| M | LMP_quality_of_service_req | poll interval N_{BC} |

Table 4.8: PDUs used for quality of service.

4.1.8.1 Master notifies slave of the quality of service

The master notifies the slave of the new poll interval and N_{BC} by sending the LMP_quality_of_service PDU. The slave cannot reject the notification.

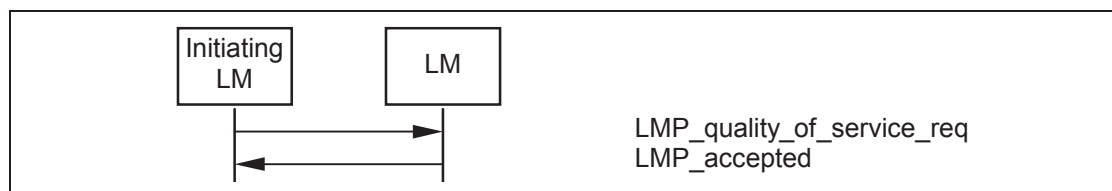


Sequence 12: Master notifies slave of quality of service.

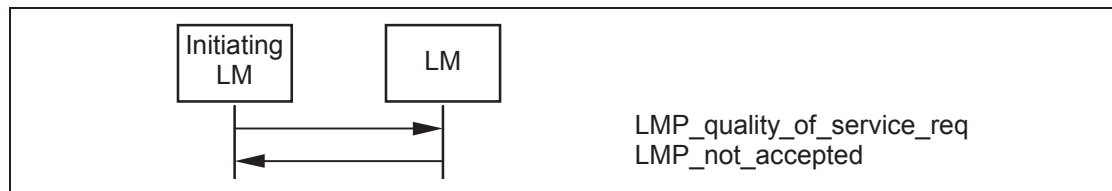
4.1.8.2 Device requests new quality of service

Either the master or the slave may request a new poll interval and N_{BC} by sending an LMP_quality_of_service_req PDU to the slave. The parameter N_{BC} is meaningful only when it is sent by a master to a slave. For transmission of LMP_quality_of_service_req PDUs from a slave, this parameter shall be ignored by the master. The request can be accepted or rejected. This allows the master and slave to dynamically negotiate the quality of service as needed.

The selected poll interval by the slave shall be less than or equal to the specified Access Latency for the outgoing traffic of the ACL link (see L2CAP “[Quality of Service \(QoS\) Option](#)” on page 60[vol. 4]).



Sequence 13: Device accepts new quality of service



Sequence 14: Device rejects new quality of service.



4.1.9 Paging scheme parameters

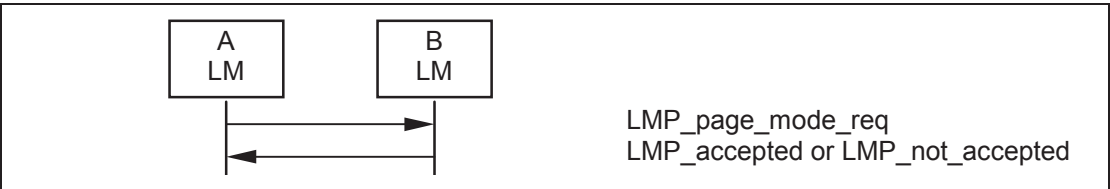
LMP provides a means to negotiate the paging scheme parameters that are used the next time a device is paged.

| M/O | PDU | Contents |
|-------|------------------------|---|
| O(17) | LMP_page_mode_req | paging scheme paging scheme settings |
| O(17) | LMP_page_scan_mode_req | paging scheme paging scheme settings |

Table 4.9: PDUs used to request paging scheme.

4.1.9.1 Page mode

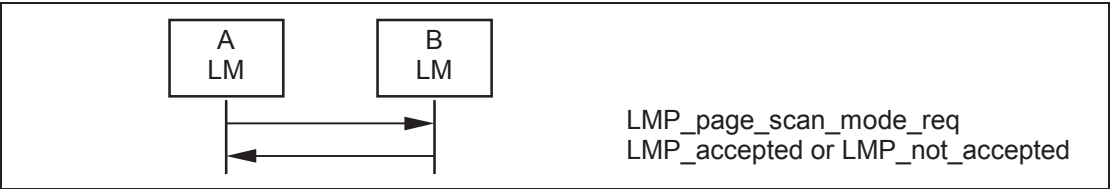
This procedure is initiated from device A and negotiates the paging scheme used when device A pages device B. Device A proposes a paging scheme including the parameters for this scheme and device B can accept or reject. On rejection the old setting will not be changed. A request to switch to a reserved paging scheme shall be rejected.



Sequence 15: Negotiation for page mode.

4.1.9.2 Page scan mode

This procedure is initiated from device A and negotiates the paging scheme and paging scheme settings used when device B pages device A. Device A proposes a paging scheme and paging scheme settings and device B may accept or reject. On reject the old setting is not changed. A request specifying the mandatory scheme shall be accepted. A request specifying a non-mandatory scheme shall be rejected. This procedure should be used when device A changes its paging scheme settings. A slave should also send this message to the master after connection establishment, to inform the master of the slave's current paging scheme and paging scheme settings.



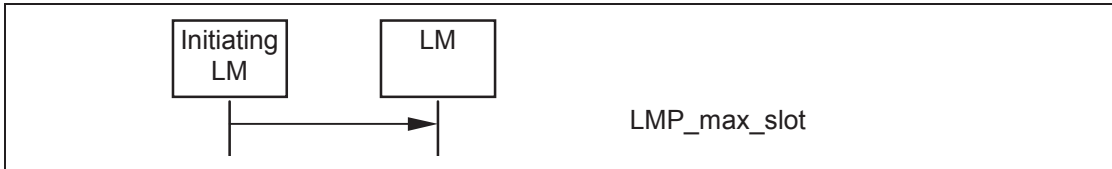
Sequence 16: Negotiation for page scan mode

4.1.10 Control of multi-slot packets

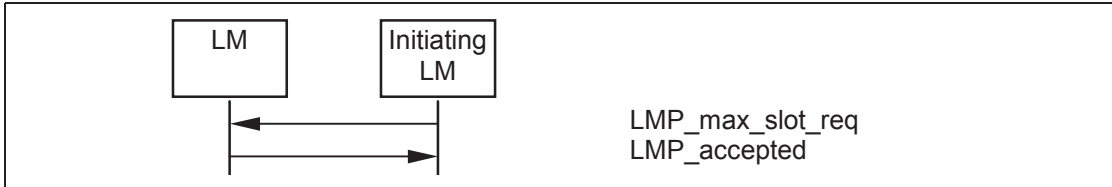
The number of consecutive slots used by a device on an ACL-U logical link can be limited. It does not affect traffic on the eSCO links where the packet sizes are defined as part of link setup. A device allows the remote device to use a maximum number of slots by sending the PDU LMP_max_slot providing max slots as parameter. Each device can request to use a maximal number of slots by sending the PDU LMP_max_slot_req providing max slots as parameter. After a new connection, as a result of page, page scan, role switch or unpark, the default value is 1 slot. These PDUs can be sent at anytime after connection setup is completed.

| M/O | PDU | Contents |
|-----|------------------|-----------|
| M | LMP_max_slot | max slots |
| M | LMP_max_slot_req | max slots |

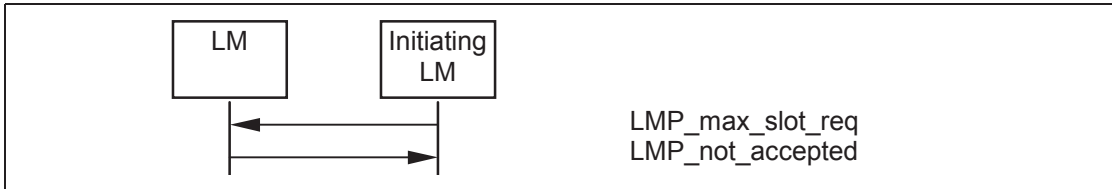
Table 4.10: PDUs used to control the use of multi-slot packets.



Sequence 17: Device allows Remote Device to use a maximum number of slots.



Sequence 18: Device requests a maximum number of slots. Remote Device accepts.



Sequence 19: Device requests a maximum number of slots. Remote Device rejects.

4.1.11 Enhanced Data Rate

A device may change the packet type table, ptt, to select which if any of the optional modulation schemes are to be used on an ACL logical transport.



Either the master or the slave may request a new packet type table and therefore the modulation scheme to be used on this ACL link. After a new baseband connection, as a result of page or page scan, the default value for ptt shall be 0.

The change of the modulation mode for an ACL logical transport shall not affect the packet types used for an associated SCO logical transport on the same LT_ADDR.

Note: Enhanced Data Rate eSCO links are negotiated using the LMP eSCO link_req as described in [section 4.6.2](#).

Before changing the packet type table, the initiator shall finalize the transmission of the current ACL packet with ACL-U information and shall stop ACL-U transmissions. It shall then send the LMP_packet_type_table_req PDU.

If the receiver rejects the change, then it shall respond with an LMP_not_accepted_ext PDU.

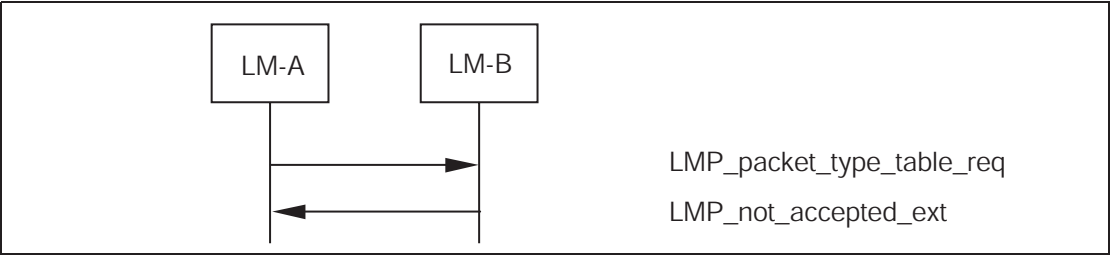
If the receiver accepts the change, then it shall finalize the transmission of the current ACL packet with ACL-U information and shall stop ACL-U transmissions, it shall change to the new packet type table and shall respond with an LMP_accepted_ext PDU. When it receives the baseband level acknowledgement for the LMP_accepted_ext PDU it shall restart ACL-U transmissions.

When the initiator receives an LMP_not_accepted_ext PDU the initiator shall restart ACL-U transmissions.

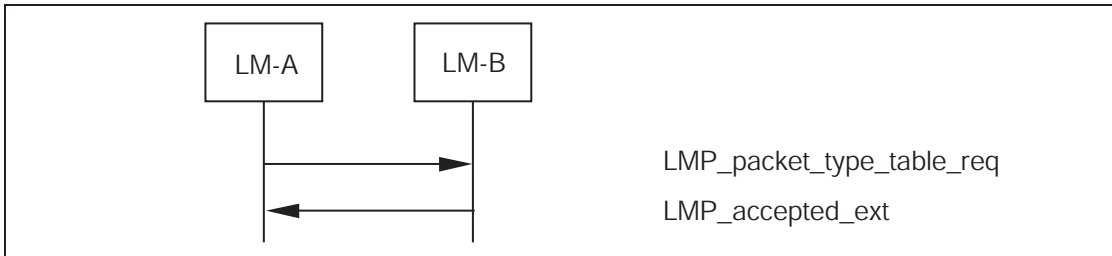
When the initiator receives an LMP_accepted_ext PDU it shall change the packet type table and restart ACL-U transmissions.

| M/O | PDU | Contents |
|-------|---------------------------|-------------------|
| O(25) | LMP_packet_type_table_req | packet type table |

Table 4.11: PDUs used for Enhanced Data Rate



Sequence 20: Packet type table change is rejected.



Sequence 21: Packet type table change is accepted.

4.2 SECURITY

4.2.1 Authentication

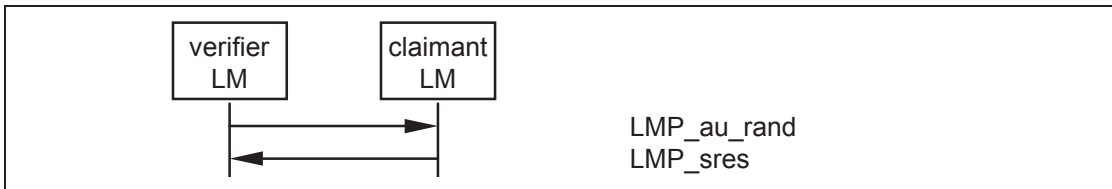
The authentication procedure is based on a challenge-response scheme as described in [\[Part H\] Section 3.2.2 on page 780](#). The verifier sends an LMP_au_rand PDU that contains a random number (the challenge) to the claimant. The claimant calculates a response, that is a function of this challenge, the claimant’s BD_ADDR and a secret key. The response is sent back to the verifier, that checks if the response was correct or not. The response shall be calculated as described in [\[Part H\] Section 6.1 on page 801](#). A successful calculation of the authentication response requires that two devices share a secret key. This key is created as described in [Section 4.2.2 on page 251](#). Both the master and the slave can be verifiers.

| M/O | PDU | Contents |
|-----|-------------|-------------------------|
| M | LMP_au_rand | random number |
| M | LMP_sres | authentication response |

Table 4.12: PDUs used for authentication.

4.2.1.1 Claimant has link key

If the claimant has a link key associated with the verifier, it shall calculate the response and sends it to the verifier with LMP_sres. The verifier checks the response. If the response is not correct, the verifier can end the connection by sending an LMP_detach PDU with the error code *authentication failure*, see [Section 4.1.2 on page 234](#).



Sequence 22: Authentication. Claimant has link key.

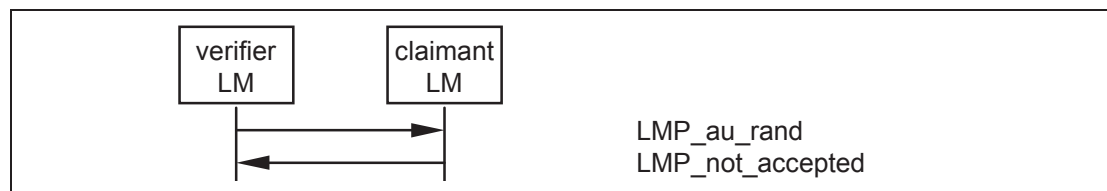


Upon reception of an LMP_au_rand, an LM shall reply with LMP_sres before initiating its own authentication.

Note: there can be concurrent requests caused by the master and slave simultaneously initiating an authentication. The procedures in [Section 2.5.1 on page 223](#) assures that devices will not have different Authenticated Ciphering Offset (ACO, see [\[Part H\] Section 6.1 on page 801](#)) when they calculate the encryption key.

4.2.1.2 Claimant has no link key

If the claimant does not have a link key associated with the verifier it shall send an LMP_not_accepted PDU with the error code *key missing* after receiving an LMP_au_rand PDU.



Sequence 23: Authentication fails. Claimant has no link key.

4.2.1.3 Repeated attempts

The scheme described in [\[Part H\] Section 5.1 on page 799](#) shall be applied when an authentication fails. This will prevent an intruder from trying a large number of keys in a relatively short time.

4.2.2 Pairing

When two devices do not have a common link key an initialization key (K_{init}) shall be created based on a PIN, and a random number and a BD_ADDR. K_{init} shall be created as specified in [Part H] Section 6.3 on page 805. When both devices have calculated K_{init} the link key shall be created, and a mutual authentication is performed. The pairing procedure starts with a device sending an LMP_in_rand PDU; this device is referred to as the "initiating LM" or "initiator" in Section 4.2.2.1 on page 251 - Section 4.2.2.5 on page 253. The other device is referred to as the "responding LM" or "responder". The PDUs used in the pairing procedure are:

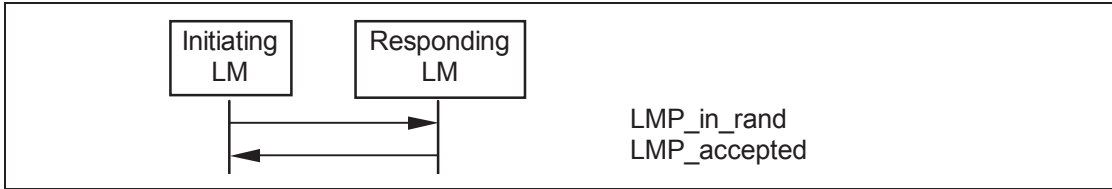
| M/O | PDU | Contents |
|-----|--------------|-------------------------|
| M | LMP_in_rand | random number |
| M | LMP_au_rand | random number |
| M | LMP_sres | authentication response |
| M | LMP_comb_key | random number |
| M | LMP_unit_key | key |

Table 4.13: PDUs used for pairing

All sequences described in Section 4 on page 233, including the mutual authentication after the link key has been created, shall form a single transaction. The transaction ID from the first LMP_in_rand shall be used for all subsequent sequences.

4.2.2.1 Responder accepts pairing

When the initiator sends an LMP_in_rand PDU and the responder shall reply with an LMP_accepted PDU. Both devices shall then calculate K_{init} based on the BD_ADDR of the responder and the procedure continues with creation of the link key; see Section 4.2.2.4 on page 253.

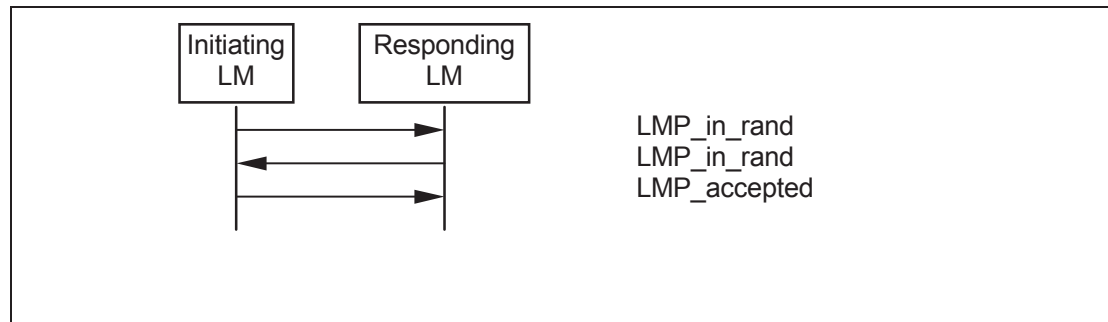


Sequence 24: Pairing accepted. Responder has a variable PIN. Initiator has a variable or fixed PIN.



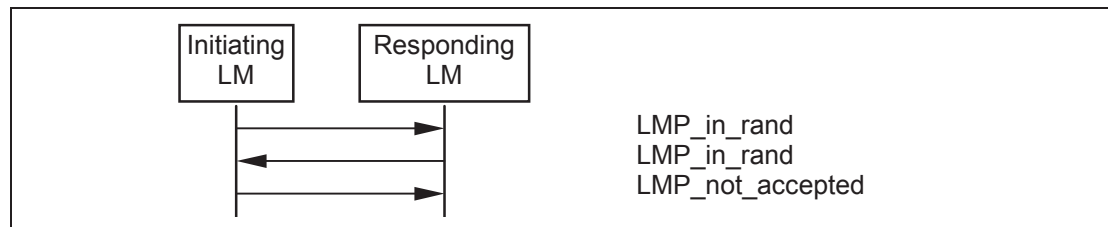
4.2.2.2 Responder has a fixed PIN

If the responder has a fixed PIN it shall generate a new random number and send it back in an LMP_in_rand PDU. If the initiator has a variable PIN it shall accept the LMP_in_rand PDU and shall respond with an LMP_accepted PDU. Both sides shall then calculate K_{init} based on the last IN_RAND and the BD_ADDR of the initiator. The procedure continues with creation of the link key; see [Section 4.2.2.4 on page 253](#).



Sequence 25: Responder has a fixed PIN and initiator has a variable PIN.

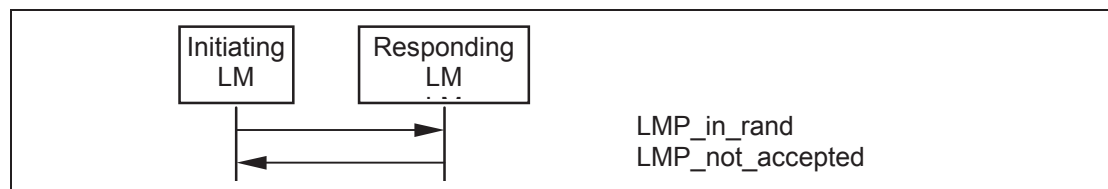
If the responder has a fixed PIN and the initiator also has a fixed PIN, the second LMP_in_rand shall be rejected by the initiator sending an LMP_not_accepted PDU with the error code *pairing not allowed*.



Sequence 26: Both devices have a fixed PIN.

4.2.2.3 Responder rejects pairing

If the responder rejects pairing it shall send an LMP_not_accepted PDU with the error code *pairing not allowed* after receiving an LMP_in_rand PDU.



Sequence 27: Responder rejects pairing.

4.2.2.4 Creation of the link key

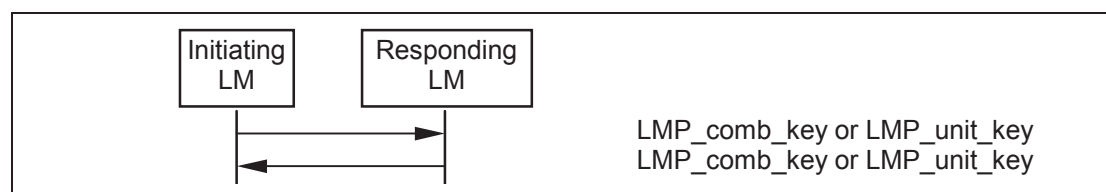
When K_{init} is calculated in both devices the link key shall be created. This link key will be used in the authentication between the two devices for all subsequent connections until it is changed; see [Section 4.2.3 on page 254](#) and [Section 4.2.4 on page 255](#). The link key created in the pairing procedure will either be a combination key or one of the device's unit keys. The following rules shall apply to the selection of the link key:

- if one device sends an LMP_unit_key PDU and the other device sends LMP_comb_key, the unit key will be the link key.
- if both devices send an LMP_unit_key PDU, the master's unit key will be the link key.
- if both devices send an LMP_comb_key PDU, the link key shall be calculated as described in [\[Part H\] Section 3.2 on page 779](#).

The content of the LMP_unit_key PDU is the unit key bitwise XORed with K_{init} . The content of the LMP_comb_key PDU is LK_RAND bitwise XORed with K_{init} . Any device configured to use a combination key shall store the link key.

The use of unit keys is deprecated since it is implicitly insecure.

When the link key, combination or unit key, has been created mutual authentication shall be performed to confirm that the same link key has been created in both devices. The first authentication in the mutual authentication is performed with the initiator as the verifier. When finalized an authentication in the reverse direction is performed.



Sequence 28: Creation of the link key.

4.2.2.5 Repeated attempts

When the authentication after creation of the link key fails because of an incorrect authentication response, the same scheme as in [Section 4.2.1.3 on page 250](#) shall be used. This prevents an intruder from trying a large number of different PINs in a relatively short time.



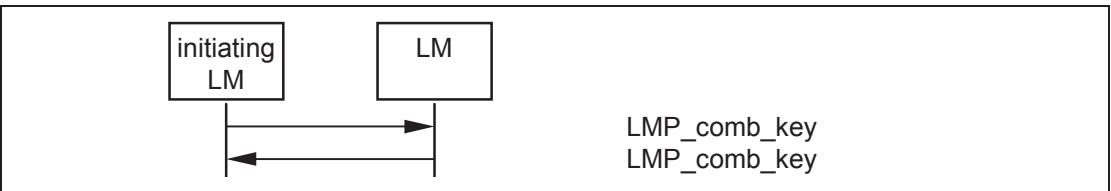
4.2.3 Change link key

If the link key is derived from combination keys and the current link is the semi-permanent link key, the link key can be changed. If the link key is a unit key, the devices shall go through the pairing procedure in order to change the link key. The contents of the LMP_comb_key PDU is protected by a bitwise XOR with the current link key.

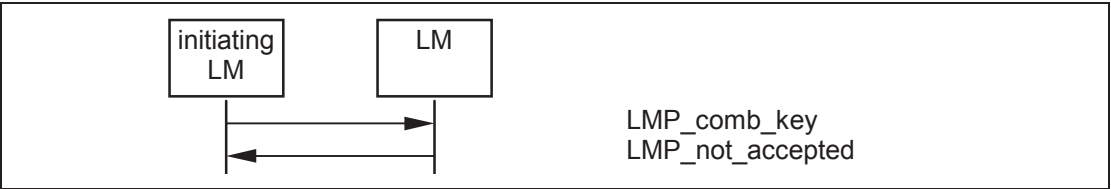
| M/O | PDU | Contents |
|-----|--------------|---------------|
| M | LMP_comb_key | random number |

Table 4.14: PDUs used for change of link key.

All sequences described in [Section 4.2.3](#) , including the mutual authentication after the link key has been changed, shall form a single transaction. The transaction ID from the first LMP_comb_key PDU shall be used for all subsequent sequences.



Sequence 29: Successful change of the link key.



Sequence 30: Change of the link key not possible since the other device uses a unit key.

If the change of link key is successful the new link key shall be stored and the old link key shall be discarded. The new link key shall be used as link key for all the following connections between the two devices until the link key is changed again. The new link key also becomes the current link key. It will remain the current link key until the link key is changed again, or until a temporary link key is created, see [Section 4.2.4 on page 255](#).

When the new link key has been created mutual authentication shall be performed to confirm that the same link key has been created in both devices. The first authentication in the mutual authentication is performed with the device that initiated change link key as verifier. When finalized an authentication in the reverse direction is performed.

4.2.4 Change current link key type

The current link key can be a semi-permanent link key or a temporary link key. It may be changed temporarily, but the change shall only be valid for the current connection, see [\[Part H\] Section 3.1 on page 777](#). Changing to a temporary link key is necessary if the piconet is to support encrypted broadcast. The current link key may not be changed before the connection establishment procedure has completed. This feature is only supported if broadcast encryption is supported as indicated by the LMP features mask.

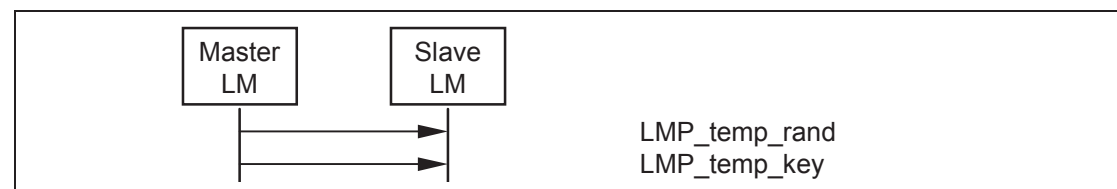
| M/O | PDU | Contents |
|-------|----------------------------|---------------|
| O(23) | LMP_temp_rand | random number |
| O(23) | LMP_temp_key | key |
| O(23) | LMP_use_semi_permanent_key | - |

Table 4.15: PDUs used to change the current link key.

4.2.4.1 Change to a temporary link key

The master starts by creating the master key K_{master} as specified in [Security Specification \(EQ 4\)](#), on page 784. Then the master shall generate a random number, RAND, and shall send it to the slave in an LMP_temp_rand PDU. Both sides then calculate an overlay denoted OVL as $\text{OVL} = \bar{E}_{22}(\text{current link key}, \text{RAND}, 16)$. The master shall then send K_{master} protected by a modulo-2 addition with OVL to the slave in an LMP_temp_key PDU. The slave calculates K_{master} , based on OVL, that becomes the current link key. It shall be the current link key until the devices fall back to the semi-permanent link key, see [section 4.2.4.2 on page 256](#).

Note: the terminology in this section is the same as used in [\[Part H\] Section 3.2.8 on page 784](#).



Sequence 31: Change to a temporary link key.

All sequences described in [Section 4.2.4.1 on page 255](#), including the mutual authentication after K_{master} has been created, shall form a single transaction. The transaction ID shall be set to 0.

When the devices have changed to the temporary key, a mutual authentication shall be made to confirm that the same link key has been created in both devices. The first authentication in the mutual authentication shall be per-

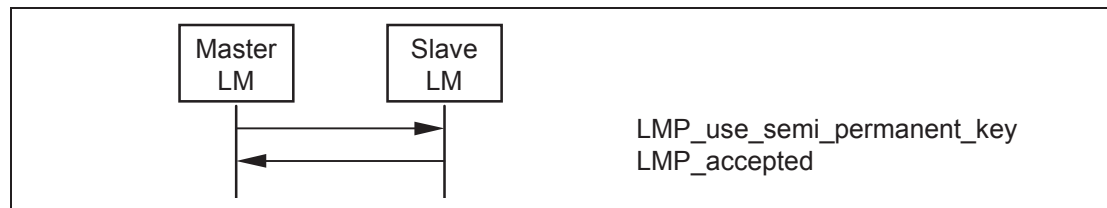


formed with the master as verifier. When finalized an authentication in the reverse direction is performed.

Should the mutual authentication fail at either side, the LM of the verifier should start the detach procedure. This will allow the procedure to succeed even though one of the devices may be erroneous.

4.2.4.2 Make the semi-permanent link key the current link key

After the current link key has been changed to K_{master} , this change can be undone and the semi-permanent link key becomes the current link key again. If encryption is used on the link, the procedure to go back to the semi-permanent link key shall be immediately followed by the master stopping encryption using the procedure described in [Section 4.2.5.4 on page 260](#). Encryption may be restarted by the master according to the procedures in [section 4.2.5.1 on page 257](#) subsection 3. This is to assure that encryption with encryption parameters known by other devices in the piconet is not used when the semi-permanent link key is the current link key.



Sequence 32: Link key changed to the semi-permanent link key.

4.2.5 Encryption

If at least one authentication has been performed encryption may be used. In order for the master to use the same encryption parameters for all slaves in the piconet it shall issue a temporary key, K_{master} . The master shall make this key the current link key for all slaves in the piconet before encryption is started, see [Section 4.2.4 on page 255](#). This is required if broadcast packets are to be encrypted.

| M/O | PDU | Contents |
|-----|-----------------------------|-----------------|
| O | LMP_encryption_mode_req | encryption mode |
| O | LMP_encryption_key_size_req | key size |
| O | LMP_start_encryption_req | random number |
| O | LMP_stop_encryption_req | - |

Table 4.16: PDUs used for handling encryption.

All sequences described in [Section 4.2.5](#) shall form a single transaction. The transaction ID from the LMP_encryption_mode_req PDU shall be used for all subsequent sequences.

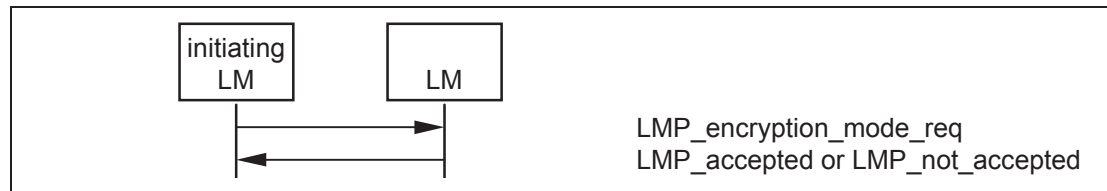
4.2.5.1 Encryption mode

The master and the slave must agree upon whether to use encryption (encryption mode=1 in Lmp_encryption_mode_req) or not (encryption mode=0). If the semi-permanent key is used (Key_Flag=0x00) encryption shall only apply to point-to-point packets. If the master link key is used (Key_Flag=0x01) encryption shall apply to both point-to-point packets and broadcast packets. If master and slave agree on the encryption mode, the master continues to give more detailed information about the encryption.

Devices should never send LMP_encryption_mode_req with an encryption mode value of 2 however for backwards compatibility if the LMP_encryption_mode_req is received with an encryption mode value of 2 then it should be treated the same as an encryption mode value of 1.

The initiating LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). The initiating device shall then send the LMP_encryption_mode_req PDU. If the responding device accepts the change in encryption mode then it shall complete the transmission of the current packet on the ACL logical transport and shall then suspend transmission on the ACL-U logical link. The responding device shall then send the LMP_accepted PDU.

ACL-U logical link traffic shall only be resumed after the attempt to encrypt or decrypt the logical transport is completed i.e. at the end of Sequence [33](#), [34](#) or [35](#).

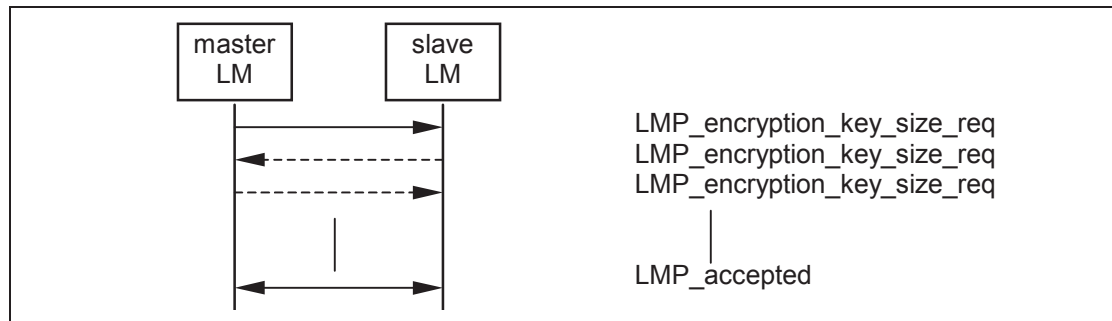


Sequence 33: Negotiation for encryption mode.

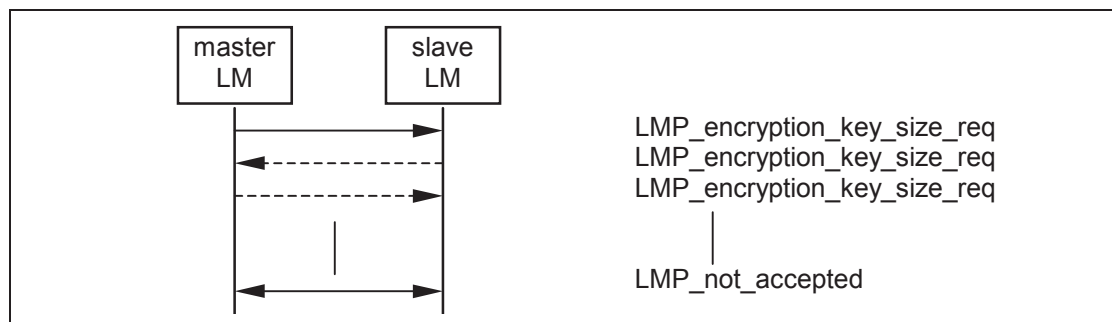
After a device has sent an LMP_encryption_mode_req PDU it shall not send an LMP_aud_rand PDU before encryption is started. After a device has received an LMP_encryption_mode_req PDU and sent an LMP_accepted PDU it shall not send an LMP_aud_rand PDU before encryption is started. If an LMP_aud_rand PDU is sent violating these rules, the claimant shall respond with an LMP_not_accepted PDU with the error code *PDU not allowed*. This assures that devices will not have different ACOs when they calculate the encryption key. If the encryption mode is not accepted or the encryption key size negotiation results in disagreement the devices may send an LMP_aud_rand PDU again.

4.2.5.2 Encryption key size

Note: this section uses the same terms as in [\[Part H\] Section 4.1 on page 788](#). The master sends an LMP_encryption_key_size_req PDU including the suggested key size $L_{\text{sug}, m}$, that is initially equal to $L_{\text{max}, m}$. If $L_{\text{min}, s} \leq L_{\text{sug}, m}$ and the slave supports $L_{\text{sug}, m}$ it shall respond with an LMP_accepted PDU and $L_{\text{sug}, m}$ shall be used as the key size. If both conditions are not fulfilled the slave sends back an LMP_encryption_key_size_req PDU including the slave's suggested key size $L_{\text{sug}, s}$. This value shall be the slave's largest supported key size that is less than $L_{\text{sug}, m}$. Then the master performs the corresponding test on the slave's suggestion. This procedure is repeated until a key size agreement is reached or it becomes clear that no such agreement can be reached. If an agreement is reached a device sends an LMP_accepted PDU and the key size in the last LMP_encryption_key_size_req PDU shall be used. After this, encryption is started; see [Section 4.2.5.3 on page 259](#). If an agreement is not reached a device sends an LMP_not_accepted PDU with the error code *unsupported parameter value* and the devices shall not communicate using encryption.



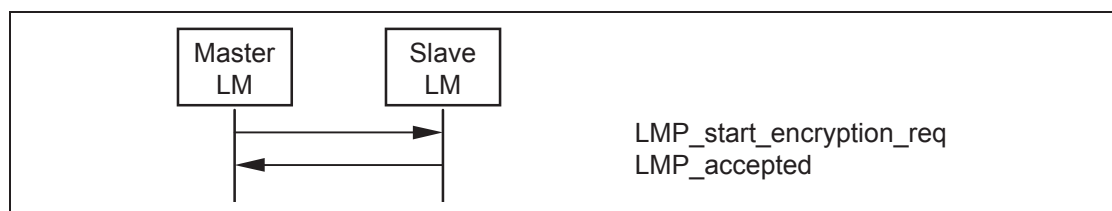
Sequence 34: Encryption key size negotiation successful.



Sequence 35: Encryption key size negotiation failed.

4.2.5.3 Start encryption

To start encryption, the master issues the random number EN_RANDOM and calculates the encryption key. See [\[Part H\] Section 3.2.5 on page 782](#). The random number shall be the same for all slaves in the piconet when broadcast encryption is used. The master then sends an LMP_start_encryption_req PDU, that includes EN_RANDOM. The slave shall calculate the encryption key when this message is received and shall acknowledge with an LMP_accepted PDU.



Sequence 36: Start of encryption.

Starting encryption shall be performed in three steps:

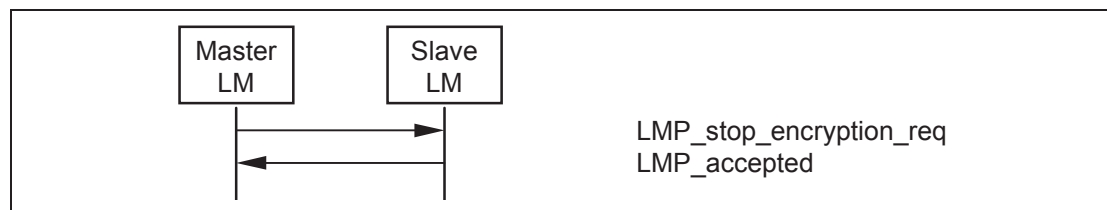
1. Master is configured to transmit unencrypted packets and to receive encrypted packets.
2. Slave is configured to transmit and receive encrypted packets.
3. Master is configured to transmit and receive encrypted packets.



Between step 1 and step 2, master-to-slave transmission is possible. This is when an LMP_start_encryption_req PDU is transmitted. Step 2 is triggered when the slave receives this message. Between step 2 and step 3, slave-to-master transmission is possible. This is when an LMP_accepted PDU is transmitted. Step 3 is triggered when the master receives this message.

4.2.5.4 Stop encryption

To stop encryption a device shall send an LMP_encryption_mode_req PDU with the parameter encryption mode equal to 0 (no encryption). The other device responds with an LMP_accepted PDU or an LMP_not_accepted PDU (the procedure is described in [Sequence 33](#) in [section 4.2.5.1 on page 257](#)). If accepted, encryption shall be stopped by the master sending an LMP_stop_encryption_req PDU and the slave shall respond with an LMP_accepted PDU according to [Sequence 37](#).



Sequence 37: Stop of encryption.

Stopping encryption shall be performed in three steps, similar to the procedure for starting encryption.

1. Master is configured to transmit encrypted packets and to receive unencrypted packets.
2. Slave is configured to transmit and receive unencrypted packets.
3. Master is configured to transmit and receive unencrypted packets.

Between step 1 and step 2 master to slave transmission is possible. This is when an LMP_stop_encryption_req PDU is transmitted. Step 2 is triggered when the slave receives this message. Between step 2 and step 3 slave to master transmission is possible. This is when an LMP_accepted PDU is transmitted. Step 3 is triggered when the master receives this message.

4.2.5.5 Change encryption mode, key or random number

If the encryption key or encryption random number need to be changed or if the current link key needs to be changed according to the procedures in [Section 4.2.4 on page 255](#), encryption shall be stopped and re-started after completion, using the procedures in [Section 4.2.5 on page 257](#), subsections 3-4 for the new parameters to take effect.

4.2.6 Request supported encryption key size

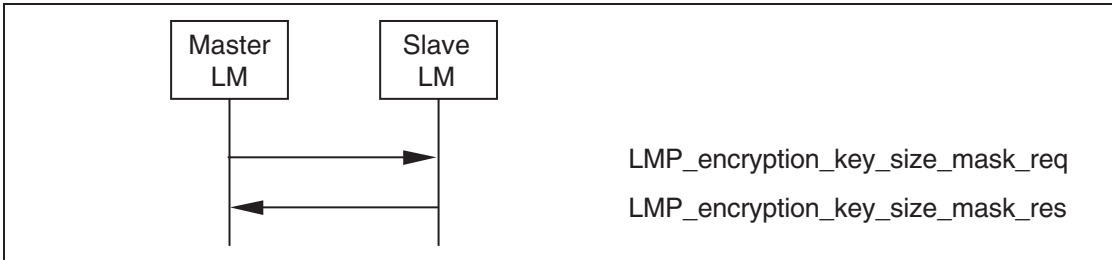
When broadcast encryption is supported via the LMP features mask, it is possible for the master to request a slave's supported encryption key sizes.

| M/O | PDU | Contents |
|-------|----------------------------------|---------------|
| O(23) | LMP_encryption_key_size_mask_req | |
| O(23) | LMP_encryption_key_size_mask_res | key size mask |

Table 4.17: PDUs used for encryption key size request

The master shall send an LMP_key_size_req PDU to the slave to obtain the slaves supported encryption key sizes.

The slave shall return a bit mask indicating all broadcast encryption key sizes supported. The least significant bit shall indicate support for a key size of 1, the next most significant bit shall indicate support for a key size of 2 and so on up to a key size of 16. In all cases a bit set to 1 shall indicate support for a key size; a bit set to 0 shall indicate that the key size is not supported.



Sequence 38: Request for supported encryption key sizes.



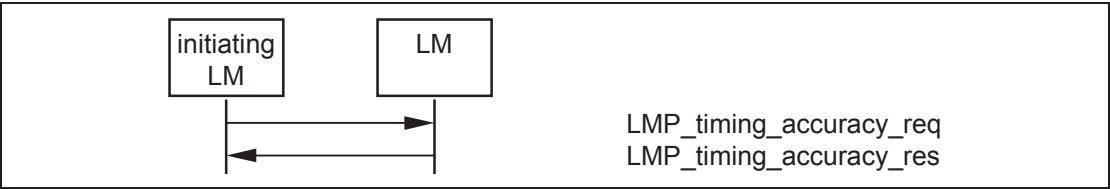
4.3 INFORMATIONAL REQUESTS

4.3.1 Timing accuracy

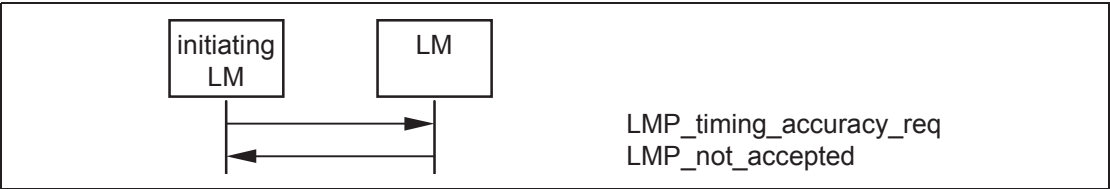
LMP supports requests for the timing accuracy. This information can be used to minimize the scan window during piconet physical channel re-synchronization (see [Baseband Specification, Section 2.2.5.2, on page 74](#)). The timing accuracy parameters returned are the long term drift measured in ppm and the long term jitter measured in μs of the worst case clock used. These parameters are fixed for a certain device and shall be identical when requested several times. Otherwise, the requesting device shall assume worst case values (drift=250ppm and jitter=10 μs).

| M/O | PDU | Contents |
|------|-------------------------|-----------------|
| O(4) | LMP_timing_accuracy_req | - |
| O(4) | LMP_timing_accuracy_res | drift jitter |

Table 4.18: PDUs used for requesting timing accuracy information.



Sequence 39: The requested device supports timing accuracy information.



Sequence 40: The requested device does not support timing accuracy information.

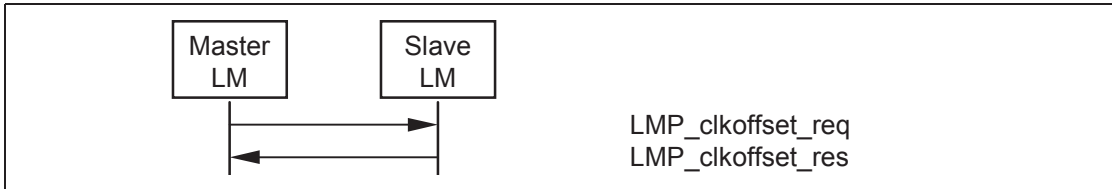
4.3.2 Clock offset

The clock offset can be used to speed up the paging time the next time the same device is paged. The master can request the clock offset at anytime following a successful baseband paging procedure (i.e., before, during or after connection setup). The clock offset shall be defined by the following equation:

$$(\text{CLKN}_{16-2 \text{ slave}} - \text{CLKN}_{16-2 \text{ master}}) \bmod 2^{**15}.$$

| M/O | PDU | Contents |
|-----|-------------------|--------------|
| M | LMP_clkoffset_req | - |
| M | LMP_clkoffset_res | clock offset |

Table 4.19: PDUs used for clock offset request.



Sequence 41: Clock offset requested.

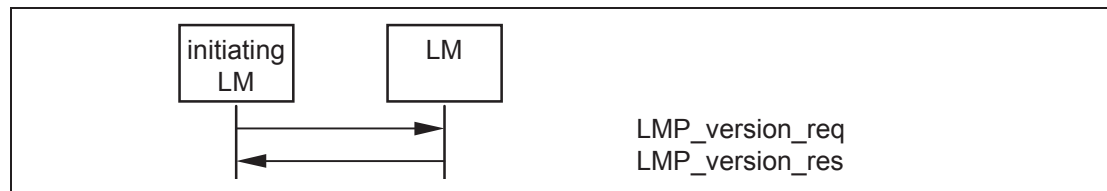
4.3.3 LMP version

LMP supports requests for the version of the LM protocol. The LMP_version_req and LMP_version_res PDUs contain three parameters: VersNr, Compld and SubVersNr. VersNr specifies the version of the Bluetooth LMP specification that the device supports. Compld is used to track possible problems with the lower Bluetooth layers. All companies that create a unique implementation of the LM shall have their own Compld. The same company is also responsible for the administration and maintenance of the SubVersNr. It is recommended that each company has a unique SubVersNr for each RF/BB/LM implementation. For a given VersNr and Compld, the values of the SubVersNr shall increase each time a new implementation is released. For both Compld and SubVersNr the value 0xFFFF means that no valid number applies. There is no ability to negotiate the version of the LMP. The sequence below is only used to exchange the parameters. LMP version can be requested at anytime following a successful baseband paging procedure.



| M/O | PDU | Contents |
|-----|-----------------|-------------------------------|
| M | LMP_version_req | VersNr Compld SubVersNr |
| M | LMP_version_res | VersNr Compld SubVersNr |

Table 4.20: PDUs used for LMP version request.



Sequence 42: Request for LMP version.

4.3.4 Supported features

The supported features may be requested at anytime following a successful baseband paging procedure by sending the LMP_features_req PDU. Upon reception of an LMP_features_req PDU, the receiving device shall return an LMP_features_res PDU.

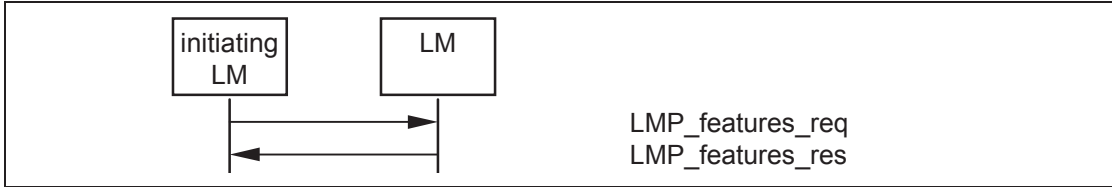
The number of features bits required will in the future exceed the size of a single page of features. An extended features mask is therefore provided to allow support for more than 64 features. Support for the extended features mask is indicated by the presence of the appropriate bit in the LMP features mask. The LMP_features_req_ext and LMP_features_res_ext PDUs operate in precisely the same way as the LMP_features_req and LMP_features_res PDUs except that they allow the various pages of the extended features mask to be requested. The LMP_features_req_ext may be sent at any time following the exchange of the LMP_features_req and LMP_features_rsp PDUs.

The LMP_features_req_ext PDU contains a feature page index that specifies which page is requested and the contents of that page for the requesting device. Pages are numbered from 0-255 with page 0 corresponding to the normal features mask. Each page consists of 64 bits. If a device does not support any page number it shall return a mask with every bit set to 0. It also contains the maximum features page number containing any non-zero bit for this device. The recipient of an LMP_features_req_ext PDU shall respond with an LMP_features_res_ext PDU containing the same page number and the appropriate features page along with its own maximum features page number.

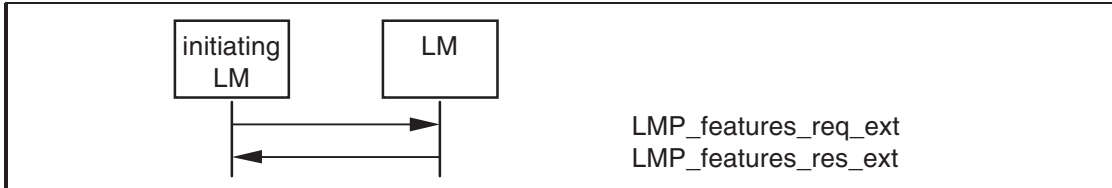
If the extended features request is not supported then all bits in all extended features pages for that device shall be assumed to be zero.

| M/O | PDU | Contents |
|-------|----------------------|--|
| M | LMP_features_req | features |
| M | LMP_features_res | features |
| O(63) | LMP_features_req_ext | features page max supported page extended features |
| O(63) | LMP_features_res_ext | features page max supported page extended features |

Table 4.21: PDUs used for features request.



Sequence 43: Request for supported features.



Sequence 44: Request for extended features.



4.3.5 Name request

LMP supports name request to another device. The name is a user-friendly name associated with the device and consists of a maximum of 248 bytes coded according to the UTF-8 standard. The name is fragmented over one or more DM1 packets. When an LMP_name_req PDU is sent, a name offset indicates which fragment is expected. The corresponding LMP_name_res PDU carries the same name offset, the name length indicating the total number of bytes in the name of the device and the name fragment, where:

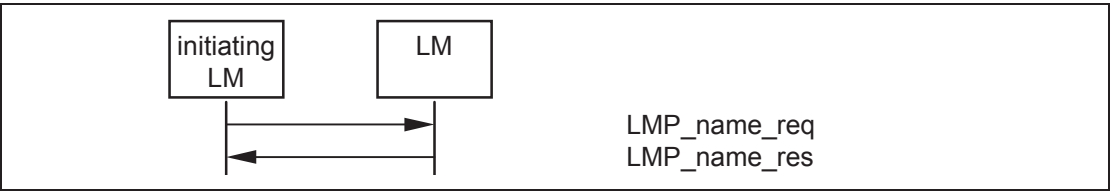
- name fragment(N) = name(N + name offset), if (N + name offset) < name length
- name fragment(N) = 0, otherwise.

Here $0 \leq N \leq 13$. In the first sent LMP_name_req PDU, name offset=0.

Sequence 45 is then repeated until the initiator has collected all fragments of the name. The name request may be made at any time following a successful baseband paging procedure.

| M/O | PDU | Contents |
|-----|--------------|---|
| M | LMP_name_req | name offset |
| M | LMP_name_res | name offset name length name fragment |

Table 4.22: PDUs used for name request.



Sequence 45: Device's name requested and it responses.

4.4 ROLE SWITCH

4.4.1 Slot offset

With LMP_slot_offset the information about the difference between the slot boundaries in different piconets is transmitted. The LMP_slot_offset PDU may be sent anytime after the baseband paging procedure has completed. This PDU carries the parameters slot offset and BD_ADDR. The slot offset shall be the time in microseconds between the start of a master transmission in the current piconet to the start of the next following master transmission in the piconet where the BD_ADDR device (normally the slave) is master at the time that the request is interpreted by the BD_ADDR device.

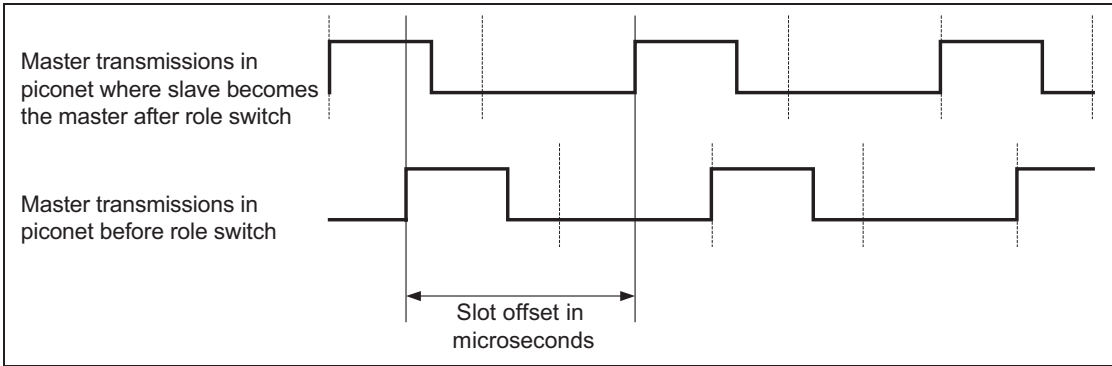
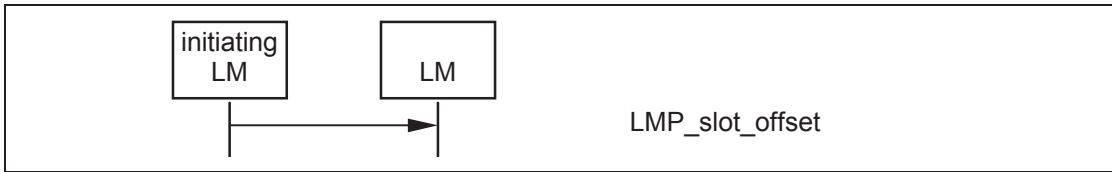


Figure 4.2: Slot offset for role switch.

See [Section 4.4 on page 267](#) for the use of LMP_slot_offset in the context of the role switch. In the case of role switch the BD_ADDR is that of the slave device.

| M/O | PDU | Contents |
|------|-----------------|------------------------|
| O(3) | LMP_slot_offset | slot offset BD_ADDR |

Table 4.23: PDU used for slot offset information.



Sequence 46: Slot offset information is sent.



4.4.2 Role switch

Since the paging device always becomes the master of the piconet, a switch of the master slave role is sometimes needed, see [Baseband Specification, Section 8.6.5, on page 175](#). The LMP_switch_req PDU may be sent anytime after the baseband paging procedure has completed.

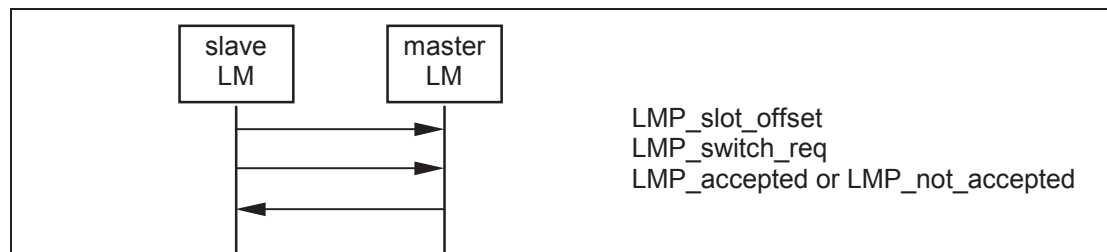
Support for LMP_slot_offset is mandatory if LMP_switch_req is supported.

The LMP_slot_offset shall be sent only if the ACL logical transport is in active mode. The LMP_switch_req shall be sent only if the ACL logical transport is in active mode, when encryption is disabled, and all synchronous logical transports on the same physical link are disabled. Additionally, LMP_slot_offset or LMP_switch_req shall not be initiated or accepted while a synchronous logical transport is being negotiated by LM.

| M/O | PDU | Contents |
|------|-----------------|------------------------|
| O(5) | LMP_switch_req | switch instant |
| O(5) | LMP_slot_offset | slot offset BD_ADDR |

Table 4.24: PDUs used for role switch.

The initiating LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). It shall then send an LMP_slot_offset PDU immediately followed by an LMP_switch_req PDU. If the master accepts the role switch it shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)) and respond with an LMP_accepted PDU. When the role switch has been completed at the baseband level (successfully or not) both devices re-enable transmission on the ACL-U logical link. If the master rejects the role switch it responds with an LMP_not_accepted PDU and the slave re-enables transmission on the ACL-U logical link. The transaction ID for all PDUs in the sequence shall be set to 1.

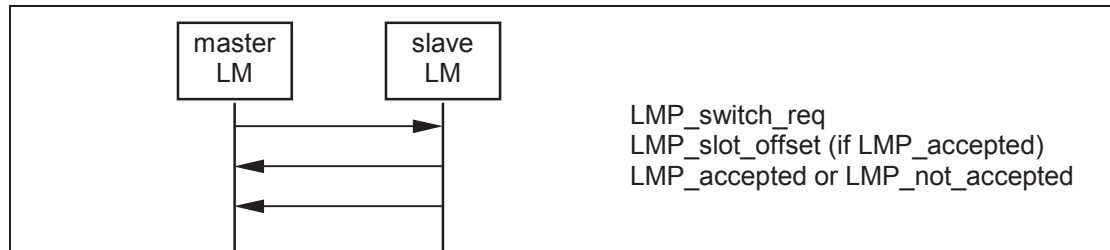


Sequence 47: Role switch (slave initiated).

If the master initiates the role switch it shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)) and send an LMP_switch_req PDU. If the slave accepts the role switch it shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)) and responds with an LMP_slot_offset PDU immediately followed by an



LMP_accepted PDU. When the role switch has been completed at the base-band (successfully or not) both devices re-enable transmission on the ACL-U logical link. If the slave rejects the role switch it responds with an LMP_not_accepted PDU and the master re-enables transmission on the ACL-U logical link. The transaction ID for all PDUs in the sequence shall be set to 0.



Sequence 48: Role switch (master initiated).

The LMP_switch_req PDU contains a parameter, switch instant, which specifies the instant at which the TDD switch is performed. This is specified as a Bluetooth clock value of the master's clock, that is available to both devices. This instant is chosen by the sender of the message and shall be at least $2 \cdot T_{\text{poll}}$ or 32 (whichever is greater) slots in the future. The switch instant shall be within 12 hours of the current clock value to avoid clock wrap.

The sender of the LMP_switch_req PDU selects the switch instant and queues the LMP_switch_req PDU to LC for transmission and starts a timer to expire at the switch instant. When the timer expires it initiates the mode switch. In the case of a master initiated switch if the LMP_slot_offset PDU has not been received by the switch instant the role switch is carried out without an estimate of the slave's slot offset. If an LMP_not_accepted PDU is received before the timer expires then the timer is stopped and the role switch shall not be initiated.

When the LMP_switch_req is received the switch instant is compared with the current master clock value. If it is in the past then the instant has been passed and an LMP_not_accepted PDU with the error code *instant passed* shall be returned. If it is in the future then an LMP_accepted PDU shall be returned assuming the role switch is allowed and a timer is started to expire at the switch instant. When this timer expires the role switch shall be initiated.

After a successful role switch the supervision timeout and poll interval (T_{poll}) shall be set to their default values. The authentication state and the ACO shall remain unchanged. Adaptive Frequency Hopping shall follow the procedures described in [Baseband Specification, Section 8.6.5, on page 175](#). The default value for max_slots shall be used.



4.5 MODES OF OPERATION

4.5.1 Hold mode

The ACL logical transport of a connection between two Bluetooth devices can be placed in hold mode for a specified hold time. See [Baseband Specification, Section 8.8, on page 185](#) for details.

| M/O | PDU | Contents |
|------|--------------|-------------------------|
| O(6) | LMP_hold | hold time, hold instant |
| O(6) | LMP_hold_req | hold time, hold instant |

Table 4.25: PDUs used for hold mode.

The LMP_hold and LMP_hold_req PDUs both contain a parameter, hold instant, that specifies the instant at which the hold becomes effective. This is specified as a Bluetooth clock value of the master's clock, that is available to both devices. The hold instant is chosen by the sender of the message and should be at least $6 \cdot T_{poll}$ slots in the future. The hold instant shall be within 12 hours of the current clock value to avoid clock wrap.

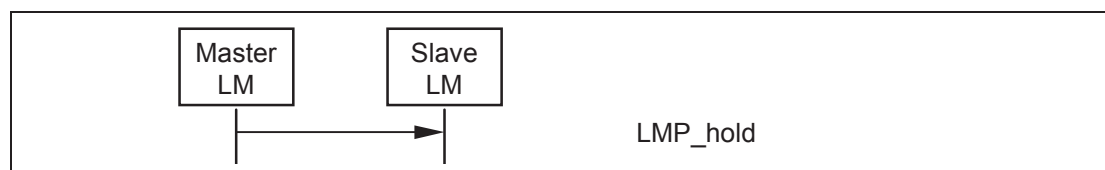
4.5.1.1 Master forces hold mode

The master may force hold mode if there has previously been a request for hold mode that has been accepted. The hold time included in the PDU when the master forces hold mode shall not be longer than any hold time the slave has previously accepted when there was a request for hold mode.

The master LM shall first pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). It shall select the hold instant and queue the LMP_hold PDU to its LC for transmission. It shall then start a timer to wait until the hold instant occurs. When this timer expires then the connection shall enter hold mode. If the baseband acknowledgement for the LMP_hold PDU is not received then the master may enter hold mode, but it shall not use its low accuracy clock during the hold.

When the slave LM receives an LMP_hold PDU it compares the hold instant with the current master clock value. If it is in the future then it starts a timer to expire at this instant and enters hold mode when it expires.

When the master LM exits from Hold mode it re-enables transmission on the ACL-U logical link.



Sequence 49: Master forces slave into hold mode.

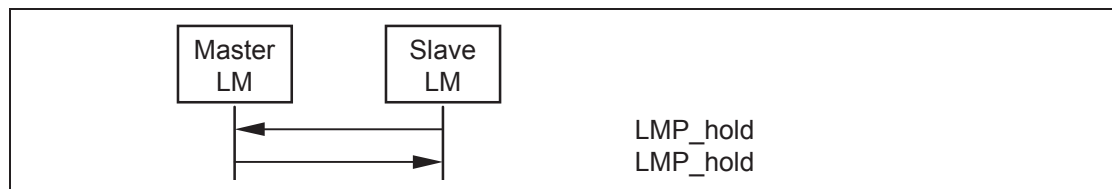
4.5.1.2 Slave forces hold mode

The slave may force hold mode if there has previously been a request for hold mode that has been accepted. The hold time included in the PDU when the slave forces hold mode shall not be longer than any hold time the master has previously accepted when there was a request for hold mode.

The slave LM shall first complete the transmission of the current packet on the ACL logical transport and then shall suspend transmission on the ACL-U logical link. It shall select the hold instant and queue the LMP_hold PDU to its LC for transmission. It shall then wait for an LMP_hold PDU from the master acting according to the procedure described in [Section 4.5.1.1](#).

When the master LM receives an LMP_hold PDU it shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). It shall then inspect the hold instant. If this is less than $6 \cdot T_{poll}$ slots in the future it shall modify the instant so that it is at least $6 \cdot T_{poll}$ slots in the future. It shall then send an LMP_hold PDU using the mechanism described in [Section 4.5.1.1](#).

When the master and slave LMs exit from Hold mode they shall re-enable transmission on the ACL-U logical link.



Sequence 50: Slave forces master into hold mode.

4.5.1.3 Master or slave requests hold mode

The master or the slave can request to enter hold mode. Upon receipt of the request, the same request with modified parameters can be returned or the negotiation can be terminated. If an agreement is seen an LMP_accepted PDU terminates the negotiation and the ACL link is placed in hold mode. If no agreement is seen, an LMP_not_accepted PDU with the error code *unsupported parameter value* terminates the negotiation and hold mode is not entered.

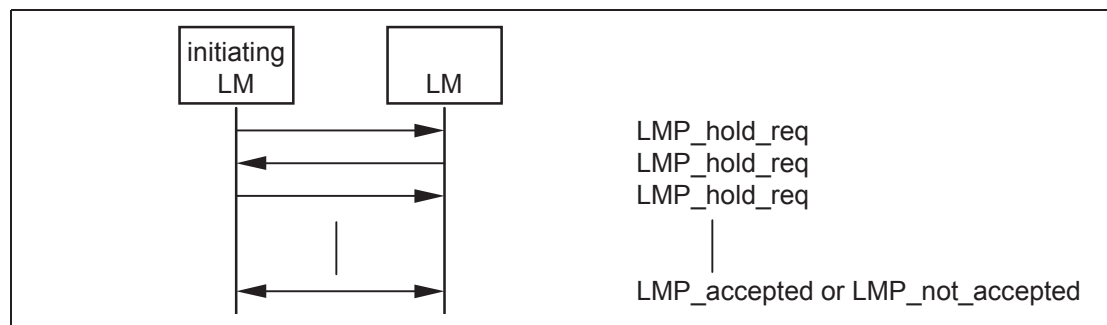
The initiating LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). On receiving an LMP_hold_req PDU the receiving LM shall complete the transmission of the current packet on the ACL logical transport and then shall suspend transmission on the ACL-U logical link.

The LM sending the LMP_hold_req PDU selects the hold instant, that shall be at least $9 \cdot T_{poll}$ slots in the future. If this is a response to a previous LMP_hold_req PDU and the contained hold instant is at least $9 \cdot T_{poll}$ slots in the



future then this shall be used. The LMP_hold_req PDU shall then be queued to its LC for transmission and a timer shall be started to expire at this instant and the connection enters hold mode when it expires unless an LMP_not_accepted or LMP_hold_req PDU is received by its LM before that point. If the LM receiving LMP_hold_req PDU agrees to enter hold mode it shall return an LMP_accepted PDU and shall start a timer to expire at the hold instant. When this timer expires it enters hold mode.

When each LM exits from Hold mode it shall re-enable transmission on the ACL-U logical link.



Sequence 51: Negotiation for hold mode.

4.5.2 Park state

If a slave does not need to participate in the channel, but should still remain synchronized to the master, it may be placed in park state. See [Baseband Specification, Section 8.9, on page 185](#) for details.

Note: to keep a parked slave connected the master shall periodically unpark and repark the slave if the supervision timeout is not set to zero (see [Baseband Specification, Section 3.1, on page 95](#)).

All PDUs sent from the master to parked slaves are carried on the PSB-C logical link (LMP link of parked slave broadcast logical transport). These PDUs, LMP_set_broadcast_scan_window, LMP_modify_beacon, LMP_unpark_BD_addr_req and LMP_unpark_PM_addr_req, are the only PDUs that shall be sent to a slave in park state and the only PDUs that shall be broadcast. To increase reliability for broadcast, the packets are as short as possible. Therefore the format for these LMP PDUs are somewhat different. The parameters are not always byte-aligned and the length of the PDUs is variable.

The messages for controlling park state include parameters, defined in [Baseband Specification, Section 8.9, on page 185](#). When a slave is placed in park state it is assigned a unique PM_ADDR, that can be used by the master to unpark that slave. The all-zero PM_ADDR has a special meaning; it is not a valid PM_ADDR. If a device is assigned this PM_ADDR, it shall be identified with its BD_ADDR when it is unparked by the master.

| M/O | PDU | Contents |
|------|-------------------------------|---|
| O(8) | LMP_park_req | timing control flags D_B T_B N_B Δ_B PM_ADDR AR_ADDR $N_{B_{sleep}}$ $D_{B_{sleep}}$ D_{access} T_{access} $N_{acc-slots}$ N_{poll} M_{access} access scheme |
| O(8) | LMP_set_broadcast_scan_window | timing control flags D_B (optional) broadcast scan window |
| O(8) | LMP_modify_beacon | timing control flags D_B (optional) T_B N_B Δ_B D_{access} T_{access} $N_{acc-slots}$ N_{poll} M_{access} access scheme |

Table 4.26: PDUs used for park state.

| M/O | PDU | Contents |
|------|------------------------|---|
| O(8) | LMP_unpark_PM_ADDR_req | timing control flags D _B (optional) LT_ADDR 1 st unpark LT_ADDR 2 nd unpark PM_ADDR 1 st unpark PM_ADDR 2 nd unpark LT_ADDR 3 rd unpark LT_ADDR 4 th unpark PM_ADDR 3 rd unpark PM_ADDR 4 th unpark LT_ADDR 5 th unpark LT_ADDR 6 th unpark PM_ADDR 5 th unpark PM_ADDR 6 th unpark LT_ADDR 7 th unpark PM_ADDR 7 th unpark |
| O(8) | LMP_unpark_BD_ADDR_req | timing control flags D _B (optional) LT_ADDR LT_ADDR (optional) BD_ADDR BD_ADDR (optional) |

Table 4.26: PDUs used for park state.

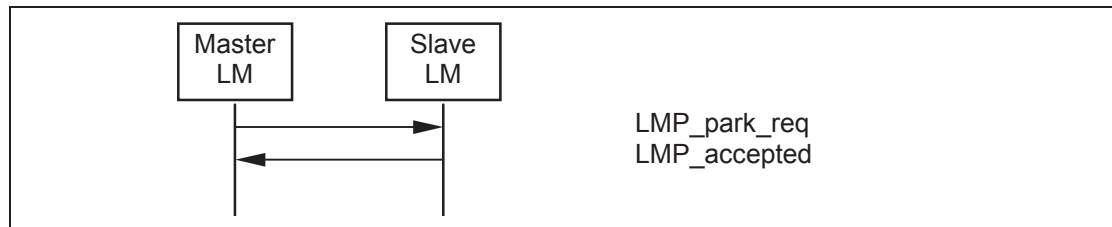
4.5.2.1 Master requests slave to enter park state

The master can request park state. The master LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)) and then send an LMP_park_req PDU. If the slave agrees to enter park state it shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)). and then respond with an LMP_accepted PDU.

When the slave queues an LMP_accepted PDU it shall start a timer for 6**T*_{poll} slots. If the baseband acknowledgement is received before this timer expires it shall enter park state immediately otherwise it shall enter park state when the timer expires.

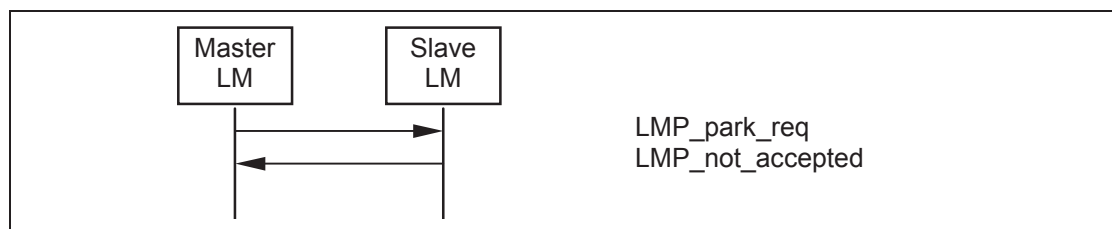
When the master receives an LMP_accepted PDU it shall start a timer for 6**T*_{poll} slots. When this timer expires the slave is in park state and the LT_ADDR may be re-used.

If the master never receives an LMP_accepted PDU then a link supervision timeout will occur.



Sequence 52: Slave accepts to enter park state.

If the slave rejects the attempt to enter park state it shall respond with an LMP_not_accepted PDU and the master shall re-enable transmission on the ACL-U logical link.



Sequence 53: Slave rejects to enter into park state

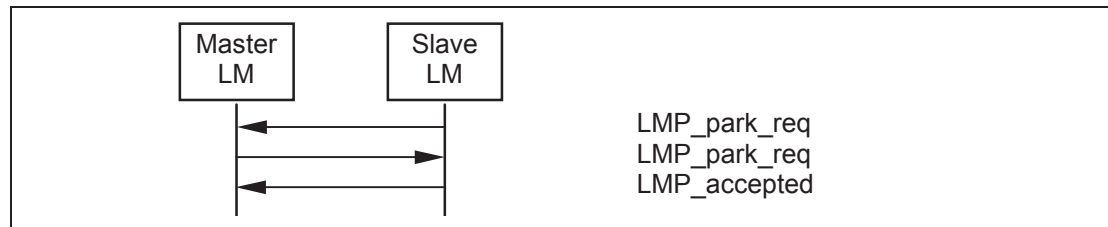
4.5.2.2 Slave requests to enter park state

The slave can request park state. The slave LM shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)) and then send an LMP_park_req PDU. When sent by the slave, the parameters PM_ADDR and AR_ADDR are not valid and the other parameters represent suggested values. If the master accepts the slave's request to enter park state it shall pause traffic on the ACL-U logical link (see [Baseband Specification, Section 5.3.1, on page 108](#)) and then send an LMP_park_req PDU, where the parameter values may be different from the values in the PDU sent from the slave. If the slave can accept these parameter it shall respond with an LMP_accepted PDU.

When the slave queues an LMP_accepted PDU for transmission it shall start a timer for $6 \cdot T_{poll}$ slots. If the baseband acknowledgement is received before this timer expires it shall enter park state immediately otherwise it shall enter park state when the timer expires.

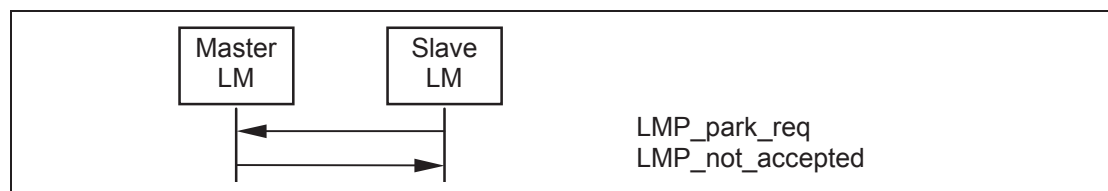
When the master receives an LMP_accepted PDU it shall start a timer for $6 \cdot T_{poll}$ slots. When this timer expires the slave is in park state and the LT_ADDR may be re-used.

If the master never receives the LMP_accepted PDU then a link supervision timeout will occur.



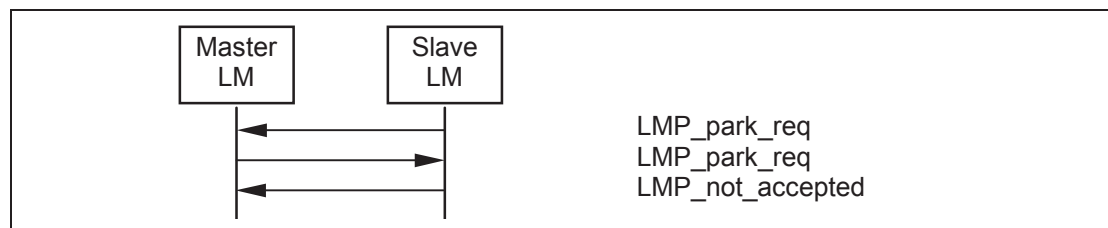
Sequence 54: Slave requests to enter park state and accepts master's beacon parameters.

If the master does not agree that the slave enters park state it shall send an LMP_not_accepted PDU. The slave shall then re-enable transmission on the ACL-U logical link.



Sequence 55: Master rejects slave's request to enter park state

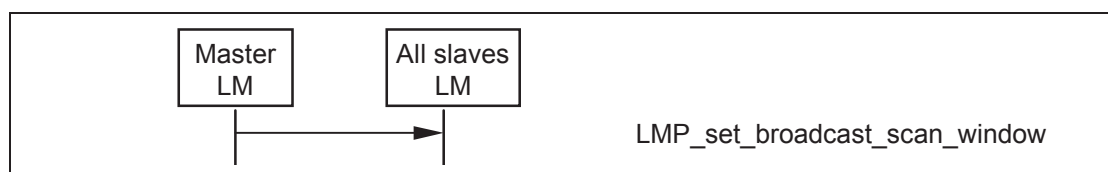
If the slave does not accept the parameters in the LMP_park_req PDU sent from the master it shall respond with an LMP_not_accepted PDU and both devices shall re-enable transmission on the ACL-U logical link.



Sequence 56: Slave requests to enter park state, but rejects master's beacon parameters.

4.5.2.3 Master sets up broadcast scan window

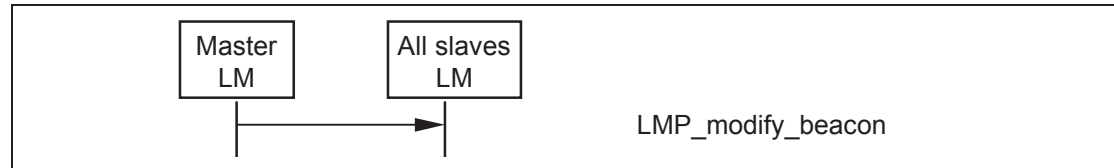
If more broadcast capacity is needed than the beacon train, the master may indicate to the slaves that more broadcast information will follow the beacon train by sending an LMP_set_broadcast_scan_window PDU. This message shall be sent in a broadcast packet at the beacon slot(s). The scan window shall start in the beacon instant and shall only be valid for the current beacon.



Sequence 57: Master notifies all slaves of increase in broadcast capacity.

4.5.2.4 Master modifies beacon parameters

When the beacon parameters change the master notifies the parked slaves of this by sending an LMP_modify_beacon PDU. This PDU shall be sent in a broadcast packet.



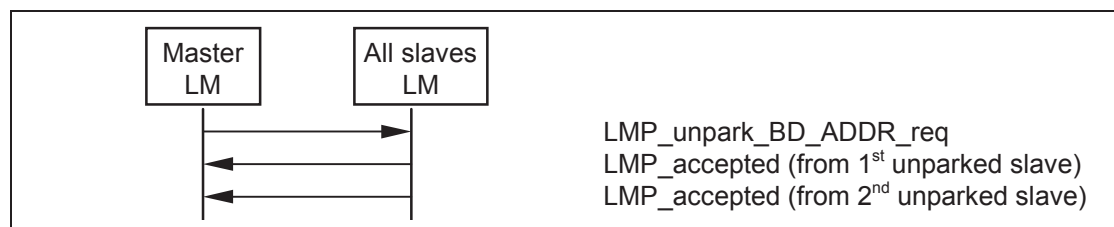
Sequence 58: Master modifies beacon parameters.

4.5.2.5 Unparking slaves

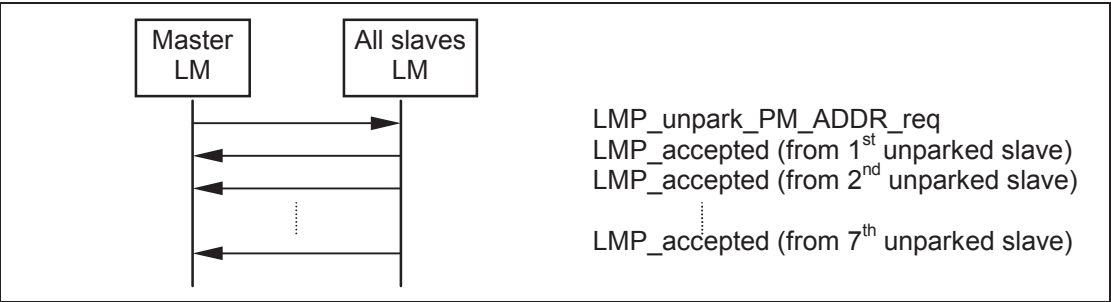
The master can unpark one or many slaves by sending a broadcast LMP message including the PM_ADDR or the BD_ADDR of the device(s) to be unparked. Broadcast LMP messages are carried on the PSB-C logical link. See [Baseband Specification, Section 8.9.5, on page 192](#) for further details. This message also includes the LT_ADDR that the master assigns to the slave(s). After sending this message, the master shall check the success of the unpark by polling each unparked slave by sending POLL packets, so that the slave is granted access to the channel. The unparked slave shall then send a response with an LMP_accepted PDU. If this message is not received from the slave within a certain time after the master sent the unpark message, the unpark failed and the master shall consider the slave as still being in park state.

One PDU is used where the parked device is identified with the PM_ADDR, and another PDU is used where it is identified with the BD_ADDR. Both messages have variable length depending on the number of slaves the master unparks. For each slave the master wishes to unpark an LT_ADDR followed by the PM_ADDR or BD_ADDR of the device that is assigned this LT_ADDR is included in the payload. If the slaves are identified with the PM_ADDR a maximum of 7 slaves can be unparked with the same message. If they are identified with the BD_ADDR a maximum of 2 slaves can be unparked with the same message.

After a successful unparking, both devices re-enable transmission on the ACL-U logical link.



Sequence 59: Master unparks slaves addressed with their BD_ADDR.



Sequence 60: Master unparks slaves addressed with their PM_ADDR.

4.5.3 Sniff mode

To enter sniff mode, master and slave negotiate a sniff interval T_{sniff} and a sniff offset, D_{sniff} , that specifies the timing of the sniff slots. The offset determines the time of the first sniff slot; after that the sniff slots follow periodically with the sniff interval T_{sniff} . To avoid clock wrap-around during the initialization, one of two options is chosen for the calculation of the first sniff slot. A timing control flag in the message from the master indicates this. Only bit1 of the timing control flag is valid.

When the ACL logical transport is in sniff mode the master shall only start a transmission in the sniff slots. Two parameters control the listening activity in the slave: the sniff attempt and the sniff timeout. The sniff attempt parameter determines for how many slots the slave shall listen when the slave is not treating this as a scatternet link, beginning at the sniff slot, even if it does not receive a packet with its own LT_ADDR. The sniff timeout parameter determines for how many additional slots the slave shall listen when the slave is not treating this as a scatternet link if it continues to receive only packets with its own LT_ADDR. It is not possible to modify the sniff parameters while the device is in sniff mode.

| M/O | PDU | Contents |
|------|-----------------|--|
| O(7) | LMP_sniff_req | timing control flags D_{sniff} T_{sniff} sniff attempt sniff timeout |
| O(7) | LMP_unsniff_req | - |

Table 4.27: PDUs used for sniff mode.

4.5.3.1 Master or slave requests sniff mode

Either the master or the slave may request entry to sniff mode.

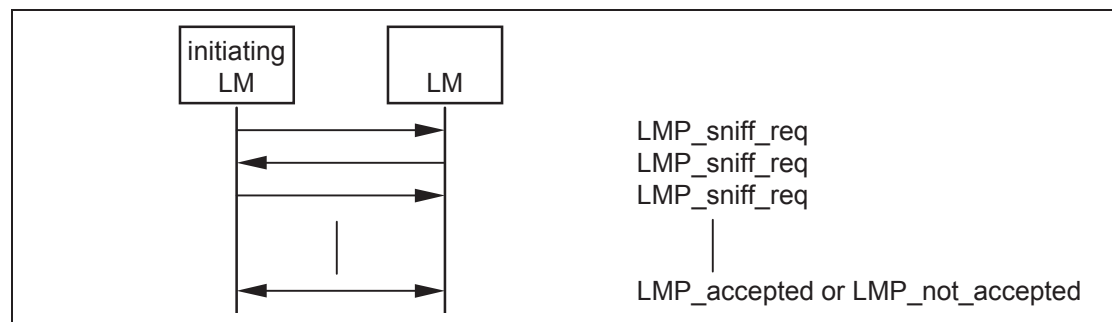
The process is initiated by sending an LMP_sniff_req PDU containing a set of parameters. The receiving LM shall then decide whether to reject the attempt by sending an LMP_not_accepted PDU, to suggest different parameters by replying with an LMP_sniff_req PDU or to accept the request.

Before the first time that the master sends LMP_sniff_req it shall enter sniff transition mode. If the master receives or sends an LMP_not_accepted PDU it shall exit from sniff transition mode. If the master receives an LMP_sniff_req PDU it shall enter sniff transition mode.

If the master decides to accept the request it shall send an LMP_accepted PDU. When the master receives the baseband acknowledgement for this PDU it shall exit sniff transition mode and enter sniff mode.

If the master receives an LMP_accepted PDU the master shall exit from sniff transition mode and enter sniff mode.

If the slave receives an LMP_sniff_req PDU it must decide whether to accept the request. If the slave does not wish to enter sniff mode then it replies with an LMP_not_accepted PDU. If it is happy to enter sniff mode but requires a different set of parameters it shall respond with an LMP_sniff_req PDU containing the new parameters. If the slave decides that the parameters are acceptable then it shall send an LMP_accepted PDU and enter sniff mode. If the slave receives an LMP_not_accepted PDU it shall terminate the attempt to enter sniff mode.



Sequence 61: Negotiation for sniff mode.

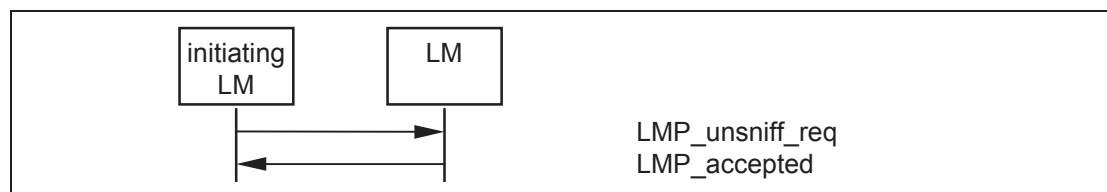


4.5.3.2 Moving a slave from sniff mode to active mode

Sniff mode may be exited by either the master or the slave sending an LMP_unsniff_req PDU. The requested device must reply with an LMP_accepted PDU.

If the master requests an exit from sniff mode it shall enter sniff transition mode and then send an LMP_unsniff_req PDU. When the slave receives the LMP_unsniff_req it shall exit from sniff mode and reply with an LMP_accepted PDU. When the master receives the LMP_accepted PDU it shall exit from sniff transition mode and enter active mode.

If the slave requests an exit from sniff mode it shall send an LMP_unsniff_req PDU. When the master receives the LMP_unsniff_req PDU it shall enter sniff transition mode and then send an LMP_accepted PDU. When the slave receives the LMP_accepted PDU it shall exit from sniff mode and enter active mode. When the master receives the baseband acknowledgement for the LMP_accepted PDU it shall leave sniff transition mode and enter active mode.



Sequence 62: Slave moved from sniff mode to active mode.

4.6 LOGICAL TRANSPORTS

When a connection is first established between two devices the connection consists of the default ACL logical links: ACL-C (for LMP messages) and ACL-U (for L2CAP data.) One or more synchronous logical transports (SCO or eSCO) may then be added. A new logical transport shall not be created if it would cause all slots to be allocated to reserved slots on secondary LT_ADDRs.

4.6.1 SCO logical transport

The SCO logical transport reserves slots separated by the SCO interval, T_{SCO} . The first slot reserved for the SCO logical transport is defined by T_{SCO} and the SCO offset, D_{SCO} . See [Baseband Specification, Section 8.6.2, on page 169](#) for details. A device shall initiate a request for HV2 or HV3 packet type only if the other device supports it (bits 12, 13) in its features mask. A device shall initiate CVSD, μ -law or A-law coding or uncoded (transparent) data only if the other device supports the corresponding feature. To avoid problems with a wrap-around of the clock during initialization of the SCO logical transport, the timing control flags parameter is used to indicate how the first SCO slot shall be calculated. Only bit1 of the timing control flags parameter is valid. The SCO link is distinguished from all other SCO links by an SCO handle. The SCO handle zero shall not be used.

| M/O | PDU | Contents |
|-------|-------------------------|--|
| O(11) | LMP_SCO_link_req | SCO handle timing control flags D_{SCO} T_{SCO} SCO packet air mode |
| O(11) | LMP_remove_SCO_link_req | SCO handle error |

Table 4.28: PDUs used for managing the SCO links.

4.6.1.1 Master initiates an SCO link

When establishing an SCO link the master sends a request, a LMP_SCO_link_req PDU, with parameters that specify the timing, packet type and coding that will be used on the SCO link. Each of the SCO packet types supports three different voice coding formats on the air-interface: μ -law log PCM, A-law log PCM and CVSD. The air coding by log PCM or CVSD may be deactivated to achieve a transparent synchronous data link at 64 kbits/s.

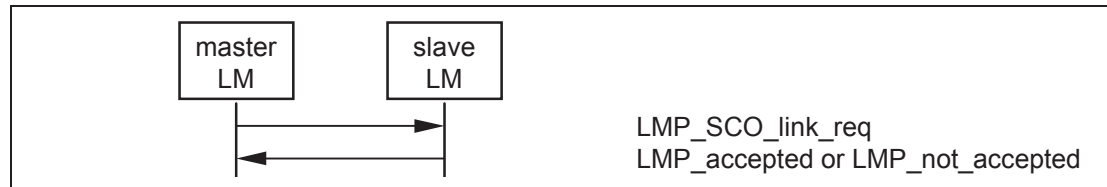
The slots used for the SCO links are determined by three parameters controlled by the master: T_{SCO} , D_{SCO} and a flag indicating how the first SCO slot is calculated. After the first slot, the SCO slots follow periodically at an interval of T_{SCO} .



If the slave does not accept the SCO link, but is willing to consider another possible set of SCO parameters, it can indicate what it does not accept in the error code field of LMP_not_accepted PDU. The master may then issue a new request with modified parameters.

The SCO handle in the message shall be different from existing SCO link(s).

If the SCO packet type is HV1 the LMP_accepted shall be sent using the DM1 packet.

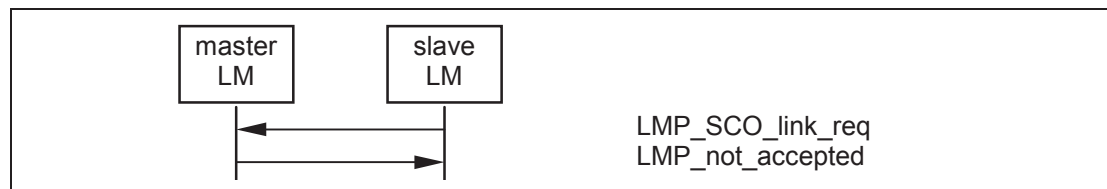


Sequence 63: Master requests an SCO link.

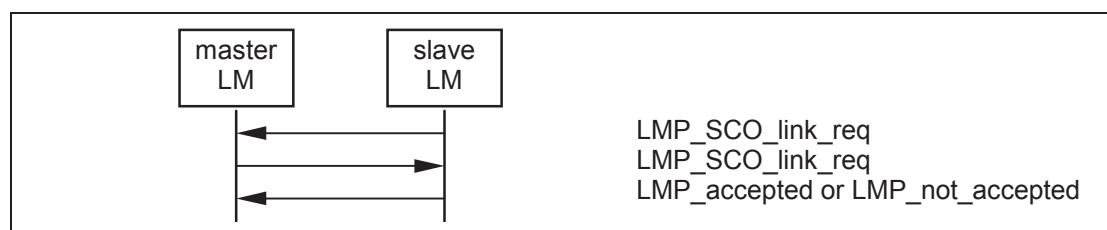
4.6.1.2 Slave initiates an SCO link

The slave may initiate the establishment of an SCO link. The slave sends an LMP_SCO_link_req PDU, but the parameters timing control flags and D_{SCO} are invalid as well as the SCO handle, that shall be zero. If the master is not capable of establishing an SCO link, it replies with an LMP_not_accepted PDU. Otherwise it sends back an LMP_SCO_link_req PDU. This message includes the assigned SCO handle, D_{SCO} and the timing control flags. The master should try to use the same parameters as in the slave request; if the master cannot meet that request, it is allowed to use other values. The slave shall then reply with LMP_accepted or LMP_not_accepted PDU.

If the SCO packet type is HV1 the LMP_accepted shall be sent using the DM1 packet.



Sequence 64: Master rejects slave's request for an SCO link.



Sequence 65: Master accepts slave's request for an SCO link.

4.6.1.3 Master requests change of SCO parameters

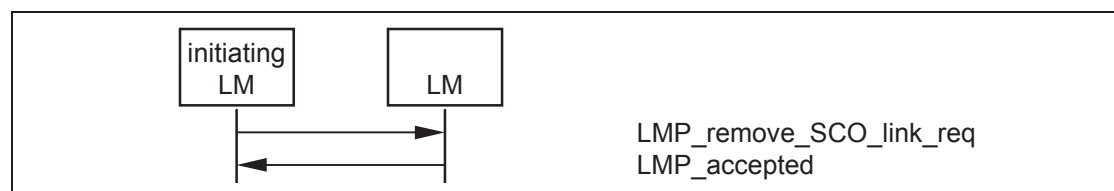
The master sends an LMP_SCO_link_req PDU, where the SCO handle is the handle of the SCO link the master wishes to change parameters for. If the slave accepts the new parameters, it replies with an LMP_accepted PDU and the SCO link will change to the new parameters. If the slave does not accept the new parameters, it shall reply with an LMP_not_accepted PDU and the SCO link is left unchanged. When the slave replies with an LMP_not_accepted PDU it shall indicate in the error code parameter what it does not accept. The master may then try to change the SCO link again with modified parameters. The sequence is the same as in [Section 4.6.1.1 on page 281](#).

4.6.1.4 Slave requests change of SCO parameters

The slave sends an LMP_SCO_link_req PDU, where the SCO handle is the handle of the SCO link to be changed. The parameters timing control flags and D_{SCO} are not valid in this PDU. If the master does not accept the new parameters it shall reply with an LMP_not_accepted PDU and the SCO link is left unchanged. If the master accepts the new parameters it shall reply with an LMP_SCO_link_req PDU containing the same parameters as in the slave request. When receiving this message the slave replies with an LMP_not_accepted PDU if it does not accept the new parameters. The SCO link is then left unchanged. If the slave accepts the new parameters it replies with an LMP_accepted PDU and the SCO link will change to the new parameters. The sequence is the same as in [Section 4.6.1.2 on page 282](#).

4.6.1.5 Remove an SCO link

Master or slave can remove the SCO link by sending a request including the SCO handle of the SCO link to be removed and an error code indicating why the SCO link is removed. The receiving side shall respond with an LMP_accepted PDU.



Sequence 66: SCO link removed.



4.6.2 eSCO logical transport

After an ACL link has been established, one or more extended SCO (eSCO) links can be set up to the remote device. The eSCO links are similar to SCO links using timing control flags, an interval T_{eSCO} and an offset D_{eSCO} . Only bit 1 of the timing control flags parameter is valid. As opposed to SCO links, eSCO links have a configurable data rate that may be asymmetric, and can be set up to provide limited retransmissions of lost or damaged packets inside a retransmission window of size W_{eSCO} . The D_{eSCO} shall be based on CLK.

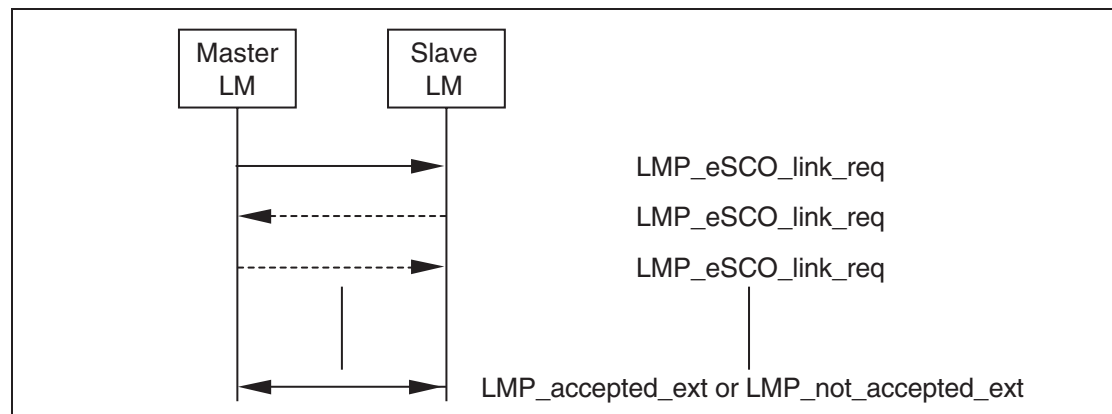
| M/O | PDU | Contents |
|-------|--------------------------|---|
| O(31) | LMP_eSCO_link_req | eSCO handle eSCO LT_ADDR timing control flags D_{eSCO} T_{eSCO} W_{eSCO} eSCO packet type M->S eSCO packet type S->M packet length M->S packet length S->M air mode negotiation state |
| O(31) | LMP_remove_eSCO_link_req | eSCO handle error |

Table 4.29: PDUs used for managing the eSCO links

The parameters D_{eSCO} , T_{eSCO} , W_{eSCO} , eSCO packet type M->S, eSCO packet type S->M, packet length M->S, packet length S->M are henceforth referred to as the negotiable parameters.

4.6.2.1 Master initiates an eSCO link

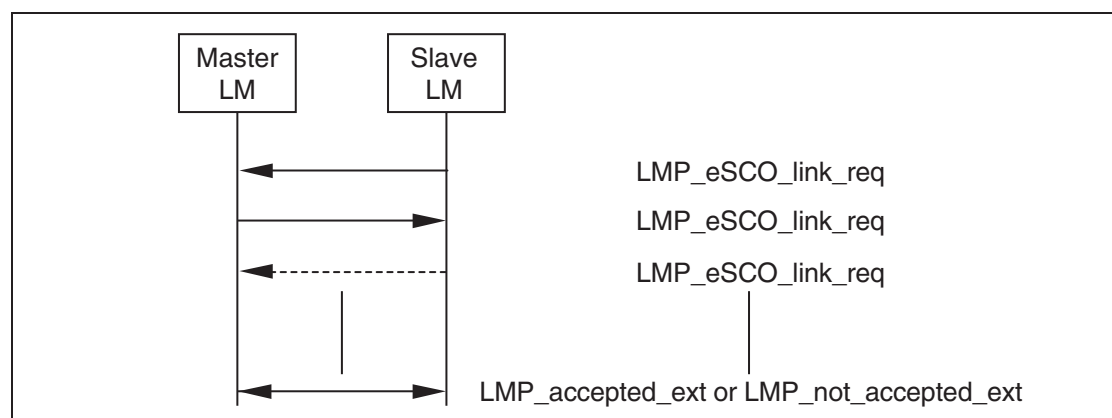
When establishing an eSCO link the master sends an LMP_eSCO_link_req PDU specifying all parameters. The slave may accept this with an LMP_accepted_ext PDU, reject it with an LMP_not_accepted_ext PDU, or respond with its own LMP_eSCO_link_req specifying alternatives for some or all parameters. The slave shall not negotiate the eSCO handle or eSCO LT_ADDR parameters. The negotiation of parameters continues until the master or slave either accepts the latest parameters with an LMP_accepted_ext PDU, or terminates the negotiation with an LMP_not_accepted_ext PDU. The negotiation shall use the procedures defined in [Section 4.6.2.5 on page 287](#).



Sequence 67: Master requests an eSCO link.

4.6.2.2 Slave initiates an eSCO link

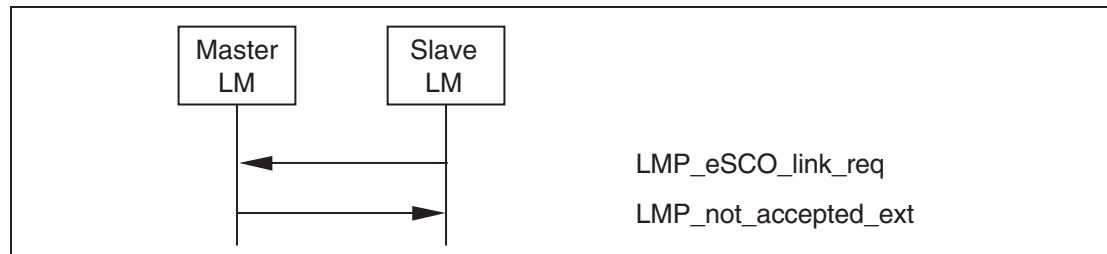
When attempting to establish an eSCO link the slave shall send an LMP_eSCO_link_req PDU specifying all parameters, with the exception of eSCO LT_ADDR and eSCO handle, which are invalid. The latter shall be set to zero. The master may respond to this with an LMP_eSCO_link_req PDU, filling in these missing parameters, and potentially changing the other requested parameters. The slave can accept this with an LMP_accepted_ext PDU, or respond with a further LMP_eSCO_link_req PDU specifying alternatives for some or all of the parameters. The negotiation of parameters continues until the master or slave either accepts the latest parameters with an LMP_accepted_ext PDU, or terminates the negotiation with an LMP_not_accepted_ext PDU.



Sequence 68: Slave requests an eSCO link.

Note that the slave should use the initialization flag appropriate to the master's Bluetooth clock. See Baseband section [section 8.6.3](#).

The master may reject the request immediately with an LMP_not_accepted_ext PDU. The negotiation shall use the procedures defined in [Section 4.6.2.5 on page 287](#).



Sequence 69: Master rejects slave's request for an eSCO link.

4.6.2.3 Master or slave requests change of eSCO parameters

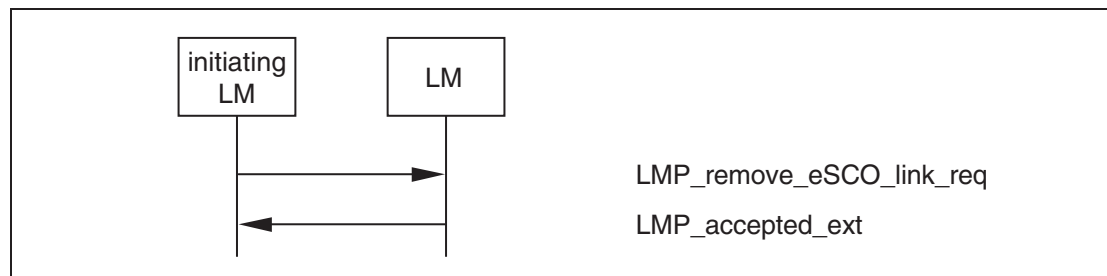
The master or slave may request a renegotiation of the eSCO parameters. The master or slave shall send an LMP_eSCO_link_req PDU with the eSCO handle of the eSCO link the device wishes to renegotiate. The remote device may accept the changed parameters immediately with LMP_accepted_ext PDU, or the negotiation may be continued with further LMP_eSCO_link_req PDUs until the master or slave accepts the latest parameters with an LMP_accepted_ext PDU or terminates the negotiation with an LMP_not_accepted_ext PDU. In the case of termination with an LMP_not_accepted_ext PDU, the eSCO link continues on the previously negotiated parameters.

The sequence is the same as in [Section 4.6.2.2 on page 285](#).

During re-negotiation, the eSCO LT_ADDR and eSCO handle shall not be re-negotiated and shall be set to the originally negotiated values. The negotiation shall use the procedures defined in [Section 4.6.2.5 on page 287](#).

4.6.2.4 Remove an eSCO link

Either the master or slave may remove the eSCO link by sending a request including the eSCO handle of the eSCO link to be removed and a error code indicating why the eSCO link is removed. The receiving side shall respond with an LMP_accepted_ext PDU.



Sequence 70: eSCO link removed



4.6.2.5 Rules for the LMP negotiation and renegotiation

Rule 1: the negotiation_state shall be set to 0 by the initiating LM. After the initial LMP_eSCO_link_req is sent the negotiation_state shall not be set to 0.

Rule 2: if the bandwidth (defined as 1600 times the packet length in bytes divided by T_{eSCO} in slots) for either RX or TX or the air_mode cannot be accepted the device shall send LMP_not_accepted_ext with the appropriate error code.

Rule 3: Bandwidth and air_mode are not negotiable and shall not be changed for the duration of the negotiation. Once one side has rejected the negotiation (with LMP_not_accepted_ext) a new negotiation may be started with different bandwidth and air_mode parameters.

Rule 4: if the parameters will cause a latency violation ($T_{eSCO} + W_{eSCO} +$ reserved synchronous slots > allowed local latency) the device should propose new parameters that shall not cause a reserved slot violation or latency violation for the device that is sending the parameters. In this case the negotiation_state shall be set to 3. Otherwise the device shall send LMP_not_accepted_ext.

Rule 5: once a device has received an LMP_eSCO_link_req with the negotiation_state set to 3 (latency violation), the device shall not propose any combination of packet type, T_{eSCO} , and W_{eSCO} that will give an equal or larger latency than the combination that caused the latency violation for the other device.

Rule 6: if the parameters cause both a reserved slot violation and a latency violation the device shall set the negotiation_state to 3 (latency violation).

Rule 7: if the parameters will cause a reserved slot violation the device should propose new parameters that shall not cause a reserved slot violation. In this case the negotiation_state shall be set to 2. Otherwise the device shall send LMP_not_accepted_ext.

Rule 8: If the requested parameters are not supported the device should propose a setting that is supported, and set the negotiation_state to 4. If it is not possible to find such a parameter set, the device shall send LMP_not_accepted_ext.

Rule 9: when proposing new parameters for reasons other than a latency violation, reserved slot violation, or configuration not supported, the negotiation_state shall be set to 1.



4.6.2.6 Negotiation state definitions

Reserved Slot Violation: a reserved slot violation is when the receiving LM cannot setup the requested eSCO logical transport because the eSCO reserved slots would overlap with other regularly scheduled slots (e.g. other synchronous reserved slots, sniff instants, or park beacons).

Latency Violation: a latency violation is when the receiving LM cannot setup the requested eSCO logical transport because the latency ($W_{\text{eSCO}} + T_{\text{eSCO}} +$ reserved synchronous slots) is greater than the maximum allowed latency.

Configuration not supported: The combination of parameters requested is not inside the supported range for the device.

4.7 TEST MODE

LMP has PDUs to support different test modes used for certification and compliance testing of the Bluetooth radio and baseband. See “[Test Methodology](#)” on page 231[vol. 4] for a detailed description of these test modes.

4.7.1 Activation and deactivation of test mode

The activation may be carried out locally (via a HW or SW interface), or using the air interface.

- For activation over the air interface, entering the test mode shall be locally enabled for security and type approval reasons. The implementation of this local enabling is not subject to standardization.

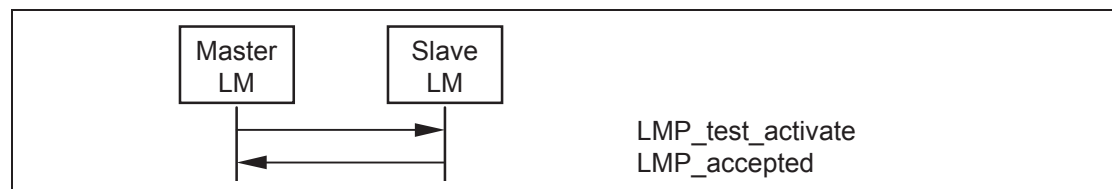
The tester sends an LMP command that shall force the DUT to enter test mode. The DUT shall terminate all normal operation before entering the test mode.

The DUT shall return an LMP_Accepted on reception of an activation command. LMP_Not_Accepted shall be returned if the DUT is not locally enabled.

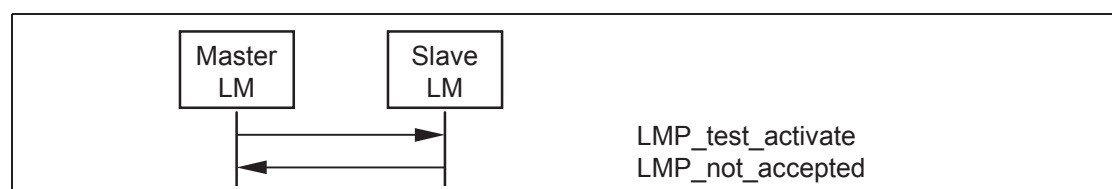
- If the activation is performed locally using a HW or SW interface, the DUT shall terminate all normal operation before entering the test mode.

Until a connection to the tester exists, the device shall perform page scan and inquiry scan. Extended scan activity is recommended.

The test mode is activated by sending an LMP_test_activate PDU to the device under test (DUT). The DUT is always the slave. The Im shall be able to receive this message anytime. If entering test mode is locally enabled in the DUT it shall respond with an LMP_accepted PDU and test mode is entered. Otherwise the DUT responds with an LMP_not_accepted PDU and the DUT remains in normal operation. The error code in the LMP_not_accepted PDU shall be *PDU not allowed*.



Sequence 71: Activation of test mode successful.



Sequence 72: Activation of test mode fails. Slave is not allowed to enter test mode.



The test mode can be deactivated in two ways. Sending an LMP_test_control PDU with the test scenario set to "exit test mode" exits the test mode and the slave returns to normal operation still connected to the master. Sending an LMP_detach PDU to the DUT ends the test mode and the connection.

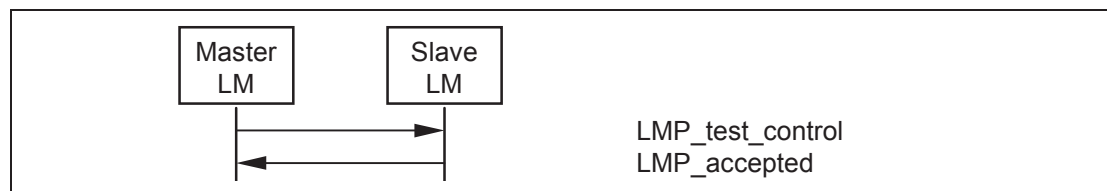
4.7.2 Control of test mode

Control and configuration is performed using special LMP commands (see [Section 4.7.3 on page 291](#)). These commands shall be rejected if the Bluetooth device is not in test mode. In this case, an LMP_not_accepted shall be returned. The DUT shall return an LMP_accepted on reception of a control command when in test mode.

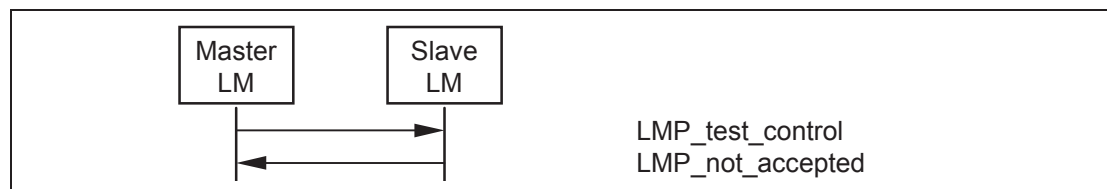
A Bluetooth device in test mode shall ignore all LMP commands not related to control of the test mode. LMP commands dealing with power control and the request for LMP features (LMP_features_req), and adaptive frequency hopping (LMP_set_AFH, LMP_channel_classification_req and LMP_channel_classification) are allowed in test mode; the normal procedures are also used to test the adaptive power control.

The DUT shall leave the test mode when an LMP_Detach command is received or an LMP_test_control command is received with test scenario set to 'exit test mode'.

When the DUT has entered test mode, the PDU LMP_test_control PDU can be sent to the DUT to start a specific test. This PDU is acknowledged with an LMP_accepted PDU. If a device that is not in test mode receives an LMP_test_control PDU it responds with an LMP_not_accepted PDU, where the error code shall be *PDU not allowed*.



Sequence 73: Control of test mode successful.



Sequence 74: Control of test mode rejected since slave is not in test mode.

4.7.3 Summary of test mode PDUs

Table 4.30 lists all LMP messages used for test mode. To ensure that the contents of LMP_test_control PDU are suitably whitened (important when sent in transmitter mode), all parameters listed in Table 4.31 on page 291 are XORED with 0x55 before being sent.

| LMP PDU | PDU number | Possible Direction | Contents | Position in Payload |
|-------------------|------------|--------------------|--|---|
| LMP_test_activate | 56 | m → s | | |
| LMP_test_control | 57 | m → s | test scenario hopping mode TX frequency RX frequency power control mode poll period packet type length of test data | 2 3 4 5 6 7 8 9-10 |
| LMP_detach | 7 | m → s | | |
| LMP_accepted | 3 | m ← s | | |
| LMP_not_accepted | 4 | m ← s | | |

Table 4.30: LMP messages used for Test Mode

| Name | Length (bytes) | Type | Unit | Detailed |
|---------------|----------------|--------|------|---|
| Test scenario | 1 | u_int8 | | 0 Pause Test Mode 1 Transmitter test – 0 pattern 2 Transmitter test – 1 pattern 3 Transmitter test – 1010 pattern 4 Pseudorandom bit sequence 5 Closed Loop Back – ACL packets 6 Closed Loop Back – Synchronous packets 7 ACL Packets without whitening 8 Synchronous Packets without whitening 9 Transmitter test – 1111 0000 pattern 10–254 reserved 255 Exit Test Mode The value is XORED with 0x55. |

Table 4.31: Parameters used in LMP_Test_Control PDU

| Name | Length (bytes) | Type | Unit | Detailed |
|---|----------------|---------|---------|--|
| Hopping mode | 1 | u_int8 | | 0 RX/TX on single frequency 1 Normal hopping 2 Reserved 3 Reserved 4 Reserved 5–255 reserved The value is XORed with 0x55. |
| TX frequency (for DUT) | 1 | u_int8 | | $f = [2402 + k] \text{ MHz}$ The value is XORed with 0x55. |
| RX frequency (for DUT) | 1 | u_int8 | | $f = [2402 + k] \text{ MHz}$ The value is XORed with 0x55. |
| Power control mode | 1 | u_int8 | | 0 fixed TX output power 1 adaptive power control The value is XORed with 0x55. |
| Poll period | 1 | u_int8 | 1.25 ms | The value is XORed with 0x55. |
| Packet type | 1 | u_int8 | | Bits 3-0 numbering as in packet header, see Baseband Specification Bits 7-4 0: ACL/SCO 1: eSCO 2: Enhanced Data Rate ACL 3: Enhanced Data Rate eSCO 4-15: reserved Other values are reserved The value is XORed with 0x55. |
| length of test sequence (=length of user data in Baseband Specification) | 2 | u_int16 | 1 byte | unsigned binary number The value is XORed with 0x5555. |

Table 4.31: Parameters used in LMP_Test_Control PDU

The control PDU is used for both transmitter and loop back tests. The following restrictions apply for the parameter settings:

| Parameter | Restrictions Transmitter Test | Restrictions Loopback Test |
|-------------------------|---|---|
| TX frequency | $0 \leq k \leq 93$ | $0 \leq k \leq 78$ |
| RX frequency | same as TX frequency | $0 \leq k \leq 78$ |
| Poll period | | not applicable (set to 0) |
| Length of test sequence | depends on packet type: [see table 6.9 and 6.10 in the Baseband specifica- tion] | For ACL and SCO packets: not applicable (set to 0) For eSCO packets: [see table 6.10 in the Base- band specification] |

Table 4.32: Restrictions for Parameters used in LMP_Test_Control PDU



5 SUMMARY

5.1 PDU SUMMARY

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|--------------------------------|----------------|---------|-------------|--------------------|----------------------------|---------------------|
| Escape 1 | variable | 124 | DM1 | m ↔ s | extended op code | 2 |
| | | | | | variable | 3-? |
| Escape 2 | variable | 125 | DM1 | m ↔ s | extended op code | 2 |
| | | | | | variable | 3-? |
| Escape 3 | variable | 126 | DM1 | m ↔ s | extended op code | 2 |
| | | | | | variable | 3-? |
| Escape 4 | variable | 127 | DM1 | m ↔ s | extended op code | 2 |
| | | | | | variable | 3-? |
| LMP_accepted | 2 | 3 | DM1/DV | m ↔ s | op code | 2 |
| LMP_accepted_ext | 4 | 127/01 | DM1 | m ↔ s | escape op code | 3 |
| | | | | | extended op code | 4 |
| LMP_au_rand | 17 | 11 | DM1 | m ↔ s | random number | 2-17 |
| LMP_auto_rate | 1 | 35 | DM1/DV | m ↔ s | - | |
| LMP_channel_classification_req | 7 | 127/16 | DM1 | m → s | AFH_reporting_mode | 3 |
| | | | | | AFH_min_interval | 4-5 |
| | | | | | AFH_max_interval | 6-7 |
| LMP_channel_classification | 12 | 127/17 | DM1 | m ← s | AFH_channel_classification | 3 – 12 |
| LMP_clkoffset_req | 1 | 5 | DM1/DV | m → s | - | |
| LMP_clkoffset_res | 3 | 6 | DM1/DV | m ← s | clock offset | 2-3 |
| LMP_comb_key | 17 | 9 | DM1 | m ↔ s | random number | 2-17 |
| LMP_decr_power_req | 2 | 32 | DM1/DV | m ↔ s | for future use | 2 |
| LMP_detach | 2 | 7 | DM1/DV | m ↔ s | error code | 2 |

Table 5.1: Coding of the different LM PDUs.

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|----------------------------------|----------------|---------|-------------|--------------------|----------------------|---------------------|
| LMP_encryption_key_size_mask_req | 1 | 58 | DM1 | m → s | | |
| LMP_encryption_key_size_mask_res | 3 | 59 | DM1 | m ← s | key size mask | 2-3 |
| LMP_encryption_key_size_req | 2 | 16 | DM1/DV | m ↔ s | key size | 2 |
| LMP_encryption_mode_req | 2 | 15 | DM1/DV | m ↔ s | encryption mode | 2 |
| LMP_eSCO_link_req | 16 | 127/12 | DM1 | m ↔ s | eSCO handle | 3 |
| | | | | | eSCO LT_ADDR | 4 |
| | | | | | timing control flags | 5 |
| | | | | | D _{eSCO} | 6 |
| | | | | | T _{eSCO} | 7 |
| | | | | | W _{eSCO} | 8 |
| | | | | | eSCO packet type M→S | 9 |
| | | | | | eSCO packet type S→M | 10 |
| | | | | | packet length M→S | 11-12 |
| | | | | | packet length S→M | 13-14 |
| LMP_features_req | 9 | 39 | DM1/DV | m ↔ s | features | 2-9 |
| | | | | | features page | 3 |
| | | | | | max supported page | 4 |
| LMP_features_req_ext | 12 | 127/03 | DM1 | m ↔ s | extended features | 5-12 |
| LMP_features_res | 9 | 40 | DM1/DV | m ↔ s | features | 2-9 |
| LMP_features_res_ext | 12 | 127/04 | DM1 | m ↔ s | features page | 3 |
| | | | | | max supported page | 4 |
| | | | | | extended features | 5-12 |
| LMP_host_connection_req | 1 | 51 | DM1/DV | m ↔ s | - | |

Table 5.1: Coding of the different LM PDUs.

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|--------------------|----------------|---------|-------------|--------------------|------------------------|---------------------|
| LMP_hold | 7 | 20 | DM1/DV | m ↔ s | hold time | 2-3 |
| | | | | | hold instant | 4-7 |
| LMP_hold_req | 7 | 21 | DM1/DV | m ↔ s | hold time | 2-3 |
| | | | | | hold instant | 4-7 |
| LMP_incr_power_req | 2 | 31 | DM1/DV | m ↔ s | for future use | 2 |
| LMP_in_rand | 17 | 8 | DM1 | m ↔ s | random number | 2-17 |
| LMP_max_power | 1 | 33 | DM1/DV | m ↔ s | - | |
| LMP_max_slot | 2 | 45 | DM1/DV | m ↔ s | max slots | 2 |
| LMP_max_slot_req | 2 | 46 | DM1/DV | m ↔ s | max slots | 2 |
| LMP_min_power | 1 | 34 | DM1/DV | m ↔ s | - | |
| LMP_modify_beacon | 11 or 13 | 28 | DM1 | m → s | timing control flags | 2 |
| | | | | | D _B | 3-4 |
| | | | | | T _B | 5-6 |
| | | | | | N _B | 7 |
| | | | | | Δ _B | 8 |
| | | | | | D _{access} | 9 |
| | | | | | T _{access} | 10 |
| | | | | | N _{acc-slots} | 11 |
| | | | | | N _{poll} | 12 |
| | | | | | M _{access} | 13:0-3 |
| | | | | | access scheme | 13:4-7 |
| LMP_name_req | 2 | 1 | DM1/DV | m ↔ s | name offset | 2 |
| LMP_name_res | 17 | 2 | DM1 | m ↔ s | name offset | 2 |
| | | | | | name length | 3 |
| | | | | | name fragment | 4-17 |

Table 5.1: Coding of the different LM PDUs.

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|---------------------------|----------------|---------|-------------|--------------------|------------------------|---------------------|
| LMP_not_accepted | 3 | 4 | DM1/DV | m ↔ s | op code | 2 |
| | | | | | error code | 3 |
| LMP_not_accepted_ext | 5 | 127/02 | DM1 | m ↔ s | escape op code | 3 |
| | | | | | extended op code | 4 |
| | | | | | error code | 5 |
| LMP_packet_type_table_req | 3 | 127/11 | DM1 | m ↔ s | packet type table | 3 |
| LMP_page_mode_req | 3 | 53 | DM1/DV | m ↔ s | paging scheme | 2 |
| | | | | | paging scheme settings | 3 |
| LMP_page_scan_mode_req | 3 | 54 | DM1/DV | m ↔ s | paging scheme | 2 |
| | | | | | paging scheme settings | 3 |
| LMP_park_req | 17 | 25 | DM1 | m ↔ s | timing control flags | 2 |
| | | | | | D _B | 3-4 |
| | | | | | T _B | 5-6 |
| | | | | | N _B | 7 |
| | | | | | Δ _B | 8 |
| | | | | | PM_ADDR | 9 |
| | | | | | AR_ADDR | 10 |
| | | | | | N _{Bsleep} | 11 |
| | | | | | D _{Bsleep} | 12 |
| | | | | | D _{access} | 13 |
| | | | | | T _{access} | 14 |
| | | | | | N _{acc-slots} | 15 |
| | | | | | N _{poll} | 16 |
| | | | | | M _{access} | 17:0-3 |
| | | | | | access scheme | 17:4-7 |
| LMP_preferred_rate | 2 | 36 | DM1/DV | m ↔ s | data rate | 2 |
| LMP_quality_of_service | 4 | 41 | DM1/DV | m → s | poll interval | 2-3 |
| | | | | | N _{BC} | 4 |

Table 5.1: Coding of the different LM PDUs.

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|--|----------------|---------|-------------|--------------------|-------------------------|---------------------|
| LMP_quality_of_service_req | 4 | 42 | DM1/DV | m ↔ s | poll interval | 2-3 |
| | | | | | N _{BC} | 4 |
| LMP_remove_eSCO_link_req [] see Note4 on page 302 | 4 | 127/13 | DM1 | m ↔ s | eSCO handle | 3 |
| | | | | | error code | 4 |
| LMP_remove_SCO_link_req | 3 | 44 | DM1/DV | m ↔ s | SCO handle | 2 |
| | | | | | error code | 3 |
| LMP_SCO_link_req | 7 | 43 | DM1/DV | m ↔ s | SCO handle | 2 |
| | | | | | timing control flags | 3 |
| | | | | | D _{sco} | 4 |
| | | | | | T _{sco} | 5 |
| | | | | | SCO packet | 6 |
| | | | | | air mode | 7 |
| LMP_set_AFH | 16 | 60 | DM1 | m → s | AFH_instant | 2-5 |
| | | | | | AFH_mode | 6 |
| | | | | | AFH_channel_map | 7-16 |
| LMP_set_broadcast_scan_window | 4 or 6 | 27 | DM1 | m → s | timing control flags | 2 |
| | | | | | D _B | 3-4 |
| | | | | | broadcast scan window | 5-6 |
| LMP_setup_complete | 1 | 49 | DM1 | m ↔ s | - | |
| LMP_slot_offset | 9 | 52 | DM1/DV | m ↔ s | slot offset | 2-3 |
| | | | | | BD_ADDR | 4-9 |
| LMP_sniff_req | 10 | 23 | DM1 | m ↔ s | timing control flags | 2 |
| | | | | | D _{sniff} | 3-4 |
| | | | | | T _{sniff} | 5-6 |
| | | | | | sniff attempt | 7-8 |
| | | | | | sniff timeout | 9-10 |
| LMP_sres | 5 | 12 | DM1/DV | m ↔ s | authentication response | 2-5 |
| LMP_start_encryption_req | 17 | 17 | DM1 | m → s | random number | 2-17 |
| LMP_stop_encryption_req | 1 | 18 | DM1/DV | m → s | - | |

Table 5.1: Coding of the different LM PDUs.

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|-------------------------|----------------|---------|-------------|--------------------|--------------------------------|---------------------|
| LMP_supervision_timeout | 3 | 55 | DM1/DV | m → s | supervision timeout | 2-3 |
| LMP_switch_req | 5 | 19 | DM1/DV | m ↔ s | switch instant | 2-5 |
| LMP_temp_rand | 17 | 13 | DM1 | m → s | random number | 2-17 |
| LMP_temp_key | 17 | 14 | DM1 | m → s | key | 2-17 |
| LMP_test_activate | 1 | 56 | DM1/DV | m → s | - | |
| LMP_test_control | 10 | 57 | DM1 | m → s | test scenario | 2 |
| | | | | | hopping mode | 3 |
| | | | | | TX frequency | 4 |
| | | | | | RX frequency | 5 |
| | | | | | power control mode | 6 |
| | | | | | poll period | 7 |
| | | | | | packet type | 8 |
| | | | | | length of test data | 9-10 |
| LMP_timing_accuracy_req | 1 | 47 | DM1/DV | m ↔ s | - | |
| LMP_timing_accuracy_res | 3 | 48 | DM1/DV | m ↔ s | drift | 2 |
| | | | | | jitter | 3 |
| LMP_unit_key | 17 | 10 | DM1 | m ↔ s | key | 2-17 |
| LMP_unpark_BD_ADDR_req | variable | 29 | DM1 | m → s | timing control flags | 2 |
| | | | | | D _B | 3-4 |
| | | | | | LT_ADDR 1 st unpark | 5:0-2 |
| | | | | | LT_ADDR 2 nd unpark | 5:4-6 |
| | | | | | BD_ADDR 1 st unpark | 6-11 |
| | | | | | BD_ADDR 2 nd unpark | 12-17 |

Table 5.1: Coding of the different LM PDUs.

| LMP PDU | Length (bytes) | op code | Packet type | Possible direction | Contents | Position in payload |
|----------------------------|----------------|---------|-------------|--------------------|--------------------------------|---------------------|
| LMP_unpark_PM_ADDR_req | variable | 30 | DM1 | m → s | timing control flags | 2 |
| | | | | | D _B | 3-4 |
| | | | | | LT_ADDR 1 st unpark | 5:0-3 |
| | | | | | LT_ADDR 2 nd unpark | 5:4-7 |
| | | | | | PM_ADDR 1 st unpark | 6 |
| | | | | | PM_ADDR 2 nd unpark | 7 |
| | | | | | LT_ADDR 3 rd unpark | 8:0-3 |
| | | | | | LT_ADDR 4 th unpark | 8:4-7 |
| | | | | | PM_ADDR 3 rd unpark | 9 |
| | | | | | PM_ADDR 4 th unpark | 10 |
| | | | | | LT_ADDR 5 th unpark | 11:0-3 |
| | | | | | LT_ADDR 6 th unpark | 11:4-7 |
| | | | | | PM_ADDR 6 th unpark | 12 |
| | | | | | PM_ADDR 6 th unpark | 13 |
| | | | | | LT_ADDR 7 th unpark | 14:0-3 |
| | | | | | PM_ADDR 7 th unpark | 15 |
| LMP_unsniff_req | 1 | 24 | DM1/DV | m ↔ s | - | |
| LMP_use_semi_permanent_key | 1 | 50 | DM1/DV | m → s | - | |
| LMP_version_req | 6 | 37 | DM1/DV | m ↔ s | VersNr | 2 |
| | | | | | Compld | 3-4 |
| | | | | | SubVersNr | 5-6 |
| LMP_version_res | 6 | 38 | DM1/DV | m ↔ s | VersNr | 2 |
| | | | | | Compld | 3-4 |
| | | | | | SubVersNr | 5-6 |

Table 5.1: Coding of the different LM PDUs.

Note1: For LMP_set_broadcast_scan_window, LMP_modify_beacon, LMP_unpark_BD_ADDR_req and LMP_unpark_PM_ADDR_req the parameter D_B is optional. This parameter is only present if bit0 of *timing control flags* is 1.



If the parameter is not included, the position in payload for all parameters following D_B are decreased by 2.

Note2: For LMP_unpark_BD_ADDR the LT_ADDR and the BD_ADDR of the 2nd unparked slave are optional. If only one slave is unparked LT_ADDR 2nd unpark shall be zero and BD_ADDR 2nd unpark is left out.

Note3: For LMP_unpark_PM_ADDR the LT_ADDR and the PM_ADDR of the 2nd – 7th unparked slaves are optional. If N slaves are unparked, the fields up to and including the Nth unparked slave are present. If N is odd, the LT_ADDR (N+1)th unpark shall be zero. The length of the message is $x + 3N/2$ if N is even and $x + 3(N+1)/2 - 1$ if N is odd, where $x = 2$ or 4 depending on if the D_B is included Or Not (See Note1).

Note4: Parameters coincide with their namesakes in LMP_<remove>_SCO_link_req apart from the following:

1. eSCO_LT_ADDR - the eSCO connection will be active on an additional LT_ADDR that needs to be defined. The master is allowed to re-assign an active eSCO link to a different LT_ADDR.
2. D_{eSCO} , T_{eSCO} - as per LMP_SCO_link_req but with a greater flexibility in values (e.g. no longer fixed with respect to HV1, HV2, and HV3 packet choice).
3. W_{eSCO} - the eSCO retransmission window size (in slots)
4. packet type and packet length may be prescribed differently in Master-to-Slave or Slave-to-Master directions for asynchronous eSCO links
5. packet length (in bytes) - eSCO packet types no longer have fixed length
6. negotiation state – this is used to better enable the negotiation of the negotiable parameters: D_{eSCO} , T_{eSCO} , W_{eSCO} , eSCO packet type M->S, eSCO packet type S->M, packet length M->S, packet length S->M. When responding to an eSCO link request with a new suggestion for these parameters, this flag may be set to 1 to indicate that the last received negotiable parameters are possible, but the new parameters specified in the response eSCO link request would be preferable, to 2 to indicate that the last received negotiable parameters are not possible as they cause a reserved slot violation or to 3 to indicate that the last received negotiable parameters would cause a latency violation. The flag shall be set to zero in the initiating LMP_eSCO_link_req.

5.2 PARAMETER DEFINITIONS

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|----------------------------|----------------|----------------|-------|--|-----------------|
| access scheme | 1 | u_int4 | | 0: polling technique 1-15: Reserved | |
| AFH_channel_classification | 10 | multiple bytes | - | <p>This parameter contains 40 2-bit fields.</p> <p>The n^{th} (numbering from 0) such field defines the classification of channels $2n$ and $2n+1$, other than the 39th field which just contains the classification of channel 78.</p> <p>Each field interpreted as an integer whose values indicate:</p> <p>0 = unknown 1 = good 2 = reserved 3 = bad</p> | |
| AFH_channel_map | 10 | multiple bytes | - | <p>If <i>AFH_mode</i> is <i>AFH_enabled</i>, this parameter contains 79 1-bit fields, otherwise the contents are reserved.</p> <p>The n^{th} (numbering from 0) such field (in the range 0 to 78) contains the value for channel n.</p> <p>Bit 79 is reserved (set to 0 when transmitted and ignored when received)</p> <p>The 1-bit field is interpreted as follows:</p> <p>0: channel n is unused 1: channel n is used</p> | |
| AFH_instant | 4 | u_int32 | slots | Bits 27:1 of the Bluetooth master clock value at the time of switching hop sequences. Must be even. | |
| AFH_max_inteval | 2 | u_int16 | slots | Range is 0x0640 to 0xBB80 slots (1 to 30s) | |
| AFH_min_inteval | 2 | u_int16 | slots | Range is 0x0640 to 0xBB80 slots (1 to 30s) | |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|-------------------------|----------------|----------------|--------|--|---------------------------|
| AFH_mode | 1 | u_int8 | - | 0: AFH_disabled 1: AFH_enabled 2-255: Reserved | |
| AFH_reporting_mode | 1 | u_int8 | - | 0: AFH_reporting_disabled 1: AFH_reporting_enabled 2-255: reserved | |
| air mode | 1 | u_int8 | | 0: μ -law log 1: A-law log 2: CVSD 3: transparent data 4-255: Reserved | See Table 5.3 on page 310 |
| AR_ADDR | 1 | u_int8 | | | |
| authentication response | 4 | multiple bytes | | | |
| BD_ADDR | 6 | multiple bytes | | BD_ADDR of the sending device | |
| broadcast scan window | 2 | u_int16 | slots | | |
| clock offset | 2 | u_int16 | 1.25ms | (CLKN ₁₆₋₂ slave - CLKN ₁₆₋₂ master) mod 2 ¹⁵ MSbit of second byte not used. | |
| CompId | 2 | u_int16 | | see Bluetooth Assigned Numbers (https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers) | |
| D _{access} | 1 | u_int8 | slots | | |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|---------------------|-------------------|---------|-------|---|---------------------------|
| data rate | 1 | u_int8 | | <p>When in Basic Rate mode:</p> <p>bit0 = 0: use FEC bit0 = 1: do not use FEC bit1-2=0: No packet-size preference available bit1-2=1: use 1-slot packets bit1-2=2: use 3-slot packets bit1-2=3: use 5-slot packets</p> <p>When in Enhanced Data Rate mode:</p> <p>bit3-4=0: use DM1 packets bit3-4=1: use 2 Mbps packets bit3-4=2: use 3 Mbps packets bit3-4=3: reserved bit5-6=0: No packet-size preference available bit5-6=1: use 1-slot packets bit5-6=2: use 3-slot packets bit5-6=3: use 5-slot packets</p> <p>bit7: Reserved - shall be zero</p> | |
| D_B | 2 | u_int16 | slots | | |
| Δ_B | 1 | u_int8 | slots | | |
| $D_{B\text{sleep}}$ | 1 | u_int8 | | | |
| D_{eSCO} | 1 | u_int8 | slots | Valid range is 0 - 254 slots | See Table 5.3 on page 310 |
| drift | 1 | u_int8 | ppm | | |
| D_{SCO} | 1 | u_int8 | slots | Only even values are valid ¹ | 0 to $T_{SCO} - 2$ |
| D_{sniff} | 2 | u_int16 | slots | Only even values are valid ¹ | 0 to $(T_{sniff} - 2)$ |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|-------------------|----------------|----------------|-------|---|---|
| encryption mode | 1 | u_int8 | | 0: no encryption 1: encryption 2: encryption 3 -255: Reserved | |
| error code | 1 | u_int8 | | See Part D on page 319 | |
| escape op code | 1 | u_int8 | | Identifies which escape op code is being acknowledged: range 124-127 | |
| eSCO handle | 1 | u_int8 | | | |
| eSCO LT_ADDR | 1 | u_int8 | | Logical transport address for the eSCO logical transport. The range is extended to 8 bits compared with the normal LT_ADDR field: range 0-7. | 0 - 7 |
| eSCO packet type | 1 | u_int8 | | 0x00: NULL/POLL 0x07: EV3 0x0C: EV4 0x0D: EV5 0x26: 2-EV3 0x2C: 2-EV5 0x37: 3-EV3 0x3D: 3-EV5 Other values are reserved | If the value is 0x00 the POLL packet shall be used by the master, the NULL packet shall be used by the slave. See Table 5.3 on page 310 |
| extended features | 8 | multiple bytes | | One page of extended features | |
| extended op code | 1 | u_int8 | | Which extended op code is being acknowledged | |
| features | 8 | multiple bytes | | See Table 3.2 on page 230 | |
| features page | 1 | u_int8 | | Identifies which page of extended features is being requested. 0 means standard features 1-255 other feature pages | |
| hold instant | 4 | u_int32 | slots | Bits 27:1 of the master Bluetooth clock value | |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|------------------------|----------------|----------------|-------|--|--|
| hold time | 2 | u_int16 | slots | Only even values are valid ¹ | 0x0014 to 0x8000; shall not exceed (supervisionTO * 0.999) |
| jitter | 1 | u_int8 | μs | | |
| key | 16 | multiple bytes | | | |
| key size | 1 | u_int8 | byte | | |
| key size mask | 2 | u_int16 | | Bit mask of supported broadcast encryption key sizes: least significant bit is support for length 1, and so on. The bit shall be one if the key size is supported. | |
| LT_ADDR | 1 | u_int4 | | | |
| M _{access} | 1 | u_int4 | | number of access windows | |
| max slots | 1 | u_int8 | slots | | |
| max supported page | 1 | u_int8 | | Highest page of extended features which contains a non-zero bit for the originating device. Range 0-255 | |
| N _{acc-slots} | 1 | u_int8 | slots | | |
| name fragment | 14 | multiple bytes | | UTF-8 characters. | |
| name length | 1 | u_int8 | bytes | | |
| name offset | 1 | u_int8 | bytes | | |
| N _B | 1 | u_int8 | | | |
| N _{BC} | 1 | u_int8 | | | |
| N _{Bsleep} | 1 | u_int8 | | | |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|------------------------|----------------|--------|-------|---|---------------------------|
| negotiation state | 1 | u_int8 | | 0: Initiate negotiation 1: the latest received set of negotiable parameters were possible but these parameters are preferred. 2: the latest received set of negotiable parameters would cause a reserved slot violation. 3: the latest received set of negotiable parameters would cause a latency violation. 4: the latest received set of negotiable parameters are not supported. Other values are reserved | |
| N _{poll} | 1 | u_int8 | | | |
| op code | 1 | u_int8 | | | |
| packet length | 2 | uint16 | bytes | Length of the eSCO payload 0 for POLL/NULL 1-30 for EV3 1-120 for EV4 1-180 for EV5 1-60 for 2-EV3 1-360 for 2-EV5 1-90 for 3-EV3 1-540 for 3-EV5 Other values are invalid | See Table 5.3 on page 310 |
| packet type table | 1 | u_int8 | | 0: 1Mbps only 1: 2/3 Mbps 2-255: reserved | 0-1 |
| paging scheme | 1 | u_int8 | | 0: mandatory scheme 1-255: Reserved | |
| paging scheme settings | 1 | u_int8 | | For mandatory scheme: 0: R0 1: R1 2: R2 3-255: Reserved | |
| PM_ADDR | 1 | u_int8 | | | |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|----------------------|----------------|----------------|----------------|--|---|
| poll interval | 2 | u_int16 | slots | Only even values are valid ¹ | 0x0006 to 0x1000 |
| random number | 16 | multiple bytes | | | |
| reserved(n) | n | u_int8 | | Reserved for future use – must be 0 when transmitted, ignore value when received | |
| SCO handle | 1 | u_int8 | | | |
| SCO packet | 1 | u_int8 | | 0: HV1 1: HV2 2: HV3 3-255: Reserved | |
| slot offset | 2 | u_int16 | μs | $0 \leq \text{slot offset} < 1250$ | |
| sniff attempt | 2 | u_int16 | received slots | Number of receive slots | 1 to $T_{\text{sniff}}/2$ |
| sniff timeout | 2 | u_int16 | received slots | Number of receive slots | 0 to 0x0028 |
| SubVersNr | 2 | u_int16 | | Defined by each company | |
| supervision timeout | 2 | u_int16 | slots | 0 means an infinite timeout | 0 and 0x0190 to 0xFFFF |
| switch instant | 4 | u_int32 | slots | Bits 27:1 of the master Bluetooth clock value | |
| T_{access} | 1 | u_int8 | slots | | |
| T_B | 2 | u_int16 | slots | | |
| T_{eSCO} | 1 | u_int8 | slots | Valid range is 4 – 254 slots | See Table 5.3 on page 310 |
| timing control flags | 1 | u_int8 | | bit0 = 0: no timing change bit0 = 1: timing change bit1 = 0: use initialization 1 bit1 = 1: use initialization 2 bit2 = 0: access window bit2 = 1: no access window bit3-7: Reserved | |
| T_{sco} | 1 | u_int8 | slots | Only even values are valid ¹ | 2 to 6 |

Table 5.2: Parameters in LM PDUs.

| Name | Length (bytes) | Type | Unit | Detailed | Mandatory range |
|--------------------|----------------|---------|-------|---|--|
| T_{sniff} | 2 | u_int16 | slots | Only even values are valid ¹ | 0x0006 to 0x0540; shall not exceed (supervisionTO * 0.999) |
| VersNr | 1 | u_int8 | | See Bluetooth Assigned Numbers, (http://www.bluetooth.org/assigned-numbers.htm) | |
| W_{eSCO} | 1 | u_int8 | slots | Number of slots in the retransmission window Valid range is 0 – 254 slots | See Table 5.3 on page 310 |

Table 5.2: Parameters in LM PDUs.

1. If a device receives an LMP PDU with an odd value in this parameter field the PDU should be rejected with an error code of *invalid LMP parameters*.

| | Single Slot Packets | 3-Slot Packets |
|--------------------|--|--|
| D_{eSCO} | 0 to $T_{\text{eSCO}}-2$ (even) | 0 to $T_{\text{eSCO}}-2$ (even) |
| T_{eSCO} | EV3: 6 2-EV3: 6-12 (even) 3-EV3: 6-18 (even) | EV4: 16 EV5: 16 2-EV5: 16 3-EV5: 16 |
| W_{eSCO} | 0, 2, and 4 | 0 and 6 |
| packet length M->S | $10 * T_{\text{eSCO}} / 2$ | $10 * T_{\text{eSCO}} / 2$ |
| packet length S->M | $10 * T_{\text{eSCO}} / 2$ | $10 * T_{\text{eSCO}} / 2$ |
| air mode | At least one of A-law, mu-law, CVSD, transparent | transparent |

Table 5.3: Mandatory parameter ranges for eSCO packet types

5.3 DEFAULT VALUES

Devices shall use these values before anything else has been negotiated:

| Parameter | Value |
|--------------------|------------------------|
| AFH_mode | AFH_disabled |
| AFH_reporting_mode | AFH_reporting_disabled |
| drift | 250 |
| jitter | 10 |
| max slots | 1 |
| poll interval | 40 |

Table 5.4: Default values.



6 LIST OF FIGURES

| | | |
|--------------|--|-----|
| Figure 1.1: | Link Manager Protocol signalling layer. | 213 |
| Figure 2.1: | Transmission of a message from master to slave. | 216 |
| Figure 2.2: | Payload body when LMP PDUs are sent. | 217 |
| Figure 2.3: | Symbols used in sequence diagrams. | 219 |
| Figure 4.1: | Connection establishment. | 229 |
| Sequence 1: | Connection closed by sending LMP_detach. | 231 |
| Sequence 2: | A device requests a change of the other device's TX power. | 232 |
| Sequence 3: | The TX power cannot be increased. | 232 |
| Sequence 4: | The TX power cannot be decreased. | 232 |
| Sequence 5: | Master Enables AFH. | 234 |
| Sequence 6: | Master disables AFH. | 234 |
| Sequence 7: | Master Updates AFH. | 235 |
| Sequence 8: | Channel classification reporting. | 237 |
| Sequence 9: | Setting the link supervision timeout. | 238 |
| Sequence 10: | A notifies B to enable CQDDR | 239 |
| Sequence 11: | B sends A a preferred packet type | 239 |
| Sequence 12: | Master notifies slave of quality of service. | 240 |
| Sequence 13: | Device accepts new quality of service | 241 |
| Sequence 14: | Device rejects new quality of service. | 241 |
| Sequence 15: | Negotiation for page mode. | 242 |
| Sequence 16: | Negotiation for page scan mode | 242 |
| Sequence 17: | Device allows Remote Device to use a maximum number of slots. | 243 |
| Sequence 18: | Device requests a maximum number of slots. Remote Device accepts. | 243 |
| Sequence 19: | Device requests a maximum number of slots. Remote Device rejects. | 243 |
| Sequence 20: | Packet type table change is rejected. | 244 |
| Sequence 21: | Packet type table change is accepted. | 245 |
| Sequence 22: | Authentication. Claimant has link key. | 245 |
| Sequence 23: | Authentication fails. Claimant has no link key. | 246 |
| Sequence 24: | Pairing accepted. Responder has a variable PIN. Initiator has a variable or fixed PIN. | 247 |
| Sequence 25: | Responder has a fixed PIN and initiator has a variable PIN. | 248 |
| Sequence 26: | Both devices have a fixed PIN. | 248 |
| Sequence 27: | Responder rejects pairing. | 248 |
| Sequence 28: | Creation of the link key. | 249 |
| Sequence 29: | Successful change of the link key. | 250 |
| Sequence 30: | Change of the link key not possible since the other device uses | |



| | |
|--|-----|
| a unit key. | 250 |
| Sequence 31: Change to a temporary link key. | 251 |
| Sequence 32: Link key changed to the semi-permanent link key. | 252 |
| Sequence 33: Negotiation for encryption mode. | 254 |
| Sequence 34: Encryption key size negotiation successful. | 255 |
| Sequence 35: Encryption key size negotiation failed. | 255 |
| Sequence 36: Start of encryption. | 255 |
| Sequence 37: Stop of encryption. | 256 |
| Sequence 38: Request for supported encryption key sizes. | 257 |
| Sequence 39: The requested device supports timing accuracy information. | 258 |
| Sequence 40: The requested device does not support timing accuracy infor- mation. | 258 |
| Sequence 41: Clock offset requested. | 259 |
| Sequence 42: Request for LMP version. | 260 |
| Sequence 43: Request for supported features. | 261 |
| Sequence 44: Request for extended features. | 261 |
| Sequence 45: Device's name requested and it responses. | 262 |
| Figure 4.2: Slot offset for role switch. | 263 |
| Sequence 46: Slot offset information is sent. | 263 |
| Sequence 47: Role switch (slave initiated). | 264 |
| Sequence 48: Role switch (master initiated). | 265 |
| Sequence 49: Master forces slave into hold mode. | 266 |
| Sequence 50: Slave forces master into hold mode. | 267 |
| Sequence 51: Negotiation for hold mode. | 268 |
| Sequence 52: Slave accepts to enter park state. | 271 |
| Sequence 53: Slave rejects to enter into park state | 271 |
| Sequence 54: Slave requests to enter park state and accepts master's beacon parameters. | 272 |
| Sequence 55: Master rejects slave's request to enter park state | 272 |
| Sequence 56: Slave requests to enter park state, but rejects master's beacon parameters. | 272 |
| Sequence 57: Master notifies all slaves of increase in broadcast capacity. 272 | |
| Sequence 58: Master modifies beacon parameters. | 273 |
| Sequence 59: Master un parks slaves addressed with their BD_ADDR. ... | 273 |
| Sequence 60: Master un parks slaves addressed with their PM_ADDR. ... | 274 |
| Sequence 61: Negotiation for sniff mode. | 275 |
| Sequence 62: Slave moved from sniff mode to active mode. | 276 |
| Sequence 63: Master requests an SCO link. | 278 |
| Sequence 64: Master rejects slave's request for an SCO link. | 278 |
| Sequence 65: Master accepts slave's request for an SCO link. | 278 |
| Sequence 66: SCO link removed. | 279 |



| | | |
|--------------|--|-----|
| Sequence 67: | Master requests an eSCO link. | 281 |
| Sequence 68: | Slave requests an eSCO link. | 281 |
| Sequence 69: | Master rejects slave's request for an eSCO link. | 282 |
| Sequence 70: | eSCO link removed | 282 |
| Sequence 71: | Activation of test mode successful. | 285 |
| Sequence 72: | Activation of test mode fails. Slave is not allowed to enter test mode. | 285 |
| Sequence 73: | Control of test mode successful. | 286 |
| Sequence 74: | Control of test mode rejected since slave is not in test mode. | 286 |



7 LIST OF TABLES

| | | |
|-------------|---|-----|
| Table 2.1: | General response messages. | 220 |
| Table 3.1: | Feature definitions. | 221 |
| Table 3.2: | Feature mask definition..... | 226 |
| Table 4.1: | PDUs used for connection establishment. | 230 |
| Table 4.2: | PDU used for detach..... | 230 |
| Table 4.3: | PDUs used for power control. | 231 |
| Table 4.4: | PDUs used for AFH..... | 233 |
| Table 4.5: | PDUs used for Channel Classification Reporting..... | 236 |
| Table 4.6: | PDU used to set the supervision timeout. | 238 |
| Table 4.7: | PDUs used for quality driven change of the data rate..... | 239 |
| Table 4.8: | PDUs used for quality of service..... | 240 |
| Table 4.9: | PDUs used to request paging scheme..... | 242 |
| Table 4.10: | PDUs used to control the use of multi-slot packets..... | 243 |
| Table 4.11: | PDUs used for Enhanced Data Rate | 244 |
| Table 4.12: | PDUs used for authentication. | 245 |
| Table 4.13: | PDUs used for pairing | 247 |
| Table 4.14: | PDUs used for change of link key. | 250 |
| Table 4.15: | PDUs used to change the current link key. | 251 |
| Table 4.16: | PDUs used for handling encryption..... | 253 |
| Table 4.17: | PDUs used for encryption key size request | 257 |
| Table 4.18: | PDUs used for requesting timing accuracy information. | 258 |
| Table 4.19: | PDUs used for clock offset request..... | 259 |
| Table 4.20: | PDUs used for LMP version request..... | 260 |
| Table 4.21: | PDUs used for features request..... | 261 |
| Table 4.22: | PDUs used for name request..... | 262 |
| Table 4.23: | PDU used for slot offset information. | 263 |
| Table 4.24: | PDUs used for role switch..... | 264 |
| Table 4.25: | PDUs used for hold mode..... | 266 |
| Table 4.26: | PDUs used for park state..... | 269 |
| Table 4.27: | PDUs used for sniff mode. | 274 |
| Table 4.28: | PDUs used for managing the SCO links..... | 277 |
| Table 4.29: | PDUs used for managing the eSCO links | 280 |
| Table 4.30: | LMP messages used for Test Mode..... | 287 |
| Table 4.31: | Parameters used in LMP_Test_Control PDU | 287 |
| Table 4.32: | Restrictions for Parameters used in LMP_Test_Control PDU .. | 289 |
| Table 5.1: | Coding of the different LM PDUs. | 291 |
| Table 5.2: | Parameters in LM PDUs. | 299 |
| Table 5.3: | Mandatory parameter ranges for eSCO packet types..... | 306 |
| Table 5.4: | Default values. | 307 |



ERROR CODES





CONTENTS

| | | |
|----------|---|------------|
| 1 | Overview of Error Codes | 323 |
| 1.1 | Usage Descriptions | 323 |
| 1.2 | HCI Command Errors | 323 |
| 1.3 | List of Error Codes | 324 |
| 2 | Error Code Descriptions | 327 |
| 2.1 | Unknown HCI Command (0X01) | 327 |
| 2.2 | Unknown Connection Identifier (0X02) | 327 |
| 2.3 | Hardware Failure (0X03) | 327 |
| 2.4 | Page Timeout (0X04) | 327 |
| 2.5 | Authentication Failure (0X05) | 327 |
| 2.6 | PIN or key Missing (0X06) | 327 |
| 2.7 | Memory Capacity Exceeded (0X07) | 327 |
| 2.8 | Connection Timeout (0X08) | 328 |
| 2.9 | Connection Limit Exceeded (0X09) | 328 |
| 2.10 | Synchronous Connection Limit to a Device Exceeded (0X0A) | 328 |
| 2.11 | ACL Connection Already Exists (0X0B) | 328 |
| 2.12 | Command Disallowed (0X0C) | 328 |
| 2.13 | Connection Rejected due to Limited Resources (0X0D) | 328 |
| 2.14 | Connection Rejected due to Security Reasons (0X0E) | 328 |
| 2.15 | Connection Rejected due to Unacceptable BD_ADDR (0X0F) | 329 |
| 2.16 | Connection Accept Timeout Exceeded (0X10) | 329 |
| 2.17 | Unsupported Feature or Parameter Value (0X11) | 329 |
| 2.18 | Invalid HCI Command Parameters (0X12) | 329 |
| 2.19 | Remote User Terminated Connection (0X13) | 329 |
| 2.20 | Remote Device Terminated Connection due to Low Resources (0X14) | 330 |
| 2.21 | Remote Device Terminated Connection due to Power Off (0X15) | 330 |
| 2.22 | Connection Terminated by Local Host (0X16) | 330 |
| 2.23 | Repeated Attempts (0X17) | 330 |
| 2.24 | Pairing not Allowed (0X18) | 330 |
| 2.25 | Unknown LMP PDU (0X19) | 330 |
| 2.26 | Unsupported Remote Feature / Unsupported LMP Feature (0X1A) | 330 |
| 2.27 | SCO Offset Rejected (0X1B) | 330 |
| 2.28 | SCO Interval Rejected (0X1C) | 331 |
| 2.29 | SCO Air Mode Rejected (0X1D) | 331 |
| 2.30 | Invalid LMP Parameters (0X1E) | 331 |
| 2.31 | Unspecified Error (0X1F) | 331 |
| 2.32 | Unsupported LMP Parameter Value (0X20) | 331 |

Error Codes

| | | |
|------|---|-----|
| 2.33 | Role Change Not Allowed (0X21) | 331 |
| 2.34 | LMP Response Timeout (0X22) | 331 |
| 2.35 | LMP Error Transaction Collision (0X23) | 332 |
| 2.36 | LMP PDU Not Allowed (0X24) | 332 |
| 2.37 | Encryption Mode Not Acceptable (0X25) | 332 |
| 2.38 | Link Key Can Not be Changed (0X26) | 332 |
| 2.39 | Requested Qos Not Supported (0X27) | 332 |
| 2.40 | Instant Passed (0X28) | 332 |
| 2.41 | Pairing with Unit Key Not Supported (0X29) | 332 |
| 2.42 | Different Transaction Collision (0x2a) | 332 |
| 2.43 | QoS Unacceptable Parameter (0X2C) | 332 |
| 2.44 | QoS Rejected (0X2D) | 333 |
| 2.45 | Channel Classification Not Supported (0X2E) | 333 |
| 2.46 | Insufficient Security (0X2F) | 333 |
| 2.47 | Parameter out of Mandatory Range (0X30) | 333 |
| 2.48 | Role Switch Pending (0X32) | 333 |
| 2.49 | Reserved Slot Violation (0X34) | 333 |
| 2.50 | Role Switch Failed (0X35) | 333 |

1 OVERVIEW OF ERROR CODES

This document lists the various possible error codes. When a command fails, or an LMP message needs to indicate a failure, error codes are used to indicate the reason for the error. Error codes have a size of one octet.

1.1 USAGE DESCRIPTIONS

The purpose of this section is to give descriptions of how the error codes should be used. It is beyond the scope of this document to give detailed descriptions of all situations where error codes can be used, especially as this may be implementation dependent.

1.2 HCI COMMAND ERRORS

If an HCI Command that should generate an HCI_Command_Complete event generates an error then this error shall be reported in the HCI_Command_Complete event.

If an HCI Command that sent an HCI_Command_Status with the error code 'Success' to the host before processing may find an error during execution then the error may be reported in the normal completion command for the original command or in an HCI_Command_Status event.

Some HCI Commands may generate errors that need to be reported to be host, but there is insufficient information to determine how the command would normally be processed. In this case, two events can be used to indicate this to the host, the HCI_Command_Complete event and HCI_Command_Status events. Which of the two events is used is implementation-dependent.

1.3 LIST OF ERROR CODES

The error code of 0x00 means Success. The possible range of failure error codes is 0x01-0xFF. Section 2 provides an error code usage description for each failure error code.

Values marked as "Reserved for Future Use", can be used in future versions of the specification. A host shall consider any error code that it does not explicitly understand equivalent to the "Unspecified Error (0x1F)."

| Error Code | Name |
|------------|--|
| 0x00 | Success |
| 0x01 | Unknown HCI Command |
| 0x02 | Unknown Connection Identifier |
| 0x03 | Hardware Failure |
| 0x04 | Page Timeout |
| 0x05 | Authentication Failure |
| 0x06 | PIN or Key Missing |
| 0x07 | Memory Capacity Exceeded |
| 0x08 | Connection Timeout |
| 0x09 | Connection Limit Exceeded |
| 0x0A | Synchronous Connection Limit To A Device Exceeded |
| 0x0B | ACL Connection Already Exists |
| 0x0C | Command Disallowed |
| 0x0D | Connection Rejected due to Limited Resources |
| 0x0E | Connection Rejected Due To Security Reasons |
| 0x0F | Connection Rejected due to Unacceptable BD_ADDR |
| 0x10 | Connection Accept Timeout Exceeded |
| 0x11 | Unsupported Feature or Parameter Value |
| 0x12 | Invalid HCI Command Parameters |
| 0x13 | Remote User Terminated Connection |
| 0x14 | Remote Device Terminated Connection due to Low Resources |
| 0x15 | Remote Device Terminated Connection due to Power Off |
| 0x16 | Connection Terminated By Local Host |
| 0x17 | Repeated Attempts |
| 0x18 | Pairing Not Allowed |

Table 1.1: List of Possible Error Codes

Error Codes



| Error Code | Name |
|------------|--|
| 0x19 | Unknown LMP PDU |
| 0x1A | Unsupported Remote Feature / Unsupported LMP Feature |
| 0x1B | SCO Offset Rejected |
| 0x1C | SCO Interval Rejected |
| 0x1D | SCO Air Mode Rejected |
| 0x1E | Invalid LMP Parameters |
| 0x1F | Unspecified Error |
| 0x20 | Unsupported LMP Parameter Value |
| 0x21 | Role Change Not Allowed |
| 0x22 | LMP Response Timeout |
| 0x23 | LMP Error Transaction Collision |
| 0x24 | LMP PDU Not Allowed |
| 0x25 | Encryption Mode Not Acceptable |
| 0x26 | Link Key Can Not be Changed |
| 0x27 | Requested QoS Not Supported |
| 0x28 | Instant Passed |
| 0x29 | Pairing With Unit Key Not Supported |
| 0x2A | Different Transaction Collision |
| 0x2B | Reserved |
| 0x2C | QoS Unacceptable Parameter |
| 0x2D | QoS Rejected |
| 0x2E | Channel Classification Not Supported |
| 0x2F | Insufficient Security |
| 0x30 | Parameter Out Of Mandatory Range |
| 0x31 | Reserved |
| 0x32 | Role Switch Pending |
| 0x33 | Reserved |
| 0x34 | Reserved Slot Violation |
| 0x35 | Role Switch Failed |

Table 1.1: List of Possible Error Codes



2 ERROR CODE DESCRIPTIONS

2.1 UNKNOWN HCI COMMAND (0X01)

The Unknown HCI Command error code indicates that the controller does not understand the HCI Command Packet OpCode that the host sent. The OpCode given might not correspond to any of the OpCodes specified in this document, or any vendor-specific OpCodes, or the command may not have been implemented.

2.2 UNKNOWN CONNECTION IDENTIFIER (0X02)

The Unknown Connection Identifier error code indicates that a command was sent from the host that should identify a connection, but that connection does not exist.

2.3 HARDWARE FAILURE (0X03)

The Hardware Failure error code indicates to the host that something in the controller has failed in a manner that cannot be described with any other error code. The meaning implied with this error code is implementation dependent.

2.4 PAGE TIMEOUT (0X04)

The Page Timeout error code indicates that a page timed out because of the Page Timeout configuration parameter. This error code may occur only with the HCI_Remote_Name_Request and HCI_Create_Connection commands.

2.5 AUTHENTICATION FAILURE (0X05)

The Authentication Failure error code indicates that pairing or authentication failed due to incorrect results in the pairing or authentication procedure. This could be due to an incorrect PIN or Link Key.

2.6 PIN OR KEY MISSING (0X06)

The PIN or Key Missing error code is used when pairing failed because of a missing PIN, or authentication failed because of a missing Key.

2.7 MEMORY CAPACITY EXCEEDED (0X07)

The Memory Capacity Exceeded error code indicates to the host that the controller has run out of memory to store new parameters.



2.8 CONNECTION TIMEOUT (0X08)

The Connection Timeout error code indicates that the link supervision timeout has expired for a given connection.

2.9 CONNECTION LIMIT EXCEEDED (0X09)

The Connection Limit Exceeded error code indicates that an attempt to create another connection failed because the controller is already at its limit of the number of connections it can support. The number of connections a device can support is implementation dependent.

2.10 SYNCHRONOUS CONNECTION LIMIT TO A DEVICE EXCEEDED (0X0A)

The Synchronous Connection Limit to a Device Exceeded error code indicates that the controller has reached the limit to the number of synchronous connections that can be achieved to a device. The number of synchronous connections a device can support is implementation dependent.

2.11 ACL CONNECTION ALREADY EXISTS (0X0B)

The ACL Connection Already Exists error code indicates that an attempt to create a new ACL Connection to a device when there is already a connection to this device.

2.12 COMMAND DISALLOWED (0X0C)

The Command Disallowed error code indicates that the command requested cannot be executed because the controller is in a state where it cannot process this command at this time. This error shall not be used for command OpCodes where the error code Unknown HCI Command is valid.

2.13 CONNECTION REJECTED DUE TO LIMITED RESOURCES (0X0D)

The Connection Rejected Due To Limited Resources error code indicates that an incoming connection was rejected due to limited resources.

2.14 CONNECTION REJECTED DUE TO SECURITY REASONS (0X0E)

The Connection Rejected Due To Security Reasons error code indicates that a connection was rejected due to security requirements not being fulfilled, like authentication or pairing.



2.15 CONNECTION REJECTED DUE TO UNACCEPTABLE BD_ADDR (0X0F)

The Connection Rejected due to Unacceptable BD_ADDR error code indicates that a connection was rejected because this device does not accept the BD_ADDR. This may be because the device will only accept connections from specific BD_ADDRs.

2.16 CONNECTION ACCEPT TIMEOUT EXCEEDED (0X10)

The Connection Accept Timeout Exceeded error code indicates that the Connection Accept Timeout has been exceeded for this connection attempt.

2.17 UNSUPPORTED FEATURE OR PARAMETER VALUE (0X11)

The Unsupported Feature Or Parameter Value error code indicates that a feature or parameter value in the HCI Command is not supported. This error code shall not be used in an LMP PDU.

2.18 INVALID HCI COMMAND PARAMETERS (0X12)

The Invalid HCI Command Parameters error code indicates that at least one of the HCI command parameters is invalid.

This shall be used when:

- the parameter total length is invalid.
- a command parameter is an invalid type.
- a connection identifier does not match the corresponding event.
- a parameter value must be even.
- a parameter is outside of the specified range.
- two or more parameter values have inconsistent values.

Note: An invalid type can be, for example, when an SCO connection handle is used where an ACL connection handle is required.

2.19 REMOTE USER TERMINATED CONNECTION (0X13)

The Remote User Terminated Connection error code indicates that the user on the remote device terminated the connection.



2.20 REMOTE DEVICE TERMINATED CONNECTION DUE TO LOW RESOURCES (0X14)

The Remote Device Terminated Connection due to Low Resources error code indicates that the remote device terminated the connection because of low resources.

2.21 REMOTE DEVICE TERMINATED CONNECTION DUE TO POWER OFF (0X15)

The Remote Device Terminated Connection due to Power Off error code indicates that the remote device terminated the connection because the device is about to power off.

2.22 CONNECTION TERMINATED BY LOCAL HOST (0X16)

The Connection Terminated By Local Host error code indicates that the local device terminated the connection.

2.23 REPEATED ATTEMPTS (0X17)

The Repeated Attempts error code indicates that the controller is disallowing an authentication or pairing procedure because too little time has elapsed since the last authentication or pairing attempt failed.

2.24 PAIRING NOT ALLOWED (0X18)

The Pairing Not Allowed error code indicates that the device does not allow pairing. For example, when a device only allows pairing during a certain time window after some user input allows pairing.

2.25 UNKNOWN LMP PDU (0X19)

The Unknown LMP PDU error code indicates that the controller has received an unknown LMP opcode.

2.26 Unsupported Remote Feature / Unsupported LMP Feature (0X1A)

The Unsupported Remote Feature error code indicates that the remote device does not support the feature associated with the issued command or LMP PDU.

2.27 SCO OFFSET REJECTED (0X1B)

The SCO Offset Rejected error code indicates that the offset requested in the LMP_SCO_link_req message has been rejected.



2.28 SCO INTERVAL REJECTED (0X1C)

The SCO Interval Rejected error code indicates that the interval requested in the LMP_SCO_link_req message has been rejected.

2.29 SCO AIR MODE REJECTED (0X1D)

The SCO Air Mode Rejected error code indicates that the air mode requested in the LMP_SCO_link_req message has been rejected.

2.30 INVALID LMP PARAMETERS (0X1E)

The Invalid LMP Parameters error code indicates that some LMP message parameters were invalid. This shall be used when:

- the PDU length is invalid.
- a parameter value must be even.
- a parameter is outside of the specified range.
- two or more parameters have inconsistent values.

2.31 UNSPECIFIED ERROR (0X1F)

The Unspecified Error error code indicates that no other error code specified is appropriate to use.

2.32 UNSUPPORTED LMP PARAMETER VALUE (0X20)

The Unsupported LMP Parameter Value error code indicates that an LMP message contains at least one parameter value that is not supported by the controller at this time. This is normally used after a long negotiation procedure, for example during an LMP_hold_req, LMP_sniff_req and LMP_encryption_key_size_req message exchanges.

2.33 ROLE CHANGE NOT ALLOWED (0X21)

The Role Change Not Allowed error code indicates that a controller will not allow a role change at this time.

2.34 LMP RESPONSE TIMEOUT (0X22)

The LMP Response Timeout error code indicates that an LMP transaction failed to respond within the LMP response timeout.



2.35 LMP ERROR TRANSACTION COLLISION (0X23)

The LMP Error Transaction Collision error code indicates that an LMP transaction has collided with the same transaction that is already in progress.

2.36 LMP PDU NOT ALLOWED (0X24)

The LMP PDU Not Allowed error code indicates that a controller sent an LMP message with an opcode that was not allowed.

2.37 ENCRYPTION MODE NOT ACCEPTABLE (0X25)

The Encryption Mode Not Acceptable error code indicates that the requested encryption mode is not acceptable at this time.

2.38 LINK KEY CAN NOT BE CHANGED (0X26)

The Link Key Can Not be Changed error code indicates that a link key can not be changed because a fixed unit key is being used.

2.39 REQUESTED QoS NOT SUPPORTED (0X27)

The Requested QoS Not Supported error code indicates that the requested Quality of Service is not supported.

2.40 INSTANT PASSED (0X28)

The Instant Passed error code indicates that an LMP PDU that includes an instant can not be performed because the instant when this would have occurred has passed.

2.41 PAIRING WITH UNIT KEY NOT SUPPORTED (0X29)

The Pairing With Unit Key Not Supported error code indicates that it was not possible to pair as a unit key was requested and it is not supported.

2.42 DIFFERENT TRANSACTION COLLISION (0X2A)

The Different Transaction Collision error code indicates that an LMP transaction was started that collides with an ongoing transaction.

2.43 QoS UNACCEPTABLE PARAMETER (0X2C)

The QoS Unacceptable Parameter error code indicates that the specified quality of service parameters could not be accepted at this time, but other parameters may be acceptable.



2.44 QoS REJECTED (0X2D)

The QoS Rejected error code indicates that the specified quality of service parameters can not be accepted and QoS negotiation should be terminated.

2.45 CHANNEL CLASSIFICATION NOT SUPPORTED (0X2E)

The Channel Classification Not Supported error code indicates that the controller can not perform channel classification because it is not supported.

2.46 INSUFFICIENT SECURITY (0X2F)

The Insufficient Security error code indicates that the HCI command or LMP message sent is only possible on an encrypted link.

2.47 PARAMETER OUT OF MANDATORY RANGE (0X30)

The Parameter Out Of Mandatory Range error code indicates that a parameter value requested is outside the mandatory range of parameters for the given HCI command or LMP message.

2.48 ROLE SWITCH PENDING (0X32)

The Role Switch Pending error code indicates that a Role Switch is pending. This can be used when an HCI command or LMP message can not be accepted because of a pending role switch. This can also be used to notify a peer device about a pending role switch.

2.49 RESERVED SLOT VIOLATION (0X34)

The Reserved Slot Violation error code indicates that the current Synchronous negotiation was terminated with the negotiation state set to Reserved Slot Violation.

2.50 ROLE SWITCH FAILED (0X35)

The Role Switch Failed error code indicates that a role switch was attempted but it failed and the original piconet structure is restored. The switch may have failed because the TDD switch or piconet switch failed.





HOST CONTROLLER INTERFACE FUNCTIONAL SPECIFICATION

This document describes the functional specification for the Host Controller Interface (HCI). The HCI provides a command interface to the baseband controller and link manager, and access to configuration parameters. This interface provides a uniform method of accessing the Bluetooth baseband capabilities.





CONTENTS

| | | |
|----------|---|------------|
| 1 | Introduction | 343 |
| 1.1 | Lower Layers of the Bluetooth Software Stack | 343 |
| 2 | Overview of Host Controller Transport Layer..... | 345 |
| 3 | Overview of Commands and Events | 347 |
| 3.1 | Generic Events..... | 348 |
| 3.2 | Device Setup..... | 348 |
| 3.3 | Controller Flow Control | 349 |
| 3.4 | Controller Information..... | 349 |
| 3.5 | Controller Configuration | 350 |
| 3.6 | Device Discovery | 351 |
| 3.7 | Connection Setup | 353 |
| 3.8 | Remote Information..... | 355 |
| 3.9 | Synchronous Connections | 356 |
| 3.10 | Connection State..... | 357 |
| 3.11 | Piconet Structure..... | 358 |
| 3.12 | Quality of Service | 359 |
| 3.13 | Physical Links | 360 |
| 3.14 | Host Flow Control..... | 361 |
| 3.15 | Link Information | 362 |
| 3.16 | Authentication and Encryption | 363 |
| 3.17 | Testing..... | 365 |
| 3.18 | Alphabetical List of Commands and Events | 366 |
| 4 | HCI Flow Control | 371 |
| 4.1 | Host to Controller Data Flow Control | 371 |
| 4.2 | Controller to Host Data Flow Control | 372 |
| 4.3 | Disconnection Behavior | 373 |
| 4.4 | Command Flow Control | 373 |
| 4.5 | Command Error Handling | 374 |
| 5 | HCI Data Formats | 375 |
| 5.1 | Introduction | 375 |
| 5.2 | Data and Parameter Formats..... | 375 |
| 5.3 | Connection Handles..... | 376 |
| 5.4 | Exchange of HCI-Specific Information | 377 |
| 5.4.1 | HCI Command Packet..... | 377 |
| 5.4.2 | HCI ACL Data Packets..... | 379 |
| 5.4.3 | HCI Synchronous Data Packets..... | 381 |
| 5.4.4 | HCI Event Packet..... | 382 |
| 6 | HCI Configuration Parameters | 383 |



| | | |
|----------|---|------------|
| 6.1 | Scan Enable | 383 |
| 6.2 | Inquiry Scan Interval | 383 |
| 6.3 | Inquiry Scan Window | 384 |
| 6.4 | Inquiry Scan Type | 384 |
| 6.5 | Inquiry Mode | 384 |
| 6.6 | Page Timeout..... | 385 |
| 6.7 | Connection Accept Timeout..... | 385 |
| 6.8 | Page Scan Interval | 386 |
| 6.9 | Page Scan Window | 386 |
| 6.10 | Page Scan Period Mode (Deprecated)..... | 386 |
| 6.11 | Page Scan Type | 387 |
| 6.12 | Voice Setting..... | 387 |
| 6.13 | PIN Type | 388 |
| 6.14 | Link Key | 388 |
| 6.15 | Authentication Enable..... | 388 |
| 6.16 | Encryption Mode..... | 389 |
| 6.17 | Failed Contact Counter | 390 |
| 6.18 | Hold Mode Activity | 390 |
| 6.19 | Link Policy Settings..... | 391 |
| 6.20 | Flush Timeout | 392 |
| 6.21 | Num Broadcast Retransmissions | 392 |
| 6.22 | Link Supervision Timeout..... | 393 |
| 6.23 | Synchronous Flow Control Enable | 393 |
| 6.24 | Local Name..... | 394 |
| 6.25 | Class Of Device | 394 |
| 6.26 | Supported Commands..... | 395 |
| 7 | HCI Commands and Events | 399 |
| 7.1 | Link Control Commands | 399 |
| 7.1.1 | Inquiry Command..... | 399 |
| 7.1.2 | Inquiry Cancel Command..... | 401 |
| 7.1.3 | Periodic Inquiry Mode Command..... | 402 |
| 7.1.4 | Exit Periodic Inquiry Mode Command..... | 405 |
| 7.1.5 | Create Connection Command..... | 406 |
| 7.1.6 | Disconnect Command..... | 409 |
| 7.1.7 | Create Connection Cancel Command | 410 |
| 7.1.8 | Accept Connection Request Command | 412 |
| 7.1.9 | Reject Connection Request Command..... | 414 |
| 7.1.10 | Link Key Request Reply Command | 415 |
| 7.1.11 | Link Key Request Negative Reply Command | 417 |
| 7.1.12 | PIN Code Request Reply Command | 418 |
| 7.1.13 | PIN Code Request Negative Reply Command | 420 |



| | | |
|--------|--|-----|
| 7.1.14 | Change Connection Packet Type Command | 421 |
| 7.1.15 | Authentication Requested Command..... | 424 |
| 7.1.16 | Set Connection Encryption Command | 425 |
| 7.1.17 | Change Connection Link Key Command | 426 |
| 7.1.18 | Master Link Key Command | 427 |
| 7.1.19 | Remote Name Request Command | 428 |
| 7.1.20 | Remote Name Request Cancel Command | 430 |
| 7.1.21 | Read Remote Supported Features Command..... | 431 |
| 7.1.22 | Read Remote Extended Features Command | 432 |
| 7.1.23 | Read Remote Version Information Command..... | 433 |
| 7.1.24 | Read Clock Offset Command..... | 434 |
| 7.1.25 | Read LMP Handle Command | 435 |
| 7.1.26 | Setup Synchronous Connection Command | 437 |
| 7.1.27 | Accept Synchronous Connection Request Command | 442 |
| 7.1.28 | Reject Synchronous Connection Request Command | 446 |
| 7.2 | Link Policy Commands..... | 447 |
| 7.2.1 | Hold Mode Command | 447 |
| 7.2.2 | Sniff Mode Command..... | 449 |
| 7.2.3 | Exit Sniff Mode Command..... | 452 |
| 7.2.4 | Park State Command | 453 |
| 7.2.5 | Exit Park State Command | 455 |
| 7.2.6 | QoS Setup Command | 456 |
| 7.2.7 | Role Discovery Command..... | 458 |
| 7.2.8 | Switch Role Command..... | 459 |
| 7.2.9 | Read Link Policy Settings Command | 460 |
| 7.2.10 | Write Link Policy Settings Command | 461 |
| 7.2.11 | Read Default Link Policy Settings Command | 463 |
| 7.2.12 | Write Default Link Policy Settings Command | 464 |
| 7.2.13 | Flow Specification Command | 465 |
| 7.3 | Controller & Baseband Commands..... | 467 |
| 7.3.1 | Set Event Mask Command..... | 467 |
| 7.3.2 | Reset Command | 469 |
| 7.3.3 | Set Event Filter Command | 470 |
| 7.3.4 | Flush Command..... | 475 |
| 7.3.5 | Read PIN Type Command | 477 |
| 7.3.6 | Write PIN Type Command..... | 478 |
| 7.3.7 | Create New Unit Key Command | 479 |
| 7.3.8 | Read Stored Link Key Command..... | 480 |



| | | |
|--------|---|-----|
| 7.3.9 | Write Stored Link Key Command | 481 |
| 7.3.10 | Delete Stored Link Key Command | 483 |
| 7.3.11 | Write Local Name Command | 484 |
| 7.3.12 | Read Local Name Command | 485 |
| 7.3.13 | Read Connection Accept Timeout Command | 486 |
| 7.3.14 | Write Connection Accept Timeout Command | 487 |
| 7.3.15 | Read Page Timeout Command | 488 |
| 7.3.16 | Write Page Timeout Command | 489 |
| 7.3.17 | Read Scan Enable Command | 490 |
| 7.3.18 | Write Scan Enable Command | 491 |
| 7.3.19 | Read Page Scan Activity Command | 492 |
| 7.3.20 | Write Page Scan Activity Command | 494 |
| 7.3.21 | Read Inquiry Scan Activity Command | 495 |
| 7.3.22 | Write Inquiry Scan Activity Command | 496 |
| 7.3.23 | Read Authentication Enable Command | 497 |
| 7.3.24 | Write Authentication Enable Command | 498 |
| 7.3.25 | Read Encryption Mode Command | 499 |
| 7.3.26 | Write Encryption Mode Command | 500 |
| 7.3.27 | Read Class of Device Command | 501 |
| 7.3.28 | Write Class of Device Command | 502 |
| 7.3.29 | Read Voice Setting Command | 503 |
| 7.3.30 | Write Voice Setting Command | 504 |
| 7.3.31 | Read Automatic Flush Timeout Command | 505 |
| 7.3.32 | Write Automatic Flush Timeout Command | 506 |
| 7.3.33 | Read Num Broadcast Retransmissions Command | 507 |
| 7.3.34 | Write Num Broadcast Retransmissions Command | 508 |
| 7.3.35 | Read Hold Mode Activity Command | 509 |
| 7.3.36 | Write Hold Mode Activity Command | 510 |
| 7.3.37 | Read Transmit Power Level Command | 511 |
| 7.3.38 | Read Synchronous Flow Control Enable Command | 513 |
| 7.3.39 | Write Synchronous Flow Control Enable Command | 514 |
| 7.3.40 | Set Controller To Host Flow Control Command | 515 |
| 7.3.41 | Host Buffer Size Command | 516 |
| 7.3.42 | Host Number Of Completed Packets Command | 518 |
| 7.3.43 | Read Link Supervision Timeout Command | 520 |
| 7.3.44 | Write Link Supervision Timeout Command | 521 |
| 7.3.45 | Read Number Of Supported IAC Command | 523 |
| 7.3.46 | Read Current IAC LAP Command | 524 |



| | | |
|--------|---|-----|
| 7.3.47 | Write Current IAC LAP Command..... | 525 |
| 7.3.48 | Read Page Scan Period Mode Command (Deprecated) | 527 |
| 7.3.49 | Write Page Scan Period Mode Command (Deprecated) | 528 |
| 7.3.50 | Set AFH Host Channel Classification Command | 529 |
| 7.3.51 | Read Inquiry Scan Type Command | 530 |
| 7.3.52 | Write Inquiry Scan Type Command | 531 |
| 7.3.53 | Read Inquiry Mode Command | 532 |
| 7.3.54 | Write Inquiry Mode Command | 533 |
| 7.3.55 | Read Page Scan Type Command | 534 |
| 7.3.56 | Write Page Scan Type Command | 535 |
| 7.3.57 | Read AFH Channel Assessment Mode Command | 536 |
| 7.3.58 | Write AFH Channel Assessment Mode Command | 537 |
| 7.4 | Informational Parameters..... | 539 |
| 7.4.1 | Read Local Version Information Command..... | 539 |
| 7.4.2 | Read Local Supported Commands Command..... | 541 |
| 7.4.3 | Read Local Supported Features Command..... | 542 |
| 7.4.4 | Read Local Extended Features Command | 543 |
| 7.4.5 | Read Buffer Size Command..... | 545 |
| 7.4.6 | Read BD_ADDR Command | 547 |
| 7.5 | Status Parameters..... | 548 |
| 7.5.1 | Read Failed Contact Counter Command | 548 |
| 7.5.2 | Reset Failed Contact Counter Command | 550 |
| 7.5.3 | Read Link Quality Command | 551 |
| 7.5.4 | Read RSSI Command..... | 552 |
| 7.5.5 | Read AFH Channel Map Command | 554 |
| 7.5.6 | Read Clock Command | 556 |
| 7.6 | Testing Commands | 558 |
| 7.6.1 | Read Loopback Mode Command | 558 |
| 7.6.2 | Write Loopback Mode Command..... | 559 |
| 7.6.3 | Enable Device Under Test Mode Command | 562 |
| 7.7 | Events | 563 |
| 7.7.1 | Inquiry Complete Event..... | 563 |
| 7.7.2 | Inquiry Result Event | 564 |
| 7.7.3 | Connection Complete Event..... | 566 |
| 7.7.4 | Connection Request Event..... | 567 |
| 7.7.5 | Disconnection Complete Event | 569 |
| 7.7.6 | Authentication Complete Event..... | 570 |



| | | |
|-----------|--|------------|
| 7.7.7 | Remote Name Request Complete Event | 571 |
| 7.7.8 | Encryption Change Event | 572 |
| 7.7.9 | Change Connection Link Key Complete Event | 573 |
| 7.7.10 | Master Link Key Complete Event | 574 |
| 7.7.11 | Read Remote Supported Features Complete Event... | 575 |
| 7.7.12 | Read Remote Version Information Complete Event ... | 576 |
| 7.7.13 | QoS Setup Complete Event | 577 |
| 7.7.14 | Command Complete Event | 579 |
| 7.7.15 | Command Status Event | 580 |
| 7.7.16 | Hardware Error Event | 581 |
| 7.7.17 | Flush Occurred Event | 581 |
| 7.7.18 | Role Change Event | 582 |
| 7.7.19 | Number Of Completed Packets Event | 583 |
| 7.7.20 | Mode Change Event | 584 |
| 7.7.21 | Return Link Keys Event | 586 |
| 7.7.22 | PIN Code Request Event | 587 |
| 7.7.23 | Link Key Request Event | 588 |
| 7.7.24 | Link Key Notification Event | 589 |
| 7.7.25 | Loopback Command Event | 590 |
| 7.7.26 | Data Buffer Overflow Event | 590 |
| 7.7.27 | Max Slots Change Event | 591 |
| 7.7.28 | Read Clock Offset Complete Event | 592 |
| 7.7.29 | Connection Packet Type Changed Event | 593 |
| 7.7.30 | QoS Violation Event | 596 |
| 7.7.31 | Page Scan Repetition Mode Change Event | 597 |
| 7.7.32 | Flow Specification Complete Event | 598 |
| 7.7.33 | Inquiry Result with RSSI Event | 600 |
| 7.7.34 | Read Remote Extended Features Complete Event | 602 |
| 7.7.35 | Synchronous Connection Complete Event | 603 |
| 7.7.36 | Synchronous Connection Changed event | 605 |
| 8 | List of Figures | 607 |
| 9 | List of Tables | 609 |
| 10 | Appendix | 609 |

1 INTRODUCTION

This document describes the functional specifications for the Host Controller Interface (HCI). The HCI provides a uniform interface method of accessing the Bluetooth controller capabilities. The next two sections provide a brief overview of the lower layers of the Bluetooth software stack and of the Bluetooth hardware. Section 2, provides an overview of the Lower HCI Device Driver Interface on the host device. Section 4, describes the flow control used between the Host and the Controller. Section 7, describes each of the HCI Commands in details, identifies parameters for each of the commands, and lists events associated with each command.

1.1 LOWER LAYERS OF THE BLUETOOTH SOFTWARE STACK

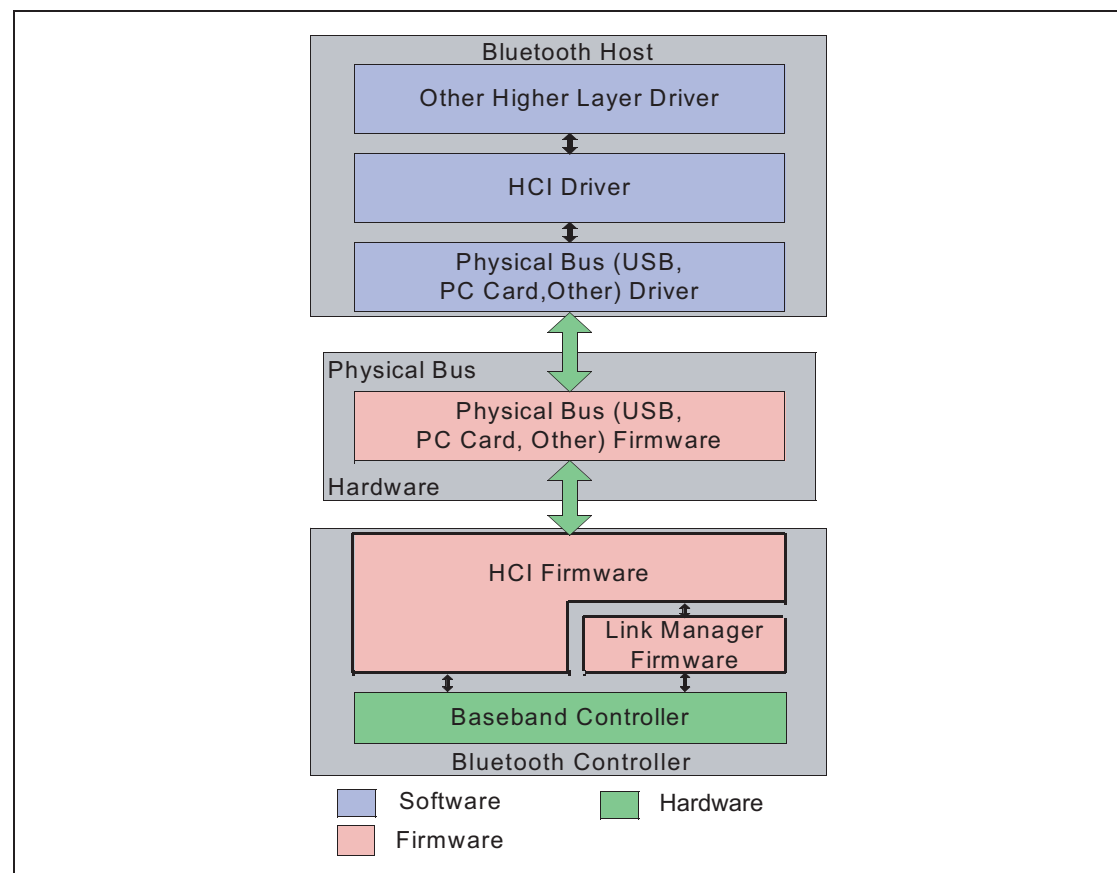


Figure 1.1: Overview of the Lower Software Layers

Figure 1.1, provides an overview of the lower software layers. The HCI firmware implements the HCI Commands for the Bluetooth hardware by accessing baseband commands link manager commands, hardware status registers, control registers, and event registers.

Several layers may exist between the HCI driver on the host system and the HCI firmware in the Bluetooth hardware. These intermediate layers, the Host

Controller Transport Layer, provide the ability to transfer data without intimate knowledge of the data.

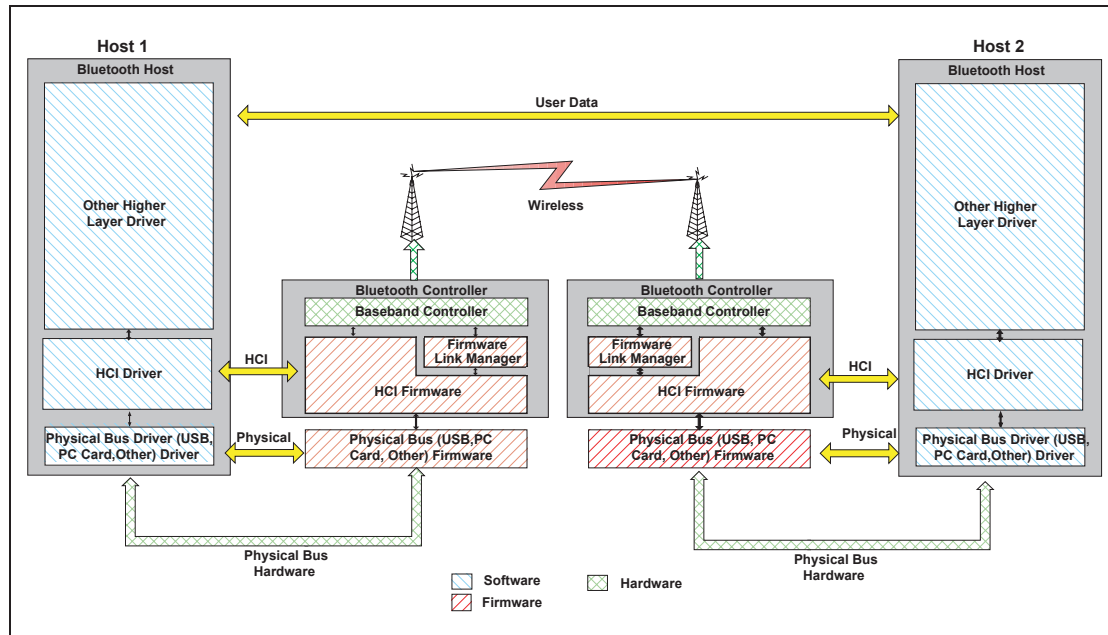


Figure 1.2: End to End Overview of Lower Software Layers to Transfer Data

Figure 1.2, illustrates the path of a data transfer from one device to another. The HCI driver on the Host exchanges data and commands with the HCI firmware on the Bluetooth hardware. The Host Control Transport Layer (i.e. physical bus) driver provides both HCI layers with the ability to exchange information with each other.

The Host will receive asynchronous notifications of HCI events independent of which Host Controller Transport Layer is used. HCI events are used for notifying the Host when something occurs. When the Host discovers that an event has occurred it will then parse the received event packet to determine which event occurred.

2 OVERVIEW OF HOST CONTROLLER TRANSPORT LAYER

The host driver stack has a transport layer between the Host Controller driver and the Host.

The main goal of this transport layer is transparency. The Host Controller driver (which interfaces to the Controller) should be independent of the underlying transport technology. Nor should the transport require any visibility into the data that the Host Controller driver passes to the Controller. This allows the interface (HCI) or the Controller to be upgraded without affecting the transport layer.

The specified Host Controller Transport Layers are described in a separate volume. (See specification volume 4)



3 OVERVIEW OF COMMANDS AND EVENTS

The commands and events are sent between the Host and the Controller. These are grouped into logical groups by function.

| | |
|--------------------------------------|--|
| Generic Events | The generic events can occur due to multiple commands, or events that can occur at any time. |
| Device Setup | The device setup commands are used to place the Controller into a known state. |
| Controller Flow Control | The controller flow control commands and events are used to control data flow from the Host to the controller. |
| Controller Information | The controller information commands allow the Host to discover local information about the device. |
| Controller Configuration | The controller configuration commands and events allow the global configuration parameters to be configured. |
| Device Discovery | The device discovery commands and events allow a device to discover other devices in the surrounding area. |
| Connection Setup | The connection setup commands and events allow a device to make a connection to another device. |
| Remote Information | The remote information commands and events allow information about a remote device's configuration to be discovered. |
| Synchronous Connections | The synchronous connection commands and events allow synchronous connections to be created |
| Connection State | The connection state commands and events allow the configuration of a link, especially for low power operation. |
| Piconet Structure | The piconet structure commands and events allow the discovery and reconfiguration of piconet. |
| Quality of Service | The quality of service commands and events allow quality of service parameters to be specified. |
| Physical Links | The physical link commands and events allow the configuration of a physical link. |
| Host Flow Control | The Host flow control commands and events allow flow control to be used towards the Host. |
| Link Information | The link information commands and events allow information about a link to be read. |
| Authentication and Encryption | The authentication and encryption commands and events allow authentication of a remote device and then encryption of the link. |
| Testing | The testing commands and events allow a device to be placed into test mode. |

Table 3.1: Overview of commands and events

The version information in this section denotes the version number of the specification that this command or event was first specified

3.1 GENERIC EVENTS

The generic events occur due to multiple commands, or events that can occur at any time.

| Name | Vers. | Summary description |
|------------------------|-------|---|
| Command Complete Event | 1.1 | The Command Complete event is used by the Controller to pass the return status of a command and the other event parameters for each HCI Command. |
| Command Status Event | 1.1 | The Command Status event is used to indicate that the command described by the Command_Opcode parameter has been received and the Controller is currently performing the task for this command. |
| Hardware Error Event | 1.1 | The Hardware Error event is used to indicate some type of hardware failure for the Controller. |

Table 3.2: Generic events

3.2 DEVICE SETUP

The device setup group of commands are used to place the Controller into a known state.

| Name | Vers. | Summary description |
|---------------|-------|---|
| Reset Command | 1.1 | The Reset command will reset the Controller, Link Manager, and the Bluetooth radio. |

Device setup

3.3 CONTROLLER FLOW CONTROL

The controller flow control group of commands and events are used to control data flow from the Host to the Controller.

| Name | Vers. | Summary description |
|-----------------------------------|-------|---|
| Read Buffer Size Command | 1.1 | The Read_Buffer_Size command returns the size of the HCI buffers. These buffers are used by the Controller to buffer data that is to be transmitted. |
| Number Of Completed Packets Event | 1.1 | The Number Of Completed Packets event is used by the Controller to indicate to the Host how many HCI Data Packets have been completed for each Connection Handle since the previous Number Of Completed Packets event was sent. |

Table 3.3: Controller flow control

3.4 CONTROLLER INFORMATION

The controller information group of commands allows the Host to discover local information about the device.

| Name | Vers. | Summary description |
|--|-------|---|
| Read Local Version Information Command | 1.1 | The Read Local Version Information command will read the version information for the local Bluetooth device. |
| Read Local Supported Commands Command | 1.2 | The Read Local Supported Commands command requests a list of the supported HCI commands for the local device. |
| Read Local Supported Features Command | 1.1 | The Read Local Supported Features command requests a list of the supported features for the local device. |
| Read Local Extended Features Command | 1.2 | The Read Local Extended Features command requests a list of the supported extended features for the local device. |
| Read BD_ADDR Command | 1.1 | The Read BD_ADDR command will read the value for the BD_ADDR parameter. |

Table 3.4: Controller information

3.5 CONTROLLER CONFIGURATION

The controller configuration group of commands and events allows the global configuration parameters to be configured.

| Name | Vers. | Summary description |
|--------------------------------------|-------|---|
| Read Local Name Command | 1.1 | The Read Local Name command provides the ability to read the stored user-friendly name for the Bluetooth device. |
| Write Local Name Command | 1.1 | The Write Local Name command provides the ability to modify the user-friendly name for the Bluetooth device. |
| Read Class of Device Command | 1.1 | The Read Class of Device command will read the value for the Class of Device configuration parameter, which is used to indicate its capabilities to other devices. |
| Write Class of Device Command | 1.1 | The Write Class of Device command will write the value for the Class_of_Device configuration parameter, which is used to indicate its capabilities to other devices. |
| Read Number Of Supported IAC Command | 1.1 | The Read Number of Supported IAC command will read the value for the number of Inquiry Access Codes (IAC) that the local Bluetooth device can simultaneously listen for during an Inquiry Scan. |
| Read Current IAC LAP Command | 1.1 | The Read Current IAC LAP command will read the LAP(s) used to create the Inquiry Access Codes (IAC) that the local Bluetooth device is simultaneously scanning for during Inquiry Scans. |
| Write Current IAC LAP Command | 1.1 | The Write Current IAC LAP command will write the LAP(s) used to create the Inquiry Access Codes (IAC) that the local Bluetooth device is simultaneously scanning for during Inquiry Scans. |
| Read Scan Enable Command | 1.1 | The Read Scan Enable command will read the value for the Scan Enable configuration parameter, which controls whether or not the Bluetooth device will periodically scan for page attempts and/or inquiry requests from other Bluetooth devices. |
| Write Scan Enable Command | 1.1 | The Write Scan Enable command will write the value for the Scan Enable configuration parameter, which controls whether or not the Bluetooth device will periodically scan for page attempts and/or inquiry requests from other Bluetooth devices. |

Table 3.5: Controller configuration

3.6 DEVICE DISCOVERY

The device discovery group of commands and events allow a device to discover other devices in the surrounding area.

| Name | Vers. | Summary description |
|-------------------------------------|-------|---|
| Inquiry Command | 1.1 | The Inquiry command will cause the Bluetooth device to enter Inquiry Mode. Inquiry Mode is used to discover other nearby Bluetooth devices. |
| Inquiry Result Event | 1.1 | The Inquiry Result event indicates that a Bluetooth device or multiple Bluetooth devices have responded so far during the current Inquiry process. |
| Inquiry Result with RSSI Event | 1.2 | The Inquiry Result with RSSI event indicates that a Bluetooth device or multiple Bluetooth devices have responded so far during the current Inquiry process. |
| Inquiry Cancel Command | 1.1 | The Inquiry Cancel command will cause the Bluetooth device to stop the current Inquiry if the Bluetooth device is in Inquiry Mode. |
| Inquiry Complete Event | 1.1 | The Inquiry Complete event indicates that the Inquiry is finished. |
| Periodic Inquiry Mode Command | 1.1 | The Periodic Inquiry Mode command is used to configure the Bluetooth device to perform an automatic Inquiry based on a specified period range. |
| Exit Periodic Inquiry Mode Command | 1.1 | The Exit Periodic Inquiry Mode command is used to end the Periodic Inquiry mode when the local device is in Periodic Inquiry Mode. |
| Read Inquiry Scan Activity Command | 1.1 | The Read Inquiry Scan Activity command will read the value for Inquiry Scan Interval and Inquiry Scan Window configuration parameters. Inquiry Scan Interval defines the amount of time between consecutive inquiry scans. Inquiry Scan Window defines the amount of time for the duration of the inquiry scan. |
| Write Inquiry Scan Activity Command | 1.1 | The Write Inquiry Scan Activity command will write the value for Inquiry Scan Interval and Inquiry Scan Window configuration parameters. Inquiry Scan Interval defines the amount of time between consecutive inquiry scans. Inquiry Scan Window defines the amount of time for the duration of the inquiry scan. |
| Read Inquiry Scan Type Command | 1.2 | The Read Inquiry Scan Type command is used to read the Inquiry Scan Type configuration parameter of the local Bluetooth device. The Inquiry Scan Type configuration parameter can set the inquiry scan to either normal or interlaced scan. |

Table 3.6: Device discovery



| Name | Vers. | Summary description |
|---------------------------------|-------|---|
| Write Inquiry Scan Type Command | 1.2 | The Write Inquiry Scan Type command is used to write the Inquiry Scan Type configuration parameter of the local Bluetooth device. The Inquiry Scan Type configuration parameter can set the inquiry scan to either normal or interlaced scan. |
| Read Inquiry Mode Command | 1.2 | The Read Inquiry Mode command is used to read the Inquiry Mode configuration parameter of the local Bluetooth device. |
| Write Inquiry Mode Command | 1.2 | The Write Inquiry Mode command is used to write the Inquiry Mode configuration parameter of the local Bluetooth device. |

Table 3.6: Device discovery

3.7 CONNECTION SETUP

The connection setup group of commands and events are used to allow a device to make a connection to another device.

| Name | Vers. | Summary description |
|-----------------------------------|-------|--|
| Create Connection Command | 1.1 | The Create Connection command will cause the link manager to create an ACL connection to the Bluetooth device with the BD_ADDR specified by the command parameters. |
| Connection Request Event | 1.1 | The Connection Request event is used to indicate that a new incoming connection is trying to be established. |
| Accept Connection Request Command | 1.1 | The Accept Connection Request command is used to accept a new incoming connection request. |
| Reject Connection Request Command | 1.1 | The Reject Connection Request command is used to decline a new incoming connection request. |
| Create Connection Cancel Command | 1.2 | The Create Connection Cancel Command is used to cancel an ongoing Create Connection. |
| Connection Complete Event | 1.1 | The Connection Complete event indicates to both of the Hosts forming the connection that a new connection has been established. |
| Disconnect Command | 1.1 | The Disconnect command is used to terminate an existing connection. |
| Disconnection Complete Event | 1.1 | The Disconnection Complete event occurs when a connection has been terminated. |
| Read Page Timeout Command | 1.1 | The Read Page Timeout command will read the value for the Page Reply Timeout configuration parameter, which determines the time the Bluetooth controller will wait for the remote device to respond to a connection request before the local device returns a connection failure. |
| Write Page Timeout Command | 1.1 | The Write Page Timeout command will write the value for the Page Reply Timeout configuration parameter, which allows the Bluetooth hardware to define the amount of time a connection request will wait for the remote device to respond before the local device returns a connection failure. |
| Read Page Scan Activity Command | 1.1 | The Read Page Scan Activity command will read the values for the Page Scan Interval and Page Scan Window configuration parameters. Page Scan Interval defines the amount of time between consecutive page scans. Page Scan Window defines the duration of the page scan. |

Table 3.7: Connection setup

| Name | Vers. | Summary description |
|---|-------|---|
| Write Page Scan Activity Command | 1.1 | The Write Page Scan Activity command will write the value for Page Scan Interval and Page Scan Window configuration parameters. Page Scan Interval defines the amount of time between consecutive page scans. Page Scan Window defines the duration of the page scan. |
| Page Scan Repetition Mode Change Event | 1.1 | The Page Scan Repetition Mode Change event indicates that the connected remote Bluetooth device with the specified Connection_Handle has successfully changed the Page_Scan_Repetition_Mode (SR)." |
| Read Page Scan Type Command | 1.2 | The Read Page Scan Type command is used to read the page scan type of the local Bluetooth device. The Page Scan Type configuration parameter can set the page scan to either normal or interlaced scan. |
| Write Page Scan Type Command | 1.2 | The Write Page Scan Type command is used to write the page scan type of the local Bluetooth device. The Page Scan Type configuration parameter can set the page scan to either normal or interlaced scan. |
| Read Connection Accept Timeout Command | 1.1 | The Read Connection Accept Timeout command will read the value for the Connection Accept Timeout configuration parameter, which allows the Bluetooth hardware to automatically deny a connection request after a specified period has occurred, and to refuse a new connection. |
| Write Connection Accept Timeout Command | 1.1 | The Write Connection Accept Timeout command will write the value for the Connection Accept Timeout configuration parameter, which allows the Bluetooth hardware to automatically deny a connection request after a specified period has occurred, and to refuse a new connection. |

Table 3.7: Connection setup

3.8 REMOTE INFORMATION

The remote information group of commands and events allows information about a remote devices configuration to be discovered.

| Name | Vers. | Summary description |
|--|-------|---|
| Remote Name Request Command | 1.1 | The Remote Name Request command is used to obtain the user-friendly name of another Bluetooth device. |
| Remote Name Request Cancel Command | 1.2 | The Remote Name Request Cancel Command is used to cancel an ongoing Remote Name Request. |
| Remote Name Request Complete Event | 1.1 | The Remote Name Request Complete event is used to indicate a remote name request has been completed. |
| Read Remote Supported Features Command | 1.1 | The Read Remote Supported Features command requests a list of the supported features of a remote device. |
| Read Remote Supported Features Complete Event | 1.1 | The Read Remote Supported Features Complete event is used to indicate the completion of the process of the Link Manager obtaining the supported features of the remote Bluetooth device specified by the Connection Handle event parameter. |
| Read Remote Extended Features Command | 1.2 | The Read Remote Extended Features command requests a list of the supported extended features of a remote device |
| Read Remote Extended Features Complete Event | 1.2 | The Read Remote Extended Features Complete Event is used to indicate the completion of the process of the Link Manager obtaining the supported Extended features of the remote Bluetooth device specified by the connection handle event parameter. |
| Read Remote Version Information Command | 1.1 | The Read Remote Version Information command will read the values for the version information for the remote Bluetooth device. |
| Read Remote Version Information Complete Event | 1.1 | The Read Remote Version Information Complete event is used to indicate the completion of the process of the Link Manager obtaining the version information of the remote Bluetooth device specified by the Connection Handle event parameter. |

Table 3.8: Remote information

3.9 SYNCHRONOUS CONNECTIONS

The synchronous connections group of commands and events allows synchronous connections to be created.

| Name | Vers. | Summary description |
|---|-------|---|
| Setup Synchronous Connection Command | 1.2 | The Setup Synchronous Connection command adds a new or modifies an existing synchronous logical transport (SCO or eSCO) on a physical link depending on the Connection Handle parameter specified. |
| Synchronous Connection Complete Event | 1.2 | The Synchronous Connection Complete event indicates to both the Hosts that a new Synchronous connection has been established. |
| Synchronous Connection Changed event | 1.2 | The Synchronous Connection Changed event indicates to the Host that an existing Synchronous connection has been reconfigured. |
| Accept Synchronous Connection Request Command | 1.2 | The Accept_Synchronous_Connection_Request command is used to accept an incoming request for a synchronous connection and to inform the local Link Manager about the acceptable parameter values for the synchronous connection. |
| Reject Synchronous Connection Request Command | 1.2 | The Reject_Synchronous_Connection_Request is used to decline an incoming request for a synchronous link. |
| Read Voice Setting Command | 1.1 | The Read Voice Setting command will read the values for the Voice Setting configuration parameter, which controls all the various settings for the voice connections. |
| Write Voice Setting Command | 1.1 | The Write Voice Setting command will write the values for the Voice Setting configuration parameter, which controls all the various settings for the voice connections. |

Table 3.9: Synchronous connections

3.10 CONNECTION STATE

The connection state group of commands and events allows the configuration of a link, especially for low power operation.

| Name | Vers. | Summary description |
|--|-------|--|
| Mode Change Event | 1.1 | The Mode Change event is used to indicate that the current mode has changed. |
| Max Slots Change Event | 1.1 | The Max Slots Change event is used to indicate a change in the max slots by the LM. |
| Hold Mode Command | 1.1 | The Hold Mode command is used to initiate Hold Mode. |
| Sniff Mode Command | 1.1 | The Sniff Mode command is used to alter the behavior of the LM and have the LM place the local or remote device into the sniff mode. |
| Exit Sniff Mode Command | 1.1 | The Exit Sniff Mode command is used to end the sniff mode for a connection handle which is currently in sniff mode. |
| Park State Command | 1.1 | The Park State command is used to alter the behavior of the LM and have the LM place the local or remote device into the park state. |
| Exit Park State Command | 1.1 | The Exit Park State command is used to switch the Bluetooth device from park state back to active mode. |
| Read Link Policy Settings Command | 1.1 | The Read Link Policy Settings command will read the Link Policy configuration parameter for the specified Connection Handle. The Link Policy settings allow the Host to specify which Link Modes the LM can use for the specified Connection Handle. |
| Write Link Policy Settings Command | 1.1 | The Write Link Policy Settings command will write the Link Policy configuration parameter for the specified Connection Handle. The Link Policy settings allow the Host to specify which Link Modes the LM can use for the specified Connection Handle. |
| Read Default Link Policy Settings Command | 1.2 | The Read Default Link Policy Settings command will read the Default Link Policy configuration parameter for all new connections. |
| Write Default Link Policy Settings Command | 1.2 | The Write Default Link Policy Settings command will write the Default Link Policy configuration parameter for all new connections. |

Table 3.10: Connection state



3.11 PICONET STRUCTURE

The piconet structure group of commands and events allows the discovery and reconfiguration a piconet.

| Name | Vers. | Summary description |
|------------------------|-------|--|
| Role Discovery Command | 1.1 | The Role Discovery command is used for a Bluetooth device to determine which role the device is performing for a particular Connection Handle. |
| Switch Role Command | 1.1 | The Switch Role command is used to switch master and slave roles of the devices on either side of a connection. |
| Role Change Event | 1.1 | The Role Change event is used to indicate that the current Bluetooth role related to the particular connection has been changed. |

Table 3.11: Piconet structure

3.12 QUALITY OF SERVICE

The quality of service group of commands and events allows the configuration of links to allow for quality of service parameters to be specified.

| Name | Vers. | Summary description |
|---|-------|---|
| Flow Specification Command | 1.2 | The Flow Specification command is used to specify the flow parameters for the traffic carried over the ACL connection identified by the Connection Handle. |
| Flow Specification Complete Event | 1.2 | The Flow Specification Complete event is used to inform the Host about the Quality of Service for the ACL connection the Controller is able to support. |
| QoS Setup Command | 1.1 | The QoS Setup command is used to specify Quality of Service parameters for a connection handle. |
| QoS Setup Complete Event | 1.1 | The QoS Setup Complete event is used to indicate that QoS is setup. |
| QoS Violation Event | 1.1 | The QoS Violation event is used to indicate the Link Manager is unable to provide the current QoS requirement for the Connection Handle. |
| Flush Command | 1.1 | The Flush command is used to discard all data that is currently pending for transmission in the Controller for the specified connection handle. |
| Flush Occurred Event | 1.1 | The Flush Occurred event is used to indicate that, for the specified Connection Handle, the data to be transmitted has been discarded. |
| Read Automatic Flush Timeout Command | 1.1 | The Read Automatic Flush Timeout will read the value for the Flush Timeout configuration parameter for the specified connection handle. The Flush Timeout parameter is only used for ACL connections. |
| Write Automatic Flush Timeout Command | 1.1 | The Write Automatic Flush Timeout will write the value for the Flush Timeout configuration parameter for the specified connection handle. The Flush Timeout parameter is only used for ACL connections. |
| Read Failed Contact Counter Command | 1.1 | The Read Failed Contact Counter will read the value for the Failed Contact Counter configuration parameter for a particular connection to another device. |
| Reset Failed Contact Counter Command | 1.1 | The Reset Failed Contact Counter will reset the value for the Failed Contact Counter configuration parameter for a particular connection to another device. |
| Read Num Broadcast Retransmissions Command | 1.1 | The Read Num Broadcast Retransmissions command will read the parameter value for the Number of Broadcast Retransmissions for the device. |
| Write Num Broadcast Retransmissions Command | 1.1 | The Write Num Broadcast Retransmissions command will write the parameter value for the Number of Broadcast Retransmissions for the device. |

Table 3.12: Quality of service

3.13 PHYSICAL LINKS

The physical links commands and events allows configuration of the physical link.

| Name | Vers. | Summary description |
|---|-------|---|
| Read Link Supervision Timeout Command | 1.1 | The Read Link Supervision Timeout command will read the value for the Link Supervision Timeout configuration parameter for the device. This parameter is used by the device to determine link loss. |
| Write Link Supervision Timeout Command | 1.1 | The Write Link Supervision Timeout command will write the value for the Link Supervision Timeout configuration parameter for the device. This parameter is used by the device to determine link loss. |
| Read AFH Channel Assessment Mode Command | 1.2 | The Read AFH Channel Assessment Mode command will read the value for the AFH Channel Classification Mode parameter. This value is used to enable or disable the Controller's channel assessment scheme. |
| Write AFH Channel Assessment Mode Command | 1.2 | The Write AFH Channel Assessment Mode command will write the value for the Channel Classification Mode configuration parameter. This value is used to enable or disable the Controller's channel assessment scheme. |
| Set AFH Host Channel Classification Command | 1.2 | The Set AFH Host Channel Classification command allows the Host to specify a channel classification based on its "local information". |
| Change Connection Packet Type Command | 1.1 | The Change Connection Packet Type command is used to change which packet types can be used for a connection that is currently established. |
| Connection Packet Type Changed Event | 1.1 | The Connection Packet Type Changed event is used to indicate the completion of the process of the Link Manager changing the packet type mask used for the specified Connection Handle. |

Table 3.13: Physical links

3.14 HOST FLOW CONTROL

The Host flow control group of commands and events allows flow control to be used towards the Host.

| Name | Vers. | Summary description |
|---|-------|--|
| Host Buffer Size Command | 1.1 | The Host Buffer Size command is used by the Host to notify the Controller about its buffer sizes for ACL and synchronous data. The Controller will segment the data to be transmitted from the Controller to the Host, so that data contained in HCI Data Packets will not exceed these sizes. |
| Set Event Mask Command | 1.1 | The Set Event Mask command is used to control which events are generated by the HCI for the Host. |
| Set Event Filter Command | 1.1 | The Set Event Filter command is used by the Host to specify different event filters. The Host may issue this command multiple times to request various conditions for the same type of event filter and for different types of event filters. |
| Set Controller To Host Flow Control Command | 1.1 | The Set Controller To Host Flow Control command is used by the Host to turn flow control on or off in the direction from the Controller to the Host. |
| Host Number Of Completed Packets Command | 1.1 | The Host Number Of Completed Packets command is used by the Host to indicate to the Controller when the Host is ready to receive more HCI packets for any connection handle. |
| Data Buffer Overflow Event | 1.1 | The Data Buffer Overflow event is used to indicate that the Controller's data buffers have overflowed, because the Host has sent more packets than allowed. |
| Read Synchronous Flow Control Enable Command | 1.1 | The Read Synchronous Flow Control Enable command provides the ability to read the Synchronous Flow Control Enable setting. By using this setting, the Host can decide if the Controller will send Number Of Completed Packets events for Synchronous Connection Handles. |
| Write Synchronous Flow Control Enable Command | 1.1 | The Write Synchronous Flow Control Enable command provides the ability to write the Synchronous Flow Control Enable setting. By using this setting, the Host can decide if the Controller will send Number Of Completed Packets events for Synchronous Connection Handles. |

Table 3.14: Controller flow control.

3.15 LINK INFORMATION

The link information group of commands and events allows information about a link to be read.

| Name | Vers. | Summary description |
|-----------------------------------|-------|---|
| Read LMP Handle Command | 1.2 | The Read LMP Handle command will read the current LMP Handle associated with the Connection Handle. |
| Read Transmit Power Level Command | 1.1 | The Read Transmit Power Level command will read the values for the Transmit Power Level parameter for the specified Connection Handle. |
| Read Link Quality Command | 1.1 | The Read Link Quality command will read the value for the Link Quality for the specified Connection Handle. |
| Read RSSI Command | 1.1 | The Read RSSI command will read the value for the Received Signal Strength Indication (RSSI) for a connection handle to another Bluetooth device. |
| Read Clock Offset Command | 1.1 | The Read Clock Offset command allows the Host to read the clock offset of remote devices. |
| Read Clock Offset Complete Event | 1.1 | The Read Clock Offset Complete event is used to indicate the completion of the process of the LM obtaining the Clock offset information. |
| Read Clock Command | 1.2 | The Read Clock command will read an estimate of a piconet or the local Bluetooth Clock. |
| Read AFH Channel Map Command | 1.2 | The Read AFH Channel Map command will read the current state of the channel map for a connection. |

Table 3.15: Link information

3.16 AUTHENTICATION AND ENCRYPTION

The authentication and encryption group of commands and events allows authentication of a remote device and then encryption of the link to one or more remote devices.

| Name | Vers. | Summary description |
|---|-------|--|
| Read Authentication Enable Command | 1.1 | The Read Authentication Enable command will read the value for the Authentication Enable parameter, which controls whether the Bluetooth device will require authentication for each connection with other Bluetooth devices. |
| Write Authentication Enable Command | 1.1 | The Write Authentication Enable command will write the value for the Authentication Enable parameter, which controls whether the Bluetooth device will require authentication for each connection with other Bluetooth devices. |
| Read Encryption Mode Command | 1.1 | The Read Encryption Mode command will read the value for the Encryption Mode parameter, which controls whether the Bluetooth device will require encryption for each connection with other Bluetooth devices. |
| Write Encryption Mode Command | 1.1 | The Write Encryption Mode command will write the value for the Encryption Mode parameter, which controls whether the Bluetooth device will require encryption for each connection with other Bluetooth devices. |
| Link Key Request Event | 1.1 | The Link Key Request event is used to indicate that a Link Key is required for the connection with the device specified in BD_ADDR. |
| Link Key Request Reply Command | 1.1 | The Link Key Request Reply command is used to reply to a Link Key Request event from the Controller, and specifies the Link Key stored on the Host to be used as the link key for the connection with the other Bluetooth device specified by BD_ADDR. |
| Link Key Request Negative Reply Command | 1.1 | The Link Key Request Negative Reply command is used to reply to a Link Key Request event from the Controller if the Host does not have a stored Link Key for the connection with the other Bluetooth Device specified by BD_ADDR. |
| PIN Code Request Event | 1.1 | The PIN Code Request event is used to indicate that a PIN code is required to create a new link key for a connection. |
| PIN Code Request Reply Command | 1.1 | The PIN Code Request Reply command is used to reply to a PIN Code Request event from the Controller and specifies the PIN code to use for a connection. |

Table 3.16: Authentication and encryption

| Name | Vers. | Summary description |
|---|-------|--|
| PIN Code Request Negative Reply Command | 1.1 | The PIN Code Request Negative Reply command is used to reply to a PIN Code Request event from the Controller when the Host cannot specify a PIN code to use for a connection. |
| Link Key Notification Event | 1.1 | The Link Key Notification event is used to indicate to the Host that a new Link Key has been created for the connection with the device specified in BD_ADDR. |
| Authentication Requested Command | 1.1 | The Authentication Requested command is used to establish authentication between the two devices associated with the specified Connection Handle. |
| Authentication Complete Event | 1.1 | The Authentication Complete event occurs when authentication has been completed for the specified connection. |
| Set Connection Encryption Command | 1.1 | The Set Connection Encryption command is used to enable and disable the link level encryption. |
| Encryption Change Event | 1.1 | The Encryption Change event is used to indicate that the change in the encryption has been completed for the Connection Handle specified by the Connection Handle event parameter. |
| Change Connection Link Key Command | 1.1 | The Change Connection Link Key command is used to force both devices of a connection associated to the connection handle, to generate a new link key. |
| Change Connection Link Key Complete Event | 1.1 | The Change Connection Link Key Complete event is used to indicate that the change in the Link Key for the Connection Handle specified by the Connection Handle event parameter had been completed. |
| Master Link Key Command | 1.1 | The Master Link Key command is used to force both devices of a connection associated to the connection handle to use the temporary link key of the Master device or the regular link keys. |
| Master Link Key Complete Event | 1.1 | The Master Link Key Complete event is used to indicate that the change in the temporary Link Key or in the semi-permanent link keys on the Bluetooth master side has been completed. |
| Read PIN Type Command | 1.1 | The Read PIN Type command is used for the Host to read the value that is specified to indicate whether the Host supports variable PIN or only fixed PINs. |
| Write PIN Type Command | 1.1 | The Write PIN Type command is used for the Host to specify whether the Host supports variable PIN or only fixed PINs. |
| Read Stored Link Key Command | 1.1 | The Read Stored Link Key command provides the ability to read one or more link keys stored in the Controller. |

Table 3.16: Authentication and encryption

| Name | Vers. | Summary description |
|--------------------------------|-------|--|
| Return Link Keys Event | 1.1 | The Return Link Keys event is used to return stored link keys after a Read Stored Link Key command is used. |
| Write Stored Link Key Command | 1.1 | The Write Stored Link Key command provides the ability to write one or more link keys to be stored in the Controller. |
| Delete Stored Link Key Command | 1.1 | The Delete Stored Link Key command provides the ability to remove one or more of the link keys stored in the Controller. |
| Create New Unit Key Command | 1.1 | The Create New Unit Key command is used to create a new unit key. |

Table 3.16: Authentication and encryption

3.17 TESTING

The testing group of commands and events allows a device to be placed into a special testing mode to allow for testing to be performed.

| Name | Vers. | Summary description |
|---------------------------------------|-------|---|
| Read Loopback Mode Command | 1.1 | The Read Loopback Mode will read the value for the setting of the Controllers Loopback Mode. The setting of the Loopback Mode will determine the path of information. |
| Write Loopback Mode Command | 1.1 | The Write Loopback Mode will write the value for the setting of the Controllers Loopback Mode. The setting of the Loopback Mode will determine the path of information. |
| Loopback Command Event | 1.1 | The Loopback Command event is used to loop back all commands that the Host sends to the Controller with some exceptions. |
| Enable Device Under Test Mode Command | 1.1 | The Enable Device Under Test Mode command will allow the local Bluetooth module to enter test mode via LMP test commands. The Host issues this command when it wants the local device to be the DUT for the Testing scenarios as described in the Bluetooth Test Mode document. |

Table 3.17: Testing

3.18 ALPHABETICAL LIST OF COMMANDS AND EVENTS

| Commands/Events | Group |
|---|-------------------------------|
| Accept Connection Request Command | Connection Setup |
| Authentication Complete Event | Authentication and Encryption |
| Authentication Requested Command | Authentication and Encryption |
| Change Connection Link Key Command | Authentication and Encryption |
| Change Connection Link Key Complete Event | Authentication and Encryption |
| Change Connection Packet Type Command | Physical Links |
| Command Complete Event | Generic Events |
| Command Status Event | Generic Events |
| Connection Complete Event | Connection Setup |
| Connection Packet Type Changed Event | Physical Links |
| Connection Request Event | Connection Setup |
| Create Connection Cancel Command | Connection Setup |
| Create Connection Command | Connection Setup |
| Create New Unit Key Command | Authentication and Encryption |
| Data Buffer Overflow Event | Host Flow Control |
| Delete Stored Link Key Command | Authentication and Encryption |
| Disconnect Command | Connection Setup |
| Disconnection Complete Event | Connection Setup |
| Enable Device Under Test Mode Command | Testing |
| Encryption Change Event | Authentication and Encryption |
| Exit Park State Command | Connection State |
| Exit Periodic Inquiry Mode Command | Device Discovery |
| Exit Sniff Mode Command | Connection State |
| Flow Specification Command | Quality of Service |
| Flow Specification Complete Event | Quality of Service |
| Flush Command | Quality of Service |
| Flush Occurred Event | Quality of Service |
| Hardware Error Eventt | Generic Events |
| Hold Mode Command | Connection State |
| Host Buffer Size Command | Host Flow Control |

Table 3.18: Alphabetical list of commands and events.

| Commands/Events | Group |
|--|-------------------------------|
| Host Number Of Completed Packets Command | Host Flow Control |
| Inquiry Cancel Command | Device Discovery |
| Inquiry Command | Device Discovery |
| Inquiry Complete Event | Device Discovery |
| Inquiry Result Event | Device Discovery |
| Inquiry Result with RSSI Event | Device Discovery |
| Link Key Notification Event | Authentication and Encryption |
| Link Key Request Event | Authentication and Encryption |
| Link Key Request Negative Reply Command | Authentication and Encryption |
| Link Key Request Reply Command | Authentication and Encryption |
| Loopback Command Event | Testing |
| Master Link Key Command | Authentication and Encryption |
| Master Link Key Complete Event | Authentication and Encryption |
| Max Slots Change Event | Connection State |
| Mode Change Event | Connection State |
| Number Of Completed Packets Event | Controller Flow Control |
| Page Scan Repetition Mode Change Event | Connection Setup |
| Park State Command | Connection State |
| Periodic Inquiry Mode Command | Device Discovery |
| PIN Code Request Event | Authentication and Encryption |
| PIN Code Request Negative Reply Command | Authentication and Encryption |
| PIN Code Request Reply Command | Authentication and Encryption |
| QoS Setup Command | Quality of Service |
| QoS Setup Complete Event | Quality of Service |
| QoS Violation Event | Quality of Service |
| Read AFH Channel Assessment Mode Command | Physical Links |
| Read AFH Channel Map Command | Link Information |
| Read Authentication Enable Command | Authentication and Encryption |
| Read Automatic Flush Timeout Command | Quality of Service |
| Read BD_ADDR Command | Controller Information |
| Read Buffer Size Command | Controller Flow Control |
| Read Class of Device Command | Controller Information |

Table 3.18: Alphabetical list of commands and events.



| Commands/Events | Group |
|---|-------------------------------|
| Read Clock Command | Link Information |
| Read Clock Offset Command | Link Information |
| Read Clock Offset Complete Event | Link Information |
| Read Connection Accept Timeout Command | Connection Setup |
| Read Current IAC LAP Command | Controller Information |
| Read Default Link Policy Settings Command | Connection State |
| Read Encryption Mode Command | Authentication and Encryption |
| Read Failed Contact Counter Command | Quality of Service |
| Read Hold Mode Activity Command | Connection State |
| Read Inquiry Mode Command | Device Discovery |
| Read Inquiry Scan Activity Command | Device Discovery |
| Read Inquiry Scan Type Command | Device Discovery |
| Read Link Policy Settings Command | Connection State |
| Read Link Quality Command | Link Information |
| Read Link Supervision Timeout Command | Physical Links |
| Read LMP Handle Command | Link Information |
| Read Local Extended Features Command | Controller Information |
| Read Local Name Command | Controller Configuration |
| Read Local Supported Commands Command | Controller Information |
| Read Local Supported Features Command | Controller Information |
| Read Local Version Information Command | Controller Information |
| Read Loopback Mode Command | Testing |
| Read Num Broadcast Retransmissions Command | Quality of Service |
| Read Number Of Supported IAC Command | Controller Information |
| Read Page Scan Activity Command | Connection Setup |
| Read Page Scan Type Command | Connection Setup |
| Read Page Timeout Command | Connection Setup |
| Read PIN Type Command | Authentication and Encryption |
| Read Remote Extended Features Command | Remote Information |
| Read Remote Extended Features Complete Event | Remote Information |
| Read Remote Supported Features Command | Remote Information |
| Read Remote Supported Features Complete Event | Remote Information |

Table 3.18: Alphabetical list of commands and events.



| Commands/Events | Group |
|--|-------------------------------|
| Read Remote Version Information Command | Remote Information |
| Read Remote Version Information Complete Event | Remote Information |
| Read RSSI Command | Link Information |
| Read Scan Enable Command | Controller Information |
| Read Stored Link Key Command | Authentication and Encryption |
| Read Synchronous Flow Control Enable Command | Host Flow Control |
| Read Transmit Power Level Command | Link Information |
| Read Voice Setting Command | Synchronous Connections |
| Reject Connection Request Command | Connection Setup |
| Remote Name Request Cancel Command | Remote Information |
| Remote Name Request Command | Remote Information |
| Remote Name Request Complete Event | Remote Information |
| Reset Command | Device Setup |
| Reset Failed Contact Counter Command | Quality of Service |
| Return Link Keys Event | Authentication and Encryption |
| Role Change Event | Piconet Structure |
| Role Discovery Command | Piconet Structure |
| Set AFH Host Channel Classification Command | Physical Links |
| Set Connection Encryption Command | Authentication and Encryption |
| Set Controller To Host Flow Control Command | Host Flow Control |
| Set Event Filter Command | Host Flow Control |
| Set Event Mask Command | Host Flow Control |
| Setup Synchronous Connection Command | Synchronous Connections |
| Sniff Mode Command | Connection State |
| Switch Role Command | Piconet Structure |
| Synchronous Connection Changed event | Synchronous Connections |
| Synchronous Connection Complete Event | Synchronous Connections |
| Write AFH Channel Assessment Mode Command | Physical Links |
| Write Authentication Enable Command | Authentication and Encryption |
| Write Automatic Flush Timeout Command | Quality of Service |
| Write Class of Device Command | Controller Information |
| Write Connection Accept Timeout Command | Connection Setup |

Table 3.18: Alphabetical list of commands and events.



| Commands/Events | Group |
|---|-------------------------------|
| Write Current IAC LAP Command | Controller Information |
| Write Default Link Policy Settings Command | Connection State |
| Write Encryption Mode Command | Authentication and Encryption |
| Write Hold Mode Activity Command | Connection State |
| Write Inquiry Mode Command | Device Discovery |
| Write Inquiry Scan Activity Command | Device Discovery |
| Write Inquiry Scan Type Command | Device Discovery |
| Write Link Policy Settings Command | Connection State |
| Write Link Supervision Timeout Command | Physical Links |
| Write Local Name Command | Controller Information |
| Write Loopback Mode Command | Testing |
| Write Num Broadcast Retransmissions Command | Quality of Service |
| Write Page Scan Activity Command | Connection Setup |
| Write Page Scan Type Command | Connection Setup |
| Write Page Timeout Command | Connection Setup |
| Write PIN Type Command | Authentication and Encryption |
| Write Scan Enable Command | Controller Information |
| Write Stored Link Key Command | Authentication and Encryption |
| Write Synchronous Flow Control Enable Command | Host Flow Control |
| Write Voice Setting Command | Synchronous Connections |

Table 3.18: Alphabetical list of commands and events.

4 HCI FLOW CONTROL

Flow control shall be used in the direction from the Host to the Controller to avoid overflowing the Controller data buffers with ACL data destined for a remote device (using a connection handle) that is not responding. The Host manages the data buffers of the Controller.

4.1 HOST TO CONTROLLER DATA FLOW CONTROL

On initialization, the Host shall issue the Read Buffer Size command. Two of the return parameters of this command determine the maximum size of HCI ACL and synchronous Data Packets (excluding header) sent from the Host to the Controller. There are also two additional return parameters that specify the total number of HCI ACL and synchronous Data Packets that the Controller may have waiting for transmission in its buffers.

When there is at least one connection to another device, or when in local loop-back mode, the Controller shall use the Number Of Completed Packets event to control the flow of data from the Host. This event contains a list of connection handles and a corresponding number of HCI Data Packets that have been completed (transmitted, flushed, or looped back to the Host) since the previous time the event was returned (or since the connection was established, if the event has not been returned before for a particular connection handle).

Based on the information returned in this event, and the return parameters of the Read Buffer Size command that specify the total number of HCI ACL and synchronous Data Packets that can be stored in the Controller, the Host decides for which Connection Handles the following HCI Data Packets should be sent.

Every time it has sent an HCI Data Packet, the Host shall assume that the free buffer space for the corresponding link type (ACL, SCO or eSCO) in the Controller has decreased by one HCI Data Packet.

Each Number Of Completed Packets event received by the Host provides information about how many HCI Data Packets have been completed (transmitted or flushed) for each Connection Handle since the previous Number Of Completed Packets event was sent to the Host. It can then calculate the actual current buffer usage.

When the Controller has completed one or more HCI Data Packet(s) it shall send a Number Of Completed Packets event to the Host, until it finally reports that all the pending HCI Data Packets have been completed. The frequency at which this event is sent is manufacturer specific.

Note: The Number Of Completed Packets events will not report on synchronous connection handles if Synchronous Flow Control is disabled. (See Read/



Write Synchronous Flow Control Enable, [Section 7.3.38 on page 513](#) and [Section 7.3.39 on page 514](#))

For each individual Connection Handle, the data must be sent to the Controller in HCI Data Packets in the order in which it was created in the Host. The Controller shall also transmit data on the air that is received from the Host for a given Connection Handle in the same order as it is received from the Host.

Data that is received on the air from another device shall, for the corresponding Connection Handle, be sent in HCI Data Packets to the Host in the same order as it is received. This means the scheduling shall be decided separately for each Connection Handle basis. For each individual Connection Handle, the order of the data shall not be changed from the order in which the data has been created.

4.2 CONTROLLER TO HOST DATA FLOW CONTROL

In some implementations, flow control may also be necessary in the direction from the Controller to the Host. The Set Host Controller To Host Flow Control command can be used to turn flow control on or off in that direction.

On initialization, the Host uses the Host Buffer Size command to notify the Controller about the maximum size of HCI ACL and synchronous Data Packets sent from the Controller to the Host. The command also contains two additional command parameters to notify the Controller about the total number of ACL and synchronous Data Packets that can be stored in the data buffers of the Host.

The Host uses the Host Number Of Completed Packets command in exactly the same way as the Controller uses the Number Of Completed Packets event as was previously described in this section.

The Host Number Of Completed Packets command is a special command for which no command flow control is used, and which can be sent anytime there is a connection or when in local loopback mode. The command also has no event after the command has completed. This makes it possible for the flow control to work in exactly the same way in both directions, and the flow of normal commands will not be disturbed.

4.3 DISCONNECTION BEHAVIOR

When the Host receives a Disconnection Complete event, the Host shall assume that all unacknowledged HCI Data Packets that have been sent to the Controller for the returned Connection Handle have been flushed, and that the corresponding data buffers have been freed. The Controller does not have to notify the Host about this in a Number Of Completed Packets event.

If flow control is also enabled in the direction from the Controller to the Host, the Controller may, after it has sent a Disconnection Complete event, assume that the Host will flush its data buffers for the sent Connection Handle when it receives the Disconnection Complete event. The Host does not have to notify the Controller about this in a Host Number Of Completed Packets command.

4.4 COMMAND FLOW CONTROL

On initial power-on, and after a reset, the Host shall send a maximum of one outstanding HCI Command Packet until a Command Complete or Command Status event has been received.

The Command Complete and Command Status events contain a parameter called Num HCI Command Packets, which indicates the number of HCI Command Packets the Host is currently allowed to send to the Controller. The Controller may buffer one or more HCI command packets, but the Controller must start performing the commands in the order in which they are received. The Controller can start performing a command before it completes previous commands. Therefore, the commands do not always complete in the order they are started.

To indicate to the Host that the Controller is ready to receive HCI command packets, the Controller may generate a Command Complete event with the Command Opcode 0x0000, and the Num HCI Command Packets event parameter is set to 1 or more. Command Opcode 0x0000 is a NOP (No Operation), and can be used to change the number of outstanding HCI command packets that the Host can send. The Controller may generate a Command Complete event with the Num HCI Command Packets event parameter set to zero to inform Host it must stop sending commands.

For most commands, a Command Complete event shall be sent to the Host when the Controller completes the command. Some commands are executed in the background and do not return a Command Complete event when they have been completed. Instead, the Controller shall send a Command Status event back to the Host when it has begun to execute the command. When the actions associated with the command have finished, an event that is associated with the command shall be sent by the Controller to the Host.

If the command does not begin to execute (for example, if there was a parameter error or the command is currently not allowed), the Command Status event shall be returned with the appropriate error code in the Status parameter, and the event associated with the sent command shall not be returned.



4.5 COMMAND ERROR HANDLING

If an error occurs for a command for which a Command Complete event is returned, the Return Parameters field may not contain all the return parameters specified for the command. The Status parameter, which explains the error reason and which is the first return parameter, shall always be returned. If there is a Connection Handle parameter or a BD_ADDR parameter right after the Status parameter, this parameter shall also be returned so that the Host can identify to which instance of a command the Command Complete event belongs. In this case, the Connection Handle or BD_ADDR parameter shall have exactly the same value as that in the corresponding command parameter. It is implementation specific whether more parameters will be returned in case of an error.

The above also applies to commands that have associated command specific completion events with a status parameter in their completion event, with two exceptions. The exceptions are the Connection Complete and the Synchronous Connection Complete events. On failure, for these two events only, the second parameter, Connection_Handle, is not valid and the third parameter, BD_ADDR, is valid for identification purposes. The validity of other parameters is likewise implementation specific for failed commands in this group.

Note: The BD_ADDR return parameter of the command Read BD_ADDR is not used to identify to which instance of the Read BD_ADDR command the Command Complete event belongs. It is optional for the Controller to return this parameter in case of an error.

5 HCI DATA FORMATS

5.1 INTRODUCTION

The HCI provides a uniform command method of accessing the Bluetooth capabilities. The HCI Link commands provide the Host with the ability to control the link layer connections to other Bluetooth devices. These commands typically involve the Link Manager (LM) to exchange LMP commands with remote Bluetooth devices. For details see [“Link Manager Protocol” on page 211 \[Part C\]](#).

The HCI Policy commands are used to affect the behavior of the local and remote LM. These Policy commands provide the Host with methods of influencing how the LM manages the piconet. The Controller & Baseband, Informational, and Status commands provide the Host access to various registers in the Controller.

HCI commands may take different amounts of time to be completed. Therefore, the results of commands will be reported back to the Host in the form of an event. For example, for most HCI commands the Controller will generate the Command Complete event when a command is completed. This event contains the return parameters for the completed HCI command. For enabling the Host to detect errors on the HCI-Transport Layer, there needs to be a timeout between the transmission of the Host's command and the reception of the Controller's response (e.g. a Command Complete or Command Status event). Since the maximum response timeout is strongly dependent on the HCI-Transport Layer used, it is recommended to use a default value of one second for this timer. This amount of time is also dependent on the number of commands unprocessed in the command queue.

5.2 DATA AND PARAMETER FORMATS

- All values are in Binary and Hexadecimal Little Endian formats unless otherwise noted
- In addition, all parameters which can have negative values must use 2's complement when specifying values
- Arrayed parameters are specified using the following notation: ParameterA[i]. If more than one set of arrayed parameters are specified (e.g. ParameterA[i], ParameterB[i]), then the order of the parameters are as follows: ParameterA[0], ParameterB[0], ParameterA[1], ParameterB[1], ParameterA[2], ParameterB[2], ... ParameterA[n], ParameterB[n]
- Unless noted otherwise, all parameter values are sent and received in Little Endian format (i.e. for multi-octet parameters the rightmost (Least Signification Octet) is transmitted first)
- All command and event parameters that are not-arrayed and all elements in an arrayed parameter have fixed sizes (an integer number of octets). The parameters and the size of each not arrayed parameter (or of each element in an arrayed parameter) contained in a command or an event is specified



for each command or event. The number of elements in an arrayed parameter is not fixed.

- Where bit strings are specified, the low order bit is the right hand bit, e.g. 0 is the low order bit in '10'.
- Values or parameters marked as Reserved for Future Use, shall be set to 0 unless explicitly stated otherwise on transmission, and shall be ignored on reception. Parameter values or opcodes that an implementation does not know how to interpret shall be ignored, and the operation that is being attempted shall be completed with the correct signaling. The host or controller shall not stop functioning because of receiving a reserved value.

5.3 CONNECTION HANDLES

Connection Handles are used to identify logical channels between the Host and Controller. Connection Handles are assigned by the Controller when a new logical link is created, using the Connection Complete or Synchronous Connection Complete events. Broadcast Connection Handles are handled differently, and are described below.

The first time the Host sends an HCI Data Packet with Broadcast_Flag set to 01b (active slave broadcast) or 10b (parked slave broadcast) after a power-on or a reset, the value of the Connection Handle parameter must be a value which is not currently assigned by the Host Controller. The Host must use different connection handles for active broadcast and piconet broadcast.

The Controller must then continue to use the same connection handles for each type of broadcast until a reset is made. Note: The Host Controller must not send a Connection Complete event containing a new Connection_Handle that it knows is used for broadcast.

Note: In some situations, it may happen that the Host Controller sends a Connection Complete event before having interpreted a Broadcast packet received from the Host, and that the Connection_Handles of both Connection Complete event and HCI Data packet are the same. This conflict has to be avoided as follows:

If a Connection Complete event is received containing one of the connection handles used for broadcast, the Host has to wait before sending any packets for the new connection until it receives a Number Of Completed Packets event indicating that there are no pending broadcast packets belonging to the connection handle. In addition, the Host must change the Connection_Handle used for the corresponding type of broadcast to a Connection_Handle which is currently not assigned by the Host Controller.

This Connection_Handle must then be used for all the following broadcasts of that type until a reset is performed or the same conflict situation happens again. However, this will occur very rarely.



The Host Controller must, in the above conflict case, be able to distinguish between the Broadcast message sent by the Host and the new connection made (this could be even a new synchronous link) even though the connection handles are the same.

For an HCI Data Packet sent from the Host Controller to the Host where the Broadcast_Flag is 01 or 10, the Connection_Handle parameter should contain the connection handle for the ACL connection to the master that sent the broadcast.

Note: Connection handles used for Broadcast do not identify an ACL point-to-point connection, so they must not be used in any command having a Connection_Handle parameter and they will not be returned in any event having a Connection_Handle parameter except the Number Of Completed Packets event.

5.4 EXCHANGE OF HCI-SPECIFIC INFORMATION

The Host Controller Transport Layer provides transparent exchange of HCI specific information. These transporting mechanisms provide the ability for the Host to send HCI commands, ACL data and synchronous data to the Controller. These transport mechanisms also provide the ability for the Host to receive HCI events, ACL data and synchronous data from the Controller. Since the Host Controller Transport Layer provides transparent exchange of HCI-specific information, the HCI specification specifies the format of the commands, events, and data exchange between the Host and the Controller. The next sections specify the HCI packet formats.

5.4.1 HCI Command Packet

The HCI Command Packet is used to send commands to the Controller from the Host. The format of the HCI Command Packet is shown in [Figure 5.1](#), and the definition of each field is explained below.

The Controller must be able to accept HCI Command Packets with up to 255 bytes of data excluding the HCI Command Packet header.

Each command is assigned a 2 byte Opcode used to uniquely identify different types of commands. The Opcode parameter is divided into two fields, called the OpCode Group Field (OGF) and OpCode Command Field (OCF). The OGF occupies the upper 6 bits of the Opcode, while the OCF occupies the remaining 10 bits. The OGF of 0x3F is reserved for vendor-specific debug commands. The OGF of 0x3E is reserved for Bluetooth Logo Testing. The organization of the Opcodes allows additional information to be inferred without fully decoding the entire Opcode.

Note: the OGF composed of all 'ones' has been reserved for vendor-specific debug commands. These commands are vendor-specific and are used during manufacturing, for a possible method for updating firmware, and for debugging.



Note: the OGF composed of all ‘zeros’ and an OCF or all ‘zeros’ is the NOP command. This command Opcode may be used in Command Flow Control. (See [Section 4.4 on page 373](#))

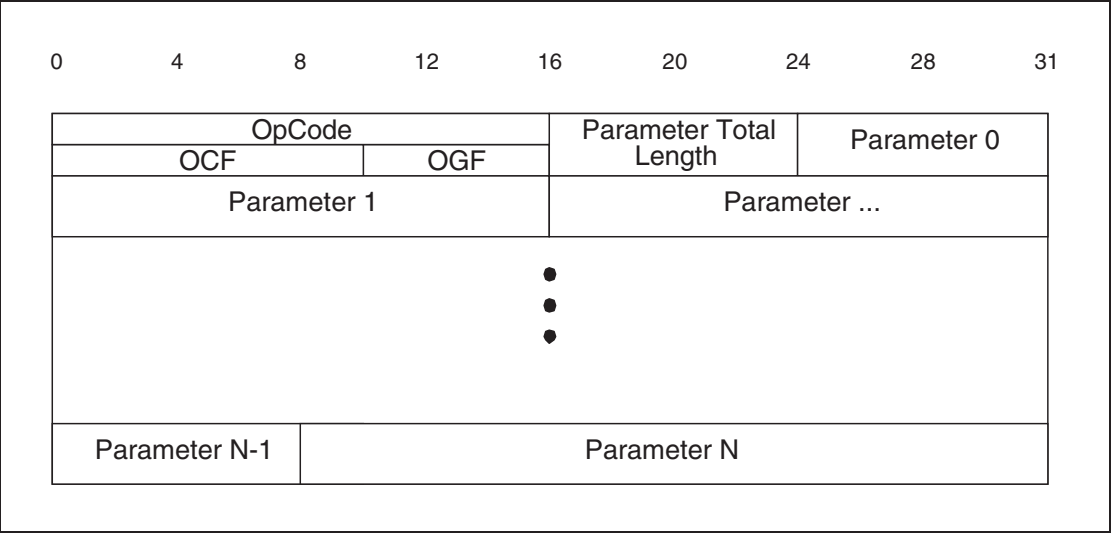


Figure 5.1: HCI Command Packet

Op_Code: *Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | OGFRange (6 bits): 0x00-0x3F (0x3E reserved for Bluetooth logo testing and 0x3F reserved for vendor-specific debug commands) OCF Range (10 bits): 0x0000-0x03FF |

Parameter_Total_Length: *Size: 1 Octet*

| Value | Parameter Description |
|-------|---|
| 0xFF | Lengths of all of the parameters contained in this packet measured in octets. (N.B.: total length of parameters, <u>not</u> number of parameters) |

Parameter 0 - N: *Size: Parameter Total Length*

| Value | Parameter Description |
|-------|---|
| 0xFF | Each command has a specific number of parameters associated with it. These parameters and the size of each of the parameters are defined for each command. Each parameter is an integer number of octets in size. |

5.4.2 HCI ACL Data Packets

HCI ACL Data Packets are used to exchange data between the Host and Controller. The format of the HCI ACL Data Packet is shown in [Figure 5.2](#). The definition for each of the fields in the data packets is explained [below](#).

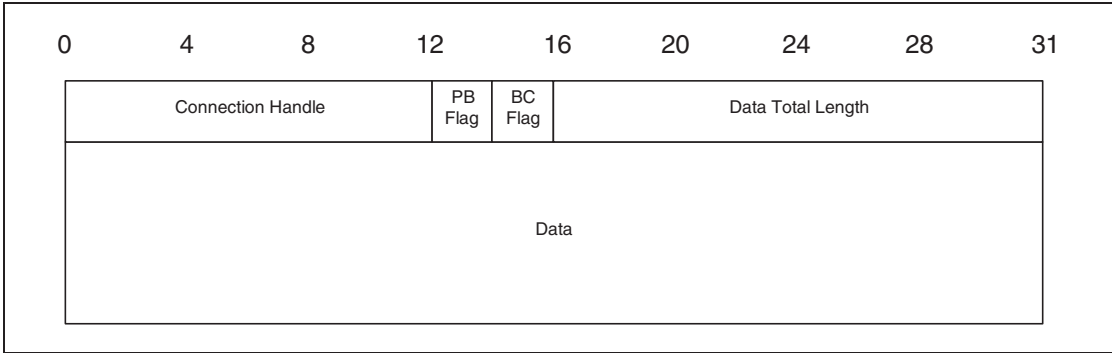


Figure 5.2: HCI ACL Data Packet

Connection_Handle: Size: 12 Bits

| Value | Parameter Description |
|-------|---|
| 0xXXX | Connection Handle to be used for transmitting a data packet or segment. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Flags: Size: 2 Bits

The Flag Bits consist of the Packet_Boundary_Flag and Broadcast_Flag. The Packet_Boundary_Flag is located in bit 4 and bit 5, and the Broadcast_Flag is located in bit 6 and 7 in the second octet of the HCI ACL Data packet.

Packet_Boundary_Flag: Size: 2 Bits

| Value | Parameter Description |
|-------|--|
| 00 | Reserved for future use |
| 01 | Continuing fragment packet of Higher Layer Message |
| 10 | First packet of Higher Layer Message (i.e. start of an L2CAP packet) |
| 11 | Reserved for future use |

**Broadcast_Flag** (in packet from Host to Controller):

Size: 2 Bits

| Value | Parameter Description |
|-------|--|
| 00 | No broadcast. Only point-to-point. |
| 01 | Active Slave Broadcast: packet is sent to all active slaves (i.e. packet is usually not sent during park beacon slots), and it may be received by slaves in sniff mode or park state. |
| 10 | Parked Slave Broadcast: packet is sent to all slaves and all slaves in park state (i.e. packet is sent during park beacon slots if there are parked slaves), and it may be received by slaves in sniff mode. |
| 11 | Reserved for future use. |

Broadcast_Flag (in packet from Controller to Host):

Size: 2 Bits

| Value | Parameter Description |
|-------|--|
| 00 | Point-to-point |
| 01 | Packet received as a slave not in park state (either Active Slave Broadcast or Parked Slave Broadcast) |
| 10 | Packet received as a slave in park state (Parked Slave Broadcast) |
| 11 | Reserved for future use. |

Note: active slave broadcast packets may be sent in park beacon slots.

Note: slaves in sniff mode may or may not receive a broadcast packet depending on whether they happen to be listening at sniff slots, when the packet is sent.

Data_Total_Length:

Size: 2 Octets

| Value | Parameter Description |
|--------|------------------------------------|
| 0xFFFF | Length of data measured in octets. |

5.4.3 HCI Synchronous Data Packets

HCI synchronous (SCO and eSCO) Data Packets are used to exchange synchronous data between the Host and Controller. The format of the synchronous Data Packet is shown in Figure 5.3. The definition for each of the fields in the data packets is explained below.

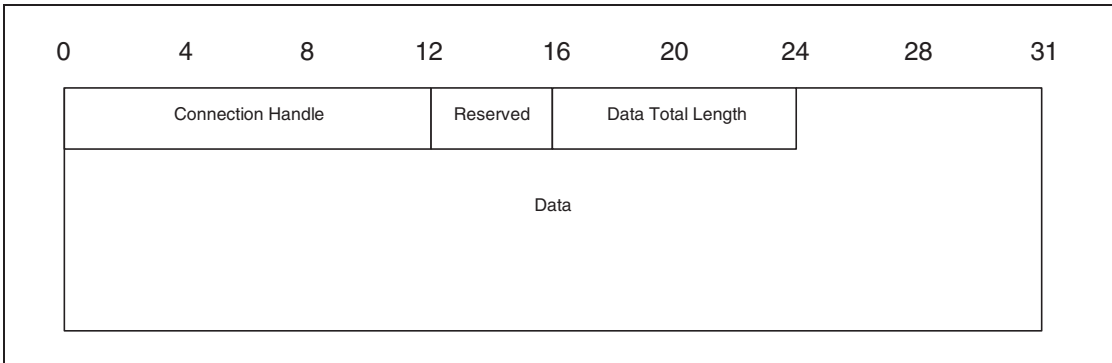


Figure 5.3: HCI Synchronous Data Packet

Connection_Handle: Size: 12 Bits

| Value | Parameter Description |
|-------|---|
| 0xXXX | Connection handle to be used to for transmitting a synchronous data packet or segment. Range: 0x0000-0x0EFF (0x0F00- 0x0FFF Reserved for future use) |

The Reserved Bits consist of four bits which are located from bit 4 to bit 7 in the second octet of the HCI Synchronous Data packet.

Reserved: Size: 4 Bits

| Value | Parameter Description |
|-------|--------------------------|
| XXXX | Reserved for future use. |

Data_Total_Length: Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0xXX | Length of synchronous data measured in octets |



5.4.4 HCI Event Packet

The HCI Event Packet is used by the Controller to notify the Host when events occur. The Host must be able to accept HCI Event Packets with up to 255 octets of data excluding the HCI Event Packet header. The format of the HCI Event Packet is shown in Figure 5.4, and the definition of each field is explained below.

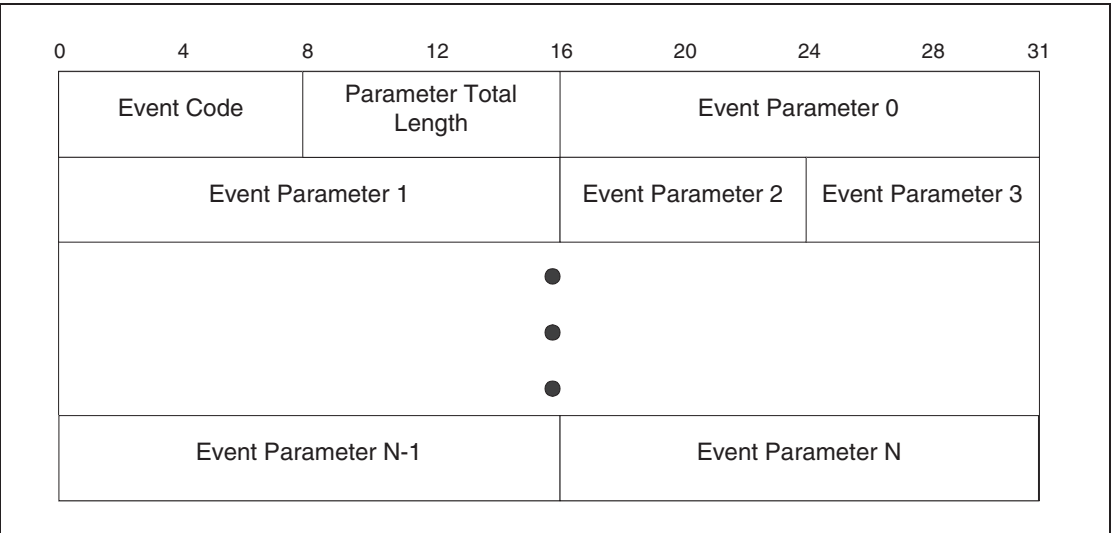


Figure 5.4: HCI Event Packet

Event_Code: *Size: 1 Octet*

| Value | Parameter Description |
|-------|---|
| 0xXX | Each event is assigned a 1-Octet event code used to uniquely identify different types of events. Range: 0x00-0xFF (The event code 0xFF is reserved for the event code used for vendor-specific debug events. In addition, the event code 0xFE is also reserved for Bluetooth Logo Testing) |

Parameter_Total_Length: *Size: 1 Octet*

| Value | Parameter Description |
|-------|--|
| 0xXX | Length of all of the parameters contained in this packet, measured in octets |

Event_Parameter 0 - N: *Size: Parameter Total Length*

| Value | Parameter Description |
|-------|---|
| 0xXX | Each event has a specific number of parameters associated with it. These parameters and the size of each of the parameters are defined for each event. Each parameter is an integer number of octets in size. |

6 HCI CONFIGURATION PARAMETERS

6.1 SCAN ENABLE

The Scan_Enable parameter controls whether or not the Bluetooth device will periodically scan for page attempts and/or inquiry requests from other Bluetooth devices. If Page_Scan is enabled, then the device will enter page scan mode based on the value of the Page_Scan_Interval and Page_Scan_Window parameters. If Inquiry_Scan is enabled, then the device will enter Inquiry Scan mode based on the value of the Inquiry_Scan_Interval and Inquiry_Scan_Window parameters.

| Value | Parameter Description |
|-----------|---|
| 0x00 | No Scans enabled. |
| 0x01 | Inquiry Scan enabled. Page Scan always disabled. |
| 0x02 | Inquiry Scan disabled. Page Scan enabled. |
| 0x03 | Inquiry Scan enabled. Page Scan enabled. |
| 0x04-0xFF | Reserved |

6.2 INQUIRY SCAN INTERVAL

The Inquiry_Scan_Interval configuration parameter defines the amount of time between consecutive inquiry scans. This is defined as the time interval from when the Controller started its last inquiry scan until it begins the next inquiry scan.

| Value | Parameter Description |
|------------|--|
| N = 0xFFFF | Size: 2 Octets Range: 0x0012 to 0x1000; only even values are valid Default: 0x1000 Mandatory Range: 0x0012 to 0x1000 Time = N * 0.625 msec Time Range: 11.25 to 2560 msec Time Default: 2.56 sec |

6.3 INQUIRY SCAN WINDOW

The Inquiry_Scan_Window configuration parameter defines the amount of time for the duration of the inquiry scan. The Inquiry_Scan_Window can only be less than or equal to the Inquiry_Scan_Interval.

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Size: 2 Octets Range: 0x0011 to 0x1000 Default: 0x0012 Mandatory Range: 0x0011 to Inquiry Scan Interval Time = $N * 0.625$ msec Time Range: 10.625 msec to 2560 msec Time Default: 11.25 msec |

6.4 INQUIRY SCAN TYPE

The Inquiry_Scan_Type configuration parameter indicates whether inquiry scanning will be done using non-interlaced scan or interlaced scan. Currently, one mandatory inquiry scan type and one optional inquiry scan type are defined. For details, see the Baseband Specification, [“Inquiry scan substate” on page 164 \[Part B\]](#).

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Mandatory: Standard Scan (default) |
| 0x01 | Optional: Interlaced Scan |
| 0x02-0xFF | Reserved |

6.5 INQUIRY MODE

The Inquiry_Mode configuration parameter indicates whether inquiry returns Inquiry Result events in the standard format or with RSSI.

| Value | Parameter Description |
|-----------|--------------------------------------|
| 0x00 | Standard Inquiry Result event format |
| 0x01 | Inquiry Result format with RSSI |
| 0x02-0xFF | Reserved |

6.6 PAGE TIMEOUT

The Page_Timeout configuration parameter defines the maximum time the local Link Manager will wait for a baseband page response from the remote device at a locally initiated connection attempt. If this time expires and the remote device has not responded to the page at baseband level, the connection attempt will be considered to have failed.

| Value | Parameter Description |
|------------|--|
| N = 0xXXXX | Size: 2 Octets Range: 0x0001 to 0xFFFF Default: 0x2000 Mandatory Range: 0x0016 to 0xFFFF Time = N * 0.625 msec Time Range: 0.625 msec to 40.9 sec Time Default: 5.12 sec |

6.7 CONNECTION ACCEPT TIMEOUT

The Connection_Accept_Timeout configuration parameter allows the Bluetooth hardware to automatically deny a connection request after a specified time period has occurred and the new connection is not accepted. The parameter defines the time duration from when the Controller sends a Connection Request event until the Controller will automatically reject an incoming connection.

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Size: 2 Octets Range: 0x0001 to 0xB540 Default: 0x1F40 Mandatory Range: 0x00A0 to 0xB540 Time = N * 0.625 msec Time Range: 0.625 msec to 29 sec Time Default: 5 sec |

6.8 PAGE SCAN INTERVAL

The Page_Scan_Interval configuration parameter defines the amount of time between consecutive page scans. This time interval is defined from when the Controller started its last page scan until it begins the next page scan.

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Size: 2 Octets Range: 0x0012 to 0x1000; only even values are valid Default: 0x0800 Mandatory Range: 0x0012 to 0x1000 Time = $N * 0.625$ msec Time Range: 11.25 msec to 2560 msec Time Default: 1.28 sec |

6.9 PAGE SCAN WINDOW

The Page_Scan_Window configuration parameter defines the amount of time for the duration of the page scan. The Page_Scan_Window can only be less than or equal to the Page_Scan_Interval.

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Size: 2 Octets Range: 0x0011 to 0x1000 Default: 0x0012 Mandatory Range: 0x0011 to Page Scan Interval Time = $N * 0.625$ msec Time Range: 10.625 msec to Page Scan Interval Time Default: 11.25 msec |

6.10 PAGE SCAN PERIOD MODE (DEPRECATED)

Every time an inquiry response message is sent, the Bluetooth device will start a timer ($T_{\text{mandatory_pscan}}$), the value of which is dependent on the Page_Scan_Period_Mode. As long as this timer has not expired, the Bluetooth device will use the mandatory page scan mode for all following page scans.

Note: the timer $T_{\text{mandatory_pscan}}$ will be reset at each new inquiry response. For details see the [“Baseband Specification” on page 55 \[Part B\]](#). (Keyword: SP-Mode, FHS-Packet, $T_{\text{mandatory_pscan}}$, Inquiry-Response).

| Value | Parameter Description |
|-----------|-----------------------|
| 0x00 | P0 |
| 0x01 | P1 |
| 0x02 | P2 |
| 0x03-0xFF | Reserved. |

6.11 PAGE SCAN TYPE

The Page_Scan_Type parameter indicates whether inquiry scanning will be done using non-interlaced scan or interlaced scan. For details, see the Base-band Specification, “[Page scan substate](#)” on page 154 [Part B].

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Mandatory: Standard Scan (default) |
| 0x01 | Optional: Interlaced Scan |
| 0x02-0xFF | Reserved |

6.12 VOICE SETTING

The Voice_Setting parameter controls all the various settings for voice connections. The input settings apply to all voice connections, and **cannot** be set for individual voice connections. The Voice_Setting parameter controls the configuration for voice connections: Input Coding, Air coding format, input data format, Input sample size, and linear PCM parameter. The air coding format bits in the Voice_Setting command parameter specify which air coding format the local device requests. The air coding format bits do not specify which air coding format(s) the local device accepts when a remote device requests an air coding format. This is determined by the hardware capabilities of the local device.

| Value | Parameter Description |
|------------|--|
| 00XXXXXXXX | Input Coding: Linear |
| 01XXXXXXXX | Input Coding: μ -law Input Coding |
| 10XXXXXXXX | Input Coding: A-law Input Coding |
| 11XXXXXXXX | Reserved for Future Use |
| XX00XXXXXX | Input Data Format: 1's complement |
| XX01XXXXXX | Input Data Format: 2's complement |
| XX10XXXXXX | Input Data Format: Sign-Magnitude |
| XX11XXXXXX | Input Data Format: Unsigned |
| XXXX0XXXXX | Input Sample Size: 8-bit (only for linear PCM) |
| XXXX1XXXXX | Input Sample Size: 16-bit (only for linear PCM) |
| XXXXXnnnXX | Linear_PCM_Bit_Pos: # bit positions that MSB of sample is away from starting at MSB (only for Linear PCM). |
| XXXXXXXX00 | Air Coding Format: CVSD |
| XXXXXXXX01 | Air Coding Format: μ -law |
| XXXXXXXX10 | Air Coding Format: A-law |
| XXXXXXXX11 | Air Coding Format: Transparent Data |

6.13 PIN TYPE

The PIN Type configuration parameter determines whether the Link Manager assumes that the Host supports variable PIN codes or a fixed PIN code. The host controller uses the PIN-type information during pairing.

| Value | Parameter Description |
|-------|-----------------------|
| 0x00 | Variable PIN. |
| 0x01 | Fixed PIN. |

6.14 LINK KEY

The Controller can store a limited number of link keys for other Bluetooth devices. Link keys are shared between two Bluetooth devices, and are used for all security transactions between the two devices. A Host device may have additional storage capabilities, which can be used to save additional link keys to be reloaded to the Bluetooth Controller when needed. A Link Key is associated with a BD_ADDR.

| Value | Parameter Description |
|--|-------------------------------------|
| 0xFFFFFFFF XXXXXXXXXX XXXXXXXXXX | Link Key for an associated BD_ADDR. |

6.15 AUTHENTICATION ENABLE

The Authentication_Enable parameter controls if the local device requires to authenticate the remote device at connection setup (between the Create_Connection command or acceptance of an incoming ACL connection and the corresponding Connection Complete event). At connection setup, only the device(s) with the Authentication_Enable parameter enabled will try to authenticate the other device.

Note: Changing this parameter does not affect existing connections.

| Value | Parameter Description |
|-----------|--|
| 0x00 | Authentication not required. |
| 0x01 | Authentication required for all connections. |
| 0x02-0xFF | Reserved |



6.16 ENCRYPTION MODE

The Encryption_Mode parameter controls if the local device requires encryption to the remote device at connection setup (between the Create_Connection command or acceptance of an incoming ACL connection and the corresponding Connection Complete event). At connection setup, only devices with the Authentication_Enabled configuration parameter set to required and the Encryption_Mode configuration parameter set to required will try to encrypt the physical link to the other device.

Note: Changing this parameter does not affect existing connections.

A temporary link key is used when both broadcast and point-to-point traffic are encrypted.

The Host must not specify the Encryption_Mode parameter with more encryption capability than its local device currently supports, although the parameter is used to request the encryption capability to the remote device. Note that the Host must not request the command with the Encryption_Mode parameter set to 0x01, when the local device does not support encryption.

Note: for encryption to be used, both devices must support and enable encryption.

| Value | Parameter Description |
|-----------|--|
| 0x00 | Encryption not required. |
| 0x01 | Encryption required for all connections. |
| 0x02-0xFF | Reserved. |

Note: in the Connection Complete event the Encryption_Mode parameter will show whether encryption was successfully turned on. The remote device may not support encryption or may have set Encryption_Mode to 0x01 when the local device has not, so the encryption mode returned in the Connection Complete event may not equal the encryption mode set in the HCI_Write_Encryption_Mode Command.

6.17 FAILED CONTACT COUNTER

The Failed_Contact_Counter records the number of consecutive incidents in which either the slave or master didn't respond after the flush timeout had expired, and the L2CAP packet that was currently being transmitted was automatically 'flushed'. When this occurs, the Failed_Contact_Counter is incremented by 1. The Failed_Contact_Counter for a connection is reset to zero on the following conditions:

1. When a new connection is established
2. When the Failed_Contact_Counter is > zero and an L2CAP packet is acknowledged for that connection
3. When the Reset_Failed_Contact_Counter command has been issued

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Number of consecutive failed contacts for a connection corresponding to the connection handle. |

6.18 HOLD MODE ACTIVITY

The Hold_Mode_Activity value is used to determine what activities should be suspended when the device is in hold mode. After the hold period has expired, the device will return to the previous mode of operation. Multiple hold mode activities may be specified for the Hold_Mode_Activity parameter by performing a bitwise OR operation of the different activity types. If no activities are suspended, then all of the current Periodic Inquiry, Inquiry Scan, and Page Scan settings remain valid during the Hold Mode. If the Hold_Mode_Activity parameter is set to Suspend Page Scan, Suspend Inquiry Scan, and Suspend Periodic Inquiries, then the device can enter a low-power state during the Hold Mode period, and all activities are suspended. Suspending multiple activities can be specified for the Hold_Mode_Activity parameter by performing a bitwise OR operation of the different activity types. The Hold Mode Activity is only valid if all connections are in Hold Mode.

| Value | Parameter Description |
|-----------|-------------------------------|
| 0x00 | Maintain current Power State. |
| 0x01 | Suspend Page Scan. |
| 0x02 | Suspend Inquiry Scan. |
| 0x04 | Suspend Periodic Inquiries. |
| 0x08-0xFF | Reserved for Future Use. |

6.19 LINK POLICY SETTINGS

The Link_Policy_Settings parameter determines the behavior of the local Link Manager when it receives a request from a remote device or it determines itself to change the master-slave role or to enter park state, hold, or sniff mode. The local Link Manager will automatically accept or reject such a request from the remote device, and may even autonomously request itself, depending on the value of the Link_Policy_Settings parameter for the corresponding Connection_Handle. When the value of the Link_Policy_Settings parameter is changed for a certain Connection_Handle, the new value will only be used for requests from a remote device or from the local Link Manager itself made after this command has been completed. By enabling each mode individually, the Host can choose any combination needed to support various modes of operation. Multiple LM policies may be specified for the Link_Policy_Settings parameter by performing a bitwise OR operation of the different activity types.

Note: The local device may be forced into hold mode (regardless of whether the local device is master or slave) by the remote device regardless of the value of the Link_Policy_Settings parameter. The forcing of hold mode can however only be done once the connection has already been placed into hold mode through an LMP request (the Link_Policy_Settings determine if requests from a remote device should be accepted or rejected). The forcing of hold mode can after that be done as long as the connection lasts regardless of the setting for hold mode in the Link_Policy_Settings parameter.

Note that the previous description implies that if the implementation in the remote device is a "polite" implementation that does not force another device into hold mode via LMP PDUs, then the Link_Policy_Settings will never be overruled.

| Value | Parameter Description |
|--------|------------------------------|
| 0x0000 | Disable All LM Modes Default |
| 0x0001 | Enable Role switch. |
| 0x0002 | Enable Hold Mode. |
| 0x0004 | Enable Sniff Mode. |
| 0x0008 | Enable Park State. |
| 0x0010 | Reserved for Future Use. |
| — | |
| 0x8000 | |

6.20 FLUSH TIMEOUT

The Flush_Timeout configuration parameter is used for ACL connections only. The Flush Timeout is defined in the Baseband specification [Section 7.6.3, “Flushing payloads,” on page 150](#). This parameter allows ACL packets to be automatically flushed without the Host device issuing a Flush command. This provides support for isochronous data, such as audio. When the L2CAP packet that is currently being transmitted is automatically ‘flushed’, the Failed Contact Counter is incremented by one.

| Value | Parameter Description |
|------------|--|
| 0 | Timeout = ∞ ; No Automatic Flush |
| N = 0xXXXX | Size: 2 Octets Range: 0x0001 to 0x07FF Mandatory Range: 0x0002 to 0x07FF Time = $N * 0.625$ msec Time Range: 0.625 msec to 1279.375 msec |

6.21 NUM BROADCAST RETRANSMISSIONS

Broadcast packets are not acknowledged and are unreliable. The Number of Broadcast Retransmissions parameter, N, is used to increase the reliability of a broadcast message by retransmitting the broadcast message multiple times. This sets the value N_{BC} in the baseband to one greater than the Num Broadcast Retransmissions value. (See [Baseband Specification, Section 7.6.5, on page 150](#)) This parameter should be adjusted as the link quality measurement changes.

| Value | Parameter Description |
|----------|-------------------------------------|
| N = 0xXX | $N_{BC} = N + 1$ Range 0x00-0xFE |



6.22 LINK SUPERVISION TIMEOUT

The Link_Supervision_Timeout parameter is used by the master or slave Bluetooth device to monitor link loss. If, for any reason, no Baseband packets are received from that Connection Handle for a duration longer than the Link_Supervision_Timeout, the connection is disconnected. The same timeout value is used for both synchronous and ACL connections for the device specified by the Connection Handle.

Note: Setting the Link_Supervision_Timeout to No Link_Supervision_Timeout (0x0000) will disable the Link_Supervision_Timeout check for the specified Connection Handle. This makes it unnecessary for the master of the piconet to unpark and then park each Bluetooth Device every ~40 seconds. By using the No Link_Supervision_Timeout setting, the scalability of the Park state is not limited.

| Value | Parameter Description |
|------------|--|
| 0x0000 | No Link_Supervision_Timeout. |
| N = 0xXXXX | Size: 2 Octets Range: 0x0001 to 0xFFFF Default: 0x7D00 Mandatory Range: 0x0190 to 0xFFFF Time = N * 0.625 msec Time Range: 0.625 msec to 40.9 sec Time Default: 20 sec |

6.23 SYNCHRONOUS FLOW CONTROL ENABLE

The Synchronous Flow Control Enable configuration parameter allows the Host to decide if the Controller will send Number Of Completed Packets events for synchronous Connection Handles. This setting allows the Host to enable and disable synchronous flow control.

| Value | Parameter Description |
|-------|--|
| 0x00 | Synchronous Flow Control is disabled. No Number of Completed Packets events will be sent from the Controller for synchronous Connection Handles. |
| 0x01 | Synchronous Flow Control is enabled. Number of Completed Packets events will be sent from the Controller for synchronous Connection Handles. |



6.24 LOCAL NAME

The user-friendly Local Name provides the user the ability to distinguish one Bluetooth device from another. The Local Name configuration parameter is a UTF-8 encoded string with up to 248 octets in length. The Local Name configuration parameter will be null terminated (0x00) if the UTF-8 encoded string is less than 248 octets.

Note: the Local Name configuration parameter is a string parameter. Endian-ess does therefore not apply to the Local Name configuration parameter. The first octet of the name is received first.

| Value | Parameter Description |
|-------|--|
| | A UTF-8 encoded User Friendly Descriptive Name for the device. If the name contained in the parameter is shorter than 248 octets, the end of the name is indicated by a NULL octet (0x00), and the following octets (to fill up 248 octets, which is the length of the parameter) do not have valid values. |

6.25 CLASS OF DEVICE

The Class_of_Device parameter is used to indicate the capabilities of the local device to other devices.

| Value | Parameter Description |
|----------|---------------------------------|
| 0xXXXXXX | Class of Device for the device. |

6.26 SUPPORTED COMMANDS

The Supported Commands configuration parameter lists which HCI commands the local controller supports. It is implied that if a command is listed as supported, the feature underlying that command is also supported.

The Supported Commands is a 64 octet bit field. If a bit is set to 1, then this command is supported.

| Octet | Bit | Command Supported |
|-------|-----|---------------------------------|
| 0 | 0 | Inquiry |
| | 1 | Inquiry Cancel |
| | 2 | Periodic Inquiry Mode |
| | 3 | Exit Periodic Inquiry Mode |
| | 4 | Create Connection |
| | 5 | Disconnect |
| | 6 | Add SCO Connection |
| | 7 | Cancel Create Connection |
| 1 | 0 | Accept Connection Request |
| | 1 | Reject Connection Request |
| | 2 | Link Key Request Reply |
| | 3 | Link Key Request Negative Reply |
| | 4 | PIN Code Request Reply |
| | 5 | PIN Code Request Negative Reply |
| | 6 | Change Connection Packet Type |
| | 7 | Authentication Request |
| 2 | 0 | Set Connection Encryption |
| | 1 | Change Connection Link Key |
| | 2 | Master Link Key |
| | 3 | Remote Name Request |
| | 4 | Cancel Remote Name Request |
| | 5 | Read Remote Supported Features |
| | 6 | Read Remote Extended Features |
| | 7 | Read Remote Version Information |
| 3 | 0 | Read Clock Offset |
| | 1 | Read LMP Handle |
| | 2 | Reserved |
| | 3 | Reserved |
| | 4 | Reserved |
| | 5 | Reserved |
| | 6 | Reserved |
| | 7 | Reserved |



| Octet | Bit | Command Supported |
|-------|-----|------------------------------------|
| 4 | 0 | Reserved |
| | 1 | Hold Mode |
| | 2 | Sniff Mode |
| | 3 | Exit Sniff Mode |
| | 4 | Park State |
| | 5 | Exit Park State |
| | 6 | QoS Setup |
| | 7 | Role Discovery |
| 5 | 0 | Switch Role |
| | 1 | Read Link Policy Settings |
| | 2 | Write Link Policy Settings |
| | 3 | Read Default Link Policy Settings |
| | 4 | Write Default Link Policy Settings |
| | 5 | Flow Specification |
| | 6 | Set Event Mark |
| | 7 | Reset |
| 6 | 0 | Set Event Filter |
| | 1 | Flush |
| | 2 | Read PIN Type |
| | 3 | Write PIN Type |
| | 4 | Create New Unit Key |
| | 5 | Read Stored Link Key |
| | 6 | Write Stored Link Key |
| | 7 | Delete Stored Link Key |
| 7 | 0 | Write Local Name |
| | 1 | Read Local Name |
| | 2 | Read Connection Accept Timeout |
| | 3 | Write Connection Accept Timeout |
| | 4 | Read Page Timeout |
| | 5 | Write Page Timeout |
| | 6 | Read Scan Enable |
| | 7 | Write Scan Enable |
| 8 | 0 | Read Page Scan Activity |
| | 1 | Write Page Scan Activity |
| | 2 | Read Inquiry Scan Activity |
| | 3 | Write Inquiry Scan Activity |
| | 4 | Read Authentication Enable |
| | 5 | Write Authentication Enable |
| | 6 | Read Encryption Mode |
| | 7 | Write Encryption Mode |



| Octet | Bit | Command Supported |
|-------|-----|--|
| 9 | 0 | Read Class Of Device |
| | 1 | Write Class Of Device |
| | 2 | Read Voice Setting |
| | 3 | Write Voice Setting |
| | 4 | Read Automatic Flush Timeout |
| | 5 | Write Automatic Flush Timeout |
| | 6 | Read Num Broadcast Retransmissions |
| | 7 | Write Num Broadcast Retransmissions |
| 10 | 0 | Read Hold Mode Activity |
| | 1 | Write Hold Mode Activity |
| | 2 | Read Transmit Power Level |
| | 3 | Read Synchronous Flow Control Enable |
| | 4 | Write Synchronous Flow Control Enable |
| | 5 | Set Host Controller To Host Flow Control |
| | 6 | Host Buffer Size |
| | 7 | Host Number Of Completed Packets |
| 11 | 0 | Read Link Supervision Timeout |
| | 1 | Write Link Supervision Timeout |
| | 2 | Read Number of Supported IAC |
| | 3 | Read Current IAC LAP |
| | 4 | Write Current IAC LAP |
| | 5 | Reserved |
| | 6 | Reserved |
| | 7 | Read Page Scan Mode |
| 12 | 0 | Write Page Scan Mode |
| | 1 | Set AFH Channel Classification |
| | 2 | reserved |
| | 3 | reserved |
| | 4 | Read Inquiry Scan Type |
| | 5 | Write Inquiry Scan Type |
| | 6 | Read Inquiry Mode |
| | 7 | Write Inquiry Mode |
| 13 | 0 | Read Page Scan Type |
| | 1 | Write Page Scan Type |
| | 2 | Read AFH Channel Assessment Mode |
| | 3 | Write AFH Channel Assessment Mode |
| | 4 | Reserved |
| | 5 | Reserved |
| | 6 | Reserved |
| | 7 | Reserved |



| Octet | Bit | Command Supported |
|-------|-----|--------------------------------|
| 14 | 0 | Reserved |
| | 1 | Reserved |
| | 2 | Reserved |
| | 3 | Read Local Version Information |
| | 4 | Reserved |
| | 5 | Read Local Supported Features |
| | 6 | Read Local Extended Features |
| | 7 | Read Buffer Size |
| 15 | 0 | Read Country Code |
| | 1 | Read BD ADDR |
| | 2 | Read Failed Contact Count |
| | 3 | Reset Failed Contact Count |
| | 4 | Get Link Quality |
| | 5 | Read RSSI |
| | 6 | Read AFH Channel Map |
| | 7 | Read BD Clock |
| 16 | 0 | Read Loopback Mode |
| | 1 | Write Loopback Mode |
| | 2 | Enable Device Under Test Mode |
| | 3 | Setup Synchronous Connection |
| | 4 | Accept Synchronous Connection |
| | 5 | Reject Synchronous Connection[|
| | 6 | Reserved |
| | 7 | Reserved |

7 HCI COMMANDS AND EVENTS

7.1 LINK CONTROL COMMANDS

The Link Control commands allow the Controller to control connections to other Bluetooth devices. When the Link Control commands are used, the Link Manager (LM) controls how the Bluetooth piconets and scatternets are established and maintained. These commands instruct the LM to create and modify link layer connections with Bluetooth remote devices, perform Inquiries of other Bluetooth devices in range, and other LMP commands. For the Link Control commands, the OGF is defined as 0x01.

7.1.1 Inquiry Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------|--------|---------------------------------------|-------------------|
| HCI_Inquiry | 0x0001 | LAP, Inquiry_Length, Num_Responses | |

Description:

This command will cause the Bluetooth device to enter Inquiry Mode. Inquiry Mode is used to discover other nearby Bluetooth devices. The LAP input parameter contains the LAP from which the inquiry access code shall be derived when the inquiry procedure is made. The Inquiry_Length parameter specifies the total duration of the Inquiry Mode and, when this time expires, Inquiry will be halted. The Num_Responses parameter specifies the number of responses that can be received before the Inquiry is halted. A Command Status event is sent from the Controller to the Host when the Inquiry command has been started by the Bluetooth device. When the Inquiry process is completed, the Controller will send an Inquiry Complete event to the Host indicating that the Inquiry has finished. The event parameters of Inquiry Complete event will have a summary of the result from the Inquiry process, which reports the number of nearby Bluetooth devices that responded. When a Bluetooth device responds to the Inquiry message, an Inquiry Result event will occur to notify the Host of the discovery.

A device which responds during an inquiry or inquiry period should always be reported to the Host in an Inquiry Result event if the device has not been reported earlier during the current inquiry or inquiry period and the device has not been filtered out using the command Set_Event_Filter. If the device has been reported earlier during the current inquiry or inquiry period, it may or may not be reported depending on the implementation (depending on if earlier results have been saved in the Controller and in that case how many responses that have been saved). It is recommended that the Controller tries to report a particular device only once during an inquiry or inquiry period.

**Command Parameters:****LAP:****Size: 3 Octets**

| Value | Parameter Description |
|-----------------------|--|
| 0x9E8B00– 0X9E8B3F | This is the LAP from which the inquiry access code should be derived when the inquiry procedure is made; see “Bluetooth Assigned Numbers” (https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers). |

Inquiry_Length:**Size: 1 Octet**

| Value | Parameter Description |
|----------|---|
| N = 0xXX | Maximum amount of time specified before the Inquiry is halted. Size: 1 octet Range: 0x01 – 0x30 Time = N * 1.28 sec Range: 1.28 – 61.44 Sec |

Num_Responses:**Size: 1 Octet**

| Value | Parameter Description |
|-------|--|
| 0x00 | Unlimited number of responses. |
| 0xXX | Maximum number of responses from the Inquiry before the Inquiry is halted. Range: 0x01 – 0xFF |

Return Parameters:

None.

Event(s) generated (unless masked away):

A Command Status event is sent from the Controller to the Host when the Controller has started the Inquiry process. An Inquiry Result event will be created for each Bluetooth device which responds to the Inquiry message. In addition, multiple Bluetooth devices which respond to the Inquire message may be combined into the same event. An Inquiry Complete event is generated when the Inquiry process has completed.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Inquiry Complete event will indicate that this command has been completed. No Inquiry Complete event will be generated for the canceled Inquiry process.



7.1.2 Inquiry Cancel Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------|--------|--------------------|-------------------|
| HCI_Inquiry_Cancel | 0x0002 | | Status |

Description:

This command will cause the Bluetooth device to stop the current Inquiry if the Bluetooth device is in Inquiry Mode. This command allows the Host to interrupt the Bluetooth device and request the Bluetooth device to perform a different task. The command should only be issued after the Inquiry command has been issued, a Command Status event has been received for the Inquiry command, and before the Inquiry Complete event occurs.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Inquiry_Cancel command succeeded. |
| 0x01-0xFF | Inquiry_Cancel command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Inquiry Cancel command has completed, a Command Complete event will be generated. No Inquiry Complete event will be generated for the canceled Inquiry process.

7.1.3 Periodic Inquiry Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------|--------|--|-------------------|
| HCI_Periodic_Inquiry_Mode | 0x0003 | Max_Period_Length, Min_Period_Length, LAP, Inquiry_Length, Num_Responses | Status |

Description:

The Periodic_Inquiry_Mode command is used to configure the Bluetooth device to enter the Periodic Inquiry Mode that performs an automatic Inquiry. Max_Period_Length and Min_Period_Length define the time range between two consecutive inquiries, from the beginning of an inquiry until the start of the next inquiry. The Controller will use this range to determine a new random time between two consecutive inquiries for each Inquiry. The LAP input parameter contains the LAP from which the inquiry access code shall be derived when the inquiry procedure is made. The Inquiry_Length parameter specifies the total duration of the InquiryMode and, when time expires, Inquiry will be halted. The Num_Responses parameter specifies the number of responses that can be received before the Inquiry is halted. This command is completed when the Inquiry process has been started by the Bluetooth device, and a Command Complete event is sent from the Controller to the Host. When each of the periodic Inquiry processes are completed, the Controller will send an Inquiry Complete event to the Host indicating that the latest periodic Inquiry process has finished. When a Bluetooth device responds to the Inquiry message an Inquiry Result event will occur to notify the Host of the discovery.

Note: Max_Period_Length > Min_Period_Length > Inquiry_Length

A device which responds during an inquiry or inquiry period should always be reported to the Host in an Inquiry Result event if the device has not been reported earlier during the current inquiry or inquiry period and the device has not been filtered out using the command Set_Event_Filter. If the device has been reported earlier during the current inquiry or inquiry period, it may or may not be reported depending on the implementation (depending on if earlier results have been saved in the Controller and in that case how many responses that have been saved). It is recommended that the Controller tries to report a particular device only once during an inquiry or inquiry period.

**Command Parameters:***Max_Period_Length:**Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Maximum amount of time specified between consecutive inquiries. Size: 2 octets Range: 0x03 – 0xFFFF Time = N * 1.28 sec Range: 3.84 – 83884.8 Sec 0.0 – 23.3 hours |

*Min_Period_Length:**Size: 2 Octets*

| Value | Parameter Description |
|------------|--|
| N = 0xXXXX | Minimum amount of time specified between consecutive inquiries. Size: 2 octets Range: 0x02 – 0xFFFE Time = N * 1.28 sec Range: 2.56 – 83883.52 Sec 0.0 – 23.3 hours |

*LAP:**Size: 3 Octets*

| Value | Parameter Description |
|-----------------------|--|
| 0x9E8B00– 0X9E8B3F | This is the LAP from which the inquiry access code should be derived when the inquiry procedure is made, see “Bluetooth Assigned Numbers” (https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers). |

*Inquiry_Length:**Size: 1 Octet*

| Value | Parameter Description |
|----------|---|
| N = 0xXX | Maximum amount of time specified before the Inquiry is halted. Size: 1 octet Range: 0x01 – 0x30 Time = N * 1.28 sec Range: 1.28 – 61.44 Sec |

*Num_Responses:**Size: 1 Octet*

| Value | Parameter Description |
|-------|--|
| 0x00 | Unlimited number of responses. |
| 0xXX | Maximum number of responses from the Inquiry before the Inquiry is halted. Range: 0x01 – 0xFF |



Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Periodic Inquiry Mode command succeeded. |
| 0x01-0xFF | Periodic Inquiry Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

The Periodic Inquiry Mode begins when the Controller sends the Command Complete event for this command to the Host. An Inquiry Result event will be created for each Bluetooth device which responds to the Inquiry message. In addition, multiple Bluetooth devices which response to the Inquiry message may be combined into the same event. An Inquiry Complete event is generated when each of the periodic Inquiry processes has completed. No Inquiry Complete event will be generated for the canceled Inquiry process.

7.1.4 Exit Periodic Inquiry Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------|--------|--------------------|-------------------|
| HCI_Exit_Periodic_Inquiry_Mode | 0x0004 | | Status |

Description:

The Exit Periodic Inquiry Mode command is used to end the Periodic Inquiry mode when the local device is in Periodic Inquiry Mode. If the local device is currently in an Inquiry process, the Inquiry process will be stopped directly and the Controller will no longer perform periodic inquiries until the Periodic Inquiry Mode command is reissued.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Exit Periodic Inquiry Mode command succeeded. |
| 0x01-0xFF | Exit Periodic Inquiry Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

A Command Complete event for this command will occur when the local device is no longer in Periodic Inquiry Mode. No Inquiry Complete event will be generated for the canceled Inquiry process.

7.1.5 Create Connection Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------|--------|---|-------------------|
| HCI_Create_Connection | 0x0005 | BD_ADDR, Packet_Type, Page_Scan_Repetition_Mode, Reserved, Clock_Offset, Allow_Role_Switch | |

Description:

This command will cause the Link Manager to create a connection to the Bluetooth device with the BD_ADDR specified by the command parameters. This command causes the local Bluetooth device to begin the Page process to create a link level connection. The Link Manager will determine how the new ACL connection is established. This ACL connection is determined by the current state of the device, its piconet, and the state of the device to be connected. The Packet_Type command parameter specifies which packet types the Link Manager shall use for the ACL connection. When sending HCI ACL Data Packets the Link Manager shall only use the packet type(s) specified by the Packet_Type command parameter or the always-allowed DM1 packet type. Multiple packet types may be specified for the Packet Type parameter by performing a bit-wise OR operation of the different packet types. The Link Manager may choose which packet type to be used from the list of acceptable packet types. The Page_Scan_Repetition_Mode parameter specifies the page scan repetition mode supported by the remote device with the BD_ADDR. This is the information that was acquired during the inquiry process. The Clock_Offset parameter is the difference between its own clock and the clock of the remote device with BD_ADDR. Only bits 2 through 16 of the difference are used, and they are mapped to this parameter as bits 0 through 14 respectively. A Clock_Offset_Valid_Flag, located in bit 15 of the Clock_Offset parameter, is used to indicate if the Clock Offset is valid or not. A Connection handle for this connection is returned in the Connection Complete event (see below). The Allow_Role_Switch parameter specifies if the local device accepts or rejects the request of a master-slave role switch when the remote device requests it at the connection setup (in the Role parameter of the Accept_Connection_Request command) (before the local Controller returns a Connection Complete event). For a definition of the different packet types see the [“Baseband Specification” on page 55 \[Part B\]](#).

Note: The Host should enable as many packet types as possible for the Link Manager to perform efficiently. However, the Host must not enable packet types that the local device does not support.

**Command Parameters:*****BD_ADDR:******Size: 6 Octets***

| Value | Parameter Description |
|----------------|--|
| 0XXXXXXXXXXXXX | BD_ADDR of the Device to be connected. |

Packet_Type:***Size: 2 Octets***

| Value | Parameter Description |
|---------------------|--------------------------|
| 0x0001 | Reserved for future use. |
| 0x0002 | 2-DH1 may not be used. |
| 0x0004 | 3-DH1 may not be used. |
| 0x0008 ¹ | DM1 may be used. |
| 0x0010 | DH1 may be used. |
| 0x0020 | Reserved for future use. |
| 0x0040 | Reserved for future use. |
| 0x0080 | Reserved for future use. |
| 0x0100 | 2-DH3 may not be used. |
| 0x0200 | 3-DH3 may not be used. |
| 0x0400 | DM3 may be used. |
| 0x0800 | DH3 may be used. |
| 0x1000 | 2-DH5 may not be used. |
| 0x2000 | 3-DH5 may not be used. |
| 0x4000 | DM5 may be used. |
| 0x8000 | DH5 may be used. |

1. This bit will be interpreted as set to 1 by Bluetooth V1.2 or later controllers.

Page_Scan_Repetition_Mode:***Size: 1 Octet***

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | R0 |
| 0x01 | R1 |
| 0x02 | R2 |
| 0x03 – 0xFF | Reserved. |

**Reserved:****Size: 1 Octet**

| Value | Parameter Description |
|-------|---|
| 0x00 | Reserved, must be set to 0x00. See “Page Scan Mode” on page 612. |

Clock_Offset:**Size: 2 Octets**

| Bit format | Parameter Description |
|------------|---|
| Bit 14-0 | Bit 16-2 of CLKslave-CLKmaster. |
| Bit 15 | Clock_Offset_Valid_Flag Invalid Clock Offset = 0 Valid Clock Offset = 1 |

Allow_Role_Switch:**Size: 1 Octet**

| Value | Parameter Description |
|-----------|---|
| 0x00 | The local device will be a master, and will not accept a role switch requested by the remote device at the connection setup. |
| 0x01 | The local device may be a master, or may become a slave after accepting a role switch requested by the remote device at the connection setup. |
| 0x02-0xFF | Reserved for future use. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Create Connection command, the Controller sends the Command Status event to the Host. In addition, when the LM determines the connection is established, the Controller, on both Bluetooth devices that form the connection, will send a Connection Complete event to each Host. The Connection Complete event contains the Connection Handle if this command is successful.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Connection Complete event will indicate that this command has been completed.

7.1.6 Disconnect Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------|--------|------------------------------|-------------------|
| HCI_Disconnect | 0x0006 | Connection_Handle, Reason | |

Description:

The Disconnection command is used to terminate an existing connection. The Connection_Handle command parameter indicates which connection is to be disconnected. The Reason command parameter indicates the reason for ending the connection. The remote Bluetooth device will receive the Reason command parameter in the Disconnection Complete event. All synchronous connections on a physical link should be disconnected before the ACL connection on the same physical connection is disconnected.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle for the connection being disconnected. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Reason:

Size: 1 Octet

| Value | Parameter Description |
|-----------------------------|--|
| 0x05, 0x13-0x15, 0x1A, 0x29 | Authentication Failure error code (0x05), Other End Terminated Connection error codes (0x13-0x15), Unsupported Remote Feature error code (0x1A) and Pairing with Unit Key Not Supported error code (0x29), see “Error Codes” on page 319 [Part D] for list of Error Codes. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Disconnect command, it sends the Command Status event to the Host. The Disconnection Complete event will occur at each Host when the termination of the connection has completed, and indicates that this command has been completed.

Note: No Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Disconnection Complete event will indicate that this command has been completed.



7.1.7 Create Connection Cancel Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------|--------|--------------------|--------------------|
| HCI_Create_Connection_Cancel | 0x0008 | BD_ADDR | Status, BD_ADDR |

Description:

This command is used to request cancellation of the ongoing connection creation process, which was started by a Create_Connection command of the local device.

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---|
| 0xFFFFFFFFXXXX | BD_ADDR of the Create Connection command request that was issued before and is subject of this cancellation request |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Create Connection Cancel command succeeded |
| 0x01-0xff | Create Connection Cancel command failed. See “Error Codes” on page 319 [Part D] for list of error codes |

BD_ADDR:

Size: 6 Octet

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR of the Create Connection command that was issued before and is the subject of this cancellation request. |

**Event(s) generated (unless masked away):**

When the Create Connection Cancel command has completed, a Command Complete event shall be generated.

If the connection is already established by the baseband, but the Controller has not yet sent the Connection Complete event, then the local device shall detach the link and return a Command Complete event with the status "Success".

If the connection is already established, and the Connection Complete event has been sent, then the Controller shall return a Command Complete event with the error code *ACL Connection already exists* (0x0B).

If the Create Connection Cancel command is sent to the Controller without a preceding Create Connection command to the same device, the Controller shall return a Command Complete event with the error code *Unknown Connection Identifier* (0x02).

The Connection Complete event for the corresponding Create Connection Command shall always be sent. The Connection Complete event shall be sent after the Command Complete event for the Create Connection Cancel command. If the cancellation was successful, the Connection Complete event will be generated with the error code *Unknown Connection Identifier* (0x02).



7.1.8 Accept Connection Request Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------|--------|--------------------|-------------------|
| HCI_Accept_Connection_Request | 0x0009 | BD_ADDR, Role | |

Description:

The Accept_Connection_Request command is used to accept a new incoming connection request. The Accept_Connection_Request command shall only be issued after a Connection Request event has occurred. The Connection Request event will return the BD_ADDR of the device which is requesting the connection. This command will cause the Link Manager to create a connection to the Bluetooth device, with the BD_ADDR specified by the command parameters. The Link Manager will determine how the new connection will be established. This will be determined by the current state of the device, its piconet, and the state of the device to be connected. The Role command parameter allows the Host to specify if the Link Manager shall request a role switch and become the Master for this connection. This is a preference and not a requirement. If the Role Switch fails then the connection will still be accepted, and the Role Discovery Command will reflect the current role.

Note: The Link Manager may terminate the connection if it would be low on resources if the role switch fails. The decision to accept a connection must be completed before the connection accept timeout expires on the local Bluetooth Module.

Note: when accepting synchronous connection request, the Role parameter is not used and will be ignored by the Controller.

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---------------------------------------|
| 0XXXXXXXXXXXXX | BD_ADDR of the Device to be connected |

Role:

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0x00 | Become the Master for this connection. The LM will perform the role switch. |
| 0x01 | Remain the Slave for this connection. The LM will NOT perform the role switch. |

Return Parameters:

None.

**Event(s) generated (unless masked away):**

The `Accept_Connection_Request` command will cause the `Command Status` event to be sent from the Controller when the Controller begins setting up the connection. In addition, when the Link Manager determines the connection is established, the local Controller will send a `Connection Complete` event to its Host, and the remote Controller will send a `Connection Complete` event or a `Synchronous Connection Complete` event to the Host. The `Connection Complete` event contains the `Connection Handle` if this command is successful.

Note: no `Command Complete` event will be sent by the Controller to indicate that this command has been completed. Instead, the `Connection Complete` event will indicate that this command has been completed.

7.1.9 Reject Connection Request Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------|--------|--------------------|-------------------|
| HCI_Reject_Connection_Request | 0x000A | BD_ADDR, Reason | |

Description:

The Reject_Connection_Request command is used to decline a new incoming connection request. The Reject_Connection_Request command shall only be called after a Connection Request event has occurred. The Connection Request event will return the BD_ADDR of the device that is requesting the connection. The Reason command parameter will be returned to the connecting device in the Status parameter of the Connection Complete event returned to the Host of the connection device, to indicate why the connection was declined.

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0XXXXXXXXXXXXX | BD_ADDR of the Device to reject the connection from. |

Reason:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x0D-0x0F | Host Reject Error Code. See “Error Codes” on page 319 [Part D] for list of Error Codes and descriptions. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Reject_Connection_Request command, the Controller sends the Command Status event to the Host. Then, the local Controller will send a Connection Complete event to its host, and the remote Controller will send a Connection Complete event or a Synchronous Connection Complete event to the host. The Status parameter of the Connection Complete event, which is sent to the Host of the device attempting to make the connection, will contain the Reason command parameter from this command.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Connection Complete event will indicate that this command has been completed.



7.1.10 Link Key Request Reply Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------|--------|--------------------|-------------------|
| HCI_Link_Key_Request_Reply | 0x000B | BD_ADDR, Link_Key | Status, BD_ADDR |

Description:

The Link_Key_Request_Reply command is used to reply to a Link Key Request event from the Controller, and specifies the Link Key stored on the Host to be used as the link key for the connection with the other Bluetooth Device specified by BD_ADDR. The Link Key Request event will be generated when the Controller needs a Link Key for a connection.

When the Controller generates a Link Key Request event in order for the local Link Manager to respond to the request from the remote Link Manager (as a result of a Create_Connection or Authentication_Requested command from the remote Host), the local Host must respond with either a Link_Key_Request_Reply or Link_Key_Request_Negative_Reply command before the remote Link Manager detects LMP response timeout. (See [“Link Manager Protocol” on page 211 \[Part C\]](#).)

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---|
| 0xxxxxxxxxxxxx | BD_ADDR of the Device of which the Link Key is for. |

Link_Key:

Size: 16 Octets

| Value | Parameter Description |
|--|--------------------------------------|
| 0xxxxxxxxxxxxx xxxxxxxxxxxxx xxxxxxxxxxxxx | Link Key for the associated BD_ADDR. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Link_Key_Request_Reply command succeeded. |
| 0x01-0xFF | Link_Key_Request_Reply command failed. See “Error Codes” on page 319 [Part D] for error codes and description. |



BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|--------------------|--|
| 0XXXXXXXXX XXXX | BD_ADDR of the Device of which the Link Key request reply has completed. |

Event(s) generated (unless masked away):

The Link_Key_Request_Reply command will cause a Command Complete event to be generated.

7.1.11 Link Key Request Negative Reply Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------------|--------|--------------------|-------------------|
| HCI_Link_Key_Request_Negative_Reply | 0x000C | BD_ADDR | Status, BD_ADDR |

Description:

The Link_Key_Request_Negative_Reply command is used to reply to a Link Key Request event from the Controller if the Host does not have a stored Link Key for the connection with the other Bluetooth Device specified by BD_ADDR. The Link Key Request event will be generated when the Controller needs a Link Key for a connection.

When the Controller generates a Link Key Request event in order for the local Link Manager to respond to the request from the remote Link Manager (as a result of a Create_Connection or Authentication_Requested command from the remote Host), the local Host must respond with either a Link_Key_Request_Reply or Link_Key_Request_Negative_Reply command before the remote Link Manager detects LMP response timeout. (See [“Link Manager Protocol” on page 211 \[Part C\]](#).)

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|------------------|--|
| 0XXXXXXXXX XX | BD_ADDR of the Device which the Link Key is for. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Link_Key_Request_Negative_Reply command succeeded. |
| 0x01-0xFF | Link_Key_Request_Negative_Reply command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|--------------------|--|
| 0XXXXXXXXX XXXX | BD_ADDR of the Device which the Link Key request negative reply has completed. |

Event(s) generated (unless masked away):

The Link_Key_Request_Negative_Reply command will cause a Command Complete event to be generated.



7.1.12 PIN Code Request Reply Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------|--------|--|-------------------|
| HCI_PIN_Code_Request_Reply | 0x000D | BD_ADDR, PIN_Code_Length, PIN_Code | Status, BD_ADDR |

Description:

The PIN_Code_Request_Reply command is used to reply to a PIN Code request event from the Controller, and specifies the PIN code to use for a connection. The PIN Code Request event will be generated when a connection with remote initiating device has requested pairing.

When the Controller generates a PIN Code Request event in order for the local Link Manager to respond to the request from the remote Link Manager (as a result of a Create_Connection or Authentication_Requested command from the remote Host), the local Host must respond with either a PIN_Code_Request_Reply or PIN_Code_Request_Negative_Reply command before the remote Link Manager detects LMP response timeout. (See “Link Manager Protocol” on page 211 [Part C].)

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|-------------------|--|
| 0XXXXXXXXXX XX | BD_ADDR of the Device which the PIN code is for. |

PIN_Code_Length:

Size: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0xXX | The PIN code length specifies the length, in octets, of the PIN code to be used. Range: 0x01-0x10 |

PIN_Code:

Size: 16 Octets

| Value | Parameter Description |
|---|---|
| 0XXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX | PIN code for the device that is to be connected. The Host should insure that strong PIN Codes are used. PIN Codes can be up to a maximum of 128 bits. Note: the PIN_Code Parameter is a string parameter. Endianness does therefore not apply to the PIN_Code Parameter. The first octet of the PIN code should be transmitted first. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | PIN_Code_Request_Reply command succeeded. |
| 0x01-0xFF | PIN_Code_Request_Reply command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|--------------------|---|
| 0XXXXXXXXX XXXX | BD_ADDR of the Device which the PIN Code request reply has completed. |

Event(s) generated (unless masked away):

The PIN_Code_Request_Reply command will cause a Command Complete event to be generated.



7.1.13 PIN Code Request Negative Reply Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------------|--------|--------------------|-------------------|
| HCI_PIN_Code_Request_Negative_Reply | 0x000E | BD_ADDR | Status, BD_ADDR |

Description:

The PIN_Code_Request_Negative_Reply command is used to reply to a PIN Code request event from the Controller when the Host cannot specify a PIN code to use for a connection. This command will cause the pair request with remote device to fail.

When the Controller generates a PIN Code Request event in order for the local Link Manager to respond to the request from the remote Link Manager (as a result of a Create_Connection or Authentication_Requested command from the remote Host), the local Host must respond with either a PIN_Code_Request_Reply or PIN_Code_Request_Negative_Reply command before the remote Link Manager detects LMP response timeout. (See [“Link Manager Protocol” on page 211 \[Part C\]](#).)

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR of the Device which this command is responding to. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | PIN_Code_Request_Negative_Reply command succeeded. |
| 0x01-0xFF | PIN_Code_Request_Negative_Reply command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR of the Device which the PIN Code request negative reply has completed. |

Event(s) generated (unless masked away):

The PIN_Code_Request_Negative_Reply command will cause a Command Complete event to be generated.



7.1.14 Change Connection Packet Type Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|-----------------------------------|-------------------|
| HCI_Change_Connection_Packet_Type | 0x000F | Connection_Handle, Packet_Type | |

Description:

The Change_Connection_Packet_Type command is used to change which packet types can be used for a connection that is currently established. This allows current connections to be dynamically modified to support different types of user data. The Packet_Type command parameter specifies which packet types the Link Manager can use for the connection. When sending HCI ACL Data Packets the Link Manager shall only use the packet type(s) specified by the Packet_Type command parameter or the always-allowed DM1 packet type. The interpretation of the value for the Packet_Type command parameter will depend on the Link_Type command parameter returned in the Connection Complete event at the connection setup. Multiple packet types may be specified for the Packet_Type command parameter by bitwise OR operation of the different packet types. For a definition of the different packet types see the [“Baseband Specification” on page 55 \[Part B\]](#).

Note: The Host should enable as many packet types as possible for the Link Manager to perform efficiently. However, the Host must not enable packet types that the local device does not support.

Note: to change an eSCO connection, use the Setup Synchronous Connection command.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle to be used to for transmitting and receiving voice or data. Returned from creating a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Packet_Type:**Size: 2 Octets**For ACL Link_Type*

| Value | Parameter Description |
|---------------------|--------------------------|
| 0x0001 | Reserved for future use. |
| 0x0002 | 2-DH1 may not be used. |
| 0x0004 | 3-DH1 may not be used. |
| 0x0008 ¹ | DM1 may be used. |
| 0x0010 | DH1 may be used. |
| 0x0020 | Reserved for future use. |
| 0x0040 | Reserved for future use. |
| 0x0080 | Reserved for future use. |
| 0x0100 | 2-DH3 may not be used. |
| 0x0200 | 3-DH3 may not be used. |
| 0x0400 | DM3 may be used. |
| 0x0800 | DH3 may be used. |
| 0x1000 | 2-DH5 may not be used. |
| 0x2000 | 3-DH5 may not be used. |
| 0x4000 | DM5 may be used. |
| 0x8000 | DH5 may be used. |

1. This bit will be interpreted as set to 1 by Bluetooth V1.2 or later controllers.

*For SCO Link Type*

| Value | Parameter Description |
|--------|--------------------------|
| 0x0001 | Reserved for future use. |
| 0x0002 | Reserved for future use. |
| 0x0004 | Reserved for future use. |
| 0x0008 | Reserved for future use. |
| 0x0010 | Reserved for future use. |
| 0x0020 | HV1 |
| 0x0040 | HV2 |
| 0x0080 | HV3 |
| 0x0100 | Reserved for future use. |
| 0x0200 | Reserved for future use. |
| 0x0400 | Reserved for future use. |
| 0x0800 | Reserved for future use. |
| 0x1000 | Reserved for future use. |
| 0x2000 | Reserved for future use. |
| 0x4000 | Reserved for future use. |
| 0x8000 | Reserved for future use. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Change Connection Packet Type command, the Controller sends the Command Status event to the Host. In addition, when the Link Manager determines the packet type has been changed for the connection, the Controller on the local device will send a Connection Packet Type Changed event to the Host. This will be done at the local side only.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Connection Packet Type Changed event will indicate that this command has been completed.



7.1.15 Authentication Requested Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------|--------|--------------------|-------------------|
| HCI_Authentication_Requested | 0x0011 | Connection_Handle | |

Description:

The Authentication_Requested command is used to try to authenticate the remote device associated with the specified Connection Handle. On an authentication failure, the Controller or Link Manager shall not automatically detach the link. The Host is responsible for issuing a Disconnect command to terminate the link if the action is appropriate.

Note: the Connection_Handle command parameter is used to identify the other Bluetooth device, which forms the connection. The Connection Handle should be a Connection Handle for an ACL connection.

Command Parameters:

Connection_Handle:

Size 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle to be used to set up authentication for all Connection Handles with the same Bluetooth device end-point as the specified Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Authentication_Requested command, it sends the Command Status event to the Host. The Authentication Complete event will occur when the authentication has been completed for the connection and is indication that this command has been completed.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Authentication Complete event will indicate that this command has been completed.

Note: When the local or remote Controller does not have a link key for the specified Connection_Handle, it will request the link key from its Host, before the local Host finally receives the Authentication Complete event.



7.1.16 Set Connection Encryption Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------|--------|---|-------------------|
| HCI_Set_Connection_Encryption | 0x0013 | Connection_Handle, Encryption_Enable | |

Description:

The Set_Connection_Encryption command is used to enable and disable the link level encryption. Note: the Connection_Handle command parameter is used to identify the other Bluetooth device which forms the connection. The Connection Handle should be a Connection Handle for an ACL connection. While the encryption is being changed, all ACL traffic must be turned off for all Connection Handles associated with the remote device.

Command Parameters:

Connection_Handle: *Size 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle to be used to enable/disable the link layer encryption for all Connection Handles with the same Bluetooth device end-point as the specified Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Encryption_Enable: *Size: 1 Octet*

| Value | Parameter Description |
|-------|---------------------------------|
| 0x00 | Turn Link Level Encryption OFF. |
| 0x01 | Turn Link Level Encryption ON. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Set_Connection_Encryption command, the Controller sends the Command Status event to the Host. When the Link Manager has completed enabling/disabling encryption for the connection, the Controller on the local Bluetooth device will send an Encryption Change event to the Host, and the Controller on the remote device will also generate an Encryption Change event.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Encryption Change event will indicate that this command has been completed.



7.1.17 Change Connection Link Key Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------|--------|--------------------|-------------------|
| HCI_Change_Connection_Link_Key | 0x0015 | Connection_Handle | |

Description:

The Change_Connection_Link_Key command is used to force both devices of a connection associated with the connection handle to generate a new link key. The link key is used for authentication and encryption of connections. Note: the Connection_Handle command parameter is used to identify the other Bluetooth device forming the connection. The Connection Handle should be a Connection Handle for an ACL connection.

Command Parameters:

Connection_Handle: Size 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Change_Connection_Link_Key command, the Controller sends the Command Status event to the Host. When the Link Manager has changed the Link Key for the connection, the Controller on the local Bluetooth device will send a Link Key Notification event and a Change Connection Link Key Complete event to the Host, and the Controller on the remote device will also generate a Link Key Notification event. The Link Key Notification event indicates that a new connection link key is valid for the connection. Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Change Connection Link Key Complete event will indicate that this command has been completed.

7.1.18 Master Link Key Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------|--------|--------------------|-------------------|
| HCI_Master_Link_Key | 0x0017 | Key_Flag | |

Description:

The Master Link Key command is used to force the device that is master of the piconet to use the temporary link key of the master device, or the semi-permanent link keys. The temporary link key is used for encryption of broadcast messages within a piconet, and the semi-permanent link keys are used for private encrypted point-to-point communication. The Key_Flag command parameter is used to indicate which Link Key (temporary link key of the Master, or the semi-permanent link keys) shall be used.

Command Parameters:

Key_Flag:

Size: 1 Octet

| Value | Parameter Description |
|-------|-------------------------------|
| 0x00 | Use semi-permanent Link Keys. |
| 0x01 | Use Temporary Link Key. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Master_Link_Key command, the Controller sends the Command Status event to the Host. When the Link Manager has changed link key, the Controller on both the local and the remote device will send a Master Link Key Complete event to the Host. The Connection Handle on the master side will be a Connection Handle for one of the existing connections to a slave. On the slave side, the Connection Handle will be a Connection Handle to the initiating master.

The Master Link Key Complete event contains the status of this command. Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Master Link Key Complete event will indicate that this command has been completed.

7.1.19 Remote Name Request Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------|--------|---|-------------------|
| HCI_Remote_Name_Request | 0x0019 | BD_ADDR, Page_Scan_Repetition_Mode, Reserved, Clock_Offset | |

Description:

The Remote_Name_Request command is used to obtain the user-friendly name of another Bluetooth device. The user-friendly name is used to enable the user to distinguish one Bluetooth device from another. The BD_ADDR command parameter is used to identify the device for which the user-friendly name is to be obtained. The Page_Scan_Repetition_Mode parameter specifies the page scan repetition mode supported by the remote device with the BD_ADDR. This is the information that was acquired during the inquiry process. The Clock_Offset parameter is the difference between its own clock and the clock of the remote device with BD_ADDR. Only bits 2 through 16 of the difference are used and they are mapped to this parameter as bits 0 through 14 respectively. A Clock_Offset_Valid_Flag, located in bit 15 of the Clock_Offset command parameter, is used to indicate if the Clock Offset is valid or not. Note: if no connection exists between the local device and the device corresponding to the BD_ADDR, a temporary link layer connection will be established to obtain the name of the remote device.

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|-------------------|---|
| 0XXXXXXXXXX XX | BD_ADDR for the device whose name is requested. |

Page_Scan_Repetition_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | R0 |
| 0x01 | R1 |
| 0x02 | R2 |
| 0x03 – 0xFF | Reserved. |

**Reserved:****Size: 1 Octet**

| Value | Parameter Description |
|-------|---|
| 0x00 | Reserved, must be set to 0x00. See “Page Scan Mode” on page 612. |

Clock_Offset:**Size: 2 Octets**

| Bit format | Parameter Description |
|------------|---|
| Bit 14.0 | Bit 16.2 of CLKslave-CLKmaster. |
| Bit 15 | Clock_Offset_Valid_Flag Invalid Clock Offset = 0 Valid Clock Offset = 1 |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Remote_Name_Request command, the Controller sends the Command Status event to the Host. When the Link Manager has completed the LMP messages to obtain the remote name, the Controller on the local Bluetooth device will send a Remote Name Request Complete event to the Host. Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Remote Name Request Complete event will indicate that this command has been completed.



7.1.20 Remote Name Request Cancel Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------|--------|--------------------|--------------------|
| HCI_Remote_Name_Request_Cancel | 0x001A | BD_ADDR | Status, BD_ADDR |

Description:

This command is used to request cancellation of the ongoing remote name request process, which was started by the Remote Name Request command.

Command Parameters:

BD_ADDR: *Size: 6 Octets*

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR of the Remote Name Request command that was issued before and that is subject of this cancellation request |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Remote Name Request Cancel command succeeded |
| 0x01-0xff | Remote Name Request Cancel command failed. See “Error Codes” on page 319 [Part D] for list of error codes |

BD_ADDR: *Size: 6 Octets*

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR of the Remote Name Request Cancel command that was issued before and that was subject of this cancellation request |

Event(s) generated (unless masked away):

When the Remote Name Request Cancel command has completed, a Command Complete event shall be generated.

If the Remote Name Request Cancel command is sent to the Controller without a preceding Remote Name Request command to the same device, the Controller will return a Command Complete event with the error code *Invalid HCI Command Parameters* (0x12).

The Remote Name Request Complete event for the corresponding Remote Name Request Command shall always be sent. The Remote Name Request

Complete event shall be sent after the Command Complete event for the Remote Name Request Cancel command. If the cancellation was successful, the Remote Name Request Complete event will be generated with the error code *Unknown Connection Identifier (0x02)*.

7.1.21 Read Remote Supported Features Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------------|--------|--------------------|-------------------|
| HCI_Read_Remote_Supported_Features | 0x001B | Connection_Handle | |

Description:

This command requests a list of the supported features for the remote device identified by the Connection_Handle parameter. The Connection_Handle must be a Connection_Handle for an ACL connection. The Read Remote Supported Features Complete event will return a list of the LMP features. For details see [“Link Manager Protocol” on page 211 \[Part C\]](#).

Command Parameters:

Connection_Handle: Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xXXXX | Specifies which Connection Handle’s LMP-supported features list to get. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Read_Remote_Supported_Features command, the Controller sends the Command Status event to the Host. When the Link Manager has completed the LMP messages to determine the remote features, the Controller on the local Bluetooth device will send a Read Remote Supported Features Complete event to the Host. The Read Remote Supported Features Complete event contains the status of this command, and parameters describing the supported features of the remote device. Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Read Remote Supported Features Complete event will indicate that this command has been completed.



7.1.22 Read Remote Extended Features Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|-----------------------------------|-------------------|
| HCI_Read_Remote_Extended_Features | 0x001C | Connection_Handle, Page Number | |

Description:

The HCI_Read_Remote_Extended_Features command returns the requested page of the extended LMP features for the remote device identified by the specified connection handle. The connection handle must be the connection handle for an ACL connection. This command is only available if the extended features feature is implemented by the remote device. The Read Remote Extended Features Complete event will return the requested information. For details see [“Link Manager Protocol” on page 211 \[Part C\]](#).

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The connection handle identifying the remote device for which extended feature information is required. Range: 0x0000-0x0EFF (0x0F00-0x0FFF Reserved for future use) |

Page Number: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Requests the normal LMP features as returned by HCI_Read_Remote_Supported_Features |
| 0x01-0xFF | Return the corresponding page of features |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the HCI_Read_Remote_Extended_Features command the Controller sends the Command Status command to the Host. When the Link Manager has completed the LMP sequence to determine the remote extended features the controller on the local device will generate a Read Remote Extended Features Complete event to the host. The Read Remote Extended Features Complete event contains the page number and the remote features returned by the remote device.



Note: no Command Complete event will ever be sent by the Controller to indicate that this command has been completed. Instead the Read Remote Extended Features Complete event will indicate that this command has been completed.

7.1.23 Read Remote Version Information Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------------|--------|--------------------|-------------------|
| HCI_Read_Remote_Version_Information | 0x001D | Connection_Handle | |

Description:

This command will obtain the values for the version information for the remote Bluetooth device identified by the Connection_Handle parameter. The Connection_Handle must be a Connection_Handle for an ACL connection.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xXXXX | Specifies which Connection Handle's version information to get. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Read_Remote_Version_Information command, the Controller sends the Command Status event to the Host. When the Link Manager has completed the LMP messages to determine the remote version information, the Controller on the local Bluetooth device will send a Read Remote Version Information Complete event to the Host. The Read Remote Version Information Complete event contains the status of this command, and parameters describing the version and subversion of the LMP used by the remote device.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Read Remote Version Information Complete event will indicate that this command has been completed.



7.1.24 Read Clock Offset Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------|--------|--------------------|-------------------|
| HCI_Read_Clock_Offset | 0x001F | Connection_Handle | |

Description:

Both the System Clock and the clock offset to a remote device are used to determine what hopping frequency is used by a remote device for page scan. This command allows the Host to read clock offset to remote devices. The clock offset can be used to speed up the paging procedure when the local device tries to establish a connection to a remote device, for example, when the local Host has issued Create_Connection or Remote_Name_Request. The Connection_Handle must be a Connection_Handle for an ACL connection.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Specifies which Connection Handle's Clock Offset parameter is returned. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Read_Clock_Offset command, the Controller sends the Command Status event to the Host. If this command was requested at the master and the Link Manager has completed the LMP messages to obtain the Clock Offset information, the Controller on the local Bluetooth device will send a Read Clock Offset Complete event to the Host.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Read Clock Offset Complete event will indicate that this command has been completed. If the command is requested at the slave, the LM will immediately send a Command Status event and a Read Clock Offset Complete event to the Host, without an exchange of LMP PDU.



7.1.25 Read LMP Handle Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------|--------|--------------------|--|
| HCI_Read_LMP_Handle | 0x0020 | Connection_Handle | Status, Connection_Handle, LMP_Handle, Reserved |

Description:

This command will read the current LMP Handle associated with the Connection_Handle. The Connection_Handle must be a SCO or eSCO Handle. If the Connection_Handle is a SCO connection handle, then this command shall read the LMP SCO Handle for this connection. If the Connection_Handle is an eSCO connection handle, then this command shall read the LMP eSCO Handle for this connection.

Command Parameters:

Connection_Handle: *Size 2 Octets (12 bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle to be used to identify which connection to be used for reading the LMP Handle. This must be a synchronous handle. Range: 0x0000-0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-------------|---|
| 0x00 | Read_LMP_Handle command succeeded. |
| 0x01 – 0xFF | Read_LMP_Handle command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The Connection Handle for the Connection for which the LMP_Handle has been read. Range: 0x0000-0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |



LMP_Handle:

Size: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0xXX | The LMP Handle is the LMP Handle that is associated with this connection handle. For a synchronous handle, this would be the LMP Synchronous Handle used when negotiating the synchronous connection in the link manager. |

Reserved:

Size: 4 Octets

| Value | Parameter Description |
|------------|--|
| 0xFFFFFFFF | This parameter is reserved, must to set to zero. |

Events(s) generated (unless masked away):

When the Read_LMP_Handle command has completed, a Command Complete event will be generated.

7.1.26 Setup Synchronous Connection Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------------|--------|--|-------------------|
| HCI_Setup_Synchronous_Connection | 0x0028 | Connection_Handle Transmit_Bandwidth Receive_Bandwidth Max_Latency Voice_Setting Retransmission_Effort Packet_Type | |

Description:

The HCI Setup Synchronous Connection command adds a new or modifies an existing synchronous logical transport (SCO or eSCO) on a physical link depending on the Connection_Handle parameter specified. If the Connection_Handle refers to an ACL link a new synchronous logical transport will be added. If the Connection_Handle refers to an already existing synchronous logical transport (eSCO only) this link will be modified. The parameters are specified per connection. This synchronous connection can be used to transfer synchronous voice at 64kbps or transparent synchronous data.

When used to setup a new synchronous logical transport, the Connection_Handle parameter shall specify an ACL connection with which the new synchronous connection will be associated. The other parameters relate to the negotiation of the link, and may be reconfigured during the lifetime of the link. The transmit and receive bandwidth specify how much bandwidth shall be available for transmitting and for receiving data. While in many cases the receive and transmit bandwidth parameters may be equal, they may be different. The latency specifies an upper limit to the time in milliseconds between the eSCO (or SCO) instants, plus the size of the retransmission window, plus the length of the reserved synchronous slots for this logical transport. The content format specifies the settings for voice or transparent data on this connection. The retransmission effort specifies the extra resources that are allocated to this connection if a packet may need to be retransmitted. The Retransmission_Effort parameter shall be set to indicate the required behavior, or to don't care.

When used to modify an existing synchronous logical transport, the Transmit_Bandwidth, Receive_Bandwidth and Voice_Settings shall be set to the same values as were used during the initial setup. The Packet_Type, Retransmission_Effort and Max_Latency parameters may be modified.

The Packet_Type field is a bitmap specifying which packet types the LM shall accept in the negotiation of the link parameters. Multiple packet types are specified by bitwise OR of the packet type codes in the table. At least one packet type must be specified for each negotiation. It is recommended to enable as many packet types as possible. Note that it is allowed to enable packet types that are not supported by the local device.



A connection handle for the new synchronous connection will be returned in the synchronous connection complete event.

Note: The link manager may choose any combination of packet types, timing, and retransmission window sizes that satisfy the parameters given. This may be achieved by using more frequent transmissions of smaller packets. The link manager may choose to set up either a SCO or an eSCO connection, if the parameters allow, using the corresponding LMP sequences.

Note: To modify a SCO connection, use the Change Connection Packet Type command.

Note: If the lower layers cannot achieve the exact transmit and receive bandwidth requested subject to the other parameters, then the link shall be rejected.

A synchronous connection may only be created when an ACL connection already exists and when it is not in park state.

Command Parameters:

Connection_Handle: 2 octets (12 bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle for the ACL connection being used to create a synchronous Connection or for the existing Connection that shall be modified. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

Transmit_Bandwidth: 4 octets

| Value | Parameter Description |
|------------|--|
| 0xFFFFFFFF | Transmit bandwidth in octets per second. |

Receive_Bandwidth: 4 octets

| Value | Parameter Description |
|------------|---|
| 0xFFFFFFFF | Receive bandwidth in octets per second. |



Max_Latency:

2 octets

| Value | Parameter Description |
|----------------|--|
| 0x0000-0x0003 | Reserved |
| 0x0004-0xFFFFE | This is a value in milliseconds representing the upper limit of the sum of the synchronous interval, the size of the eSCO window. (See Figure 8.7 in the Baseband specification) |
| 0xFFFF | Don't care. |

Voice_Setting:

2 octets (10 bits meaningful)

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.12 on page 387 . | |

Retransmission_Effort:

1 octet

| Value | Parameter Description |
|-------------|--|
| 0x00 | No retransmissions |
| 0x01 | At least one retransmission, optimize for power consumption. |
| 0x02 | At least one retransmission, optimize for link quality |
| 0xFF | Don't care |
| 0x03 – 0xFE | Reserved |

**Packet_Type:****2 octets**

| Value | Parameter Description |
|--------|-------------------------|
| 0x0001 | HV1 may be used. |
| 0x0002 | HV2 may be used. |
| 0x0004 | HV3 may be used. |
| 0x0008 | EV3 may be used. |
| 0x0010 | EV4 may be used. |
| 0x0020 | EV5 may be used. |
| 0x0040 | 2-EV3 may not be used. |
| 0x0080 | 3-EV3 may not be used. |
| 0x0100 | 2-EV5 may not be used. |
| 0x0200 | 3-EV5 may not be used. |
| 0x0400 | Reserved for future use |
| 0x0800 | Reserved for future use |
| 0x1000 | Reserved for future use |
| 0x2000 | Reserved for future use |
| 0x4000 | Reserved for future use |
| 0x8000 | Reserved for future use |

Return Parameters:

None

Event(s) generated (unless masked away)

When the Controller receives the Setup_Synchronous_Connection command, it sends the Command Status event to the Host. In addition, when the LM determines the connection is established, the local Controller will send a Synchronous Connection Complete event to the local Host, and the remote Controller will send a Synchronous Connection Complete event or a Connection Complete event to the remote Host. The synchronous Connection Complete event contains the Connection Handle if this command is successful.

If this command is used to change the parameters of an existing eSCO link, the Synchronous Connection Changed Event is sent to both hosts. In this case no Connection Setup Complete Event or Connection Request Event will be sent to either host. This command cannot be used to change the parameters of an SCO link.



Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the synchronous Connection Complete event will indicate that this command has been completed.

7.1.27 Accept Synchronous Connection Request Command

| Command | OCF | Command Parameters | Return Parameters |
|---|--------|---|-------------------|
| HCI_Accept_Synchronous_Connection_Request | 0x0029 | BD_ADDR Transmit_Bandwidth Receive_Bandwidth Max_Latency Content_Format Retransmission_Effort Packet_Type | |

Description:

The Accept_Synchronous_Connection_Request command is used to accept an incoming request for a synchronous connection and to inform the local Link Manager about the acceptable parameter values for the synchronous connection. The Command shall only be issued after a Connection_Request event with link type SCO or eSCO has occurred. Connection_Request event contains the BD_ADDR of the device requesting the connection. The decision to accept a connection must be taken before the connection accept timeout expires on the local device.

The parameter set of the Accept_Synchronous_Connection_Request command is the same as for the Setup_Synchronous_Connection command. The Transmit_Bandwidth and Receive_Bandwidth values are required values for the new link and shall be met. The Max_Latency is an upper bound to the acceptable latency for the Link, as defined in [Section 7.1.26 on page 437](#) Setup_Synchronous_Connection and shall not be exceeded. Content_Format specifies the encoding in the same way as in the Setup_Synchronous_Connection command and shall be met. The Retransmission_Effort parameter shall be set to indicate the required behavior, or to don't care. The Packet_Type parameter is a bit mask specifying the synchronous packet types that are allowed on the link and shall be met. The reserved bits in the Packet_Type field shall be set to one. If all bits are set in the packet type field then all packets types shall be allowed.

If the Link Type of the incoming request is SCO, then only the Transmit_Bandwidth, Max_Latency, Content_Format, and Packet_Type fields are valid.

If the Connection_Request event is masked away, and the Controller is not set to auto-accept this connection attempt, the Controller will automatically reject it. If the controller is set to automatically accept the connection attempt, the LM should assume default parameters. In that case the Synchronous_Connection_Complete Event shall be generated, unless masked away.

**Command Parameters:*****BD_ADDR:*** 6 octets

| Value | Parameter Description |
|----------------|---|
| 0XXXXXXXXXXXXX | BD_ADDR of the device requesting the connection |

Transmit_Bandwidth: 4 octets

| Value | Parameter Description |
|-----------------------|---|
| 0x00000000-0xFFFFFFFF | Maximum possible transmit bandwidth in octets per second. |
| 0xFFFFFFFF | Don't care |

Default: Don't care

Receive_Bandwidth: 4 octets

| Value | Parameter Description |
|-----------------------|--|
| 0x00000000-0xFFFFFFFF | Maximum possible receive bandwidth in octets per second. |
| 0xFFFFFFFF | Don't care |

Default: Don't care

Max_Latency: 2 octets

| Value | Parameter Description |
|---------------|--|
| 0x0000-0x0003 | Reserved |
| 0x0004-0xFFFE | This is a value in milliseconds representing the upper limit of the sum of the synchronous interval and the size of the eSCO window. |
| 0xFFFF | Don't care. |

Default: Don't care

**Content_Format:****2 octets (10 bits meaningful)**

| Value | Parameter Description |
|------------|--|
| 00XXXXXXXX | Input Coding: Linear |
| 01XXXXXXXX | Input Coding: u-law |
| 10XXXXXXXX | Input Coding: A-law |
| 11XXXXXXXX | Reserved for future use. |
| XX00XXXXXX | Input Data Format: 1's complement |
| XX01XXXXXX | Input Data Format: 2's complement |
| XX10XXXXXX | Input Data Format: Sign-Magnitude |
| XX11XXXXXX | Input Data Format: Unsigned |
| XXXX0XXXXX | Input Sample Size: 8 bit (only for Linear PCM) |
| XXXX1XXXXX | Input Sample Size: 16 bit (only for Linear PCM) |
| XXXXXnnnXX | Linear PCM Bit Position: number of bit positions that MSB of sample is away from starting at MSB (only for Linear PCM) |
| XXXXXXXX00 | Air Coding Format: CVSD |
| XXXXXXXX01 | Air Coding Format: u-law |
| XXXXXXXX10 | Air Coding Format: A-law |
| XXXXXXXX11 | Air Coding Format: Transparent Data |

Default: When links are auto-accepted, the values written by the HCI_Write_Voice_Settings are used.

Retransmission_Effort:**1 octet**

| Value | Parameter Description |
|-----------|--|
| 0x00 | No retransmissions |
| 0x01 | At least one retransmission, optimize for power consumption. |
| 0x02 | At least one retransmission, optimize for link quality. |
| 0x03-0xFE | Reserved |
| 0xFF | Don't care |

Default: Don't care

**Packet_Type:****2 octets**

| Value | Parameter Description |
|--------|-------------------------|
| 0x0001 | HV1 may be used. |
| 0x0002 | HV2 may be used. |
| 0x0004 | HV3 may be used. |
| 0x0008 | EV3 may be used. |
| 0x0010 | EV4 may be used. |
| 0x0020 | EV5 may be used. |
| 0x0040 | 2-EV3 may not be used. |
| 0x0080 | 3-EV3 may not be used |
| 0x0100 | 2-EV5 may not be used. |
| 0x0200 | 3-EV5 may not be used. |
| 0x0400 | Reserved for future use |
| 0x0800 | Reserved for future use |
| 0x1000 | Reserved for future use |
| 0x2000 | Reserved for future use |
| 0x4000 | Reserved for future use |
| 0x8000 | Reserved for future use |

Default: 0xFFFF - means all packet types may be used.

Return Parameters:

None

Event(s) generated (unless masked away):

The `Accept_Synchronous_Request` command will cause the Command Status event to be sent from the Host Controller when the Host Controller starts setting up the connection. When the link setup is complete, the local Controller will send a Synchronous Connection Complete event to its Host, and the remote Controller will send a Connection Complete event or a Synchronous Connection Complete event to the Host. The Synchronous Connection Complete will contain the connection handle and the link parameters if the setup is successful. No Command Complete event will be sent by the host controller as the result of this command.



7.1.28 Reject Synchronous Connection Request Command

| Command | OCF | Command Parameters | Return Parameters |
|---|--------|--------------------|-------------------|
| HCI_Reject_Synchronous_Connection_Request | 0x002A | BD_ADDR Reason | |

Description:

The Reject_Synchronous_Connection_Request is used to decline an incoming request for a synchronous link. It shall only be issued after a Connection Request Event with Link Type equal to SCO or eSCO has occurred. The Connection Request Event contains the BD_ADDR of the device requesting the connection. The Reason parameter will be returned to the initiating host in the Status parameter of the Synchronous connection complete event on the remote side.

Command Parameters:

BD_ADDR: 6 octets

| Value | Parameter Description |
|----------------|---|
| 0xFFFFFFFFXXXX | BD_ADDR of the device requesting the connection |

Reason: 1 octet

| Value | Parameter Description |
|-----------|---|
| 0x0D-0x0F | Host Reject Error Code. See “Error Codes” on page 319 [Part D] for error codes and description. |

Return Parameters:

None.

Event(s) Generated (unless masked away):

When the Host Controller receives the Reject_Synchronous_Connection_Request, it sends a Command Status Event to the Host. When the setup is terminated, the local Controller will send a Synchronous Connection Complete event to its Host, and the remote Controller will send a Connection Complete event or a Synchronous Connection Complete event to the Host with the Reason code from this command. No Command complete Event will be sent by the Host Controller to indicate that this command has been completed.

7.2 LINK POLICY COMMANDS

The Link Policy Commands provide methods for the Host to affect how the Link Manager manages the piconet. When Link Policy Commands are used, the LM still controls how Bluetooth piconets and scatternets are established and maintained, depending on adjustable policy parameters. These policy commands modify the Link Manager behavior that can result in changes to the link layer connections with Bluetooth remote devices.

Note: only one ACL connection can exist between two Bluetooth Devices, and therefore there can only be one ACL HCI Connection Handle for each physical link layer Connection. The Bluetooth Controller provides policy adjustment mechanisms to provide support for a number of different policies. This capability allows one Bluetooth module to be used to support many different usage models, and the same Bluetooth module can be incorporated in many different types of Bluetooth devices. For the Link Policy Commands, the OGF is defined as 0x02.

7.2.1 Hold Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------|--------|---|-------------------|
| HCI_Hold_Mode | 0x0001 | Connection_Handle, Hold_Mode_Max_Interval, Hold_Mode_Min_Interval | |

Description:

The Hold_Mode command is used to alter the behavior of the Link Manager, and have it place the ACL baseband connection associated by the specified Connection Handle into the hold mode. The Hold_Mode_Max_Interval and Hold_Mode_Min_Interval command parameters specify the length of time the Host wants to put the connection into the hold mode. The local and remote devices will negotiate the length in the hold mode. The Hold_Mode_Max_Interval parameter is used to specify the maximum length of the Hold interval for which the Host may actually enter into the hold mode after negotiation with the remote device. The Hold interval defines the amount of time between when the Hold Mode begins and when the Hold Mode is completed. The Hold_Mode_Min_Interval parameter is used to specify the minimum length of the Hold interval for which the Host may actually enter into the hold mode after the negotiation with the remote device. Therefore the Hold_Mode_Min_Interval cannot be greater than the Hold_Mode_Max_Interval. The Controller will return the actual Hold interval in the Interval parameter of the Mode Change event, if the command is successful. This command enables the Host to support a low-power policy for itself or several other Bluetooth devices, and allows the devices to enter Inquiry Scan, Page Scan, and a number of other possible actions.

Note: the connection handle cannot be of the SCO or eSCO link type



If the Host sends data to the Controller with a `Connection_Handle` corresponding to a connection in hold mode, the Controller will keep the data in its buffers until either the data can be transmitted (the hold mode has ended) or a flush, a flush timeout or a disconnection occurs. This is valid even if the Host has not yet been notified of the hold mode through a Mode Change event when it sends the data.

Note: the above is not valid for an HCI Data Packet sent from the Host to the Controller on the master side where the `Connection_Handle` is a `Connection_Handle` used for broadcast and the `Broadcast_Flag` is set to Active Broadcast or Piconet Broadcast. The broadcast data will then never be received by slaves in hold mode.

The `Hold_Mode_Max_Interval` shall be less than the Link Supervision Timeout configuration parameter.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Hold_Mode_Max_Interval: *Size: 2 Octets*

| Value | Parameter Description |
|------------|--|
| N = 0xXXXX | Maximum acceptable number of Baseband slots to wait in Hold Mode. Time Length of the Hold = $N * 0.625$ msec (1 Baseband slot) Range for N: 0x0002-0xFFFE; only even values are valid. Time Range: 1.25ms - 40.9 sec Mandatory Range: 0x0014 to 0x8000 |

Hold_Mode_Min_Interval: *Size: 2 Octets*

| Value | Parameter Description |
|------------|--|
| N = 0xXXXX | Minimum acceptable number of Baseband slots to wait in Hold Mode. Time Length of the Hold = $N * 0.625$ msec (1 Baseband slot) Range for N: 0x0002-0xFF00; only even values are valid Time Range: 1.25 msec - 40.9 sec Mandatory Range: 0x0014 to 0x8000 |

Return Parameters:

None.

Event(s) generated (unless masked away):

The Controller sends the Command Status event for this command to the Host when it has received the Hold_Mode command. The Mode Change event will occur when the Hold Mode has started and the Mode Change event will occur again when the Hold Mode has completed for the specified connection handle. The Mode Change event signaling the end of the Hold Mode is an estimation of the hold mode ending if the event is for a remote Bluetooth device.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Mode Change event will indicate that this command has been completed. If an error occurs after the Command Status event has occurred, then the status in the Mode Change event will indicate the error.

7.2.2 Sniff Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------|--------|---|-------------------|
| HCI_Sniff_Mode | 0x0003 | Connection_Handle, Sniff_Max_Interval, Sniff_Min_Interval, Sniff_Attempt, Sniff_Timeout | |

Description:

The Sniff Mode command is used to alter the behavior of the Link Manager and have it place the ACL baseband connection associated with the specified Connection Handle into the sniff mode. The Connection_Handle command parameter is used to identify which ACL link connection is to be placed in sniff mode. The Sniff_Max_Interval and Sniff_Min_Interval command parameters are used to specify the requested acceptable maximum and minimum periods in the Sniff Mode. The Sniff_Min_Interval shall not be greater than the Sniff_Max_Interval. The sniff interval defines the amount of time between each consecutive sniff period. The Controller will return the actual sniff interval in the Interval parameter of the Mode Change event, if the command is successful. For a description of the meaning of the Sniff_Attempt and Sniff_Timeout parameters, see [Baseband Specification, Section 8.7, on page 183](#).

Sniff_Attempt is there called $N_{\text{sniff attempt}}$ and Sniff_Timeout is called $N_{\text{sniff time-out}}$. This command enables the Host to support a low-power policy for itself or several other Bluetooth devices, and allows the devices to enter Inquiry Scan, Page Scan, and a number of other possible actions.

Note: in addition, the connection handle cannot be one of the synchronous link types. If the Host sends data to the Controller with a Connection_Handle corresponding to a connection in sniff mode, the Controller will keep the data in its buffers until either the data can be transmitted or a flush, a flush timeout or a disconnection occurs. This is valid even if the Host has not yet been notified of the sniff mode through a Mode Change event when it sends the data. Note that it is possible for the master to transmit data to a slave without exiting sniff mode



(see description in [Baseband Specification, Section 8.7, on page 183](#)).

Note: the above is not valid for an HCI Data Packet sent from the Host to the Controller on the master side where the Connection_Handle is a Connection_Handle used for broadcast and the Broadcast_Flag is set to Active Broadcast or Piconet Broadcast. In that case, the broadcast data will only be received by a slave in sniff mode if that slave happens to listen to the master when the broadcast is made.

The Sniff_Max_Interval shall be less than the Link Supervision Timeout configuration parameter.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Sniff_Max_Interval: *Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Range: 0x0002 to 0xFFFFE; only even values are valid Mandatory Range: 0x0006 to 0x0540 Time = N * 0.625 msec Time Range: 1.25 msec to 40.9 sec |

Sniff_Min_Interval: *Size: 2 Octets*

| Value | Parameter Description |
|------------|--|
| N = 0xXXXX | Range: 0x0002 to 0xFFFFE; only even values are valid Mandatory Range: 0x0006 to 0x0540 Time = N * 0.625 msec Time Range: 1.25 msec to 40.9 sec) |

Sniff_Attempt: *Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Number of Baseband receive slots for sniff attempt. Length = N * 1.25 msec Range for N: 0x0001 – 0x7FFF Time Range: 0.625msec - 40.9 Seconds Mandatory Range for Controller: 1 to $T_{sniff}/2$ |

Sniff_Timeout:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Number of Baseband receive slots for sniff timeout. Length = N * 1.25 msec Range for N: 0x0000 – 0x7FFF Time Range: 0 msec - 40.9 Seconds Mandatory Range for Controller: 0 to 0x0028 |

Return Parameters:

None.

Event(s) generated (unless masked away):

The Controller sends the Command Status event for this command to the Host when it has received the Sniff_Mode command. The Mode Change event will occur when the Sniff Mode has started for the specified connection handle. Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead only the Mode Change event will indicate that this command has been completed. If an error occurs after the Command Status event has occurred, then the status in the Mode Change event will indicate the error.

7.2.3 Exit Sniff Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------|--------|--------------------|-------------------|
| HCI_Exit_Sniff_Mode | 0x0004 | Connection_Handle | |

Description:

The Exit_Sniff_Mode command is used to end the sniff mode for a connection handle, which is currently in sniff mode. The Link Manager will determine and issue the appropriate LMP commands to remove the sniff mode for the associated Connection Handle.

Note: in addition, the connection handle cannot be one of the synchronous link types.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

A Command Status event for this command will occur when Controller has received the Exit_Sniff_Mode command. The Mode Change event will occur when the Sniff Mode has ended for the specified connection handle.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Mode Change event will indicate that this command has been completed.

7.2.4 Park State Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------|--------|---|-------------------|
| HCI_Park_State | 0x0005 | Connection_Handle, Beacon_Max_Interval, Beacon_Min_Interval | |

Description:

The Park State command is used to alter the behavior of the Link Manager, and have the LM place the baseband connection associated by the specified Connection Handle into Park state. The Connection_Handle command parameter is used to identify which connection is to be placed in Park state. The Connection_Handle must be a Connection_Handle for an ACL connection. The Beacon Interval command parameters specify the acceptable length of the interval between beacons. However, the remote device may request shorter interval. The Beacon_Max_Interval parameter specifies the acceptable longest length of the interval between beacons. The Beacon_Min_Interval parameter specifies the acceptable shortest length of the interval between beacons. Therefore, the Beacon Min Interval cannot be greater than the Beacon Max Interval. The Controller will return the actual Beacon interval in the Interval parameter of the Mode Change event, if the command is successful. This command enables the Host to support a low-power policy for itself or several other Bluetooth devices, allows the devices to enter Inquiry Scan, Page Scan, provides support for large number of Bluetooth Devices in a single piconet, and a number of other possible activities.

Note: when the Host issues the Park State command, no Connection Handles for synchronous connections are allowed to exist to the remote device that is identified by the Connection_Handle parameter. If one or more Connection Handles for synchronous connections exist to that device, depending on the implementation, a Command Status event or a Mode Change event (following a Command Status event where Status=0x00) will be returned with the error code 0x0C *Command Disallowed*.

If the Host sends data to the Controller with a Connection_Handle corresponding to a parked connection, the Controller will keep the data in its buffers until either the data can be transmitted (after unpark) or a flush, a flush timeout or a disconnection occurs. This is valid even if the Host has not yet been notified of park state through a Mode Change event when it sends the data.

Note: the above is not valid for an HCI Data Packet sent from the Host to the Controller on the master side where the Connection_Handle is a Connection_Handle used for Piconet Broadcast and the Broadcast_Flag is set to Piconet Broadcast. In that case, slaves in park state will also receive the broadcast data. (If the Broadcast_Flag is set to Active Broadcast, the broadcast data will usually not be received by slaves in park state.)

It is possible for the Controller to do an automatic unpark to transmit data and then park the connection again depending on the value of the Link_Policy_Settings parameter (see Write_Link_Policy_Settings) and depending on whether the imple-



mentation supports this or not (optional feature). The optional feature of automatic unpark/park can also be used for link supervision. Whether Mode Change events are returned or not at automatic unpark/park if this is implemented, is vendor specific. This could be controlled by a vendor specific HCI command.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Beacon_Max_Interval: *Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| N = 0xFFFF | Range: 0x000E to 0xFFFFE; only even values are valid Mandatory Range: 0x000E to 0x1000 Time = N * 0.625 msec Time Range: 8.75 msec to 40.9 sec |

Beacon_Min_Interval *Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| N = 0xFFFF | Range: 0x000E to 0xFFFFE; only even values are valid Mandatory Range: 0x000E to 0x1000 Time = N * 0.625 msec Time Range: 8.75 msec to 40.9 sec |

Return Parameters:

None.

Event(s) generated (unless masked away):

The Controller sends the Command Status event for this command to the Host when it has received the Park State command. The Mode Change event will occur when the Park State has started for the specified connection handle.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Mode Change event will indicate that this command has been completed. If an error occurs after the Command Status event has occurred, then the status in the Mode Change event will indicate the error.



7.2.5 Exit Park State Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------|--------|--------------------|-------------------|
| HCI_Exit_Park_State | 0x0006 | Connection_Handle | |

Description:

The Exit_Park_State command is used to switch the Bluetooth device from park state back to the active mode. This command may only be issued when the device associated with the specified Connection Handle is in park state. The Connection_Handle must be a Connection_Handle for an ACL connection. This function does not complete immediately.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

None.

Event(s) generated (unless masked away):

A Command Status event for this command will occur when the Controller has received the Exit_Park_State command. The Mode Change event will occur when park state has ended for the specified connection handle.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Mode Change event will indicate that this command has been completed.



7.2.6 QoS Setup Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------|--------|--|-------------------|
| HCI_QoS_Setup | 0x0007 | Connection_Handle, Flags, Service_Type, Token_Rate, Peak_Bandwidth, Latency, Delay_Variation | |

Description:

The QoS_Setup command is used to specify Quality of Service parameters for a connection handle. The Connection_Handle must be a Connection_Handle for an ACL connection. These QoS parameter are the same parameters as L2CAP QoS. For more detail see “[Logical Link Control and Adaptation Protocol Specification](#)” on page 15[vol. 4]. This allows the Link Manager to have all of the information about what the Host is requesting for each connection. The LM will determine if the QoS parameters can be met. Bluetooth devices that are both slaves and masters can use this command. When a device is a slave, this command will trigger an LMP request to the master to provide the slave with the specified QoS as determined by the LM. When a device is a master, this command is used to request a slave device to accept the specified QoS as determined by the LM of the master. The Connection_Handle command parameter is used to identify for which connection the QoS request is requested.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify which connection for the QoS Setup. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Flags:

Size: 1 Octet

| Value | Parameter Description |
|-------------|--------------------------|
| 0x00 – 0xFF | Reserved for Future Use. |

**Service_Type:****Size: 1 Octet**

| Value | Parameter Description |
|-----------|--------------------------|
| 0x00 | No Traffic. |
| 0x01 | Best Effort. |
| 0x02 | Guaranteed. |
| 0x03-0xFF | Reserved for Future Use. |

Token_Rate:**Size: 4 Octets**

| Value | Parameter Description |
|-----------|----------------------------------|
| 0XXXXXXXX | Token Rate in octets per second. |

Peak_Bandwidth:**Size: 4 Octets**

| Value | Parameter Description |
|-----------|--------------------------------------|
| 0XXXXXXXX | Peak Bandwidth in octets per second. |

Latency:**Size: 4 Octets**

| Value | Parameter Description |
|-----------|--------------------------|
| 0XXXXXXXX | Latency in microseconds. |

Delay_Variation:**Size: 4 Octets**

| Value | Parameter Description |
|-----------|----------------------------------|
| 0XXXXXXXX | Delay Variation in microseconds. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the QoS_Setup command, the Controller sends the Command Status event to the Host. When the Link Manager has completed the LMP messages to establish the requested QoS parameters, the Controller on the local Bluetooth device will send a QoS Setup Complete event to the Host, and the event may also be generated on the remote side if there was LMP negotiation. The values of the parameters of the QoS Setup Complete event may, however, be different on the initiating and the remote side. The QoS Setup Complete event returned by the Controller on the local side contains the status of this command, and returned QoS parameters describing the supported QoS for the connection.

Note: No Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the QoS Setup Complete event will indicate that this command has been completed.



7.2.7 Role Discovery Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------|--------|--------------------|---|
| HCI_Role_Discovery | 0x0009 | Connection_Handle | Status, Connection_Handle, Current_Role |

Description:

The Role_Discovery command is used for a Bluetooth device to determine which role the device is performing for a particular Connection Handle. The Connection_Handle must be a Connection_Handle for an ACL connection.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Role_Discovery command succeeded, |
| 0x01-0xFF | Role_Discovery command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle to be used to identify which connection the Role_Discovery command was issued on. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Current_Role: *Size: 1 Octet*

| Value | Parameter Description |
|-------|--|
| 0x00 | Current Role is Master for this Connection Handle. |
| 0x01 | Current Role is Slave for this Connection Handle. |

Event(s) generated (unless masked away):

When the Role_Discovery command has completed, a Command Complete event will be generated.



7.2.8 Switch Role Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------|--------|--------------------|-------------------|
| HCI_Switch_Role | 0x000B | BD_ADDR, Role | |

Description:

The Switch_Role command is used for a Bluetooth device to switch the current role the device is performing for a particular connection with another specified Bluetooth device. The BD_ADDR command parameter indicates for which connection the role switch is to be performed. The Role indicates the requested new role that the local device performs.

Note: the BD_ADDR command parameter must specify a Bluetooth device for which a connection already exists.

Note: If there is an SCO connection between the local device and the device identified by the BD_ADDR parameter, an attempt to perform a role switch shall be rejected by the local device.

Note: If the connection between the local device and the device identified by the BD_ADDR parameter is placed in Sniff Mode, an attempt to perform a role switch will be rejected by the local device.

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|------------------|---|
| 0XXXXXXXXX XX | BD_ADDR for the connected device with which a role switch is to be performed. |

Role:

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0x00 | Change own Role to Master for this BD_ADDR. |
| 0x01 | Change own Role to Slave for this BD_ADDR. |

Return Parameters:

None.

Event(s) generated (unless masked away):

A Command Status event for this command will occur when the Controller has received the Switch_Role command. When the role switch is performed, a Role Change event will occur to indicate that the roles have been changed, and will be communicated to both Hosts.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, only the Role Change event will indicate that this command has been completed.



7.2.9 Read Link Policy Settings Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------|--------|--------------------|--|
| HCI_Read_Link_Policy_Settings | 0x000C | Connection_Handle | Status, Connection_Handle Link_Policy_Settings |

Description:

This command will read the Link Policy setting for the specified Connection Handle. The Connection_Handle must be a Connection_Handle for an ACL connection. [Section 6.19 on page 391](#).

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Link_Policy_Settings command succeeded. |
| 0x01-0xFF | Read_Link_Policy_Settings command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

**Link_Policy_Settings****Size: 2 Octets**

| Value | Parameter Description |
|--------|-------------------------------|
| 0x0000 | Disable All LM Modes Default. |
| 0x0001 | Enable Role Switch. |
| 0x0002 | Enable Hold Mode. |
| 0x0004 | Enable Sniff Mode. |
| 0x0008 | Enable Park State. |
| 0x0010 | Reserved for Future Use. |
| – | |
| 0x8000 | |

Event(s) generated (unless masked away):

When the Read_Link_Policy_Settings command has completed, a Command Complete event will be generated.

7.2.10 Write Link Policy Settings Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------|--------|--|------------------------------|
| HCI_Write_Link_Policy_Settings | 0x000D | Connection_Handle, Link_Policy_Settings | Status, Connection_Handle |

Description:

This command will write the Link Policy setting for the specified Connection Handle. The Connection_Handle must be a Connection_Handle for an ACL connection. See [Section 6.19 on page 391](#).

The default value is the value set by the Write Default Link Policy Settings Command.

Command Parameters:**Connection_Handle:****Size: 2 Octets (12 Bits meaningful)**

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



Link_Policy_Settings

Size: 2 Octets

| Value | Parameter Description |
|--------|--------------------------|
| 0x0000 | Disable All LM Modes. |
| 0x0001 | Enable Role Switch. |
| 0x0002 | Enable Hold Mode. |
| 0x0004 | Enable Sniff Mode. |
| 0x0008 | Enable Park State. |
| 0x0010 | Reserved for Future Use. |
| – | |
| 0x8000 | |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Link_Policy_Settings command succeeded. |
| 0x01-0xFF | Write_Link_Policy_Settings command failed. See “Error Codes” on page 319 [Part D] for error codes and description. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

Event(s) generated (unless masked away):

When the Write_Link_Policy_Settings command has completed, a Command Complete event will be generated.

7.2.11 Read Default Link Policy Settings Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------------------|--------|--------------------|---|
| HCI_Read_Default_Link_Policy_Settings | 0x000E | | Status, Default_Link_Policy_Settings |

Description:

This command will read the Default Link Policy setting for all new connections.

Note: Please refer to the Link Policy Settings configuration parameter for more information. See [Section 6.19 on page 391](#).

Command Parameters:

None

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Link_Policy_Settings command succeeded |
| 0x01-0xFF | Read_Link_Policy_Settings command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Default_Link_Policy_Settings

Size: 2 Octets

| Value | Parameter Description |
|-----------------------|------------------------------|
| 0x0000 | Disable All LM Modes Default |
| 0x0001 | Enable Role Switch |
| 0x0002 | Enable Hold Mode |
| 0x0004 | Enable Sniff Mode |
| 0x0008 | Enable Park State |
| 0x0010 - 0x8000 | Reserved for future use. |

Event(s) generated (unless masked away):

When the Read_Default_Link_Policy_Settings command has completed, a Command Complete event will be generated.



7.2.12 Write Default Link Policy Settings Command

| Command | OCF | Command Parameters | Return Parameters |
|--|--------|------------------------------|-------------------|
| HCI_Write_Default_Link_Policy_Settings | 0x000F | Default_Link_Policy_Settings | Status |

Description:

This command will write the Default Link Policy configuration value. The Default_Link_Policy_Settings parameter determines the initial value of the Link_Policy_Settings for all new connections.

Note: Please refer to the Link Policy Settings configuration parameter for more information. See [Section 6.19 on page 391](#).

Command Parameters:

Default_Link_Policy_Settings

Size: 2 Octets

| Value | Parameter Description |
|--------|------------------------------|
| 0x0000 | Disable All LM Modes Default |
| 0x0001 | Enable Role Switch |
| 0x0002 | Enable Hold Mode |
| 0x0004 | Enable Sniff Mode |
| 0x0008 | Enable Park State |
| 0x0010 | Reserved for future use. |
| - | |
| 0x8000 | |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Link_Policy_Settings command succeeded |
| 0x01-0xFF | Write_Link_Policy_Settings command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Default_Link_Policy_Settings command has completed, a Command Complete event will be generated.



7.2.13 Flow Specification Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------|--------|--|-------------------|
| HCI_Flow_Specification | 0x0010 | Connection_Handle, Flags, Flow_direction, Service_Type, Token_Rate, Token_Bucket_Size, Peak_Bandwidth, Access_Latency | |

Description:

The Flow_Specification command is used to specify the flow parameters for the traffic carried over the ACL connection identified by the Connection_Handle. The Connection_Handle must be a Connection_Handle for an ACL connection. The Connection_Handle command parameter is used to identify for which connection the Flow Specification is requested. The flow parameters refer to the outgoing or incoming traffic of the ACL link, as indicated by the Flow_direction field. The Flow Specification command allows the Link Manager to have the parameters of the outgoing as well as the incoming flow for the ACL connection. The flow parameters are defined in the L2CAP specification “[Quality of Service \(QoS\) Option](#)” on [page 60](#)[vol. 4]. The Link Manager will determine if the flow parameters can be supported. Bluetooth devices that are both master and slave can use this command.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle used to identify for which ACL connection the Flow is specified. Range: 0x0000 - 0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

Flags: *Size: 1 Octet*

| Value | Parameter Description |
|-------------|--------------------------|
| 0x00 – 0xFF | Reserved for Future Use. |

Flow_direction: *Size: 1 Octet*

| Value | Parameter Description |
|-------------|---|
| 0x00 | Outgoing Flow i.e. traffic send over the ACL connection |
| 0x01 | Incoming Flow i.e. traffic received over the ACL connection |
| 0x02 – 0xFF | Reserved for Future Use. |

**Service_Type:****Size: 1 Octet**

| Value | Parameter Description |
|-------------|-------------------------|
| 0x00 | No Traffic |
| 0x01 | Best Effort |
| 0x02 | Guaranteed |
| 0x03 – 0xFF | Reserved for Future Use |

Token Rate:**Size: 4 Octets**

| Value | Parameter Description |
|------------|---------------------------------|
| 0xFFFFFFFF | Token Rate in octets per second |

Token Bucket Size:**Size: 4 Octets**

| Value | Parameter Description |
|------------|-----------------------------|
| 0xFFFFFFFF | Token Bucket Size in octets |

Peak_Bandwidth:**Size: 4 Octets**

| Value | Parameter Description |
|------------|-------------------------------------|
| 0xFFFFFFFF | Peak Bandwidth in octets per second |

Access Latency:**Size: 4 Octets**

| Value | Parameter Description |
|------------|-------------------------|
| 0xFFFFFFFF | Latency in microseconds |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Flow Specification command, the Controller sends the Command Status event to the Host. When the Link Manager has determined if the Flow specification can be supported, the Controller on the local Bluetooth device sends a Flow Specification Complete event to the Host. The Flow Specification Complete event returned by the Controller on the local side contains the status of this command, and returned Flow parameters describing the supported QoS for the ACL connection.

Note: No Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Flow Specification Complete event will indicate that this command has been completed.



7.3 CONTROLLER & BASEBAND COMMANDS

The Controller & Baseband Commands provide access and control to various capabilities of the Bluetooth hardware. These parameters provide control of Bluetooth devices and of the capabilities of the Controller, Link Manager, and Baseband. The host device can use these commands to modify the behavior of the local device. For the HCI Control and Baseband Commands, the OGF is defined as 0x03.

7.3.1 Set Event Mask Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------|--------|--------------------|-------------------|
| HCI_Set_Event_Mask | 0x0001 | Event_Mask | Status |

Description:

The Set_Event_Mask command is used to control which events are generated by the HCI for the Host. If the bit in the Event_Mask is set to a one, then the event associated with that bit will be enabled. The Host has to deal with each event that occurs by the Bluetooth devices. The event mask allows the Host to control how much it is interrupted.

Command Parameters:

Event_Mask:

Size: 8 Octets

| Value | Parameter Description |
|--------------------|--|
| 0x0000000000000000 | No events specified |
| 0x0000000000000001 | Inquiry Complete Event |
| 0x0000000000000002 | Inquiry Result Event |
| 0x0000000000000004 | Connection Complete Event |
| 0x0000000000000008 | Connection Request Event |
| 0x0000000000000010 | Disconnection Complete Event |
| 0x0000000000000020 | Authentication Complete Event |
| 0x0000000000000040 | Remote Name Request Complete Event |
| 0x0000000000000080 | Encryption Change Event |
| 0x0000000000000100 | Change Connection Link Key Complete Event |
| 0x0000000000000200 | Master Link Key Complete Event |
| 0x0000000000000400 | Read Remote Supported Features Complete Event |
| 0x0000000000000800 | Read Remote Version Information Complete Event |
| 0x0000000000001000 | QoS Setup Complete Event |
| 0x0000000000002000 | Reserved |
| 0x0000000000004000 | Reserved |
| 0x0000000000008000 | Hardware Error Event |



| Value | Parameter Description |
|---------------------|--|
| 0x00000000000010000 | Flush Occurred Event |
| 0x00000000000020000 | Role Change Event |
| 0x00000000000040000 | Reserved |
| 0x00000000000080000 | Mode Change Event |
| 0x00000000000100000 | Return Link Keys Event |
| 0x00000000000200000 | PIN Code Request Event |
| 0x00000000000400000 | Link Key Request Event |
| 0x00000000000800000 | Link Key Notification Event |
| 0x00000000001000000 | Loopback Command Event |
| 0x00000000002000000 | Data Buffer Overflow Event |
| 0x00000000004000000 | Max Slots Change Event |
| 0x00000000008000000 | Read Clock Offset Complete Event |
| 0x00000000010000000 | Connection Packet Type Changed Event |
| 0x00000000020000000 | QoS Violation Event |
| 0x00000000040000000 | Page Scan Mode Change Event [deprecated] |
| 0x00000000080000000 | Page Scan Repetition Mode Change Event |
| 0x00000000100000000 | Flow Specification Complete Event |
| 0x00000000200000000 | Inquiry Result with RSSI Event |
| 0x00000000400000000 | Read Remote Extended Features Complete Event |
| 0x00000000800000000 | Reserved |
| 0x00000001000000000 | Reserved |
| 0x00000002000000000 | Reserved |
| 0x00000004000000000 | Reserved |
| 0x00000008000000000 | Reserved |
| 0x00000010000000000 | Reserved |
| 0x00000020000000000 | Reserved |
| 0x00000040000000000 | Reserved |
| 0x00000080000000000 | Synchronous Connection Complete Event |
| 0x00000100000000000 | Synchronous Connection Changed event |
| 0xFFFFE000000000000 | Reserved for future use |
| 0x00001FFFFFFFFFFFF | Default (All events enabled) |

**Return Parameters:***Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Set_Event_Mask command succeeded. |
| 0x01-0xFF | Set_Event_Mask command failed. See “Error Codes” on page 319 [Part D] for error codes and description. |

Event(s) generated (unless masked away):

When the Set_Event_Mask command has completed, a Command Complete event will be generated.

7.3.2 Reset Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------|--------|--------------------|-------------------|
| HCI_Reset | 0x0003 | | Status |

Description:

The Reset command will reset the Controller and the Link Manager. The reset command shall not affect the used HCI transport layer since the HCI transport layers may have reset mechanisms of their own. After the reset is completed, the current operational state will be lost, the Bluetooth device will enter standby mode and the Controller will automatically revert to the default values for the parameters for which default values are defined in the specification.

Note: the Host is not allowed to send additional HCI commands before the Command Complete event related to the Reset command has been received.

Command Parameters:

None.

Return Parameters:*Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Reset command succeeded, was received and will be executed. |
| 0x01-0xFF | Reset command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the reset has been performed, a Command Complete event will be generated.

7.3.3 Set Event Filter Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------|--------|---|-------------------|
| HCI_Set_Event_Filter | 0x0005 | Filter_Type, Filter_Condition_Type, Condition | Status |

Description:

The Set_Event_Filter command is used by the Host to specify different event filters. The Host may issue this command multiple times to request various conditions for the same type of event filter and for different types of event filters. The event filters are used by the Host to specify items of interest, which allow the Controller to send only events which interest the Host. Only some of the events have event filters. By default (before this command has been issued after power-on or Reset) no filters are set, and the Auto_Accept_Flag is off (incoming connections are not automatically accepted). An event filter is added each time this command is sent from the Host and the Filter_Condition_Type is not equal to 0x00. (The old event filters will not be overwritten). To clear all event filters, the Filter_Type = 0x00 is used. The Auto_Accept_Flag will then be set to off. To clear event filters for only a certain Filter_Type, the Filter_Condition_Type = 0x00 is used.

The Inquiry Result filter allows the Controller to filter out Inquiry Result events. The Inquiry Result filter allows the Host to specify that the Controller only sends Inquiry Results to the Host if the Inquiry Result event meets one of the specified conditions set by the Host. For the Inquiry Result filter, the Host can specify one or more of the following Filter Condition Types:

1. Return responses from all devices during the Inquiry process
2. A device with a specific Class of Device responded to the Inquiry process
3. A device with a specific BD_ADDR responded to the Inquiry process

The Inquiry Result filter is used in conjunction with the Inquiry and Periodic Inquiry command.

The Connection Setup filter allows the Host to specify that the Controller only sends a Connection Complete or Connection Request event to the Host if the event meets one of the specified conditions set by the Host. For the Connection Setup filter, the Host can specify one or more of the following Filter Condition Types:

1. Allow Connections from all devices
2. Allow Connections from a device with a specific Class of Device
3. Allow Connections from a device with a specific BD_ADDR

For each of these conditions, an `Auto_Accept_Flag` parameter allows the Host to specify what action should be done when the condition is met. The `Auto_Accept_Flag` allows the Host to specify if the incoming connection should be auto accepted (in which case the Controller will send the Connection Complete event to the Host when the connection is completed) or if the Host should make the decision (in which case the Controller will send the Connection Request event to the Host, to elicit a decision on the connection).

The Connection Setup filter is used in conjunction with the `Read/Write_Scan_Enable` commands. If the local device is in the process of a page scan, and is paged by another device which meets one on the conditions set by the Host, and the `Auto_Accept_Flag` is off for this device, then a Connection Request event will be sent to the Host by the Controller. A Connection Complete event will be sent later on after the Host has responded to the incoming connection attempt. In this same example, if the `Auto_Accept_Flag` is on, then a Connection Complete event will be sent to the Host by the Controller. (No Connection Request event will be sent in that case.)

The Controller will store these filters in volatile memory until the Host clears the event filters using the `Set_Event_Filter` command or until the Reset command is issued. The number of event filters the Controller can store is implementation dependent. If the Host tries to set more filters than the Controller can store, the Controller will return the *Memory Full* error code and the filter will not be installed.

Note: the Clear All Filters has no Filter Condition Types or Conditions.
Note: In the condition that a connection is auto accepted, a Link Key Request event and possibly also a PIN Code Request event and a Link Key Notification event could be sent to the Host by the Controller before the Connection Complete event is sent.

If there is a contradiction between event filters, the latest set event filter will override older ones. An example is an incoming connection attempt where more than one Connection Setup filter matches the incoming connection attempt, but the `Auto-Accept_Flag` has different values in the different filters.

Command Parameters:

Filter_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Clear All Filters (Note: In this case, the <code>Filter_Condition_type</code> and <code>Condition</code> parameters should not be given, they should have a length of 0 octets. <code>Filter_Type</code> should be the only parameter.) |
| 0x01 | Inquiry Result. |
| 0x02 | Connection Setup. |
| 0x03-0xFF | Reserved for Future Use. |



Filter Condition Types: For each Filter Type one or more Filter Condition types exists.

Inquiry_Result_Filter_Condition_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Return responses from all devices during the Inquiry process. (Note: A device may be reported to the Host in an Inquiry Result event more than once during an inquiry or inquiry period depending on the implementation, see description in Section 7.1.1 on page 399 and Section 7.1.3 on page 402) |
| 0x01 | A device with a specific Class of Device responded to the Inquiry process. |
| 0x02 | A device with a specific BD_ADDR responded to the Inquiry process. |
| 0x03-0xFF | Reserved for Future Use |

Connection_Setup_Filter_Condition_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Allow Connections from all devices. |
| 0x01 | Allow Connections from a device with a specific Class of Device. |
| 0x02 | Allow Connections from a device with a specific BD_ADDR. |
| 0x03-0xFF | Reserved for Future Use. |

Condition: For each Filter Condition Type defined for the Inquiry Result Filter and the Connection Setup Filter, zero or more Condition parameters are required – depending on the filter condition type and filter type.

Condition for Inquiry_Result_Filter_Condition_Type = 0x00

Condition:

Size: 0 Octet

| Value | Parameter Description |
|-------|--------------------------------------|
| | The Condition parameter is not used. |

Condition for Inquiry_Result_Filter_Condition_Type = 0x01

Condition:

Size: 6 Octets

Class_of_Device:

Size: 3 Octets

| Value | Parameter Description |
|----------|------------------------------|
| 0x000000 | Default, Return All Devices. |
| 0XXXXXXX | Class of Device of Interest. |

**Class_of_Device_Mask:****Size: 3 Octets**

| Value | Parameter Description |
|----------|---|
| 0xxxxxxx | Bit Mask used to determine which bits of the Class of Device parameter are 'don't care'. Zero-value bits in the mask indicate the 'don't care' bits of the Class of Device. |

*Condition for Inquiry_Result_Filter_Condition_Type = 0x02***Condition:**

Size: 6 Octets

BD_ADDR:**Size: 6 Octets**

| Value | Parameter Description |
|--------------------|-----------------------------------|
| 0xxxxxxxxxxx xx | BD_ADDR of the Device of Interest |

*Condition for Connection_Setup_Filter_Condition_Type = 0x00***Condition:**

Size: 1 Octet

Auto_Accept_Flag:**Size: 1 Octet**

| Value | Parameter Description |
|-------------|---|
| 0x01 | Do NOT Auto accept the connection. (Auto accept is off) |
| 0x02 | Do Auto accept the connection with role switch disabled. (Auto accept is on). |
| 0x03 | Do Auto accept the connection with role switch enabled. (Auto accept is on). Note: When auto accepting an incoming synchronous connection, no role switch will be performed. The value 0x03 of the Auto_Accept_Flag will then get the same effect as if the value had been 0x02. |
| 0x04 – 0xFF | Reserved for future use. |



Condition for Connection_Setup_Filter_Condition_Type = 0x01

Condition:

Size: 7 Octets

Class_of_Device:

Size: 3 Octets

| Value | Parameter Description |
|----------|-------------------------------------|
| 0x000000 | Default, Return All Devices. |
| 0xFFFFXX | <i>Class of Device</i> of Interest. |

Class_of_Device_Mask:

Size: 3 Octets

| Value | Parameter Description |
|----------|--|
| 0xFFFFXX | Bit Mask used to determine which bits of the Class of Device parameter are 'don't care'. Zero-value bits in the mask indicate the 'don't care' bits of the Class of Device. Note: For an incoming SCO connection, if the class of device is unknown then the connection will be accepted. |

Auto_Accept_Flag:

Size: 1 Octet

| Value | Parameter Description |
|-------------|---|
| 0x01 | Do NOT Auto accept the connection. (Auto accept is off) |
| 0x02 | Do Auto accept the connection with role switch disabled. (Auto accept is on). |
| 0x03 | Do Auto accept the connection with role switch enabled. (Auto accept is on). Note: When auto accepting an incoming synchronous connection, no role switch will be performed. The value 0x03 of the Auto_Accept_Flag will then get the same effect as if the value had been 0x02. |
| 0x04 – 0xFF | Reserved for future use. |

Condition for Connection_Setup_Filter_Condition_Type = 0x02

Condition:

Size: 7 Octets

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|-------------------|------------------------------------|
| 0XXXXXXXXXX XX | BD_ADDR of the Device of Interest. |

Auto_Accept_Flag:

Size: 1 Octet

| Value | Parameter Description |
|-------------|---|
| 0x01 | Do NOT Auto accept the connection. (Auto accept is off) |
| 0x02 | Do Auto accept the connection with role switch disabled. (Auto accept is on). |
| 0x03 | Do Auto accept the connection with role switch enabled. (Auto accept is on). Note: When auto accepting an incoming synchronous connection, no role switch will be performed. The value 0x03 of the Auto_Accept_Flag will then get the same effect as if the value had been 0x02. |
| 0x04 – 0xFF | Reserved for future use. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Set_Event_Filter command succeeded. |
| 0x01-0xFF | Set_Event_Filter command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

A Command Complete event for this command will occur when the Controller has enabled the filtering of events. When one of the conditions are met, a specific event will occur.

7.3.4 Flush Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------|--------|--------------------|---------------------------|
| HCI_Flush | 0x0008 | Connection_Handle | Status, Connection_Handle |

Description:

The Flush command is used to discard all data that is currently pending for transmission in the Controller for the specified connection handle, even if there currently are chunks of data that belong to more than one L2CAP packet in the Controller. After this, all data that is sent to the Controller for the same connection handle will be discarded by the Controller until an HCI Data Packet with the start Packet_Boundary_Flag (0x02) is received. When this happens, a new transmission attempt can be made. This command will allow higher-level software to control how long the baseband should try to retransmit a baseband packet for a connection handle before all data that is currently pending for transmission in the Controller should be flushed. Note that the Flush command



is used for ACL connections ONLY. In addition to the Flush command, the automatic flush timers (see [section 7.3.31 on page 505](#)) can be used to automatically flush the L2CAP packet that is currently being transmitted after the specified flush timer has expired.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle to be used to identify which connection to flush. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Flush command succeeded. |
| 0x01-0xFF | Flush command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify which connection the flush command was issued on. Range: 0x0000-0x0EFF (0x0F00 - 0xFFFF Reserved for future use) |

Event(s) generated (unless masked away):

The Flush Occurred event will occur once the flush is completed. A Flush Occurred event could be from an automatic Flush or could be cause by the Host issuing the Flush command. When the Flush command has completed, a Command Complete event will be generated, to indicate that the Host caused the Flush.

7.3.5 Read PIN Type Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------|--------|--------------------|-------------------|
| HCI_Read_PIN_Type | 0x0009 | | Status, PIN_Type |

Description:

The Read PIN Type command is used to read the PIN_Type configuration parameter. See [Section 6.13 on page 388](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_PIN_Type command succeeded. |
| 0x01-0xFF | Read_PIN_Type command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

PIN_Type:

Size: 1 Octet

| Value | Parameter Description |
|-------|-----------------------|
| 0x00 | Variable PIN. |
| 0x01 | Fixed PIN. |

Event(s) generated (unless masked away):

When the Read_PIN_Type command has completed, a Command Complete event will be generated.

7.3.6 Write PIN Type Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------|--------|--------------------|-------------------|
| HCI_Write_PIN_Type | 0x000A | PIN_Type | Status |

Description:

The Write_PIN_Type command is used to write the PIN Type configuration parameter. See [Section 6.13 on page 388](#).

Command Parameters:

PIN_Type:

Size: 1 Octet

| Value | Parameter Description |
|-------|-----------------------|
| 0x00 | Variable PIN. |
| 0x01 | Fixed PIN. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write PIN Type command succeeded. |
| 0x01-0xFF | Write PIN Type command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_PIN_Type command has completed, a Command Complete event will be generated.



7.3.7 Create New Unit Key Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------|--------|--------------------|-------------------|
| HCI_Create_New_Unit_Key | 0x000B | | Status |

Description:

The Create_New_Unit_Key command is used to create a new unit key. The Bluetooth hardware will generate a random seed that will be used to generate the new unit key. All new connection will use the new unit key, but the old unit key will still be used for all current connections.

Note: this command will not have any effect for a device which doesn't use unit keys (i.e. a device which uses only combination keys).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Create New Unit Key command succeeded. |
| 0x01-0xFF | Create New Unit Key command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Create_New_Unit_Key command has completed, a Command Complete event will be generated.



7.3.8 Read Stored Link Key Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------|--------|---------------------------|---|
| HCI_Read_Stored_Link_Key | 0x000D | BD_ADDR, Read_All_Flag | Status, Max_Num_Keys, Num_Keys_Read |

Description:

The Read_Stored_Link_Key command provides the ability to read one or more link keys stored in the Bluetooth Controller. The Bluetooth Controller can store a limited number of link keys for other Bluetooth devices. Link keys are shared between two Bluetooth devices, and are used for all security transactions between the two devices. A Host device may have additional storage capabilities, which can be used to save additional link keys to be reloaded to the Bluetooth Controller when needed. The Read_All_Flag parameter is used to indicate if all of the stored Link Keys should be returned. If Read_All_Flag indicates that all Link Keys are to be returned, then the BD_ADDR command parameter must be ignored. The BD_ADDR command parameter is used to identify which link key to read. The stored Link Keys are returned by one or more Return Link Keys events. See [Section 6.14 on page 388](#).

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---|
| 0xFFFFFFFFXXXX | BD_ADDR for the stored link key to be read. |

Read_All_Flag:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Return Link Key for specified BD_ADDR. |
| 0x01 | Return all stored Link Keys. |
| 0x02-0xFF | Reserved for future use. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Stored_Link_Key command succeeded. |
| 0x01-0xFF | Read_Stored_Link_Key command failed. See “Error Codes” on page 319 [Part D] for error codes and description. |

Max_Num_Keys:

Size: 2 Octets

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Total Number of Link Keys that the Controller can store. Range: 0x0000 – 0xFFFF |

Num_Keys_Read:

Size: 2 Octets

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Number of Link Keys Read. Range: 0x0000 – 0xFFFF |

Event(s) generated (unless masked away):

Zero or more instances of the Return Link Keys event will occur after the command is issued. When there are no link keys stored, no Return Link Keys events will be returned. When there are link keys stored, the number of link keys returned in each Return Link Keys event is implementation specific. When the Read Stored Link Key command has completed a Command Complete event will be generated.

7.3.9 Write Stored Link Key Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------|--------|--|-----------------------------|
| HCI_Write_Stored_Link_Key | 0x0011 | Num_Keys_To_Write, BD_ADDR[i], Link_Key[i] | Status, Num_Keys_Written |

Description:

The Write_Stored_Link_Key command provides the ability to write one or more link keys to be stored in the Bluetooth Controller. The Bluetooth Controller can store a limited number of link keys for other Bluetooth devices. If no additional space is available in the Bluetooth Controller then no additional link keys will be stored. If space is limited and if all the link keys to be stored will not fit in the limited space, then the order of the list of link keys without any error will determine which link keys are stored. Link keys at the beginning of the list will be stored first. The Num_Keys_Written parameter will return the number of link keys that were successfully stored. If no additional space is available, then the Host must delete one or more stored link keys before any additional link keys are stored. The link key replacement algorithm is implemented by the Host and not the Controller. Link keys are shared between two Bluetooth devices and are used for all security transactions between the two devices. A Host device may have additional storage capabilities, which can be used to save additional link keys to be reloaded to the



Bluetooth Controller when needed. See [Section 6.14 on page 388](#).

Note: Link Keys are only stored by issuing this command.

Command Parameters:

Num_Keys_To_Write:

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0xXX | Number of Link Keys to Write. Range: 0x01 - 0x0B |

BD_ADDR [i]:

*Size: 6 Octets * Num_Keys_To_Write*

| Value | Parameter Description |
|----------------|--------------------------------------|
| 0XXXXXXXXXXXXX | BD_ADDR for the associated Link Key. |

Link_Key:

Size: 16 Octets

| Value | Parameter Description |
|--|-------------------------------------|
| 0XXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXX | Link Key for an associated BD_ADDR. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Stored_Link_Key command succeeded. |
| 0x01-0xFF | Write_Stored_Link_Key command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Num_Keys_Written:

Size: 1 Octets

| Value | Parameter Description |
|-------|---|
| 0xXX | Number of Link Keys successfully written. Range: 0x00 – 0x0B |

Event(s) generated (unless masked away):

When the Write_Stored_Link_Key command has completed, a Command Complete event will be generated.



7.3.10 Delete Stored Link Key Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------|--------|-----------------------------|-----------------------------|
| HCI_Delete_Stored_Link_Key | 0x0012 | BD_ADDR, Delete_All_Flag | Status, Num_Keys_Deleted |

Description:

The Delete_Stored_Link_Key command provides the ability to remove one or more of the link keys stored in the Bluetooth Controller. The Bluetooth Controller can store a limited number of link keys for other Bluetooth devices. Link keys are shared between two Bluetooth devices and are used for all security transactions between the two devices. The Delete_All_Flag parameter is used to indicate if all of the stored Link Keys should be deleted. If the Delete_All_Flag indicates that all Link Keys are to be deleted, then the BD_ADDR command parameter must be ignored. This command provides the ability to negate all security agreements between two devices. The BD_ADDR command parameter is used to identify which link key to delete. If a link key is currently in use for a connection, then the link key will be deleted when all of the connections are disconnected. See [Section 6.14 on page 388](#).

Command Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---|
| 0xxxxxxxxxxxxx | BD_ADDR for the link key to be deleted. |

Delete_All_Flag:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Delete only the Link Key for specified BD_ADDR. |
| 0x01 | Delete all stored Link Keys. |
| 0x02-0xFF | Reserved for future use. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Delete_Stored_Link_Key command succeeded. |
| 0x01-0xFF | Delete_Stored_Link_Key command failed. See “Error Codes” on page 319 [Part D] for error codes and description. |

*Num_Keys_Deleted:**Size: 2 Octets*

| Value | Parameter Description |
|--------|-----------------------------|
| 0xFFFF | Number of Link Keys Deleted |

Event(s) generated (unless masked away):

When the Delete_Stored_Link_Key command has completed, a Command Complete event will be generated.

7.3.11 Write Local Name Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------|--------|--------------------|-------------------|
| HCI_Write_Local_Name | 0x0013 | Local Name | Status |

Description:

The Write_Local_Name command provides the ability to modify the user-friendly name for the Bluetooth device. See [Section 6.24 on page 394](#).

Command Parameters:*Local Name:**Size: 248 Octets*

| Value | Parameter Description |
|-------|--|
| | A UTF-8 encoded User-Friendly Descriptive Name for the device. If the name contained in the parameter is shorter than 248 octets, the end of the name is indicated by a NULL octet (0x00), and the following octets (to fill up 248 octets, which is the length of the parameter) do not have valid values. |
| | Null terminated Zero length String. Default. |

Return Parameters:*Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Local_Name command succeeded. |
| 0x01-0xFF | Write_Local_Name command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Local_Name command has completed, a Command Complete event will be generated.

7.3.12 Read Local Name Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------|--------|--------------------|-----------------------|
| HCI_Read_Local_Name | 0x0014 | | Status, Local Name |

Description:

The Read_Local_Name command provides the ability to read the stored user-friendly name for the Bluetooth device. See [Section 6.24 on page 394](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Local_Name command succeeded |
| 0x01-0xFF | Read_Local_Name command failed see “Error Codes” on page 319 [Part D] for list of Error Codes |

Local Name:

Size: 248 Octets

| Value | Parameter Description |
|-------|--|
| | A UTF-8 encoded User Friendly Descriptive Name for the device. If the name contained in the parameter is shorter than 248 octets, the end of the name is indicated by a NULL octet (0x00), and the following octets (to fill up 248 octets, which is the length of the parameter) do not have valid values. |

Event(s) generated (unless masked away):

When the Read_Local_Name command has completed a Command Complete event will be generated.



7.3.13 Read Connection Accept Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------------|--------|--------------------|--------------------------------|
| HCI_Read_Connection_Accept_Timeout | 0x0015 | | Status, Conn_Accept_Timeout |

Description:

This command will read the value for the Connection_Accept_Timeout configuration parameter. See [Section 6.7 on page 385](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Connection_Accept_Timeout command succeeded. |
| 0x01-0xFF | Read_Connection_Accept_Timeout command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Conn_Accept_Timeout:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Connection Accept Timeout measured in Number of Baseband slots. Interval Length = $N * 0.625 \text{ msec}$ (1 Baseband slot) Range for N: 0x0001 – 0xB540 Time Range: 0.625 msec -29 seconds |

Event(s) generated (unless masked away):

When the Read_Connection_Timeout command has completed, a Command Complete event will be generated.



7.3.14 Write Connection Accept Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------------|--------|---------------------|-------------------|
| HCI_Write_Connection_Accept_Timeout | 0x0016 | Conn_Accept_Timeout | Status |

Description:

This command will write the value for the Connection_Accept_Timeout configuration parameter. See [Section 6.7 on page 385](#).

Command Parameters:

Conn_Accept_Timeout:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Connection Accept Timeout measured in Number of Baseband slots. Interval Length = $N * 0.625 \text{ msec}$ (1 Baseband slot) Range for N: 0x0001 – 0xB540 Time Range: 0.625 msec - 29 seconds Default: N = 0x1FA0 Time = 5.06 Sec Mandatory Range for Controller: 0x00A0 to 0xB540 |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Connection_Accept_Timeout command succeeded. |
| 0x01-0xFF | Write_Connection_Accept_Timeout command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Connection_Accept_Timeout command has completed, a Command Complete event will be generated.



7.3.15 Read Page Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------|--------|--------------------|-------------------------|
| HCI_Read_Page_Timeout | 0x0017 | | Status, Page_Timeout |

Description:

This command will read the value for the Page_Timeout configuration parameter. See [Section 6.6 on page 385](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Page_Timeout command succeeded. |
| 0x01-0xFF | Read_Page_Timeout command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Page_Timeout:

Size: 2 Octets

| Value | Parameter Description |
|------------|--|
| N = 0xFFFF | Page Timeout measured in Number of Baseband slots. Interval Length = $N * 0.625 \text{ msec}$ (1 Baseband slot) Range for N: 0x0001 – 0xFFFF Time Range: 0.625 msec -40.9 Seconds |

Event(s) generated (unless masked away):

When the Read_Page_Timeout command has completed, a Command Complete event will be generated.



7.3.16 Write Page Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------|--------|--------------------|-------------------|
| HCI_Write_Page_Timeout | 0x0018 | Page_Timeout | Status |

Description:

This command will write the value for the Page_Timeout configuration parameter. The Page_Timeout configuration parameter defines the maximum time the local Link Manager will wait for a baseband page response from the remote device at a locally initiated connection attempt. If this time expires and the remote device has not responded to the page at baseband level, the connection attempt will be considered to have failed.

Command Parameters:

Page_Timeout:

Size: 2 Octets

| Value | Parameter Description |
|------------|--|
| 0 | Illegal Page Timeout. Must be larger than 0. |
| N = 0xXXXX | Page Timeout measured in Number of Baseband slots. Interval Length = $N * 0.625 \text{ msec}$ (1 Baseband slot) Range for N: 0x0001 – 0xFFFF Time Range: 0.625 msec -40.9 Seconds Default: N = 0x2000 Time = 5.12 Sec Mandatory Range for Controller: 0x0016 to 0xFFFF |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Page_Timeout command succeeded. |
| 0x01-0xFF | Write_Page_Timeout command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Page_Timeout command has completed, a Command Complete event will be generated.



7.3.17 Read Scan Enable Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------|--------|--------------------|---------------------|
| HCI_Read_Scan_Enable | 0x0019 | | Status, Scan_Enable |

Description:

This command will read the value for the Scan_Enable parameter configuration parameter. See [Section 6.1 on page 383](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Scan_Enable command succeeded. |
| 0x01-0xFF | Read_Scan_Enable command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Scan_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | No Scans enabled. |
| 0x01 | Inquiry Scan enabled. Page Scan disabled. |
| 0x02 | Inquiry Scan disabled. Page Scan enabled. |
| 0x03 | Inquiry Scan enabled. Page Scan enabled. |
| 0x04-0xFF | Reserved |

Event(s) generated (unless masked away):

When the Read_Scan_Enable command has completed, a Command Complete event will be generated.

7.3.18 Write Scan Enable Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------|--------|--------------------|-------------------|
| HCI_Write_Scan_Enable | 0x001A | Scan_Enable | Status |

Description:

This command will write the value for the Scan_Enable configuration parameter. See [Section 6.1 on page 383](#).

Command Parameters:

Scan_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | No Scans enabled. Default. |
| 0x01 | Inquiry Scan enabled. Page Scan disabled. |
| 0x02 | Inquiry Scan disabled. Page Scan enabled. |
| 0x03 | Inquiry Scan enabled. Page Scan enabled. |
| 0x04-0xFF | Reserved |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Scan_Enable command succeeded. |
| 0x01-0xFF | Write_Scan_Enable command failed. See “ Error Codes ” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Scan_Enable command has completed, a Command Complete event will be generated.

7.3.19 Read Page Scan Activity Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------|--------|--------------------|--|
| HCI_Read_Page_Scan_Activity | 0x001B | | Status, Page_Scan_Interval, Page_Scan_Window |

Description:

This command will read the value for Page_Scan_Interval and Page_Scan_Window configuration parameters. See [Section 6.8 on page 386](#) and [Section 6.9 on page 386](#).

Note: Page Scan is only performed when Page_Scan is enabled (see [6.1](#), [7.3.17](#) and [7.3.18](#)).

A changed Page_Scan_Interval could change the local Page_Scan_Repetition_Mode (see [“Baseband Specification” on page 55 \[Part B\]](#), Keyword: SR-Mode).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Page_Scan_Activity command succeeded. |
| 0x01-0xFF | Read_Page_Scan_Activity command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Page_Scan_Interval:

Size: 2 Octets

| Value | Parameter Description |
|------------|--|
| N = 0xXXXX | Size: 2 Octets Range: 0x0012 – 0x1000 Time = N * 0.625 msec Range: 11.25 msec - 2560 msec; only even values are valid |

Page_Scan_Window:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xFFFF | Size: 2 Octets Range: 0x0011 - 0x1000 Time = N * 0.625 msec Range: 10.625 msec - 2560 msec |

Event(s) generated (unless masked away):

When the Read_Page_Scan_Activity command has completed, a Command Complete event will be generated.



7.3.20 Write Page Scan Activity Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------|--------|---|-------------------|
| HCI_Write_Page_Scan_Activity | 0x001C | Page_Scan_Interval, Page_Scan_Window | Status |

Description:

This command will write the values for the Page_Scan_Interval and Page_Scan_Window configuration parameters. The Page_Scan_Window shall be less than or equal to the Page_Scan_Interval. See [Section 6.8 on page 386](#) and [Section 6.9 on page 386](#).

Note: Page Scan is only performed when Page_Scan is enabled (see [6.1](#), [7.3.17](#) and [7.3.18](#)). A changed Page_Scan_Interval could change the local Page_Scan_Repetition_Mode (see [Baseband Specification, Section 8.3.1, on page 154](#)).

Command Parameters:

Page_Scan_Interval:

Size: 2 Octets

| Value | Parameter Description |
|---|-----------------------|
| See Section 6.8 on page 386 | |

Page_Scan_Window:

Size: 2 Octets

| Value | Parameter Description |
|---|-----------------------|
| See Section 6.9 on page 386 | |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Page_Scan_Activity command succeeded. |
| 0x01-0xFF | Write_Page_Scan_Activity command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Page_Scan_Activity command has completed, a Command Complete event will be generated.



7.3.21 Read Inquiry Scan Activity Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------|--------|--------------------|--|
| HCI_Read_Inquiry_Scan_Activity | 0x001D | | Status, Inquiry_Scan_Interval, Inquiry_Scan_Window |

Description:

This command will read the value for Inquiry_Scan_Interval and Inquiry_Scan_Window configuration parameter. See [Section 6.2 on page 383](#) and [Section 6.3 on page 384](#).

Note: Inquiry Scan is only performed when Inquiry_Scan is enabled see [6.1](#), [7.3.17](#) and [7.3.18](#)).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Inquiry_Scan_Activity command succeeded. |
| 0x01-0xFF | Read_Inquiry_Scan_Activity command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Inquiry_Scan_Interval:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Size: 2 Octets Range: 0x0012 – 0x1000 Time = N * 0.625 msec Range: 11.25 - 2560 msec; only even values are valid |

Inquiry_Scan_Window:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | Size: 2 Octets Range: 0x0011 - 0x1000 Time = N * 0.625 msec Range: 10.625 msec - 2560 msec |

Event(s) generated (unless masked away):

When the Read_Inquiry_Scan_Activity command has completed, a Command Complete event will be generated.



7.3.22 Write Inquiry Scan Activity Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------------|--------|---|-------------------|
| HCI_Write_Inquiry_Scan_Activity | 0x001E | Inquiry_Scan_Interval, Inquiry_Scan_Window | Status |

Description:

This command will write the values for the Inquiry_Scan_Interval and Inquiry_Scan_Window configuration parameters. The Inquiry_Scan_Window shall be less than or equal to the Inquiry_Scan_Interval. See [Section 6.2 on page 383](#) and [Section 6.3 on page 384](#).

Note: Inquiry Scan is only performed when Inquiry_Scan is enabled (see [6.1](#), [7.3.17](#) and [7.3.18](#)).

Command Parameters:

Inquiry_Scan_Interval: *Size: 2 Octets*

| Value | Parameter Description |
|---|-----------------------|
| See Section 6.2 on page 383 . | |

Inquiry_Scan_Window: *Size: 2 Octets*

| Value | Parameter Description |
|---|-----------------------|
| See Section 6.3 on page 384 . | |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Inquiry_Scan_Activity command succeeded. |
| 0x01-0xFF | Write_Inquiry_Scan_Activity command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Inquiry_Scan_Activity command has completed, a Command Complete event will be generated.

7.3.23 Read Authentication Enable Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------------|--------|--------------------|----------------------------------|
| HCI_Read_ Authentication_Enable | 0x001F | | Status, Authentication_Enable |

Description:

This command will read the value for the Authentication_Enable configuration parameter. See [Section 6.15 on page 388](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Authentication_Enable command succeeded. |
| 0x01-0xFF | Read_Authentication_Enable command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Authentication_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Authentication not required. |
| 0x01 | Authentication required for all connections. |
| 0x02-0xFF | Reserved |

Event(s) generated (unless masked away):

When the Read_Authentication_Enable command has completed, a Command Complete event will be generated.

7.3.24 Write Authentication Enable Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------------|--------|-----------------------|-------------------|
| HCI_Write_ Authentication_Enable | 0x0020 | Authentication_Enable | Status |

Description:

This command will write the value for the Authentication_Enable configuration parameter. See [Section 6.15 on page 388](#).

Command Parameters:

Authentication_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Authentication not required. Default. |
| 0x01 | Authentication required for all connections. |
| 0x02-0xFF | Reserved |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write Authentication_Enable command succeeded. |
| 0x01-0xFF | Write Authentication_Enable command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Authentication_Enable command has completed, a Command Complete event will be generated.

7.3.25 Read Encryption Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------|--------|--------------------|----------------------------|
| HCI_Read_Encryption_Mode | 0x0021 | | Status, Encryption_Mode |

Description:

This command will read the value for the Encryption_Mode configuration parameter. See [Section 6.16 on page 389](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Encryption_Mode command succeeded. |
| 0x01-0xFF | Read_Encryption_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Encryption_Mode:

Size: 1 Octet

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.16 on page 389 | |

Event(s) generated (unless masked away):

When the Read_Encryption_Mode command has completed, a Command Complete event will be generated.



7.3.26 Write Encryption Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------|--------|--------------------|-------------------|
| HCI_Write_Encryption_Mode | 0x0022 | Encryption_Mode | Status |

Description:

This command will write the value for the Encryption_Mode configuration parameter. See [Section 6.16 on page 389](#).

Command Parameters:

Encryption_Mode: Size: 1 Octet

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.16 on page 389 . | |

Return Parameters:

Status: Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Encryption_Mode command succeeded. |
| 0x01-0xFF | Write_Encryption_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Encryption_Mode command has completed, a Command Complete event will be generated.



7.3.27 Read Class of Device Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------|--------|--------------------|----------------------------|
| HCI_Read_Class_of_Device | 0x0023 | | Status, Class_of_Device |

Description:

This command will read the value for the Class_of_Device parameter.

See [Section 6.25 on page 394](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Class_of_Device command succeeded. |
| 0x01-0xFF | Read_Class_of_Device command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Class_of_Device:

Size: 3 Octets

| Value | Parameter Description |
|----------|---------------------------------|
| 0xXXXXXX | Class of Device for the device. |

Event(s) generated (unless masked away):

When the Read_Class_of_Device command has completed, a Command Complete event will be generated.



7.3.28 Write Class of Device Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------|--------|--------------------|-------------------|
| HCI_Write_Class_of_Device | 0x0024 | Class_of_Device | Status |

Description:

This command will write the value for the Class_of_Device parameter.
See [Section 6.25 on page 394](#).

Command Parameters:

Class_of_Device: *Size: 3 Octets*

| Value | Parameter Description |
|----------|---------------------------------|
| 0xXXXXXX | Class of Device for the device. |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Class_of_Device command succeeded. |
| 0x01-0xFF | Write_Class_of_Device command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Class_of_Device command has completed, a Command Complete event will be generated.



7.3.29 Read Voice Setting Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------|--------|--------------------|--------------------------|
| HCI_Read_Voice_Setting | 0x0025 | | Status, Voice_Setting |

Description:

This command will read the values for the Voice_Setting configuration parameter. See [Section 6.12 on page 387](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Voice_Setting command succeeded. |
| 0x01-0xFF | Read_Voice_Setting command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Voice_Setting:

Size: 2 Octets (10 Bits meaningful)

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.12 on page 387 . | |

Event(s) generated (unless masked away):

When the Read_Voice_Setting command has completed, a Command Complete event will be generated.



7.3.30 Write Voice Setting Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------|--------|--------------------|-------------------|
| HCI_Write_Voice_Setting | 0x0026 | Voice_Setting | Status |

Description:

This command will write the values for the Voice_Setting configuration parameter. See [Section 6.12 on page 387](#).

Command Parameters:

Voice_Setting:

Size: 2 Octets (10 Bits meaningful)

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.12 on page 387 . | |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Voice_Setting command succeeded. |
| 0x01-0xFF | Write_Voice_Setting command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Voice_Setting command has completed, a Command Complete event will be generated.



7.3.31 Read Automatic Flush Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------------|--------|--------------------|--|
| HCI_Read_Automatic_Flush_Timeout | 0x0027 | Connection_Handle | Status, Connection_Handle, Flush_Timeout |

Description:

This command will read the value for the Flush_Timeout parameter for the specified connection handle. See [Section 6.20 on page 392](#).

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Specifies which Connection Handle's Flush Timeout to read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Automatic_Flush_Timeout command succeeded. |
| 0x01-0xFF | Read_Automatic_Flush_Timeout command failed. See "Error Codes" on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Specifies which Connection Handle's Flush Timeout has been read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Flush_Timeout: *Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| 0 | Timeout = ∞ ; No Automatic Flush |
| N = 0xXXXX | Flush Timeout = $N * 0.625$ msec Size: 11 bits Range: 0x0001 – 0x07FF |

Event(s) generated (unless masked away):

When the Read_Automatic_Flush_Timeout command has completed, a Command Complete event will be generated.

7.3.32 Write Automatic Flush Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|-------------------------------------|------------------------------|
| HCI_Write_Automatic_Flush_Timeout | 0x0028 | Connection_Handle, Flush_Timeout | Status, Connection_Handle |

Description:

This command will write the value for the Flush_Timeout parameter for the specified connection handle. See [Section 6.20 on page 392](#).

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Specifies which Connection Handle's Flush Timeout to write to. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Flush_Timeout: *Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| 0 | Timeout = ∞ ; No Automatic Flush. Default. |
| N = 0xFFFF | Flush Timeout = N * 0.625 msec Size: 11 bits Range: 0x0001 – 0x07FF Mandatory Range for Controller: 0x0002 to 0x07FF |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Automatic_Flush_Timeout command succeeded. |
| 0x01-0xFF | Write_Automatic_Flush_Timeout command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Specifies which Connection Handle's Flush Timeout has been written. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Event(s) generated (unless masked away):

When the Write_Automatic_Flush_Timeout command has completed, a Command Complete event will be generated.



7.3.33 Read Num Broadcast Retransmissions Command

| Command | OCF | Command Parameters | Return Parameters |
|--|--------|--------------------|--|
| HCI_Read_Num_Broadcast_Retransmissions | 0x0029 | | Status, Num_Broadcast_Retransmissions |

Description:

This command will read the device's parameter value for the Number of Broadcast Retransmissions. See [Section 6.21 on page 392](#)

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Num_Broadcast_Retransmissions command succeeded. |
| 0x01-0xFF | Read_Num_Broadcast_Retransmissions command failed. See "Error Codes" on page 319 [Part D] for list of Error Codes. |

Num_Broadcast_Retransmissions:

Size: 1 Octet

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.21 on page 392 . | |

Event(s) generated (unless masked away):

When the Read_Num_Broadcast_Retransmission command has completed, a Command Complete event will be generated.



7.3.34 Write Num Broadcast Retransmissions Command

| Command | OCF | Command Parameters | Return Parameters |
|---|--------|-------------------------------|-------------------|
| HCI_Write_Num_Broadcast_Retransmissions | 0x002A | Num_Broadcast_Retransmissions | Status |

Description:

This command will write the device's parameter value for the Number of Broadcast Retransmissions. See [Section 6.21 on page 392](#).

Command Parameters:

Num_Broadcast_Retransmissions:

Size: 1 Octet

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.21 on page 392 . | |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Num_Broadcast_Retransmissions command succeeded. |
| 0x01-0xFF | Write_Num_Broadcast_Retransmissions command failed. See “ Error Codes ” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Num_Broadcast_Retransmissions command has completed, a Command Complete event will be generated.

7.3.35 Read Hold Mode Activity Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------|--------|--------------------|----------------------------|
| HCI_Read_Hold_Mode_Activity | 0x002B | | Status, Hold_Mode_Activity |

Description:

This command will read the value for the Hold_Mode_Activity parameter. See [Section 6.18 on page 390](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Hold_Mode_Activity command succeeded. |
| 0x01-0xFF | Read_Hold_Mode_Activity command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Hold_Mode_Activity:

Size: 1 Octet

| Value | Parameter Description |
|-----------|-------------------------------|
| 0x00 | Maintain current Power State. |
| 0x01 | Suspend Page Scan. |
| 0x02 | Suspend Inquiry Scan. |
| 0x04 | Suspend Periodic Inquiries. |
| 0x08-0xFF | Reserved for Future Use. |

Event(s) generated (unless masked away):

When the Read_Hold_Mode_Activity command has completed, a Command Complete event will be generated.



7.3.36 Write Hold Mode Activity Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------|--------|--------------------|-------------------|
| HCI_Write_Hold_Mode_Activity | 0x002C | Hold_Mode_Activity | Status |

Description:

This command will write the value for the Hold_Mode_Activity parameter.
See [Section 6.18 on page 390](#).

Command Parameters:

Hold_Mode_Activity:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Maintain current Power State. Default. |
| 0x01 | Suspend Page Scan. |
| 0x02 | Suspend Inquiry Scan. |
| 0x04 | Suspend Periodic Inquiries. |
| 0x08-0xFF | Reserved for Future Use. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Hold_Mode_Activity command succeeded. |
| 0x01-0xFF | Write_Hold_Mode_Activity command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Hold_Mode_Activity command has completed, a Command Complete event will be generated.



7.3.37 Read Transmit Power Level Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------|--------|----------------------------|---|
| HCI_Read_Transmit_Power_Level | 0x002D | Connection_Handle, Type | Status, Connection_Handle, Transmit_Power_Level |

Description:

This command will read the values for the Transmit_Power_Level parameter for the specified Connection_Handle. The Connection_Handle must be a Connection_Handle for an ACL connection.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xXXXX | Specifies which Connection_Handle's Transmit Power Level setting to read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Type: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Read Current Transmit Power Level. |
| 0x01 | Read Maximum Transmit Power Level. |
| 0x02-0xFF | Reserved |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Transmit_Power_Level command succeeded. |
| 0x01-0xFF | Read_Transmit_Power_Level command failed. See "Error Codes" on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xXXXX | Specifies which Connection_Handle's Transmit Power Level setting is returned. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



Transmit_Power_Level:

Size: 1 Octet

| Value | Parameter Description |
|----------|---|
| N = 0xXX | Size: 1 Octet (signed integer) Range: $-30 \leq N \leq 20$ Units: dBm |

Event(s) generated (unless masked away):

When the Read_Transmit_Power_Level command has completed, a Command Complete event will be generated.

7.3.38 Read Synchronous Flow Control Enable Command

| Command | OCF | Command Parameters | Return Parameters |
|--|--------|--------------------|--|
| HCI_Read_Synchronous_Flow_Control_Enable | 0x002E | | Status, Synchronous_Flow_Control_Enable |

Description:

The Read_Synchronous_Flow_Control_Enable command provides the ability to read the Synchronous_Flow_Control_Enable setting. See [Section 6.23 on page 393](#).

Note: the Synchronous_Flow_Control_Enable setting can only be changed if no connections exist.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Synchronous_Flow_Control_Enable command succeeded |
| 0x01-0xFF | Read_Synchronous_Flow_Control_Enable command failed see “ Error Codes ” on page 319 [Part D] for list of Error Codes |

Synchronous_Flow_Control_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0x00 | Synchronous Flow Control is disabled. No Number of Completed Packets events will be sent from the Controller for Synchronous Connection Handles. |
| 0x01 | Synchronous Flow Control is enabled. Number of Completed Packets events will be sent from the Controller for Synchronous Connection Handles. |

Event(s) generated (unless masked away):

When the Read_Synchronous_Flow_Control_Enable command has completed a Command Complete event will be generated.



7.3.39 Write Synchronous Flow Control Enable Command

| Command | OCF | Command Parameters | Return Parameters |
|---|--------|---------------------------------|-------------------|
| HCI_Write_Synchronous_Flow_Control_Enable | 0x002F | Synchronous_Flow_Control_Enable | Status |

Description:

The Write_Synchronous_Flow_Control_Enable command provides the ability to write the Synchronous_Flow_Control_Enable setting. See [Section 6.23 on page 393](#).

Note: the Synchronous_Flow_Control_Enable setting can only be changed if no connections exist.

Command Parameters:

Synchronous_Flow_Control_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0x00 | Synchronous Flow Control is disabled. No Number of Completed Packets events will be sent from the Controller for synchronous Connection Handles. Default |
| 0x01 | Synchronous Flow Control is enabled. Number of Completed Packets events will be sent from the Controller for synchronous Connection Handles. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Synchronous_Flow_Control_Enable command succeeded |
| 0x01-0xFF | Write_Synchronous_Flow_Control_Enable command failed see “Error Codes” on page 319 [Part D] for list of Error Codes |

Event(s) generated (unless masked away):

When the Write_Synchronous_Flow_Control_Enable command has completed a Command Complete event will be generated.



7.3.40 Set Controller To Host Flow Control Command

| Command | OCF | Command Parameters | Return Parameters |
|---|--------|---------------------|-------------------|
| HCI_Set_Controller_To_Host_Flow_Control | 0x0031 | Flow_Control_Enable | Status |

Description:

This command is used by the Host to turn flow control on or off for data and/or voice sent in the direction from the Controller to the Host. If flow control is turned off, the Host should not send the Host_Number_Of_Completed_Packets command. That command will be ignored by the Controller if it is sent by the Host and flow control is off. If flow control is turned on for HCI ACL Data Packets and off for HCI synchronous Data Packets, Host_Number_Of_Completed_Packets commands sent by the Host should only contain Connection Handles for ACL connections. If flow control is turned off for HCI ACL Data Packets and on for HCI synchronous Data Packets, Host_Number_Of_Completed_Packets commands sent by the Host should only contain Connection Handles for synchronous connections. If flow control is turned on for HCI ACL Data Packets and HCI synchronous Data Packets, the Host will send Host_Number_Of_Completed_Packets commands both for ACL connections and synchronous connections.

The Flow_Control_Enable setting shall only be changed if no connections exist.

Command Parameters:

Flow_Control_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Flow control off in direction from Controller to Host. Default. |
| 0x01 | Flow control on for HCI ACL Data Packets and off for HCI synchronous Data Packets in direction from Controller to Host. |
| 0x02 | Flow control off for HCI ACL Data Packets and on for HCI synchronous Data Packets in direction from Controller to Host. |
| 0x03 | Flow control on both for HCI ACL Data Packets and HCI synchronous Data Packets in direction from Controller to Host. |
| 0x04-0xFF | Reserved |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Set_Controller_To_Host_Flow_Control command succeeded. |
| 0x01-0xFF | Set_Controller_To_Host_Flow_Control command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Set_Controller_To_Host_Flow_Control command has completed, a Command Complete event will be generated.

7.3.41 Host Buffer Size Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------|--------|---|-------------------|
| HCI_Host_Buffer_Size | 0x0033 | Host_ACL_Data_Packet_Length, Host_Synchronous_Data_Packet_Length, Host_Total_Num_ACL_Data_Packets, Host_Total_Num_Synchronous_Data_Packets | Status |

Description:

The `Host_Buffer_Size` command is used by the Host to notify the Controller about the maximum size of the data portion of HCI ACL and synchronous Data Packets sent from the Controller to the Host. The Controller will segment the data to be transmitted from the Controller to the Host according to these sizes, so that the HCI Data Packets will contain data with up to these sizes. The `Host_Buffer_Size` command also notifies the Controller about the total number of HCI ACL and synchronous Data Packets that can be stored in the data buffers of the Host. If flow control from the Controller to the Host is turned off, and the `Host_Buffer_Size` command has not been issued by the Host, this means that the Controller will send HCI Data Packets to the Host with any lengths the Controller wants to use, and it is assumed that the data buffer sizes of the Host are unlimited. If flow control from the Controller to the Host is turned on, the `Host_Buffer_Size` command must after a power-on or a reset always be sent by the Host before the first `Host_Number_Of_Completed_Packets` command is sent.

(The [Set Controller To Host Flow Control Command](#) command is used to turn flow control on or off.) The `Host_ACL_Data_Packet_Length` command parameter will be used to determine the size of the L2CAP segments contained in ACL Data Packets, which are transferred from the Controller to the Host. The `Host_Synchronous_Data_Packet_Length` command parameter is used to determine the maximum size of HCI synchronous Data Packets. Both the Host and the Controller must support command and event packets, where the data portion (excluding header) contained in the packets is 255 octets in size.

The `Host_Total_Num_ACL_Data_Packets` command parameter contains the total number of HCI ACL Data Packets that can be stored in the data buffers of the Host. The Controller will determine how the buffers are to be divided between different Connection Handles. The `Host_Total_Num_Synchronous_Data_Packets` command parameter gives the same information for HCI synchronous Data Packets.

Note: the `Host_ACL_Data_Packet_Length` and `Host_Synchronous_Data_Packet_Length` command parameters do not include the length of the HCI Data Packet header.

**Command Parameters:***Host_ACL_Data_Packet_Length:**Size: 2 Octets*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Maximum length (in octets) of the data portion of each HCI ACL Data Packet that the Host is able to accept. |

*Host_Synchronous_Data_Packet_Length:**Size: 1 Octet*

| Value | Parameter Description |
|-------|---|
| 0xFF | Maximum length (in octets) of the data portion of each HCI synchronous Data Packet that the Host is able to accept. |

*Host_Total_Num_ACL_Data_Packets:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Total number of HCI ACL Data Packets that can be stored in the data buffers of the Host. |

*Host_Total_Num_Synchronous_Data_Packets:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Total number of HCI synchronous Data Packets that can be stored in the data buffers of the Host. |

Return Parameters:*Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Host_Buffer_Size command succeeded. |
| 0x01-0xFF | Host_Buffer_Size command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Host_Buffer_Size command has completed, a Command Complete event will be generated.

7.3.42 Host Number Of Completed Packets Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------------|--------|---|-------------------|
| HCI_Host_Number_Of_Completed_Packets | 0x0035 | Number_Of_Handles, Connection_Handle[i], Host_Num_Of_Completed_Packets [i] | |

Description:

The `Host_Number_Of_Completed_Packets` command is used by the Host to indicate to the Controller the number of HCI Data Packets that have been completed for each Connection Handle since the previous `Host_Number_Of_Completed_Packets` command was sent to the Controller. This means that the corresponding buffer space has been freed in the Host. Based on this information, and the `Host_Total_Num_ACL_Data_Packets` and `Host_Total_Num_Synchronous_Data_Packets` command parameters of the `Host_Buffer_Size` command, the Controller can determine for which Connection Handles the following HCI Data Packets should be sent to the Host. The command should only be issued by the Host if flow control in the direction from the Controller to the Host is on and there is at least one connection, or if the Controller is in local loopback mode. Otherwise, the command will be ignored by the Controller. When the Host has completed one or more HCI Data Packet(s) it shall send a `Host_Number_Of_Completed_Packets` command to the Controller, until it finally reports that all pending HCI Data Packets have been completed. The frequency at which this command is sent is manufacturer specific.

(The [Set Controller To Host Flow Control Command](#) command is used to turn flow control on or off.) If flow control from the Controller to the Host is turned on, the `Host_Buffer_Size` command must after a power-on or a reset always be sent by the Host before the first `Host_Number_Of_Completed_Packets` command is sent.

Note: the `Host_Number_Of_Completed_Packets` command is a special command in the sense that no event is normally generated after the command has completed. The command may be sent at any time by the Host when there is at least one connection, or if the Controller is in local loopback mode independent of other commands. The normal flow control for commands is not used for the `Host_Number_Of_Completed_Packets` command.

**Command Parameters:***Number_Of_Handles:**Size: 1 Octet*

| Value | Parameter Description |
|-------|--|
| 0xXX | The number of Connection Handles and Host_Num_Of_Completed_Packets parameters pairs contained in this command. Range: 0-255 |

*Connection_Handle[i]: Size: Number_Of_Handles*2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Host_Num_Of_Completed_Packets [i]: Size: Number_Of_Handles * 2 Octets*

| Value | Parameter Description |
|------------|--|
| N = 0xFFFF | The number of HCI Data Packets that have been completed for the associated Connection Handle since the previous time the event was returned. Range for N: 0x0000-0xFFFF |

Return Parameters:

None.

Event(s) generated (unless masked away):

Normally, no event is generated after the Host_Number_Of_Completed_Packets command has completed. However, if the Host_Number_Of_Completed_Packets command contains one or more invalid parameters, the Controller will return a Command Complete event with a failure status indicating the *Invalid HCI Command Parameters error code*. The Host may send the Host_Number_Of_Completed_Packets command at any time when there is at least one connection, or if the Controller is in local loopback mode. The normal flow control for commands is not used for this command.

7.3.43 Read Link Supervision Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|--------------------|---|
| HCI_Read_Link_Supervision_Timeout | 0x0036 | Connection_Handle | Status, Connection_Handle, Link_Supervision_Timeout |

Description:

This command will read the value for the Link_Supervision_Timeout parameter for the device.

Note: the Connection_Handle used for this command must be the ACL connection to the appropriate device. See [Section 6.22 on page 393](#).

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Specifies which Connection Handle's Link Supervision Timeout value is to be read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Link_Supervision_Timeout command succeeded. |
| 0x01-0xFF | Read_Link_Supervision_Timeout command failed. See "Error Codes" on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Specifies which Connection Handle's Link Supervision Timeout value was read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Link_Supervision_Timeout:**Size: 2 Octets*

| Value | Parameter Description |
|------------|---|
| 0x0000 | No Link_Supervision_Timeout. |
| N = 0xXXXX | Measured in Number of Baseband slots Link_Supervision_Timeout = N * 0.625 msec (1 Baseband slot) Range for N: 0x0001 – 0xFFFF Time Range: 0.625ms - 40.9 sec |

Event(s) generated (unless masked away):

When the Read_Link_Supervision_Timeout command has completed, a Command Complete event will be generated.

7.3.44 Write Link Supervision Timeout Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------------|--------|--|------------------------------|
| HCI_Write_Link_Supervision_Timeout | 0x0037 | Connection_Handle, Link_Supervision_Timeout | Status, Connection_Handle |

Description:

This command will write the value for the Link_Supervision_Timeout parameter for the device. This command shall only be issued on the master for the given connection handle. If this command is issued on a slave, the command shall be rejected with the Command Disallowed.

Note: the Connection_Handle used for this command must be the ACL connection to the appropriate device. This command will set the Link_Supervision_Timeout values for other Synchronous Connection_Handles to that device. See [Section 6.22 on page 393](#).

Command Parameters:*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Specifies which Connection Handle's Link Supervision Timeout value is to be written. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



Link_Supervision_Timeout:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| 0x0000 | No Link_Supervision_Timeout. |
| N = 0xXXXX | Measured in Number of Baseband slots Link_Supervision_Timeout = N*0.625 msec (1 Baseband slot) Range for N: 0x0001 – 0xFFFF Time Range: 0.625ms – 40.9 sec Default: N = 0x7D00 Link_Supervision_Timeout = 20 sec Mandatory Range for Controller: 0x0190 to 0xFFFF; plus 0 for infinite timeout |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Link_Supervision_Timeout command succeeded. |
| 0x01-0xFF | Write_Link_Supervision_Timeout command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xXXXX | Specifies which Connection Handle’s Link Supervision Timeout value was written. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Event(s) generated (unless masked away):

When the Write_Link_Supervision_Timeout command has completed, a Command Complete event will be generated.



7.3.45 Read Number Of Supported IAC Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------------|--------|--------------------|----------------------------|
| HCI_Read_Number_Of_Supported_IAC | 0x0038 | | Status, Num_Support_IAC |

Description:

This command will read the value for the number of Inquiry Access Codes (IAC) that the local Bluetooth device can simultaneous listen for during an Inquiry Scan. All Bluetooth devices are required to support at least one IAC, the General Inquiry Access Code (the GIAC). Some Bluetooth devices support additional IACs.

Command Parameters:

None

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Number_Of_Supported_IAC command succeeded. |
| 0x01-0xFF | Read_Number_Of_Supported_IAC command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Num_Support_IAC

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0xXX | Specifies the number of Supported IAC that the local Bluetooth device can simultaneous listen for during an Inquiry Scan. Range: 0x01-0x40 |

Event(s) generated (unless masked away):

When the Read_Number_Of_Supported_IAC command has completed, a Command Complete event will be generated.



7.3.46 Read Current IAC LAP Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------|--------|--------------------|---|
| HCI_Read_Current_IAC_LAP | 0x0039 | | Status, Num_Current_IAC, IAC_LAP[i] |

Description:

This command reads the LAP(s) used to create the Inquiry Access Codes (IAC) that the local Bluetooth device is simultaneously scanning for during Inquiry Scans. All Bluetooth devices are required to support at least one IAC, the General Inquiry Access Code (the GIAC). Some Bluetooth devices support additional IACs.

Command Parameters:

None

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Current_IAC_LAP command succeeded. |
| 0x01-0xFF | Read_Current_IAC_LAP command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Num_Current_IAC

Size: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0xXX | Specifies the number of IACs which are currently in use by the local Bluetooth device to simultaneously listen for during an Inquiry Scan. Range: 0x01-0x40 |

IAC_LAP[i]

*Size: 3 Octets * Num_Current_IAC*

| Value | Parameter Description |
|----------|--|
| 0xXXXXXX | LAPs used to create the IAC which is currently in use by the local Bluetooth device to simultaneously listen for during an Inquiry Scan. Range: 0x9E8B00-0x9E8B3F |

Event(s) generated (unless masked away):

When the Read_Current_IAC_LAP command has completed, a Command Complete event will be generated.

7.3.47 Write Current IAC LAP Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------|--------|--------------------------------|-------------------|
| HCI_Write_Current_IAC_LAP | 0x003A | Num_Current_IAC, IAC_LAP[i] | Status |

Description:

This command writes the LAP(s) used to create the Inquiry Access Codes (IAC) that the local Bluetooth device is simultaneously scanning for during Inquiry Scans. All Bluetooth devices are required to support at least one IAC, the General Inquiry Access Code (the GIAC). Some Bluetooth devices support additional IACs.

This command shall clear any existing IACs and stores Num_Current_IAC and the IAC_LAPs in to the controller. If Num_Current_IAC is greater than Num_Support_IAC then only the first Num_Support_IACs shall be stored in the controller, and a Command Complete event with error code *Success (0x00)* shall be generated.

Command Parameters:

Num_Current_IACSize: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0xXX | Specifies the number of IACs which are currently in use by the local Bluetooth device to simultaneously listen for during an Inquiry Scan. Range: 0x01-0x40 |

IAC_LAP[i]Size: 3 Octets * Num_Current_IAC

| Value | Parameter Description |
|----------|---|
| 0xXXXXXX | LAP(s) used to create IAC which is currently in use by the local Bluetooth device to simultaneously listen for during an Inquiry Scan. Range: 0x9E8B00-0x9E8B3F. The GIAC is the default IAC to be used. If additional IACs are supported, additional default IAC will be determined by the manufacturer. |



Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Current_IAC_LAP command succeeded. |
| 0x01-0xFF | Write_Current_IAC_LAP command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Current_IAC_LAP command has completed, a Command Complete event will be generated.

7.3.48 Read Page Scan Period Mode Command (Deprecated)

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------------|--------|--------------------|----------------------------------|
| HCI_Read_Page_Scan_Period_Mode | 0x003B | | Status, Page_Scan_Period_Mode |

Description:

This command is used to read the mandatory Page_Scan_Period_Mode configuration parameter of the local Bluetooth device. See [Section 6.10 on page 386](#).

Command Parameters:

None

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Page_Scan_Period_Mode command succeeded. |
| 0x01-0xFF | Read_Page_Scan_Period_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Page_Scan_Period_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|-----------------------|
| 0x00 | P0 |
| 0x01 | P1 |
| 0x02 | P2 |
| 0x03-0xFF | Reserved. |

Event(s) generated (unless masked away):

When the Read_Page_Scan_Period_Mode command has completed, a Command Complete event will be generated.

7.3.49 Write Page Scan Period Mode Command (Deprecated)

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------------|--------|-----------------------|-------------------|
| HCI_Write_Page_Scan_Period_Mode | 0x003C | Page_Scan_Period_Mode | Status |

Description:

This command is used to write the mandatory Page_Scan_Period_Mode configuration parameter of the local Bluetooth device. See [Section 6.10 on page 386](#).

Command Parameters:

Page_Scan_Period_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|-----------------------|
| 0x00 | P0 |
| 0x01 | P1 |
| 0x02 | P2. Default. |
| 0x03-0xFF | Reserved. |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Page_Scan_Period_Mode command succeeded. |
| 0x01-0xFF | Write_Page_Scan_Period_Mode command failed. See “ Error Codes ” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Page_Scan_Period_Mode command has completed, a Command Complete event will be generated.



7.3.50 Set AFH Host Channel Classification Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------------------|--------|---------------------------------|-------------------|
| Set_AFH_Host_Channel_Classification | 0x003F | AFH_Host_Channel_Classification | Status |

Description:

The Set_AFH_Host_Channel_Classification command allows the Bluetooth host to specify a channel classification based on its “local information”. This classification persists until overwritten with a subsequent HCI

Set AFH Host Channel Classification command or until the Controller is reset.

This command shall be supported by a device that declares support for any of the AFH_capable_master, AFH_classification_slave or AFH_classification_master features.

If this command is used, then updates should be sent within 10 seconds, of the host knowing that the channel classification has changed. The interval between two successive commands sent shall be at least 1 second.

Command Parameters:

AFH Host Channel Classification: *Size: 10 Octets (79 Bits meaningful)*

| Value | Parameter Description |
|--------------------------------|--|
| 0xFFFFFFFF XXXXXXXXXX XX | <p>This parameter contains 79 1-bit field.</p> <p>The n^{th} such field (in the range 0 to 78) contains the value for channel n:</p> <p>Channel n is bad = 0</p> <p>Channel n is unknown = 1</p> <p>The most significant bit is reserved and shall be set to 0</p> <p>At least N_{min} channels shall be marked as unknown. (See Baseband Specification, Section 2.3.1, on page 75)</p> |

Return Parameters:

Status: Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Set_AFH_Host_Channel_Classification command succeeded. |
| 0x01-0xFF | Set_AFH_Host_Channel_Classification command failed. “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Set_AFH_Host_Channel_Classification command has completed, a Command Complete event will be generated.



7.3.51 Read Inquiry Scan Type Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------|--------|--------------------|------------------------------|
| HCI_Read_Inquiry_Scan_Type | 0x0042 | | Status, Inquiry_Scan_Type |

Description:

This command is used to read the Inquiry_Scan_Type configuration parameter of the local Bluetooth device. See [Section 6.4 on page 384](#).

For details, see the Baseband Specification, “Inquiry scan substate” on [page 164 \[Part B\]](#).

Command Parameters:

None

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Inquiry_Scan_Type command succeeded |
| 0x01-0xFF | Read_Inquiry_Scan_Type command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Inquiry_Scan_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Mandatory: Standard Scan (default) |
| 0x01 | Optional: Interlaced Scan |
| 0x02-0xFF | Reserved |

Event(s) generated (unless masked away):

When the Read_Inquiry_Scan_Type command has completed, a Command Complete event will be generated.



7.3.52 Write Inquiry Scan Type Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------|--------|--------------------|-------------------|
| HCI_Write_Inquiry_Scan_Type | 0x0043 | Scan_Type | Status |

Description:

This command is used to write the Inquiry Scan Type configuration parameter of the local Bluetooth device. See [Section 6.4 on page 384](#).

For details, see the Baseband Specification, “Inquiry scan substate” on [page 164 \[Part B\]](#).

Command Parameters:

Scan_Type: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Mandatory: Standard Scan (default) |
| 0x01 | Optional: Interlaced Scan |
| 0x02-0xFF | Reserved |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Inquiry_Scan_Type command succeeded |
| 0x01-0xFF | Write_Inquiry_Scan_Type command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Inquiry_Scan_Type command has completed, a Command Complete event will be generated.



7.3.53 Read Inquiry Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------|--------|--------------------|-------------------------|
| HCI_Read_Inquiry_Mode | 0x0044 | | Status, Inquiry_Mode |

Description:

This command is used to read the Inquiry_Mode configuration parameter of the local Bluetooth device. See [Section 6.5 on page 384](#).

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Inquiry_Mode command succeeded |
| 0x01-0xFF | Read_Inquiry_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes |

Inquiry_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--------------------------------------|
| 0x00 | Standard Inquiry Result event format |
| 0x01 | Inquiry Result format with RSSI |
| 0x02-0xFF | Reserved |

Event(s) generated (unless masked away):

When the Read_Inquiry_Mode command has completed, a Command Complete event will be generated.



7.3.54 Write Inquiry Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------|--------|--------------------|-------------------|
| HCI_Write_Inquiry_Mode | 0x0045 | Inquiry_Mode | Status |

Description:

This command is used to write the Inquiry_Mode configuration parameter of the local Bluetooth device. See [Section 6.5 on page 384](#).

Command Parameters:

Inquiry_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Standard Inquiry Result event format (default) |
| 0x01 | Inquiry Result format with RSSI |
| 0x02-0xFF | Reserved |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Inquiry_Mode command succeeded |
| 0x01-0xFF | Write_Inquiry_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Inquiry_Mode command has completed, a Command Complete event will be generated.



7.3.55 Read Page Scan Type Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------|--------|--------------------|---------------------------|
| HCI_Read_Page_Scan_Type | 0x0046 | | Status, Page_Scan_Type |

Description:

This command is used to read the Page Scan Type configuration parameter of the local Bluetooth device. See [Section 6.11 on page 387](#).
For details, see the Baseband Specification, “Page scan substate” on page 154 [\[Part B\]](#).

Return Parameters:

Status: Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Page_Scan_Type command succeeded |
| 0x01-0xFF | Read_Page_Scan_Type command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Page_Scan_Type: Size: 1 Octet

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Mandatory: Standard Scan (default) |
| 0x01 | Optional: Interlaced Scan |
| 0x02-0xFF | Reserved |

Event(s) generated (unless masked away):

When the Read_Page_Scan_Type command has completed, a Command Complete event will be generated.

7.3.56 Write Page Scan Type Command

| Command | OCF | Command Parameters | Return Parameters |
|--------------------------|--------|--------------------|-------------------|
| HCI_Write_Page_Scan_Type | 0x0047 | Page_Scan_Type | Status |

Description:

This command is used to write the Page Scan Type configuration parameter of the local Bluetooth device. See [Section 6.11 on page 387](#). For details, see the Baseband Specification, “Page scan substate” on page 154 [\[Part B\]](#).

Command Parameters:

Page_Scan_Type: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|------------------------------------|
| 0x00 | Mandatory: Standard Scan (default) |
| 0x01 | Optional: Interlaced Scan |
| 0x02-0xFF | Reserved |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Page_Scan_Type command succeeded |
| 0x01-0xFF | Write_Page_Scan_Type command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Page_Scan_Type command has completed, a Command Complete event will be generated.



7.3.57 Read AFH Channel Assessment Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------------|--------|--------------------|-------------------------------------|
| Read_AFH_Channel_Assessment_Mode | 0x0048 | | Status, AFH_Channel_Assessment_Mode |

Description:

The Read_AFH_Channel_Assessment_Mode command reads the value for the AFH_Channel_Assessment_Mode parameter. The AFH_Channel_Assessment_Mode parameter controls whether the controller's channel assessment scheme is enabled or disabled.

This command shall be supported by a device that declares support for any of the AFH_capable_master, AFH_classification_slave or AFH_classification_master features.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_AFH_Channel_Assessment_Mode command succeeded. |
| 0x01-0xFF | Read_AFH_Channel_Assessment_Mode command failed. See "Error Codes" on page 319 [Part D] for list of Error Codes. |

AFH_Channel_Assessment_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Controller channel assessment disabled. |
| 0x01 | Controller channel assessment enabled. |
| 0x02-0xFF | Reserved for future use. |

Event(s) generated (unless masked away):

When the Read_AFH_Channel_Assessment_Mode command has completed, a Command Complete event will be generated.

7.3.58 Write AFH Channel Assessment Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|-----------------------------|-------------------|
| Write_AFH_Channel_Assessment_Mode | 0x0049 | AFH_Channel_Assessment_Mode | Status |

Description:

The Write_AFH_Channel_Assessment_Mode command writes the value for the AFH_Channel_Assessment_Mode parameter. The AFH_Channel_Assessment_Mode parameter controls whether the Controller's channel assessment scheme is enabled or disabled.

Disabling channel assessment forces all channels to be unknown in the local classification, but does not affect the AFH_reporting_mode or support for the Set_AFH_Host_Channel_Classification command. A slave in the AFH_reporting_enabled state shall continue to send LMP channel classification messages for any changes to the channel classification caused by either this command (altering the AFH_Channel_Assessment_Mode) or HCI Set_AFH_Host_Channel_Classification command (providing a new channel classification from the Host).

This command shall be supported by a device that declares support for any of the AFH_capable_master, AFH_classification_slave or AFH_classification_master features.

If the AFH_Channel_Assessment_Mode parameter is enabled and the Controller does not support a channel assessment scheme, other than via the Set_AFH_Host_Channel_Classification command, then a Status parameter of 'Channel Assessment Not Supported' should be returned. See [“Error Codes” on page 319 \[Part D\]](#) for list of Error Codes.

If the Controller supports a channel assessment scheme then the default AFH_Channel_Assessment_Mode is enabled, otherwise the default is disabled.

Command Parameters:

AFH_Channel_Assessment_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Controller channel assessment disabled. |
| 0x01 | Controller channel assessment enabled. |
| 0x02-0xFF | Reserved for future use. |



Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_AFH_Channel_Assessment_Mode command succeeded. |
| 0x01-0xFF | Write_AFH_Channel_Assessment_Mode command failed. See “ Error Codes ” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_AFH_Channel_Assessment_Mode command has completed, a Command Complete event will be generated.

7.4 INFORMATIONAL PARAMETERS

The Informational Parameters are fixed by the manufacturer of the Bluetooth hardware. These parameters provide information about the Bluetooth device and the capabilities of the Controller, Link Manager, and Baseband. The host device cannot modify any of these parameters. For Informational Parameters Commands, the OGF is defined as 0x04.

7.4.1 Read Local Version Information Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------------------|--------|--------------------|--|
| HCI_Read_Local_Version_Information | 0x0001 | | Status, HCI Version, HCI Revision, LMP Version, Manufacturer_Name, LMP Subversion |

Description:

This command will read the values for the version information for the local Bluetooth device.

The HCI Version information defines the version information of the HCI layer. The LMP Version information defines the version of the LMP. The Manufacturer_Name information indicates the manufacturer of the local device.

The HCI Revision and LMP Subversion are implementation dependant.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Local_Version_Information command succeeded. |
| 0x01-0xFF | Read_Local_Version_Information command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

**HCI_Version:****Size: 1 Octet**

| Value | Parameter Description |
|---|-----------------------|
| See https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers | |

HCI_Revision:**Size: 2 Octets**

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Revision of the Current HCI in the Bluetooth device. |

LMP_Version:**Size: 1 Octet**

| Value | Parameter Description |
|-------|---|
| 0xXX | Version of the Current LMP in the Bluetooth device, See https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers |

Manufacturer_Name:**Size: 2 Octets**

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Manufacturer Name of the Bluetooth device, See https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers |

LMP_Subversion:**Size: 2 Octets**

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Subversion of the Current LMP in the Bluetooth device, see Table 5.2 on page 303 in the Link Manager Protocol for assigned values (SubVersNr). |

Event(s) generated (unless masked away):

When the Read_Local_Version_Information command has completed, a Command Complete event will be generated.



7.4.2 Read Local Supported Commands Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|--------------------|-------------------------------|
| HCI_Read_Local_Supported_Commands | 0x0002 | | Status, Supported Commands |

Description:

This command reads the list of HCI commands supported for the local device.

This command will return the Supported Commands configuration parameter. It is implied that if a command is listed as supported, the feature underlying that command is also supported.

See [Section 6.26 on page 395](#) for more information.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0 | Read Local Supported Commands command succeeded |
| 0x01-0xff | Read Local Supported Commands command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Supported Commands:

Size: 64 Octets

| Value | Parameter Description |
|-------|---|
| | Bit mask for each HCI Command. If a bit is 1, the radio supports the corresponding command and the features required for the command. Unsupported or undefined commands shall be set to 0. See Section 6.26, “Supported Commands,” on page 395 . |

Event(s) generated (unless masked away):

When the Read Local Supported Commands command has completed a Command Complete event will be generated.

7.4.3 Read Local Supported Features Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|--------------------|-------------------------|
| HCI_Read_Local_Supported_Features | 0x0003 | | Status, LMP_Features |

Description:

This command requests a list of the supported features for the local device. This command will return a list of the LMP features. For details see [“Link Manager Protocol” on page 211 \[Part C\]](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Local_Supported_Features command succeeded. |
| 0x01-0xFF | Read_Local_Supported_Features command failed. See “Error Codes” on page 319 [Part D] |

LMP_Features:

Size: 8 Octets

| Value | Parameter Description |
|------------------------|---|
| 0xFFFFFFFF XXXXXXXX | Bit Mask List of LMP features. For details see “Link Manager Protocol” on page 211 [Part C] |

Event(s) generated (unless masked away):

When the Read_Local_Supported_Features command has completed, a Command Complete event will be generated.



7.4.4 Read Local Extended Features Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------------|--------|--------------------|---|
| HCI_Read_Local_Extended_Features | 0x0004 | Page number | Status, Page number, Maximum Page Number, Extended_LMP_Features |

Description:

The HCI_Read_Local_Extended_Features command returns the requested page of the extended LMP features.

Command Parameters:

Page Number:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Requests the normal LMP features as returned by HCI_Read_Local_Supported_Features |
| 0x01-0xFF | Return the corresponding page of features |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | HCI_Read_Local_Extended_Features command succeeded |
| 0x01-0xFF | HCI_Read_Local_Extended_Features command failed. See “Error Codes” on page 319 [Part D] for list of error codes |

Page Number:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | The normal LMP features as returned by HCI_Read_Local_Supported_Features |
| 0x01-0xFF | The page number of the features returned |

Maximum Page Number:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00-0xFF | The highest features page number which contains non-zero bits for the local device |



Extended_LMP_Features:

Size: 8 Octets

| Value | Parameter Description |
|--------------------|---|
| 0xFFFFFFFFFFFFFFFF | Bit map of requested page of LMP features. See LMP specification for details |

Event(s) generated (unless masked away):

When the Controller receives the HCI_Read_Local_Extended_Features command the Controller sends the Command Complete command to the Host containing the requested information.

7.4.5 Read Buffer Size Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------|--------|--------------------|--|
| HCI_Read_Buffer_Size | 0x0005 | | Status, HC_ACL_Data_Packet_Length, HC_Synchronous_Data_Packet_Length, HC_Total_Num_ACL_Data_Packets, HC_Total_Num_Synchronous_Data_Packets |

Description:

The Read_Buffer_Size command is used to read the maximum size of the data portion of HCI ACL and synchronous Data Packets sent from the Host to the Controller. The Host will segment the data to be transmitted from the Host to the Controller according to these sizes, so that the HCI Data Packets will contain data with up to these sizes. The Read_Buffer_Size command also returns the total number of HCI ACL and synchronous Data Packets that can be stored in the data buffers of the Controller. The Read_Buffer_Size command must be issued by the Host before it sends any data to the Controller.

The HC_ACL_Data_Packet_Length return parameter will be used to determine the size of the L2CAP segments contained in ACL Data Packets, which are transferred from the Host to the Controller to be broken up into baseband packets by the Link Manager. The HC_Synchronous_Data_Packet_Length return parameter is used to determine the maximum size of HCI synchronous Data Packets. Both the Host and the Controller must support command and event packets, where the data portion (excluding header) contained in the packets is 255 octets in size. The HC_Total_Num_ACL_Data_Packets return parameter contains the total number of HCI ACL Data Packets that can be stored in the data buffers of the Controller. The Host will determine how the buffers are to be divided between different Connection Handles. The HC_Total_Num_Synchronous_Data_Packets return parameter gives the same information but for HCI synchronous Data Packets.
Note: the HC_ACL_Data_Packet_Length and HC_Synchronous_Data_Packet_Length return parameters do not include the length of the HCI Data Packet header.

Command Parameters:

None.

**Return Parameters:***Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Buffer_Size command succeeded. |
| 0x01-0xFF | Read_Buffer_Size command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

*HC_ACL_Data_Packet_Length:**Size: 2 Octets*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Maximum length (in octets) of the data portion of each HCI ACL Data Packet that the Controller is able to accept. |

*HC_Synchronous_Data_Packet_Length:**Size: 1 Octet*

| Value | Parameter Description |
|-------|---|
| 0xFF | Maximum length (in octets) of the data portion of each HCI Synchronous Data Packet that the Controller is able to accept. |

*HC_Total_Num_ACL_Data_Packets:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Total number of HCI ACL Data Packets that can be stored in the data buffers of the Controller. |

*HC_Total_Num_Synchronous_Data_Packets:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Total number of HCI Synchronous Data Packets that can be stored in the data buffers of the Controller. |

Event(s) generated (unless masked away):

When the Read_Buffer_Size command has completed, a Command Complete event will be generated.



7.4.6 Read BD_ADDR Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------|--------|--------------------|--------------------|
| HCI_Read_BD_ADDR | 0x0009 | | Status, BD_ADDR |

Description:

This command shall read the Bluetooth device address (BD_ADDR). See the [“Baseband Specification” on page 55 \[Part B\]](#) for details of how BD_ADDR is used.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_BD_ADDR command succeeded. |
| 0x01-0xFF | Read_BD_ADDR command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|-----------------------|
| 0XXXXXXXXXXXXX | BD_ADDR of the Device |

Event(s) generated (unless masked away):

When the Read_BD_ADDR command has completed, a Command Complete event will be generated.



7.5 STATUS PARAMETERS

The Controller modifies all status parameters. These parameters provide information about the current state of the Controller, Link Manager, and Baseband. The host device cannot modify any of these parameters other than to reset certain specific parameters. For the Status and baseband, the OGF is defined as 0x05.

7.5.1 Read Failed Contact Counter Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------------------------|--------|--------------------|---|
| HCI_Read_Failed_Contact_Counter | 0x0001 | Connection_Handle | Status, Connection_Handle, Failed_Contact_Counter |

Description:

This command will read the value for the Failed_Contact_Counter parameter for a particular connection to another device. The Connection_Handle must be a Connection_Handle for an ACL connection.

See [Section 6.17 on page 390](#).

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | The Connection Handle for the Connection for which the Failed Contact Counter should be read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Failed_Contact_Counter command succeeded. |
| 0x01-0xFF | Read_Failed_Contact_Counter command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0XXXXX | The Connection Handle for the Connection for which the Failed Contact Counter has been read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Failed_Contact_Counter:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0XXXXX | Number of consecutive failed contacts for a connection corresponding to the connection handle. |

Event(s) generated (unless masked away):

When the Read_Failed_Contact_Counter command has completed, a Command Complete event will be generated.



7.5.2 Reset Failed Contact Counter Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------------------|--------|--------------------|------------------------------|
| HCI_Reset_Failed_Contact_Counter | 0x0002 | Connection_Handle | Status, Connection_Handle |

Description:

This command will reset the value for the Failed_Contact_Counter parameter for a particular connection to another device. The Connection_Handle must be a Connection_Handle for an ACL connection.

See [Section 6.17 on page 390](#).

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The Connection Handle for the Connection for which the Failed Contact Counter should be reset. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|--|
| 0x00 | Reset_Failed_Contact_Counter command succeeded. |
| 0x01-0xFF | Reset_Failed_Contact_Counter command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | The Connection Handle for the Connection for which the Failed Contact Counter has been reset. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Event(s) generated (unless masked away):

When the Reset_Failed_Contact_Counter command has completed, a Command Complete event will be generated.

7.5.3 Read Link Quality Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------|--------|--------------------|---|
| HCI_Read_Link_Quality | 0x0003 | Connection_Handle | Status, Connection_Handle, Link_Quality |

Description:

This command will return the value for the Link_Quality for the specified Connection_Handle. The Connection_Handle must be a Connection_Handle for an ACL connection. This command will return a Link_Quality value from 0-255, which represents the quality of the link between two Bluetooth devices. The higher the value, the better the link quality is. Each Bluetooth module vendor will determine how to measure the link quality.

Command Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The Connection_Handle for the connection for which link quality parameters are to be read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Link_Quality command succeeded. |
| 0x01-0xFF | Read_Link_Quality command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The Connection_Handle for the connection for which the link quality parameter has been read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Link_Quality:**Size: 1 Octet*

| Value | Parameter Description |
|-------|---|
| 0xXX | The current quality of the Link connection between the local device and the remote device specified by the Connection Handle Range: 0x00 – 0xFF The higher the value, the better the link quality is. |

Event(s) generated (unless masked away):

When the Read_Link_Quality command has completed, a Command Complete event will be generated.

7.5.4 Read RSSI Command

| Command | OCF | Command Parameters | Return Parameters |
|---------------|--------|--------------------|------------------------------------|
| HCI_Read_RSSI | 0x0005 | Connection_Handle | Status, Connection_Handle, RSSI |

Description:

This command will read the value for the difference between the measured Received Signal Strength Indication (RSSI) and the limits of the Golden Receive Power Range (see Radio Specification [Section 4.1.6 on page 43](#)) for a connection handle to another Bluetooth device. The Connection_Handle must be a Connection_Handle for an ACL connection. Any positive RSSI value returned by the Controller indicates how many dB the RSSI is above the upper limit, any negative value indicates how many dB the RSSI is below the lower limit. The value zero indicates that the RSSI is inside the Golden Receive Power Range.

Note: how accurate the dB values will be depends on the Bluetooth hardware. The only requirements for the hardware are that the Bluetooth device is able to tell whether the RSSI is inside, above or below the Golden Device Power Range.

The RSSI measurement compares the received signal power with two threshold levels, which define the Golden Receive Power Range. The lower threshold level corresponds to a received power between -56 dBm and 6 dB above the actual sensitivity of the receiver. The upper threshold level is 20 dB above the lower threshold level to an accuracy of +/- 6 dB.

Command Parameters:*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0XXXXX | The Connection Handle for the Connection for which the RSSI is to be read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

**Return Parameters:***Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_RSSI command succeeded. |
| 0x01-0xFF | Read_RSSI command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The Connection Handle for the Connection for which the RSSI has been read. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*RSSI:**Size: 1 Octet*

| Value | Parameter Description |
|----------|--|
| N = 0xFF | Size: 1 Octet (signed integer) Range: $-128 \leq N \leq 127$ Units: dB |

Event(s) generated (unless masked away):

When the Read_RSSI command has completed, a Command Complete event will be generated.



7.5.5 Read AFH Channel Map Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------------|--------|--------------------|--|
| Read_AFH_Channel_Map | 0x0006 | Connection_Handle | Status, Connection_Handle, AFH_Mode, AFH_Channel_Map |

Description:

This command will return the values for the AFH_Mode and AFH_Channel_Map for the specified Connection_Handle. The Connection_Handle must be a Connection_Handle for an ACL connection.

The returned values indicate the state of the hop sequence specified by the most recent LMP_Set_AFH message for the specified Connection_Handle, regardless of whether the master has received the baseband ACK or whether the AFH_Instant has passed.

This command shall be supported by a device that declares support for either the AFH_capable_slave or AFH_capable_master feature.

Command Parameters:

Connection_Handle: Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xXXXX | The Connection Handle for the Connection for which the Channel Map is to be read. Range: 0x0000-0x0EFF (0x0F00-0x0FFF Reserved for future use) |

Return Parameters:

Status: Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_AFH_Channel_Map command succeeded. |
| 0x01-0xFF | Read_AFH_Channel_Map command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | The Connection Handle for the Connection for which the Channel Map is to be read. Range: 0x0000-0x0EFF (0x0F00-0x0FFF Reserved for future use) |

AFH_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--------------------------|
| 0x00 | AFH disabled. |
| 0x01 | AFH enabled. |
| 0x02-0xFF | Reserved for future use. |

AFH_Channel_Map:

Size: 10 Octets (79 Bits meaningful)

| Value | Parameter Description |
|---------------------------------|---|
| 0xFFFFFFFF XXXXXXXXXX XXX | If AFH_Mode is AFH enabled then this parameter contains 79 1-bit fields, otherwise the contents are reserved. The n^{th} such field (in the range 0 to 78) contains the value for channel n : Channel n is unused = 0 Channel n is used = 1 Range: 0x00000000000000000000-0x7FFFFFFFFFFFFFFFFFFFFF (0x80000000000000000000-0xFFFFFFFFFFFFFFFFFFFFFFFF Reserved for future use) |

Event(s) generated (unless masked away):

When the Read_AFH_Channel_Map command has completed, a Command Complete event will be generated.



7.5.6 Read Clock Command

| Command | OCF | Command Parameters | Return Parameters |
|----------------|--------|----------------------------------|---|
| HCI_Read_Clock | 0x0007 | Connection_Handle Which_Clock | Status, Connection_Handle, Clock, Accuracy |

Description:

This command will read the estimate of the value of the Bluetooth Clock.

If the Which_Clock value is 0, then the Connection_Handle shall be ignored, and the local Bluetooth Clock value shall be returned, and the accuracy parameter shall be set to 0.

If the Which_Clock value is 1, then the Connection_Handle must be a valid ACL connection handle. If the current role of this ACL connection is Master, then the Bluetooth Clock of this device shall be returned. If the current role is Slave, then an estimate of the Bluetooth Clock of the remote master and the accuracy of this value shall be returned.

The accuracy reflects the clock drift that might have occurred since the slave last received a valid transmission from the master.

Note: The Bluetooth Clock has a minimum accuracy of 250ppm, or about 22 seconds drift in one day.

Note: See [Baseband Specification, Section 1.1, on page 64](#) for more information about the Bluetooth Clock.

Command Parameters:

Connection_Handle: *Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle to be used to identify which connection to be used for reading the masters Bluetooth Clock. Range: 0x0000-0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

Which_Clock: *Size 1 Octet)*

| Value | Parameter Description |
|-------|--|
| 0xFF | 0x00 = Local Clock (Connection Handle does not have to be a valid handle) 0x01 = Piconet Clock (Connection Handle shall be a valid ACL Handle) 0x02 to 0xFF = Reserved |

**Return Parameters:***Status:**Size: 1 Octet*

| Value | Parameter Description |
|-------------|---|
| 0x00 | Read_BD_CLOCK command succeeded. |
| 0x01 – 0xFF | Read_BD_CLOCK command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | The Connection Handle for the Connection for which the master clock has been read. If the Which_Clock was 0, then the Connection_Handle shall be set to 0 and ignored upon receipt Range: 0x0000-0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

*Clock:**Size: 4 Octets (28 bits meaningful)*

| Value | Parameter Description |
|------------|--|
| 0xFFFFFFFF | Bluetooth Clock of the device requested. |

*Accuracy:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | +/- maximum Bluetooth Clock error. Value of 0xFFFF means Unknown. Accuracy = +/- N * 0.3125 msec (1 Bluetooth Clock) Range for N: 0x0000 - 0xFFFFE Time Range for N: 0 - 20479.375 msec |

Event(s) generated (unless masked away):

When the Read_Clock command has completed, a Command Complete event will be generated.

7.6 TESTING COMMANDS

The Testing commands are used to provide the ability to test various functionalities of the Bluetooth hardware. These commands provide the ability to arrange various conditions for testing. For the Testing Commands, the OGF is defined as 0x06.

7.6.1 Read Loopback Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|------------------------|--------|--------------------|--------------------------|
| HCI_Read_Loopback_Mode | 0x0001 | | Status, Loopback_Mode |

Description:

This command will read the value for the setting of the Controller's Loopback Mode. The setting of the Loopback Mode will determine the path of information. In Non-testing Mode operation, the Loopback Mode is set to Non-testing Mode and the path of the information is as specified by the Bluetooth specifications. In Local Loopback Mode, every Data Packet (ACL, SCO and eSCO) and Command Packet that is sent from the Host to the Controller is sent back with no modifications by the Controller, as shown in [Figure 7.1 on page 560](#).

For details of loopback modes see [Section 7.6.2 on page 559](#).

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Loopback_Mode command succeeded. |
| 0x01-0xFF | Read_Loopback_Mode command failed. See "Error Codes" on page 319 [Part D] for list of Error Codes. |

Loopback_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | No Loopback mode enabled. Default. |
| 0x01 | Enable Local Loopback. |
| 0x02 | Enable Remote Loopback. |
| 0x03-0xFF | Reserved for Future Use. |

Event(s) generated (unless masked away):

When the Read_Loopback_Mode command has completed, a Command Complete event will be generated.

7.6.2 Write Loopback Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|-------------------------|--------|--------------------|-------------------|
| HCI_Write_Loopback_Mode | 0x0002 | Loopback_Mode | Status |

Description:

This command will write the value for the setting of the Controller’s Loopback Mode. The setting of the Loopback Mode will determine the path of information. In Non-testing Mode operation, the Loopback Mode is set to Non-testing Mode and the path of the information as specified by the Bluetooth specifications. In Local Loopback Mode, every Data Packet (ACL, SCO and eSCO) and Command Packet that is sent from the Host to the Controller is sent back with no modifications by the Controller, as shown in [Figure 7.1 on page 560](#).

When the Bluetooth Host Controller enters Local Loopback Mode, it shall respond with one to four connection handles, one for an ACL connection and zero to three for synchronous connections. The Host should use these connection handles when sending data in Local Loopback Mode. The number of connection handles returned for synchronous connections (between zero and three) is implementation specific. When in Local Loopback Mode, the Controller loops back commands and data to the Host. The Loopback Command event is used to loop back commands that the Host sends to the Controller.

There are some commands that are not looped back in Local Loopback Mode: Reset, Set_Controller_To_Host_Flow_Control, Host_Buffer_Size, Host_Number_Of_Completed_Packets, Read_Buffer_Size, Read_Loopback_Mode and Write_Loopback_Mode. These commands should be executed in the way they are normally executed. The commands Reset and Write_Loopback_Mode can be used to exit local loopback mode.

If Write_Loopback_Mode is used to exit Local Loopback Mode, Disconnection Complete events corresponding to the Connection Complete events that were sent when entering Local Loopback Mode should be sent to the Host. Furthermore, no connections are allowed in Local Loopback mode. If there is a connection, and there is an attempt to set the device to Local Loopback Mode, the attempt will be refused. When the device is in Local Loopback Mode, the Controller will refuse incoming connection attempts. This allows the Host Controller Transport Layer to be tested without any other variables.

If a device is set to Remote Loopback Mode, it will send back all data (ACL, SCO and eSCO) that comes over the air. It will only allow a maximum of one ACL connection and three synchronous connections, and these shall all be to the same remote device. If there are existing connections to a remote device and there is an attempt to set the local device to Remote Loopback Mode, the attempt shall be refused.

See [Figure 7.2 on page 560](#), where the rightmost device is set to Remote Loopback Mode and the leftmost device is set to Non-testing Mode. This allows the Bluetooth Air link to be tested without any other variables.

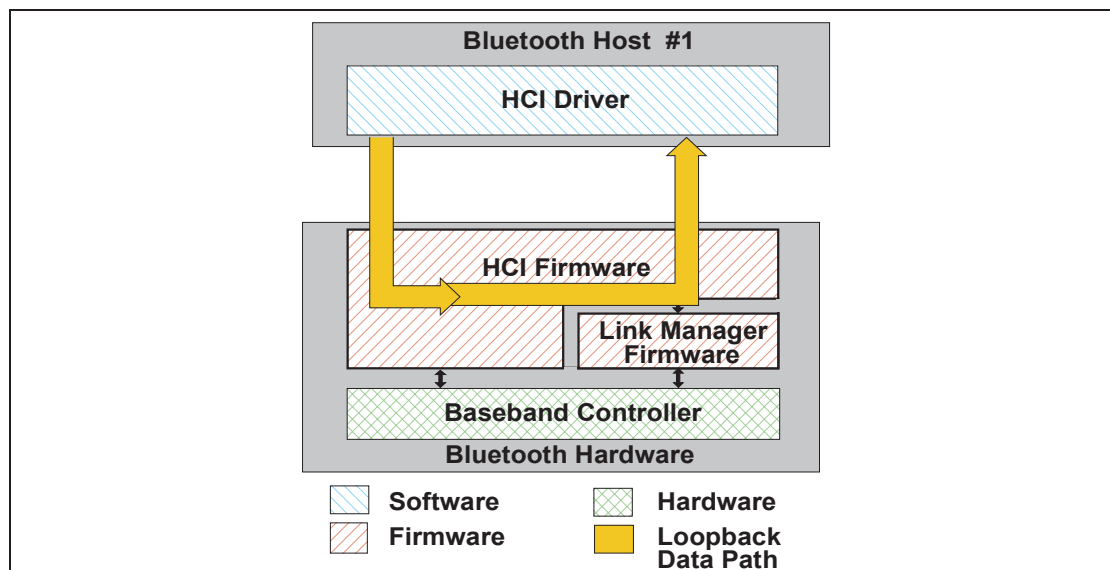


Figure 7.1: Local Loopback Mode

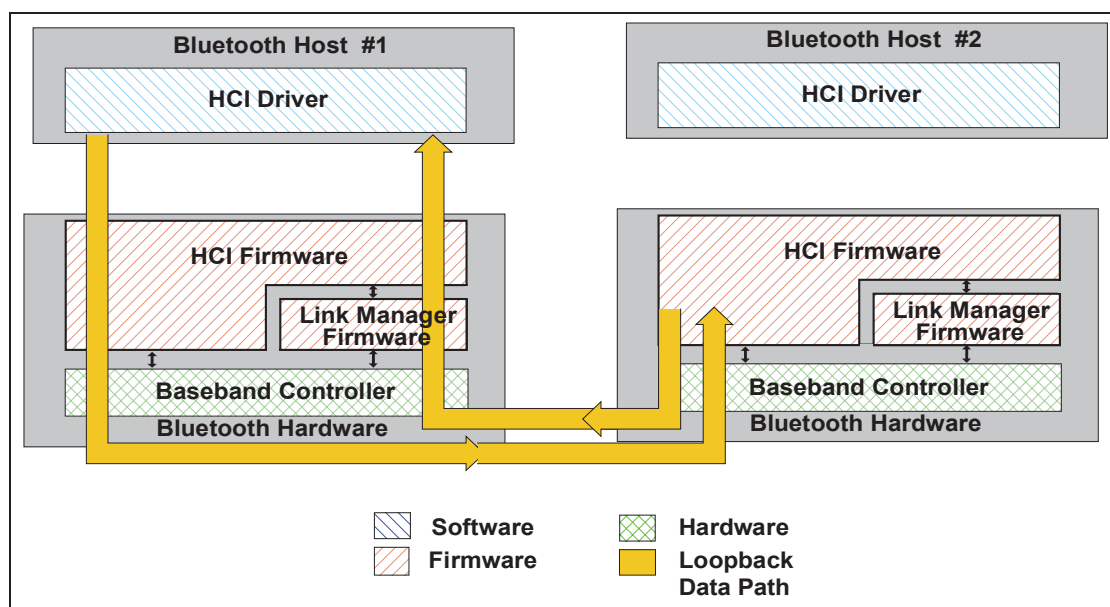


Figure 7.2: Remote Loopback Mode

**Command Parameters:***Loopback_Mode:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | No Loopback mode enabled. Default. |
| 0x01 | Enable Local Loopback. |
| 0x02 | Enable Remote Loopback. |
| 0x03-0xFF | Reserved for Future Use. |

Return Parameters:*Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Write_Loopback_Mode command succeeded. |
| 0x01-0xFF | Write_Loopback_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Loopback_Mode command has completed, a Command Complete event will be generated.



7.6.3 Enable Device Under Test Mode Command

| Command | OCF | Command Parameters | Return Parameters |
|-----------------------------------|--------|--------------------|-------------------|
| HCI_Enable_Device_Under_Test_Mode | 0x0003 | | Status |

Description:

The Enable_Device_Under_Test_Mode command will allow the local Bluetooth module to enter test mode via LMP test commands. For details see [“Link Manager Protocol” on page 211 \[Part C\]](#). The Host issues this command when it wants the local device to be the DUT for the Testing scenarios as described in the [“Test Methodology” on page 231\[vol. 4\]](#). When the Controller receives this command, it will complete the command with a Command Complete event. The Controller functions as normal until the remote tester issues the LMP test command to place the local device into Device Under Test mode. To disable and exit the Device Under Test Mode, the Host can issue the HCI_Reset command. This command prevents remote Bluetooth devices from causing the local Bluetooth device to enter test mode without first issuing this command.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Enter_Device_Under_Test_Mode command succeeded. |
| 0x01-0xFF | Enter_Device_Under_Test_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Enter_Device_Under_Test_Mode command has completed, a Command Complete event will be generated.

7.7 EVENTS

7.7.1 Inquiry Complete Event

| Event | Event Code | Event Parameters |
|------------------|------------|------------------|
| Inquiry Complete | 0x01 | Status |

Description:

The Inquiry Complete event indicates that the Inquiry is finished. This event contains a status parameter, which is used to indicate if the Inquiry completed successfully or if the Inquiry was not completed.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Inquiry command completed successfully. |
| 0x01-0xFF | Inquiry command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |



7.7.2 Inquiry Result Event

| Event | Event Code | Event Parameters |
|----------------|------------|---|
| Inquiry Result | 0x02 | Num_Responses, BD_ADDR[i], Page_Scan_Repetition_Mode[i], Reserved[i], Reserved[i], Class_of_Device[i] Clock_Offset[i] |

Description:

The Inquiry Result event indicates that a Bluetooth device or multiple Bluetooth devices have responded so far during the current Inquiry process. This event will be sent from the Controller to the Host as soon as an Inquiry Response from a remote device is received if the remote device supports only mandatory paging scheme. The Controller may queue these Inquiry Responses and send multiple Bluetooth devices information in one Inquiry Result event. The event can be used to return one or more Inquiry responses in one event.

Event Parameters:

Num_Responses: Size: 1 Octet

| Value | Parameter Description |
|-------|---------------------------------------|
| 0xXX | Number of responses from the Inquiry. |

BD_ADDR[i]: Size: 6 Octets * Num_Responses

| Value | Parameter Description |
|-------------------|--|
| 0XXXXXXXXXX XX | BD_ADDR for each device which responded. |

*Page_Scan_Repetition_Mode[i]:**Size: 1 Octet * Num_Responses*

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | R0 |
| 0x01 | R1 |
| 0x02 | R2 |
| 0x03 – 0xFF | Reserved |

Reserved[i]: ¹*Size: 1 Octet * Num_Responses*

| Value | Parameter Description |
|-------|-----------------------|
| 0xFF | Reserved. |

Reserved[i]: ²*Size: 1 Octet * Num_Responses*

| Value | Parameter Description |
|-------|--------------------------------|
| 0xFF | Reserved, must be set to 0x00. |

*Class_of_Device[i]:**Size: 3 Octets * Num_Responses*

| Value | Parameter Description |
|----------|--------------------------------|
| 0xXXXXXX | Class of Device for the device |

*Clock_Offset[i]:**Size: 2 Octets * Num_Responses*

| Bit format | Parameter Description |
|------------|---------------------------------|
| Bit 14-0 | Bit 16-2 of CLKslave-CLKmaster. |
| Bit 15 | Reserved |

1. This was the Page_Scan_Period_Mode parameter in the v1.1 specification. This parameter has no meaning in v1.2 and no default value.

2. This was the Page_Scan_Mode parameter in the v1.1 specification.

7.7.3 Connection Complete Event

| Event | Event Code | Event Parameters |
|---------------------|------------|--|
| Connection Complete | 0x03 | Status, Connection_Handle, BD_ADDR, Link_Type, Encryption_Mode |

Description:

The Connection Complete event indicates to both of the Hosts forming the connection that a new connection has been established. This event also indicates to the Host, which issued the Create Connection, or Accept_Connection_Request or Reject_Connection_Request command and then received a Command Status event, if the issued command failed or was successful.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Connection successfully completed. |
| 0x01-0xFF | Connection failed to Complete. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle to be used to identify a connection between two Bluetooth devices. The Connection Handle is used as an identifier for transmitting and receiving voice or data. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|---------------|---|
| 0XXXXXXXXXXXX | BD_ADDR of the other connected Device forming the connection. |

Link_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---------------------------------|
| 0x00 | SCO connection. |
| 0x01 | ACL connection (Data Channels). |
| 0x02-0xFF | Reserved for future use. |

Encryption_Mode:

Size: 1 Octet

| Value | Parameter Description |
|--|-----------------------|
| See Section 6.16 on page 389 . | |

7.7.4 Connection Request Event

| Event | Event Code | Event Parameters |
|--------------------|------------|---|
| Connection Request | 0x04 | BD_ADDR, Class_of_Device, Link_Type |

Description:

The Connection Request event is used to indicate that a new incoming connection is trying to be established. The connection may either be accepted or rejected. If this event is masked away and there is an incoming connection attempt and the Controller is not set to auto-accept this connection attempt, the Controller will automatically refuse the connection attempt. When the Host receives this event and the link type parameter is ACL, it should respond with either an Accept_Connection_Request or Reject_Connection_Request command before the timer Conn_Accept_Timeout expires. If the link type is SCO or eSCO, the Host should reply with the Accept_Synchronous_Connection_Request or the Reject_Synchronous_Connection_Request Command. If the link type is SCO, the host may respond with Accept_Connection_Request. If the Event is responded to with Accept_Connection_Request, then the default parameter settings of the Accept_Synchronous_Connection_Request (see [Section 7.1.27 on page 442](#)) should be used by the local LM when negotiating the SCO or eSCO link parameters. In that case, the Connection_Complete Event and not the Synchronous_Connection_Complete Event, shall be returned on completion of the connection.

Event Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---|
| 0xFFFFFFFFXXXX | BD_ADDR of the device that requests the connection. |



Class_of_Device:

Size: 3 Octets

| Value | Parameter Description |
|----------|--|
| 0XXXXXX | Class of Device for the device, which requests the connection. |
| 0x000000 | Unknown Class of Device |

Link_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---------------------------|
| 0x00 | SCO Connection requested |
| 0x01 | ACL Connection requested |
| 0x02 | eSCO Connection requested |
| 0x03-0xFF | Reserved for Future Use. |



7.7.5 Disconnection Complete Event

| Event | Event Code | Event Parameters |
|------------------------|------------|--------------------------------------|
| Disconnection Complete | 0x05 | Status, Connection_Handle, Reason |

Description:

The Disconnection Complete event occurs when a connection is terminated. The status parameter indicates if the disconnection was successful or not. The reason parameter indicates the reason for the disconnection if the disconnection was successful. If the disconnection was not successful, the value of the reason parameter can be ignored by the Host. For example, this can be the case if the Host has issued the Disconnect command and there was a parameter error, or the command was not presently allowed, or a connection handle that didn't correspond to a connection was given.

Note: When a physical link fails, one Disconnection Complete event will be returned for each logical channel on the physical link with the corresponding Connection handle as a parameter.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Disconnection has occurred. |
| 0x01-0xFF | Disconnection failed to complete. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle which was disconnected. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Reason:

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0xFF | Reason for disconnection. See “Error Codes” on page 319 [Part D] for error codes and description. |



7.7.6 Authentication Complete Event

| Event | Event Code | Event Parameters |
|-------------------------|------------|---------------------------|
| Authentication Complete | 0x06 | Status, Connection_Handle |

Description:

The Authentication Complete event occurs when authentication has been completed for the specified connection. The Connection_Handle must be a Connection_Handle for an ACL connection.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Authentication Request successfully completed. |
| 0x01-0xFF | Authentication Request failed to complete. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle for which Authentication has been performed. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



7.7.7 Remote Name Request Complete Event

| Event | Event Code | Event Parameters |
|------------------------------|------------|---------------------------------|
| Remote Name Request Complete | 0x07 | Status, BD_ADDR, Remote_Name |

Description:

The Remote Name Request Complete event is used to indicate that a remote name request has been completed. The Remote_Name event parameter is a UTF-8 encoded string with up to 248 octets in length. The Remote_Name event parameter will be null-terminated (0x00) if the UTF-8 encoded string is less than 248 octets. The BD_ADDR event parameter is used to identify which device the user-friendly name was obtained from.

Note: the Remote_Name Parameter is a string parameter. Endianess does therefore not apply to the Remote_Name Parameter. The first octet of the name is received first.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Remote_Name_Request command succeeded. |
| 0x01-0xFF | Remote_Name_Request command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR for the device whose name was requested. |

Remote_Name:

Size: 248 Octets

| Value | Parameter Description |
|-----------|---|
| Name[248] | A UTF-8 encoded user-friendly descriptive name for the remote device. If the name contained in the parameter is shorter than 248 octets, the end of the name is indicated by a NULL octet (0x00), and the following octets (to fill up 248 octets, which is the length of the parameter) do not have valid values. |

7.7.8 Encryption Change Event

| Event | Event Code | Event Parameters |
|-------------------|------------|--|
| Encryption Change | 0x08 | Status, Connection_Handle, Encryption_Enable |

Description:

The Encryption Change event is used to indicate that the change in the encryption has been completed for the Connection Handle specified by the Connection_Handle event parameter. The Connection_Handle will be a Connection_Handle for an ACL connection. The Encryption_Enable event parameter specifies the new Encryption Enable for the Connection Handle specified by the Connection_Handle event parameter. This event will occur on both devices to notify the Hosts when Encryption has changed for the specified Connection Handle between two devices.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Encryption Change has occurred. |
| 0x01-0xFF | Encryption Change failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle for which the link layer encryption has been enabled/ disabled for all Connection Handles with the same Bluetooth device endpoint as the specified Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Encryption_Enable:

Size: 1 Octet

| Value | Parameter Description |
|-------|-------------------------------|
| 0x00 | Link Level Encryption is OFF. |
| 0x01 | Link Level Encryption is ON. |

7.7.9 Change Connection Link Key Complete Event

| Event | Event Code | Event Parameters |
|-------------------------------------|------------|---------------------------|
| Change Connection Link Key Complete | 0x09 | Status, Connection_Handle |

Description:

The Change Connection Link Key Complete event is used to indicate that the change in the Link Key for the Connection Handle specified by the Connection_Handle event parameter has been completed.

The Connection_Handle will be a Connection_Handle for an ACL connection. The Change Connection Link Key Complete event is sent only to the Host which issued the Change_Connection_Link_Key command.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Change_Connection_Link_Key command succeeded. |
| 0x01-0xFF | Change_Connection_Link_Key command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle which the Link Key has been change for all Connection Handles with the same Bluetooth device end point as the specified Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



7.7.10 Master Link Key Complete Event

| Event | Event Code | Event Parameters |
|--------------------------|------------|--|
| Master Link Key Complete | 0x0A | Status, Connection_Handle, Key_Flag |

Description:

The Master Link Key Complete event is used to indicate that the Link Key managed by the master of the piconet has been changed. The Connection_Handle will be a Connection_Handle for an ACL connection. The link key used for the connection will be the temporary link key of the master device or the semi-permanent link key indicated by the Key_Flag. The Key_Flag event parameter is used to indicate which Link Key (temporary link key of the Master, or the semi-permanent link keys) is now being used in the piconet.

Note: for a master, the change from a semi-permanent Link Key to temporary Link Key will affect all Connection Handles related to the piconet. For a slave, this change affects only this particular connection handle. A temporary link key must be used when both broadcast and point-to-point traffic shall be encrypted.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Master_Link_Key command succeeded. |
| 0x01-0xFF | Master_Link_Key command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle for which the Link Key has been changed for all devices in the same piconet. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Key_Flag:

Size: 1 Octet

| Value | Parameter Description |
|-------|--------------------------------|
| 0x00 | Using Semi-permanent Link Key. |
| 0x01 | Using Temporary Link Key. |

7.7.11 Read Remote Supported Features Complete Event

| Event | Event Code | Event Parameters |
|---|------------|--|
| Read Remote Supported Features Complete | 0x0B | Status, Connection_Handle, LMP_Features |

Description:

The Read Remote Supported Features Complete event is used to indicate the completion of the process of the Link Manager obtaining the supported features of the remote Bluetooth device specified by the Connection_Handle event parameter. The Connection_Handle will be a Connection_Handle for an ACL connection. The event parameters include a list of LMP features. For details see [“Link Manager Protocol” on page 211\[vol. 3\]](#).

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Read_Remote_Supported_Features command succeeded. |
| 0x01-0xFF | Read_Remote_Supported_Features command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle which is used for the Read_Remote_Supported_Features command. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

LMP_Features:

Size: 8 Octets

| Value | Parameter Description |
|------------------------|---|
| 0xFFFFFFFF XXXXXXXX | Bit Mask List of LMP features. See “Link Manager Protocol” on page 211 [Part C] . |

7.7.12 Read Remote Version Information Complete Event

| Event | Event Code | Event Parameters |
|--|------------|---|
| Read Remote Version Information Complete | 0x0C | Status, Connection_Handle, LMP_Version, Manufacturer_Name, LMP_Subversion |

Description:

The Read Remote Version Information Complete event is used to indicate the completion of the process of the Link Manager obtaining the version information of the remote Bluetooth device specified by the Connection_Handle event parameter. The Connection_Handle will be a Connection_Handle for an ACL connection. The LMP_Version event parameter defines the specification version of the Bluetooth device. The Manufacturer_Name event parameter indicates the manufacturer of the remote Bluetooth device. The LMP_Subversion event parameter is controlled by the manufacturer and is implementation dependant. The LMP_Subversion event parameter defines the various revisions that each version of the Bluetooth hardware will go through as design processes change and errors are fixed. This allows the software to determine what Bluetooth hardware is being used and, if necessary, to work around various bugs in the hardware.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Remote_Version_Information command succeeded. |
| 0x01-0xFF | Read_Remote_Version_Information command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle which is used for the Read_Remote_Version_Information command. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

**LMP_Version:****Size: 1 Octet**

| Value | Parameter Description |
|-------|--|
| 0xXX | Version of the Current LMP in the remote Bluetooth device. For LMP_Version information see https://www.bluetooth.org/foundry/assign-numb/document/assigned_numbers |

Manufacturer_Name:**Size: 2 Octets**

| Value | Parameter Description |
|--------|--|
| 0XXXXX | Manufacturer Name of the remote Bluetooth device, see Table 5.2 on page 303 in the Link Manager Protocol for assigned values (Compld). |

LMP_Subversion:**Size: 2 Octets**

| Value | Parameter Description |
|--------|---|
| 0XXXXX | Subversion of the Current LMP in the remote Bluetooth device, see Table 5.2 on page 303 in the Link Manager Protocol for assigned values (SubVersNr). |

7.7.13 QoS Setup Complete Event

| Event | Event Code | Event Parameters |
|--------------------|------------|---|
| QoS Setup Complete | 0x0D | Status, Connection_Handle, Flags, Service_Type, Token_Rate, Peak_Bandwidth, Latency, Delay_Variation |

Description:

The QoS Setup Complete event is used to indicate the completion of the process of the Link Manager setting up QoS with the remote Bluetooth device specified by the Connection_Handle event parameter. The Connection_Handle will be a Connection_Handle for an ACL connection. For more detail see [“Logical Link Control and Adaptation Protocol Specification” on page 15\[vol. 4\]](#).

**Event Parameters:***Status:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | QoS_Setup command succeeded. |
| 0x01-0xFF | QoS_Setup command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle which is used for the QoS_Setup command. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Flags:**Size: 1 Octet*

| Value | Parameter Description |
|-------------|--------------------------|
| 0x00 – 0xFF | Reserved for Future Use. |

*Service_Type:**Size: 1 Octet*

| Value | Parameter Description |
|-----------|--------------------------|
| 0x00 | No Traffic Available. |
| 0x01 | Best Effort Available. |
| 0x02 | Guaranteed Available. |
| 0x03-0xFF | Reserved for Future Use. |

*Token_Rate:**Size: 4 Octets*

| Value | Parameter Description |
|------------|---|
| 0xFFFFFFFF | Available Token Rate, in octets per second. |

*Peak_Bandwidth:**Size: 4 Octets*

| Value | Parameter Description |
|------------|---|
| 0xFFFFFFFF | Available Peak Bandwidth, in octets per second. |

*Latency:**Size: 4 Octets*

| Value | Parameter Description |
|------------|-------------------------------------|
| 0xFFFFFFFF | Available Latency, in microseconds. |

*Delay_Variation:**Size: 4 Octets*

| Value | Parameter Description |
|------------|---|
| 0xFFFFFFFF | Available Delay Variation, in microseconds. |



7.7.14 Command Complete Event

| Event | Event Code | Event Parameters |
|------------------|------------|---|
| Command Complete | 0x0E | Num_HCI_Command_Packets, Command_Opcode, Return_Parameters |

Description:

The Command Complete event is used by the Controller for most commands to transmit return status of a command and the other event parameters that are specified for the issued HCI command.

The Num_HCI_Command_Packets event parameter allows the Controller to indicate the number of HCI command packets the Host can send to the Controller. If the Controller requires the Host to stop sending commands, the Num_HCI_Command_Packets event parameter will be set to zero. To indicate to the Host that the Controller is ready to receive HCI command packets, the Controller generates a Command Complete event with the Command_Opcode 0x0000, and the Num_HCI_Command_Packets event parameter is set to 1 or more. Command_Opcode, 0x0000 is a NOP (No Operation), and can be used to change the number of outstanding HCI command packets that the Host can send before waiting. See each command for the parameters that are returned by this event.

Event Parameters:

Num_HCI_Command_Packets:

Size: 1 Octet

| Value | Parameter Description |
|----------|---|
| N = 0xXX | The Number of HCI command packets which are allowed to be sent to the Controller from the Host. Range for N: 0 – 255 |

Command_Opcode:

Size: 2 Octets

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Opcode of the command which caused this event. |

Return_Parameter(s):

Size: Depends on Command

| Value | Parameter Description |
|-------|--|
| 0xXX | This is the return parameter(s) for the command specified in the Command_Opcode event parameter. See each command's definition for the list of return parameters associated with that command. |

7.7.15 Command Status Event

| Event | Event Code | Event Parameters |
|----------------|------------|---|
| Command Status | 0x0F | Status, Num_HCI_Command_Packets, Command_Opcode |

Description:

The Command Status event is used to indicate that the command described by the Command_Opcode parameter has been received, and that the Controller is currently performing the task for this command. This event is needed to provide mechanisms for asynchronous operation, which makes it possible to prevent the Host from waiting for a command to finish. If the command can not begin to execute (a parameter error may have occurred, or the command may currently not be allowed), the Status event parameter will contain the corresponding error code, and no complete event will follow since the command was not started. The Num_HCI_Command_Packets event parameter allows the Controller to indicate the number of HCI command packets the Host can send to the Controller. If the Controller requires the Host to stop sending commands, the Num_HCI_Command_Packets event parameter will be set to zero. To indicate to the Host that the Controller is ready to receive HCI command packets, the Controller generates a Command Status event with Status 0x00 and Command_Opcode 0x0000, and the Num_HCI_Command_Packets event parameter is set to 1 or more. Command_Opcode, 0x0000 is a NOP (No Operation) and can be used to change the number of outstanding HCI command packets that the Host can send before waiting.

Event Parameters:

Status: *Size: 1 Octet*

| Value | Parameter Description |
|-----------|---|
| 0x00 | Command currently in pending. |
| 0x01-0xFF | Command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Num_HCI_Command_Packets: *Size: 1 Octet*

| Value | Parameter Description |
|----------|---|
| N = 0xXX | The Number of HCI command packets which are allowed to be sent to the Controller from the Host. Range for N: 0 – 255 |

Command_Opcode: *Size: 2 Octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Opcode of the command which caused this event and is pending completion. |

7.7.16 Hardware Error Event

| Event | Event Code | Event Parameters |
|----------------|------------|------------------|
| Hardware Error | 0x10 | Hardware_Code |

Description:

The Hardware Error event is used to indicate some type of hardware failure for the Bluetooth device. This event is used to notify the Host that a hardware failure has occurred in the Bluetooth device.

Event Parameters:

Hardware_Code:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00-0xFF | These Hardware_Codes will be implementation-specific, and can be assigned to indicate various hardware problems. |

7.7.17 Flush Occurred Event

| Event | Event Code | Event Parameters |
|----------------|------------|-------------------|
| Flush Occurred | 0x11 | Connection_Handle |

Description:

The Flush Occurred event is used to indicate that, for the specified Connection Handle, the current user data to be transmitted has been removed. The Connection_Handle will be a Connection_Handle for an ACL connection. This could result from the flush command, or be due to the automatic flush. Multiple blocks of an L2CAP packet could have been pending in the Controller. If one baseband packet part of an L2CAP packet is flushed, then the rest of the HCI data packets for the L2CAP packet must also be flushed.

Event Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle which was flushed. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



7.7.18 Role Change Event

| Event | Event Code | Event Parameters |
|-------------|------------|------------------------------|
| Role Change | 0x12 | Status, BD_ADDR, New_Role |

Description:

The Role Change event is used to indicate that the current Bluetooth role related to the particular connection has changed. This event only occurs when both the remote and local Bluetooth devices have completed their role change for the Bluetooth device associated with the BD_ADDR event parameter. This event allows both affected Hosts to be notified when the Role has been changed.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Role change has occurred. |
| 0x01-0xFF | Role change failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0xFFFFFFFFXXXX | BD_ADDR of the Device for which a role change has completed. |

New_Role:

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0x00 | Currently the Master for specified BD_ADDR. |
| 0x01 | Currently the Slave for specified BD_ADDR. |



7.7.19 Number Of Completed Packets Event

| Event | Event Code | Event Parameters |
|-----------------------------|------------|---|
| Number Of Completed Packets | 0x13 | Number_of_Handles, Connection_Handle[i], HC_Num_Of_Completed_Packets[i] |

Description:

The Number Of Completed Packets event is used by the Controller to indicate to the Host how many HCI Data Packets have been completed (transmitted or flushed) for each Connection Handle since the previous Number Of Completed Packets event was sent to the Host. This means that the corresponding buffer space has been freed in the Controller. Based on this information, and the HC_Total_Num_ACL_Data_Packets and HC_Total_Num_Synchronous_Data_Packets return parameter of the Read_Buffer_Size command, the Host can determine for which Connection Handles the following HCI Data Packets should be sent to the Controller. The Number Of Completed Packets event must not be sent before the corresponding Connection Complete event. While the Controller has HCI data packets in its buffer, it must keep sending the Number Of Completed Packets event to the Host at least periodically, until it finally reports that all the pending ACL Data Packets have been transmitted or flushed. The rate with which this event is sent is manufacturer specific.

Note that Number Of Completed Packets events will not report on synchronous connection handles if synchronous Flow Control is disabled. (See Read/Write_Synchronous_Flow_Control_Enable on [page 513](#) and [page 514](#).)

Event Parameters:

Number_of_Handles:

Size: 1 Octet

| Value | Parameter Description |
|-------|---|
| 0xXX | The number of Connection Handles and Num_HCI_Data_Packets parameters pairs contained in this event. Range: 0-255 |

*Connection_Handle[i]: Size: Number_of_Handles * 2 Octets(12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0XXXXX | Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



HC_Num_Of_Completed_Packets [i]: *Size: Number_of_Handles * 2 Octets*

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | The number of HCI Data Packets that have been completed (transmitted or flushed) for the associated Connection Handle since the previous time the event was returned. Range for N: 0x0000-0xFFFF |

7.7.20 Mode Change Event

| Event | Event Code | Event Parameters |
|-------------|------------|--|
| Mode Change | 0x14 | Status, Connection_Handle, Current_Mode, Interval |

Description:

The Mode Change event is used to indicate when the device associated with the Connection Handle changes between Active mode, Hold mode, Sniff mode, and Park state. The Connection_Handle will be a Connection_Handle for an ACL connection. The Connection_Handle event parameter is used to indicate which connection the Mode Change event is for. The Current_Mode event parameter is used to indicate which state the connection is currently in. The Interval parameter is used to specify a time amount specific to each state. Each Controller that is associated with the Connection Handle which has changed Modes will send the Mode Change event to its Host.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | A Mode Change has occurred. |
| 0x01-0xFF | Hold_Mode, Sniff_Mode, Exit_Sniff_Mode, Park_State, or Exit_Park_State command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets(12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |



Current_Mode:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--------------------------|
| 0x00 | Active Mode. |
| 0x01 | Hold Mode. |
| 0x02 | Sniff Mode. |
| 0x03 | Park State. |
| 0x04-0xFF | Reserved for future use. |

Interval:

Size: 2 Octets

| Value | Parameter Description |
|------------|---|
| N = 0xXXXX | <div>Hold: Number of Baseband slots to wait in Hold Mode. Hold Interval = N * 0.625 msec (1 Baseband slot) Range for N: 0x0002-0xFFFFE Time Range: 1.25 msec-40.9 sec</div> <div>Sniff: Number of Baseband slots between sniff intervals. Time between sniff intervals = 0.625 msec (1 Baseband slot) Range for N: 0x0002-0xFFFFE Time Range: 1.25 msec-40.9 sec</div> <div>Park: Number of Baseband slots between consecutive beacons. Interval Length = N * 0.625 msec (1 Baseband slot) Range for N: 0x0002-0xFFFFE Time Range: 1.25 msec-40.9 Seconds</div> |



7.7.21 Return Link Keys Event

| Event | Event Code | Event Parameters |
|------------------|------------|---------------------------------------|
| Return Link Keys | 0x15 | Num_Keys, BD_ADDR [i], Link_Key[i] |

Description:

The Return Link Keys event is used by the Controller to send the Host one or more stored Link Keys. Zero or more instances of this event will occur after the Read_Stored_Link_Key command. When there are no link keys stored, no Return Link Keys events will be returned. When there are link keys stored, the number of link keys returned in each Return Link Keys event is implementation specific.

Event Parameters:

Num_Keys: Size: 1 Octet

| Value | Parameter Description |
|-------|--|
| 0xXX | Number of Link Keys contained in this event. Range: 0x01 – 0x0B |

BD_ADDR [i]: Size: 6 Octets * Num_Keys

| Value | Parameter Description |
|----------------|--------------------------------------|
| 0XXXXXXXXXXXXX | BD_ADDR for the associated Link Key. |

Link_Key[i]: Size: 16 Octets * Num_Keys

| Value | Parameter Description |
|--|--------------------------------------|
| 0XXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXX | Link Key for the associated BD_ADDR. |

7.7.22 PIN Code Request Event

| Event | Event Code | Event Parameters |
|------------------|------------|------------------|
| PIN Code Request | 0x16 | BD_ADDR |

Description:

The PIN Code Request event is used to indicate that a PIN code is required to create a new link key. The Host must respond using either the PIN Code Request Reply or the PIN Code Request Negative Reply command, depending on whether the Host can provide the Controller with a PIN code or not.
Note: If the PIN Code Request event is masked away, then the Controller will assume that the Host has no PIN Code.

When the Controller generates a PIN Code Request event in order for the local Link Manager to respond to the request from the remote Link Manager (as a result of a Create_Connection or Authentication_Requested command from the remote Host), the local Host must respond with either a PIN_Code_Request_Reply or PIN_Code_Request_Negative_Reply command before the remote Link Manager detects LMP response timeout. (See [“Link Manager Protocol” on page 211 \[Part C\]](#).)

Event Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0XXXXXXXXXXXXX | BD_ADDR of the Device which a new link key is being created for. |



7.7.23 Link Key Request Event

| Event | Event Code | Event Parameters |
|------------------|------------|------------------|
| Link Key Request | 0x17 | BD_ADDR |

Description:

The Link Key Request event is used to indicate that a Link Key is required for the connection with the device specified in BD_ADDR. If the Host has the requested stored Link Key, then the Host will pass the requested Key to the Controller using the Link_Key_Request_Reply Command. If the Host does not have the requested stored Link Key, then the Host will use the Link_Key_Request_Negative_Reply Command to indicate to the Controller that the Host does not have the requested key.

Note: If the Link Key Request event is masked away, then the Controller will assume that the Host has no additional link keys.

When the Controller generates a Link Key Request event in order for the local Link Manager to respond to the request from the remote Link Manager (as a result of a Create_Connection or Authentication_Requested command from the remote Host), the local Host must respond with either a Link_Key_Request_Reply or Link_Key_Request_Negative_Reply command before the remote Link Manager detects LMP response timeout. (See “[Link Manager Protocol](#)” on page 211 [Part C].)

Event Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|---|
| 0xFFFFFFFFXXXX | BD_ADDR of the Device which a stored link key is being requested. |



7.7.24 Link Key Notification Event

| Event | Event Code | Event Parameters |
|-----------------------|------------|-----------------------------|
| Link Key Notification | 0x18 | BD_ADDR, Link_Key, Key_Type |

Description:

The Link Key Notification event is used to indicate to the Host that a new Link Key has been created for the connection with the device specified in BD_ADDR. The Host can save this new Link Key in its own storage for future use. Also, the Host can decide to store the Link Key in the Controller's Link Key Storage by using the Write_Stored_Link_Key command. The Key_Type event parameter informs the Host about which key type (combination key, local unit key or remote unit key) that has been used during pairing. If pairing with unit key is not supported, the Host can for instance discard the key or disconnect the link.

Event Parameters:

BD_ADDR:

Size: 6 Octets

| Value | Parameter Description |
|----------------|--|
| 0XXXXXXXXXXXXX | BD_ADDR of the Device for which the new link key has been generated. |

Link_Key:

Size: 16 Octets

| Value | Parameter Description |
|--|--------------------------------------|
| 0XXXXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXX | Link Key for the associated BD_ADDR. |

Key_Type:

Size: 1 Octets

| Value | Parameter Description |
|-----------|-----------------------|
| 0x00 | Combination Key |
| 0x01 | Local Unit Key |
| 0x02 | Remote Unit Key |
| 0x03-0xFF | Reserved |



7.7.25 Loopback Command Event

| Event | Event Code | Event Parameters |
|------------------|------------|--------------------|
| Loopback Command | 0x19 | HCI_Command_Packet |

Description:

When in Local Loopback mode, the Controller loops back commands and data to the Host. The Loopback Command event is used to loop back all commands that the Host sends to the Controller with some exceptions. See [Section 7.6.1, “Read Loopback Mode Command,” on page 558](#) for a description of which commands that are not looped back. The HCI_Command_Packet event parameter contains the entire HCI Command Packet including the header. Note: the event packet is limited to a maximum of 255 octets in the payload; since an HCI Command Packet has 3 octets of header data, only the first 252 octets of the command parameters will be returned.

Event Parameters:

HCI_Command_Packet:

Size: Depends on Command

| Value | Parameter Description |
|----------|---------------------------------------|
| 0xxxxxxx | HCI Command Packet, including header. |

7.7.26 Data Buffer Overflow Event

| Event | Event Code | Event Parameters |
|----------------------|------------|------------------|
| Data Buffer Overflow | 0x1A | Link_Type |

Description:

This event is used to indicate that the Controller’s data buffers have been overflowed. This can occur if the Host has sent more packets than allowed. The Link_Type parameter is used to indicate that the overflow was caused by ACL or synchronous data.

Event Parameters:

Link_Type:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Synchronous Buffer Overflow (Voice Channels). |
| 0x01 | ACL Buffer Overflow (Data Channels). |
| 0x02-0xFF | Reserved for Future Use. |

7.7.27 Max Slots Change Event

| Event | Event Code | Event Parameters |
|------------------|------------|-------------------------------------|
| Max Slots Change | 0x1B | Connection_Handle, LMP_Max_Slots |

Description:

This event is used to notify the Host about the LMP_Max_Slots parameter when the value of this parameter changes. It will be sent each time the maximum allowed length, in number of slots, for baseband packets transmitted by the local device, changes. The Connection_Handle will be a Connection_Handle for an ACL connection.

Event Parameters:

Connection_Handle:Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xXXXX | Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

LMP_Max_Slots:Size: 1 octet

| Value | Parameter Description |
|------------------|--|
| 0x01, 0x03, 0x05 | Maximum number of slots allowed to use for baseband packets, see Section 4.1.10 on page 247 and Section 5.2 on page 303 in “Link Manager Protocol” on page 211 [Part C]. |



7.7.28 Read Clock Offset Complete Event

| Event | Event Code | Event Parameters |
|----------------------------|------------|--|
| Read Clock Offset Complete | 0x1C | Status, Connection_Handle, Clock_Offset |

Description:

The Read Clock Offset Complete event is used to indicate the completion of the process of the Link Manager obtaining the Clock Offset information of the Bluetooth device specified by the Connection_Handle event parameter. The Connection_Handle will be a Connection_Handle for an ACL connection.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Clock_Offset command succeeded. |
| 0x01-0xFF | Read_Clock_Offset command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Specifies which Connection Handle's Clock Offset parameter is returned. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

Clock_Offset:

Size: 2 Octets

| Bit format | Parameter Description |
|------------|---------------------------------|
| Bit 14-0 | Bit 16-2 of CLKslave-CLKmaster. |
| Bit 15 | Reserved. |

7.7.29 Connection Packet Type Changed Event

| Event | Event Code | Event Parameters |
|--------------------------------|------------|---|
| Connection Packet Type Changed | 0x1D | Status, Connection_Handle, Packet_Type |

Description:

The Connection Packet Type Changed event is used to indicate that the process has completed of the Link Manager changing which packet types can be used for the connection. This allows current connections to be dynamically modified to support different types of user data. The Packet_Type event parameter specifies which packet types the Link Manager can use for the connection identified by the Connection_Handle event parameter for sending L2CAP data or voice. The Packet_Type event parameter does not decide which packet types the LM is allowed to use for sending LMP PDUs.

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Connection Packet Type changed successfully. |
| 0x01-0xFF | Connection Packet Type Changed failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Packet_Type:**Size: 2 Octets**For ACL_Link_Type*

| Value | Parameter Description |
|---------------------|--------------------------|
| 0x0001 | Reserved for future use. |
| 0x0002 | 2-DH1 may not be used. |
| 0x0004 | 3-DH1 may not be used. |
| 0x0008 ¹ | DM1 may be used. |
| 0x0010 | DH1 may be used. |
| 0x0020 | Reserved for future use. |
| 0x0040 | Reserved for future use. |
| 0x0080 | Reserved for future use. |
| 0x0100 | 2-DH3 may not be used. |
| 0x0200 | 3-DH3 may not be used. |
| 0x0400 | DM3 may be used. |
| 0x0800 | DH3 may be used. |
| 0x1000 | 2-DH5 may not be used. |
| 0x2000 | 3-DH5 may not be used. |
| 0x4000 | DM5 may be used. |
| 0x8000 | DH5 may be used. |

1. This bit will be interpreted as set to 1 by Bluetooth V1.2 or later controllers.

For SCO_Link_Type

| Value | Parameter Description |
|--------|--------------------------|
| 0x0001 | Reserved for future use. |
| 0x0002 | Reserved for future use. |
| 0x0004 | Reserved for future use. |
| 0x0008 | Reserved for future use. |
| 0x0010 | Reserved for future use. |
| 0x0020 | HV1 |
| 0x0040 | HV2 |
| 0x0080 | HV3 |
| 0x0100 | Reserved for future use. |
| 0x0200 | Reserved for future use. |



| | |
|--------|--------------------------|
| 0x0400 | Reserved for future use. |
| 0x0800 | Reserved for future use. |
| 0x1000 | Reserved for future use. |
| 0x2000 | Reserved for future use. |
| 0x4000 | Reserved for future use. |
| 0x8000 | Reserved for future use. |



7.7.30 QoS Violation Event

| Event | Event Code | Event Parameters |
|---------------|------------|-------------------|
| QoS Violation | 0x1E | Connection_Handle |

Description:

The QoS Violation event is used to indicate the Link Manager is unable to provide the current QoS requirement for the Connection Handle. This event indicates that the Link Manager is unable to provide one or more of the agreed QoS parameters. The Host chooses what action should be done. The Host can reissue QoS_Setup command to renegotiate the QoS setting for Connection Handle. The Connection_Handle will be a Connection_Handle for an ACL connection.

Event Parameters:

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Connection Handle that the LM is unable to provide the current QoS requested for. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

7.7.31 Page Scan Repetition Mode Change Event

| Event | Event Code | Event Parameters |
|----------------------------------|------------|---------------------------------------|
| Page Scan Repetition Mode Change | 0x20 | BD_ADDR, Page_Scan_Repetition_Mode |

Description:

The Page Scan Repetition Mode Change event indicates that the remote Bluetooth device with the specified BD_ADDR has successfully changed the Page_Scan_Repetition_Mode (SR).

Event Parameters:

BD_ADDR: Size: 6 Octets

| Value | Parameter Description |
|--------------------|-------------------------------|
| 0XXXXXXXXX XXXX | BD_ADDR of the remote device. |

Page_Scan_Repetition_Mode: Size: 1 Octet

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | R0 |
| 0x01 | R1 |
| 0x02 | R2 |
| 0x03 – 0xFF | Reserved. |



7.7.32 Flow Specification Complete Event

| Event | Event Code | Event Parameters |
|---------------------------------|------------|---|
| HCI Flow Specification Complete | 0x21 | Status, Connection_Handle, Flags, Flow_direction, Service_Type, Token_Rate, Token_Bucket_Size, Peak_Bandwidth, Access Latency |

Description:

The Flow Specification Complete event is used to inform the Host about the Quality of Service for the ACL connection the Controller is able to support. The Connection_Handle will be a Connection_Handle for an ACL connection. The flow parameters refer to the outgoing or incoming traffic of the ACL link, as indicated by the Flow_direction field. The flow parameters are defined in the L2CAP specification “[Quality of Service \(QoS\) Option](#)” on page 60[vol. 4]. When the Status parameter indicates a successful completion, the flow parameters specify the agreed values by the Controller. When the Status parameter indicates a failed completion with the Error Code *QoS Unacceptable Parameters* (0x2C), the flow parameters specify the acceptable values of the Controller. This enables the Host to continue the 'QoS negotiation' with a new HCI Flow_Specification command with flow parameter values that are acceptable for the Controller. When the Status parameter indicates a failed completion with the Error Code *QoS Rejected* (0x2D), this indicates a request of the Controller to discontinue the 'QoS negotiation'. When the Status parameter indicates a failed completion, the flow parameter values of the most recently successful completion must be assumed (or the default values when there was no success completion).

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-------------|---|
| 0x00 | Flow Specification command succeeded |
| 0x01 – 0xFF | Flow Specification command failed. See “ Error Codes ” on page 319 [Part D] for list of Error Codes |

*Connection_Handle:**Size: 2 Octets (12 Bits meaningful)*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle used to identify for which ACL connection the Flow is specified. Range: 0x0000 - 0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

*Flags:**Size: 1 Octet)*

| Value | Parameter Description |
|-------------|--------------------------|
| 0x00 – 0xFF | Reserved for Future Use. |

*Flow_direction:**Size: 1 Octet*

| Value | Parameter Description |
|-------------|---|
| 0x00 | Outgoing Flow i.e. traffic send over the ACL connection |
| 0x01 | Incoming Flow i.e. traffic received over the ACL connection |
| 0x02 – 0xFF | Reserved for Future Use. |

*Service_Type:**Size: 1 Octet*

| Value | Parameter Description |
|-------------|-------------------------|
| 0x00 | No Traffic |
| 0x01 | Best Effort |
| 0x02 | Guaranteed |
| 0x03 – 0xFF | Reserved for Future Use |

*Token Rate:**Size: 4 Octets*

| Value | Parameter Description |
|-----------|---------------------------------|
| 0XXXXXXXX | Token Rate in octets per second |

*Token Bucket Size:**Size: 4 Octets*

| Value | Parameter Description |
|-----------|-----------------------------|
| 0XXXXXXXX | Token Bucket Size in octets |

*Peak_Bandwidth:**Size: 4 Octets*

| Value | Parameter Description |
|-----------|-------------------------------------|
| 0XXXXXXXX | Peak Bandwidth in octets per second |

*Access Latency:**Size: 4 Octets*

| Value | Parameter Description |
|-----------|--------------------------------|
| 0XXXXXXXX | Access Latency in microseconds |

7.7.33 Inquiry Result with RSSI Event

| Event | Event Code | Event Parameters |
|--------------------------|------------|--|
| Inquiry Result with RSSI | 0x22 | Num_responses, BD_ADDR[i], Page_Scan_Repetition_Mode[i], Reserved[i], Class_of_Device[i], Clock_Offset[i], RSSI[i] |

Description:

The Inquiry Result with RSSI event indicates that a Bluetooth device or multiple Bluetooth devices have responded so far during the current Inquiry process. This event will be sent from the Controller to the Host as soon as an Inquiry Response from a remote device is received if the remote device supports only mandatory paging scheme. This Controller may queue these Inquiry Responses and send multiple Bluetooth devices information in one Inquiry Result event. The event can be used to return one or more Inquiry responses in one event. The RSSI parameter is measured during the FHS packet returned by each responding slave.

This event shall only be generated if the Inquiry Mode parameter of the last Write_Inquiry_Mode command was set to 0x01 (Inquiry Result format with RSSI).

Event Parameters:

Num_Responses:

Size: 1 Octet

| Value | Parameter Description |
|-------|---------------------------------------|
| 0xXX | Number of responses from the Inquiry. |

BD_ADDR[i]:

Size: 6 Octets * Num_Responses

| Value | Parameter Description |
|-------------------|--|
| 0XXXXXXXXXX XX | BD_ADDR for each device which responded. |

*Page_Scan_Repetition_Mode[i]:**Size: 1 Octet* Num_Responses*

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | R0 |
| 0x01 | R1 |
| 0x02 | R2 |
| 0x03 – 0xFF | Reserved |

*Reserved[i]:¹**Size: 1 Octet* Num_Responses*

| Value | Parameter Description |
|-------|-----------------------|
| 0xFF | Reserved. |

*Class_of_Device[i]:**Size: 3 Octets * Num_Responses*

| Value | Parameter Description |
|----------|--------------------------------|
| 0xXXXXXX | Class of Device for the device |

*Clock_Offset[i]:**Size: 2 Octets * Num_Responses*

| Bit format | Parameter Description |
|------------|---------------------------------|
| Bit 14-0 | Bit 16-2 of CLKslave-CLKmaster. |
| Bit 15 | Reserved |

*RSSI[i]:**Size: 1 Octet * Num_Responses*

| Value | Parameter Description |
|-------|----------------------------------|
| 0xFF | Range: -127 to +20 Units: dBm |

1. This was the Page_Scan_Period_Mode parameter in the v1.1 specification. This parameter has no meaning in v1.2 and no default value.



7.7.34 Read Remote Extended Features Complete Event

| Event | Event Code | Event Parameters |
|--|------------|--|
| Read Remote Extended Features Complete | 0x23 | Status, Connection_Handle, Page_Number, Maximum page number, Extended_LMP_Features |

Description:

The Read Remote Extended Features Complete event is used to indicate the completion of the process of the Link Manager obtaining the remote extended LMP features of the remote device specified by the connection handle event parameter. The connection handle will be a connection handle for an ACL connection. The event parameters include a page of the remote devices extended LMP features. For details see “[Link Manager Protocol](#)” on page 211 [Part C].

Event Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Request for remote extended features succeeded |
| 0x01-0xFF | Request for remote extended features failed – standard HCI error value |

Connection_Handle:

Size: 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|---|
| 0xFFFF | The connection handle identifying the device to which the remote features apply. Range: 0x0000-0x0EFF (0x0F00-0x0FFF Reserved for future use) |

Page Number:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | The normal LMP features as returned by HCI_Read_Remote_Supported_Features |
| 0x01-0xFF | The page number of the features returned |

Maximum Page Number:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00-0xFF | The highest features page number which contains non-zero bits for the local device |

Extended_LMP_Features:

Size: 8 Octets

| Value | Parameter Description |
|--------------------|--|
| 0xFFFFFFFFFFFFFFFF | Bit map of requested page of LMP features. See LMP specification for details |

7.7.35 Synchronous Connection Complete Event

| Event | Event Code | Event Parameters |
|---------------------------------|------------|--|
| Synchronous Connection Complete | 0x2C | Status, Connection_Handle, BD_ADDR, Link Type, Transmission_Interval, Retransmission Window, Rx_Packet_Length, Tx_Packet_Length Air Mode |

Description:

The Synchronous Connection Complete event indicates to both the Hosts that a new Synchronous connection has been established. This event also indicates to the Host, which issued the Setup_Synchronous_Connection, or Accept_Synchronous_Connection_Request or Reject_Synchronous_Connection_Request command and then received a Command Status event, if the issued command failed or was successful.

Event Parameters:

Status: 1 octet

| Value | Parameter Description |
|-------------|--|
| 0x00 | Connection successfully completed. |
| 0x01 – 0xFF | Connection failed to complete. See “Error Codes” on page 319 [Part D] for error codes and description. |

Connection_Handle: 2 octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection between two Bluetooth devices. Range: 0x0000-0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

BD_ADDR: 6 octets

| Value | Parameter Description |
|---------------|---|
| 0XXXXXXXXXXXX | BD_ADDR of the other connected device forming the connection. |

*Link_Type:**Size: 1 Octet*

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | SCO Connection |
| 0x01 | Reserved |
| 0x02 | eSCO Connection |
| 0x03 – 0xFF | Reserved |

*Transmission_Interval:**1 octets*

| Value | Parameter Description |
|-------|---|
| 0xXX | Time between two consecutive eSCO instants measured in slots. Must be zero for SCO links. |

*Retransmission window:**1 octets*

| Value | Parameter Description |
|-------|--|
| 0xXX | The size of the retransmission window measured in slots. Must be zero for SCO links. |

*Rx_Packet_Length:**2 octets*

| Value | Parameter Description |
|--------|---|
| 0XXXXX | Length in bytes of the eSCO payload in the receive direction. Must be zero for SCO links. |

*Tx_Packet_Length:**2 octets*

| Value | Parameter Description |
|--------|--|
| 0XXXXX | Length in bytes of the eSCO payload in the transmit direction. Must be zero for SCO links. |

*Air Mode:**Size: 1 Octet*

| Value | Parameter Description |
|-------------|-----------------------|
| 0x00 | μ -law log |
| 0x01 | A-law log |
| 0x02 | CVSD |
| 0x03 | Transparent Data |
| 0x04 – 0xFF | Reserved |

7.7.36 Synchronous Connection Changed event

| Event | Event Code | Event Parameters |
|--------------------------------|------------|--|
| Synchronous Connection Changed | 0x2D | Status, Connection_Handle, Transmission_Interval, Retransmission Window, Rx_Packet_Length, Tx_Packet_Length |

Description:

The Synchronous Connection Changed event indicates to the Host that an existing Synchronous connection has been reconfigured. This event also indicates to the initiating Host (if the change was host initiated) if the issued command failed or was successful.

Command Parameters:

Status: 1 octet

| Value | Parameter Description |
|------------|--|
| 0x00 | Connection successfully reconfigured. |
| 0x01 –0xFF | Reconfiguration failed to complete. See “Error Codes” on page 319 [Part D] for error codes and description. |

Connection_Handle: 2 octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle to be used to identify a connection between two Bluetooth devices. Range: 0x0000-0x0EFF (0x0F00 – 0x0FFF Reserved for future use) |

Transmission_Interval: 1 octet

| Value | Parameter Description |
|-------|---|
| 0xFF | Time between two consecutive SCO/eSCO instants measured in slots. |

Retransmission window: 1 octet

| Value | Parameter Description |
|-------|--|
| 0xFF | The size of the retransmission window measured in slots. Must be zero for SCO links. |



Rx_Packet_Length: *2 octets*

| Value | Parameter Description |
|--------|---|
| 0xFFFF | Length in bytes of the SCO/eSCO payload in the receive direction. |

Tx_Packet_Length: *2 octets*

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Length in bytes of the SCO/eSCO payload in the transmit direction. |

8 LIST OF FIGURES

| | | |
|-------------|--|-----|
| Figure 1.1: | Overview of the Lower Software Layers | 339 |
| Figure 1.2: | End to End Overview of Lower Software Layers to Transfer Data 340 | |
| Figure 5.1: | HCI Command Packet | 374 |
| Figure 5.2: | HCI ACL Data Packet | 375 |
| Figure 5.3: | HCI Synchronous Data Packet | 377 |
| Figure 5.4: | HCI Event Packet | 378 |
| Figure 7.1: | Local Loopback Mode | 556 |
| Figure 7.2: | Remote Loopback Mode | 556 |



9 LIST OF TABLES

| | | |
|-------------|--|-----|
| Table 3.1: | Overview of commands and events | 343 |
| Table 3.2: | Generic events | 344 |
| Table 3.3: | Controller flow control | 345 |
| Table 3.4: | Controller information | 345 |
| Table 3.5: | Controller configuration | 346 |
| Table 3.6: | Device discovery | 347 |
| Table 3.7: | Connection setup | 349 |
| Table 3.8: | Remote information | 351 |
| Table 3.9: | Synchronous connections | 352 |
| Table 3.10: | Connection state | 353 |
| Table 3.11: | Piconet structure | 354 |
| Table 3.12: | Quality of service | 355 |
| Table 3.13: | Physical links | 356 |
| Table 3.14: | Controller flow control. | 357 |
| Table 3.15: | Link information | 358 |
| Table 3.16: | Authentication and encryption | 359 |
| Table 3.17: | Testing | 361 |
| Table 3.18: | Alphabetical list of commands and events. | 362 |



APPENDIX A: DEPRECATED COMMANDS, EVENTS AND CONFIGURATION PARAMETERS

Commands, events and configuration parameters in this section were in prior versions of the specification, but have been determined not to be required.

They may be implemented by a controller to allow for backwards compatibility with a host utilizing a prior version of the specification.

A host should not use these commands.

Contents:

| | |
|---|------------|
| Page Scan Mode | 658 |
| Read Page Scan Mode Command | 659 |
| Write Page Scan Mode Command | 660 |
| Read Country Code Command | 661 |
| Add SCO Connection Command | 662 |
| Page Scan Mode Change Event | 664 |



Page Scan Mode

The Page_Scan_Mode parameter indicates the page scan mode that is used for default page scan. Currently one mandatory page scan mode and three optional page scan modes are defined. Following an inquiry response, if the Baseband timer T_mandatory_pscan has not expired, the mandatory page scan mode must be applied. For details see the “[Baseband Specification](#)” on [page 55 \[Part B\]](#) (Keyword: Page-Scan-Mode, FHS-Packet, T_mandatory_pscan)

| Value | Parameter Description |
|-----------|-----------------------------|
| 0x00 | Mandatory Page Scan Mode |
| 0x01 | Optional Page Scan Mode I |
| 0x02 | Optional Page Scan Mode II |
| 0x03 | Optional Page Scan Mode III |
| 0x04-0xFF | Reserved |

Read Page Scan Mode Command

| Command | OGF | OCF | Command Parameters | Return Parameters |
|-------------------------|------|--------|--------------------|---------------------------|
| HCI_Read_Page_Scan_Mode | 0x03 | 0x003D | | Status, Page_Scan_Mode |

Description:

This command is used to read the default Page Scan Mode configuration parameter of the local Bluetooth device. See [“Page Scan Mode” on page 612..](#)

Command Parameters:

None

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Page_Scan_Mode command succeeded. |
| 0x01-0xFF | Read_Page_Scan_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Page_Scan_Mode:

Size: 1 Octet

| Value | Parameter Description |
|---|-----------------------|
| See Appendix A, “Page Scan Mode” on page 612. | |

Event(s) generated (unless masked away):

When the Read_Page_Scan_Mode command has completed, a Command Complete event will be generated.



Write Page Scan Mode Command

OGF: 0x03 (Controller and baseband commands)

| Command | OGF | OCF | Command Parameters | Return Parameters |
|--------------------------|------|--------|--------------------|-------------------|
| HCI_Write_Page_Scan_Mode | 0x03 | 0x003E | Page_Scan_Mode | Status |

Description:

This command is used to write the default Page Scan Mode configuration parameter of the local Bluetooth device. See [“Page Scan Mode” on page 612](#).

Command Parameters:

Page_Scan_Mode:

Size: 1 Octet

| Value | Parameter Description |
|--|-----------------------|
| See Appendix A, “Page Scan Mode” on page 612 . | |

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|--|
| 0x00 | Write_Page_Scan_Mode command succeeded. |
| 0x01-0xFF | Write_Page_Scan_Mode command failed. See “Error Codes” on page 319 [Part D] for list of Error Codes. |

Event(s) generated (unless masked away):

When the Write_Page_Scan_Mode command has completed, a Command Complete event will be generated.



Read Country Code Command

| Command | OGF | OCF | Command Parameters | Return Parameters |
|-----------------------|------|--------|--------------------|-------------------------|
| HCI_Read_Country_Code | 0x05 | 0x0007 | | Status, Country_Code |

Description:

This command will read the value for the Country_Code return parameter. The Country_Code defines which range of frequency band of the ISM 2.4 GHz band will be used by the device. Each country has local regulatory bodies regulating which ISM 2.4 GHz frequency ranges can be used.

Command Parameters:

None.

Return Parameters:

Status:

Size: 1 Octet

| Value | Parameter Description |
|-----------|---|
| 0x00 | Read_Country_Code command succeeded. |
| 0x01-0xFF | Read_Country_Code command failed. See “Error Codes” on page 319 [Part D] for error codes and description. |

Country_Code:

Size: 1 Octet

| Value | Parameter Description |
|---------|-----------------------------------|
| 0x00 | North America & Europe* and Japan |
| 0x01 | France |
| 0x04-FF | Reserved for Future Use. |

*. Except France

Event(s) generated (unless masked away):

When the Read_Country_Code command has completed, a Command Complete event will be generated.



Add SCO Connection Command

| Command | OGF | OCF | Command Parameters | Return Parameters |
|------------------------|------|--------|-----------------------------------|-------------------|
| HCI_Add_SCO_Connection | 0x01 | 0x0007 | Connection_Handle, Packet_Type | |

Description:

This command will cause the Link Manager to create a SCO connection using the ACL connection specified by the Connection_Handle command parameter. This command causes the local Bluetooth device to create a SCO connection. The Link Manager will determine how the new connection is established. This connection is determined by the current state of the device, its piconet, and the state of the device to be connected. The Packet_Type command parameter specifies which packet types the Link Manager should use for the connection. The Link Manager must only use the packet type(s) specified by the Packet_Type command parameter for sending HCI SCO Data Packets. Multiple packet types may be specified for the Packet_Type command parameter by performing a bitwise OR operation of the different packet types. The Link Manager may choose which packet type is to be used from the list of acceptable packet types. A Connection Handle for this connection is returned in the Connection Complete event (see below).

Note: An SCO connection can only be created when an ACL connection already exists and when it is not put in park. For a definition of the different packet types, see the “Baseband Specification” on page 55 [Part B].

Note: At least one packet type must be specified. The Host should enable as many packet types as possible for the Link Manager to perform efficiently. However, the Host must not enable packet types that the local device does not support.

Command Parameters:

Connection_Handle Size 2 Octets (12 Bits meaningful)

| Value | Parameter Description |
|--------|--|
| 0xFFFF | Connection Handle for the ACL connection being used to create an SCO connection. Range: 0x0000-0x0EFF (0x0F00 - 0x0FFF Reserved for future use) |

*Packet_Type:**Size: 2 Octets*

| Value | Parameter Description |
|--------|--------------------------|
| 0x0001 | Reserved for future use. |
| 0x0002 | Reserved for future use. |
| 0x0004 | Reserved for future use. |
| 0x0008 | Reserved for future use. |
| 0x0010 | Reserved for future use. |
| 0x0020 | HV1 |
| 0x0040 | HV2 |
| 0x0080 | HV3 |
| 0x0100 | Reserved for future use. |
| 0x0200 | Reserved for future use. |
| 0x0400 | Reserved for future use. |
| 0x0800 | Reserved for future use. |
| 0x1000 | Reserved for future use. |
| 0x2000 | Reserved for future use. |
| 0x4000 | Reserved for future use. |
| 0x8000 | Reserved for future use. |

Return Parameters:

None.

Event(s) generated (unless masked away):

When the Controller receives the Add_SCO_Connection command, it sends the Command Status event to the Host. In addition, when the LM determines the connection is established, the local Controller will send a Connection Complete event to its Host, and the remote Controller will send a Connection Complete event or a Synchronous Connection Complete event to the Host. The Connection Complete event contains the Connection Handle if this command is successful.

Note: no Command Complete event will be sent by the Controller to indicate that this command has been completed. Instead, the Connection Complete event will indicate that this command has been completed.



Page Scan Mode Change Event

| Event | Event Code | Event Parameters |
|-----------------------|------------|-------------------------|
| Page Scan Mode Change | 0x1F | BD_ADDR, Page_Scan_Mode |

Description:

The Page Scan Mode Change event indicates that the connected remote Bluetooth device with the specified BD_ADDR has successfully changed the Page_Scan_Mode.

Event Parameters:

BD_ADDR: *Size: 6 Octets*


| Value | Parameter Description |
|--------------------|-------------------------------|
| 0XXXXXXXXX XXXX | BD_ADDR of the remote device. |

Page_Scan_Mode: *Size: 1 Octet*

| Value | Parameter Description |
|-------------|------------------------------|
| 0x00 | Mandatory Page Scan Mode. |
| 0x01 | Optional Page Scan Mode I. |
| 0x02 | Optional Page Scan Mode II. |
| 0x03 | Optional Page Scan Mode III. |
| 0x04 – 0xFF | Reserved. |

MESSAGE SEQUENCE CHARTS

Between Host and Host Controller/Link Manager



Examples of interactions between Host Controller Interface Commands and Events and Link Manager Protocol Data Units are represented in the form of message sequence charts. These charts show typical interactions and do not indicate all possible protocol behavior.





CONTENTS

| | | |
|----------|--|------------|
| 1 | Introduction | 623 |
| 1.1 | Notation | 623 |
| 1.2 | Flow of Control | 624 |
| 1.3 | Example MSC | 624 |
| 2 | Services Without Connection Request | 625 |
| 2.1 | Remote Name Request..... | 625 |
| 2.2 | One-time Inquiry..... | 626 |
| 2.3 | Periodic Inquiry | 628 |
| 3 | ACL Connection Establishment and Detachment..... | 631 |
| 3.1 | Connection Setup | 632 |
| 4 | Optional Activities After ACL Connection Establishment..... | 639 |
| 4.1 | Authentication Requested | 639 |
| 4.2 | Set Connection Encryption..... | 640 |
| 4.3 | Change Connection Link Key..... | 641 |
| 4.4 | Master Link Key | 642 |
| 4.5 | Read Remote Supported Features | 644 |
| 4.6 | Read Remote Extended Features | 644 |
| 4.7 | Read Clock Offset | 645 |
| 4.8 | Read Remote Version Information | 645 |
| 4.9 | QOS Setup..... | 646 |
| 4.10 | Switch Role | 646 |
| 5 | Synchronous Connection Establishment and Detachment | 649 |
| 5.1 | Synchronous Connection Setup..... | 649 |
| 6 | Sniff, Hold and Park | 655 |
| 6.1 | sniff Mode..... | 655 |
| 6.2 | Hold Mode..... | 656 |
| 6.3 | Park State..... | 658 |
| 7 | Buffer Management, Flow Control..... | 661 |
| 8 | Loopback Mode | 663 |
| 8.1 | Local Loopback Mode | 663 |
| 8.2 | Remote Loopback Mode | 665 |
| 9 | List of Figures..... | 667 |





1 INTRODUCTION

This section shows typical interactions between Host Controller Interface (HCI) Commands and Events and Link Manager (LM) Protocol Data Units (PDU). It focuses on the message sequence charts (MSCs) for the procedures specified in [3] “Bluetooth Host Controller Interface Functional Specification” with regard to LM Procedures from [2] “Link Manager Protocol”.

This section illustrates only the most useful scenarios, it does not cover all possible alternatives. Furthermore, the message sequence charts do not consider errors over the air interface or host interface. In all message sequence charts it is assumed that all events are not masked, so the Host Controller will not filter out any events.

The sequence of messages in these message sequence charts is for illustrative purposes. The messages may be sent in a different order where allowed by the Link Manager or HCI sections. If any of these charts differ with text in the Baseband, Link Manager, or HCI sections, the text in those sections shall be considered normative. This section is informative.

1.1 NOTATION

The notation used in the message sequence charts (MSCs) consists of ovals, elongated hexagons, boxes, lines, and arrows. The vertical lines terminated on the top by a shadow box and at the bottom by solid oval indicate a protocol entity that resides in a device. MSCs describe interactions between these entities and states those entities may be in.

The following symbols represent interactions and states:

| | |
|---------------------|--|
| Oval | Defines the context for the message sequence chart. |
| Hexagon | Indicates a condition needed to start the transactions below this hexagon. The location and width of the Hexagon indicates which entity or entities make this decision. |
| Box | Replaces a group of transactions. May indicate a user action, or a procedure in the baseband. |
| Dashed Box | Optional group of transactions. |
| Solid Arrow | Represents a message, signal or transaction. Can be used to show LMP and HCI traffic. Some baseband packet traffic is also shown. These are prefixed by BB followed by either the type of packet, or an indication that there is an ACK signal in a packet. |
| Dashed Arrow | Represents a optional message, signal or transaction. Can be used to show LMP and HCI traffic. |

1.2 FLOW OF CONTROL

Some message sequences are split into several charts. These charts are marked in sequence with different step numbers with multiple paths through with optional letters after the step numbers. Numbers indicate normal or required ordering. The letters represent alternative paths. For example, Step 4 is after Step 3, and Step 5a could be executed instead of Step 5b.

1.3 EXAMPLE MSC

The protocol entities represented in the example shown in [Figure 1.1 on page 624](#) illustrate the interactions of two devices named A and B. Note that each device includes a Host and a LM entity in this example. Other MSCs in this section may show the interactions of more than two devices.

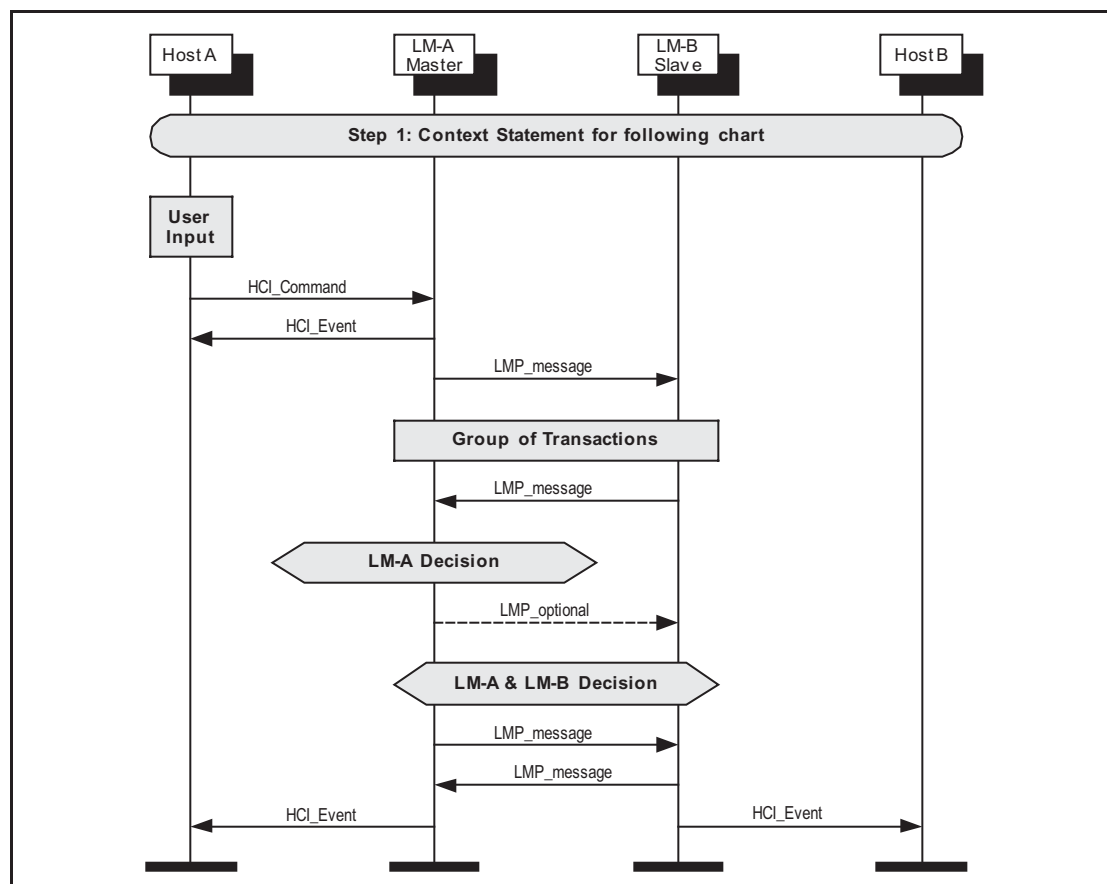


Figure 1.1: Example MSC.

2 SERVICES WITHOUT CONNECTION REQUEST

2.1 REMOTE NAME REQUEST

The service Remote Name Request is used to find out the name of the remote device without requiring an explicit ACL Connection.

Step 1: The host sends an `HCI_Remote_Name_Request` command expecting that its local device will automatically try to connect to the remote device. (See [Figure 2.1 on page 625](#))

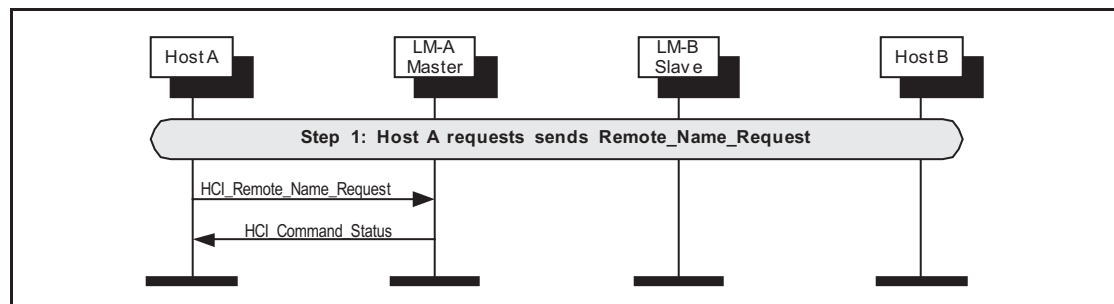


Figure 2.1: Remote name request.

Step 2a: If an ACL Connection does not exist device A pages device B. After the Baseband paging procedure, the local device attempts to get the name, disconnect, and return the name of the remote device to the Host. (See [Figure 2.2 on page 625](#))

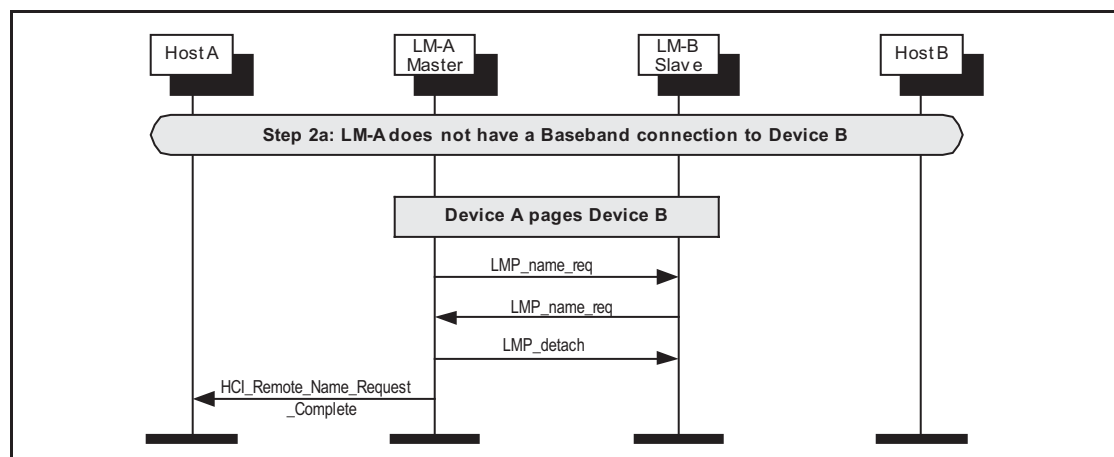


Figure 2.2: Remote name request if no current baseband connection.

Step 2b: If an ACL Connection exists when the request is made, then the Remote Name Request procedure will be executed like an optional service. No Paging and no ACL disconnect is done. (See [Figure 2.3 on page 626](#))

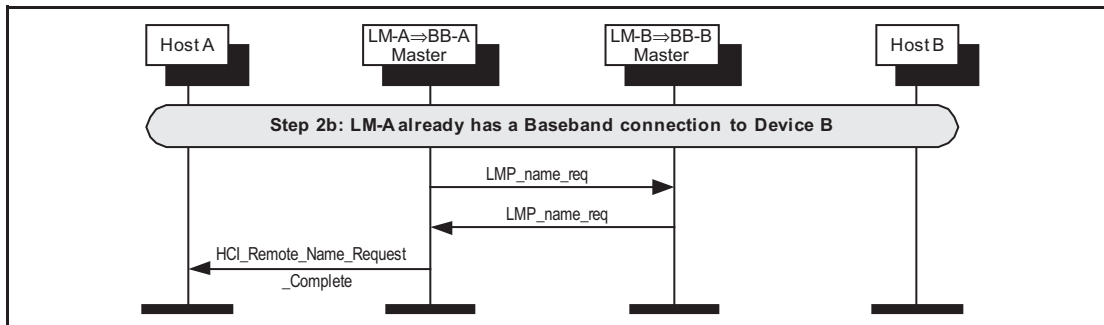


Figure 2.3: Remote name request with baseband connection.

2.2 ONE-TIME INQUIRY

Inquiry is used to detect and collect nearby devices.

Step 1: The host sends an HCI_Inquiry command. (See [Figure 2.4 on page 626](#))

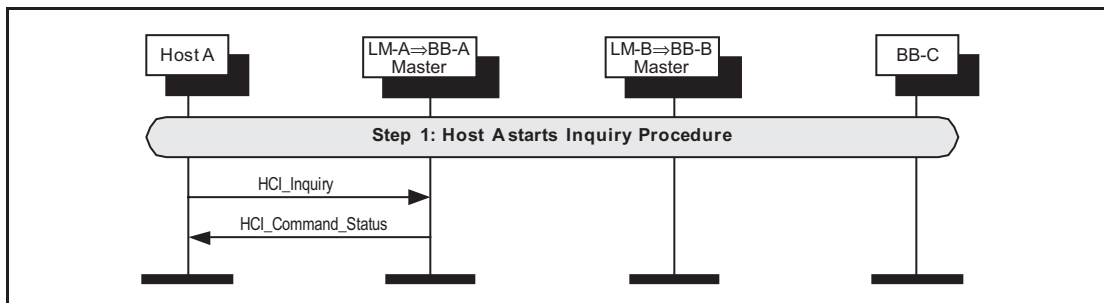


Figure 2.4: Host A starts inquiry procedure.

Step 2: The Controller will start the Baseband inquiry procedure with the specified Inquiry Access Code and Inquiry Length. When Inquiry Responses are received, the Controller extracts the required information and returns the information related to the found devices using one or more Inquiry Result events to the Host. (See [Figure 2.5 on page 627](#))

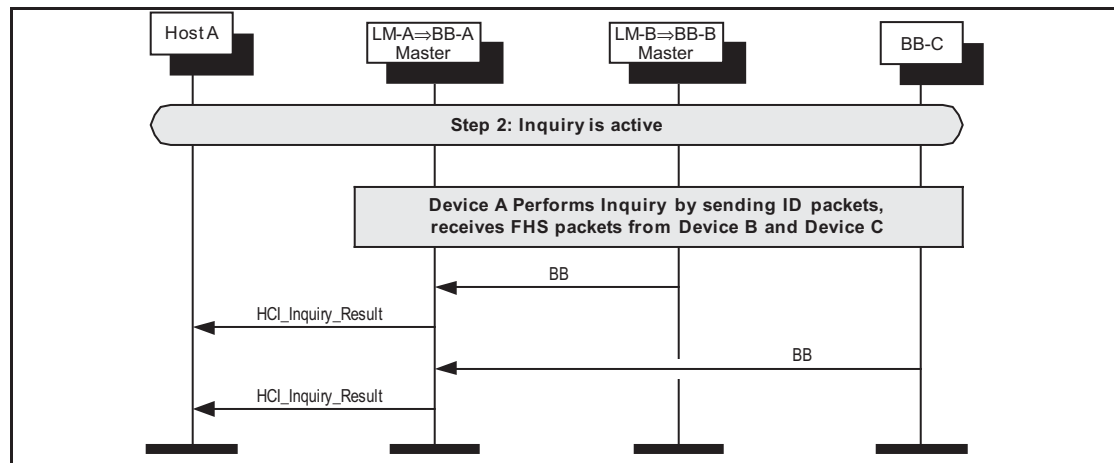


Figure 2.5: LM-A performs inquiry and reports result.

Step 3a: If the host wishes to terminate an Inquiry, the `HCI_Inquiry_Cancel` command is used to immediately stop the inquiry procedure. (See [Figure 2.6 on page 627](#))

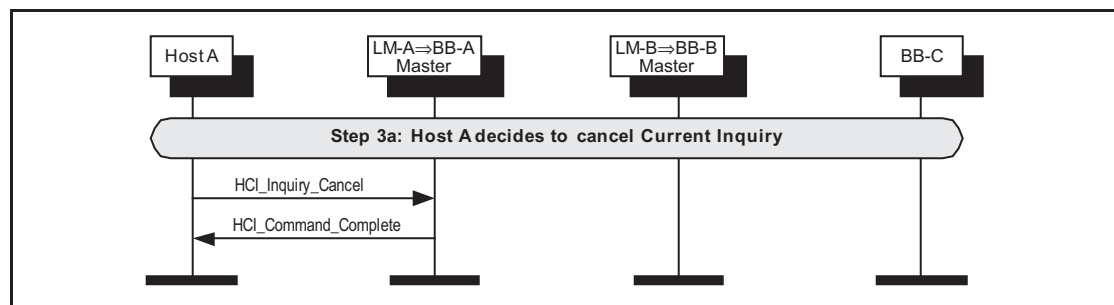


Figure 2.6: Host A cancels inquiry.

Step 3b: If the Inquiry procedure is completed due to the number of results obtained, or the Inquiry Length has expired, an Inquiry Complete event is returned to the Host. (See [Figure 2.7 on page 628](#))

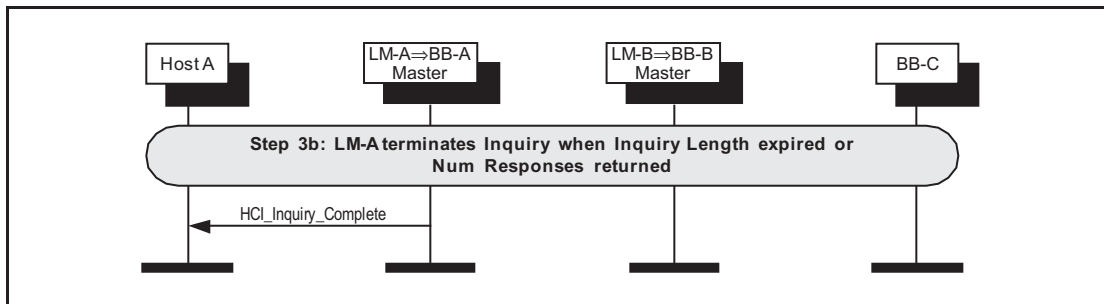


Figure 2.7: LM-A terminates current inquiry.

2.3 PERIODIC INQUIRY

Periodic inquiry is used when the inquiry procedure is to be repeated periodically.

Step 1: The hosts sends an HCI_Periodic_Inquiry_Mode command. (See [Figure 2.8 on page 628](#))

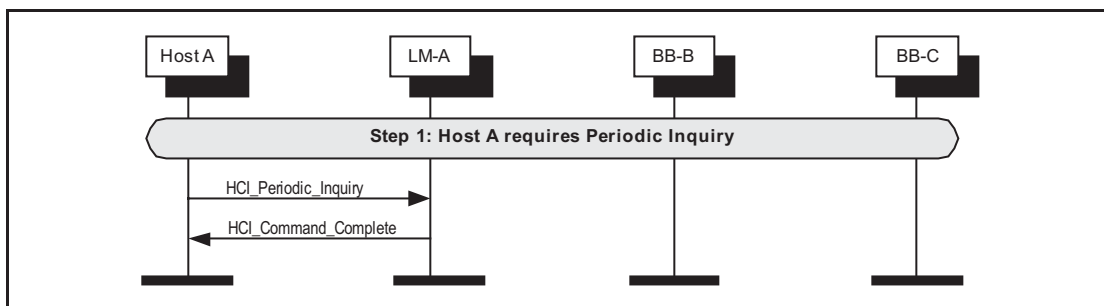


Figure 2.8: Host A starts periodic inquiry.

Step 2: The Controller will start a periodic Inquiry. In the inquiry cycle, one or several Inquiry Result events will be returned. (See [Figure 2.9 on page 629](#))

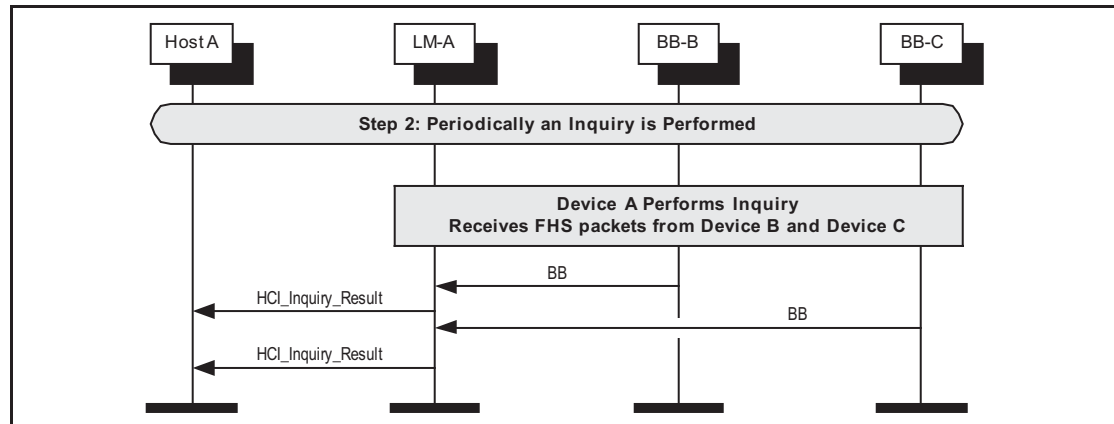


Figure 2.9: LM-A periodically performs an inquiry and reports result.

Step 3: An Inquiry Complete event will be returned to the Host when the current periodic inquiry has finished. (See [Figure 2.10 on page 629](#))

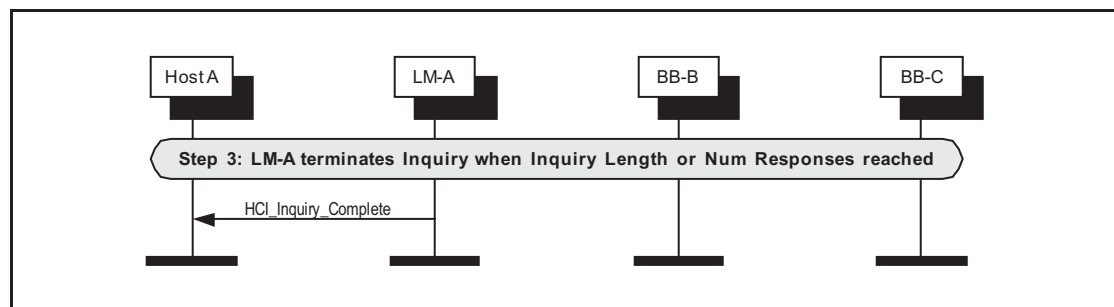


Figure 2.10: LM-A terminates current inquiry.

Step 4: The periodic Inquiry can be stopped using the HCI_Exit_Periodic_Inquiry_Mode command. (See [Figure 2.11 on page 629](#))

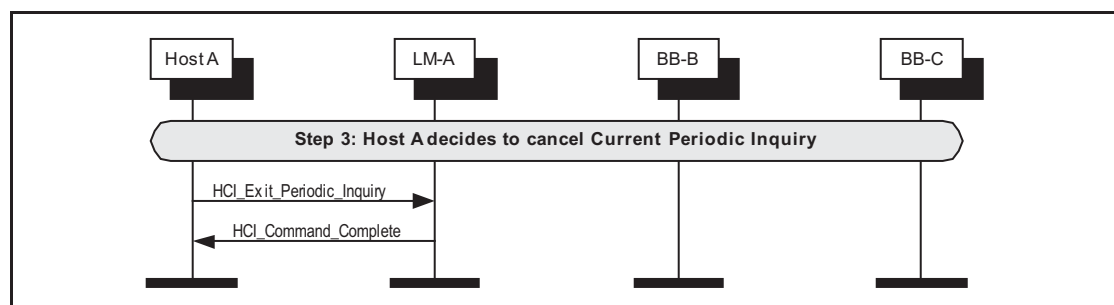


Figure 2.11: Host A decides to exit periodic inquiry.



3 ACL CONNECTION ESTABLISHMENT AND DETACHMENT

A flow diagram of the establishment and detachment of a connection between two devices is shown in [Figure 3.1 on page 631](#). The process is illustrated in 9 distinct steps. A number of these steps may be optionally performed, such as authentication and encryption. Some steps are required, such as the Connection Request and Setup Complete steps. The steps in the overview diagram directly relate to the steps in the following message sequence charts.

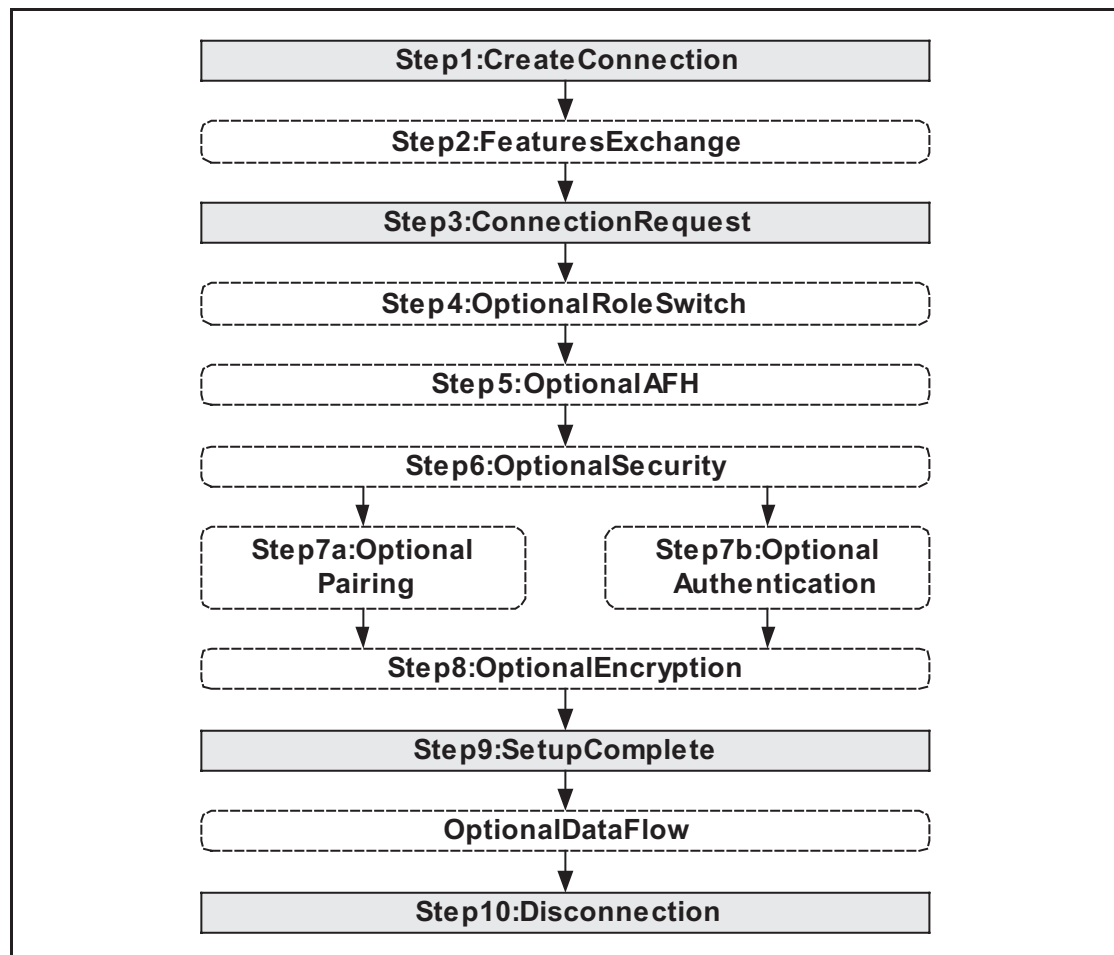


Figure 3.1: Overview diagram for connection setup.

3.1 CONNECTION SETUP

Step 1: The host sends an HCI_Create_Connection command to the Controller. The Controller then performs a Baseband paging procedure with the specified BD_ADDR. (See [Figure 3.2 on page 632](#))

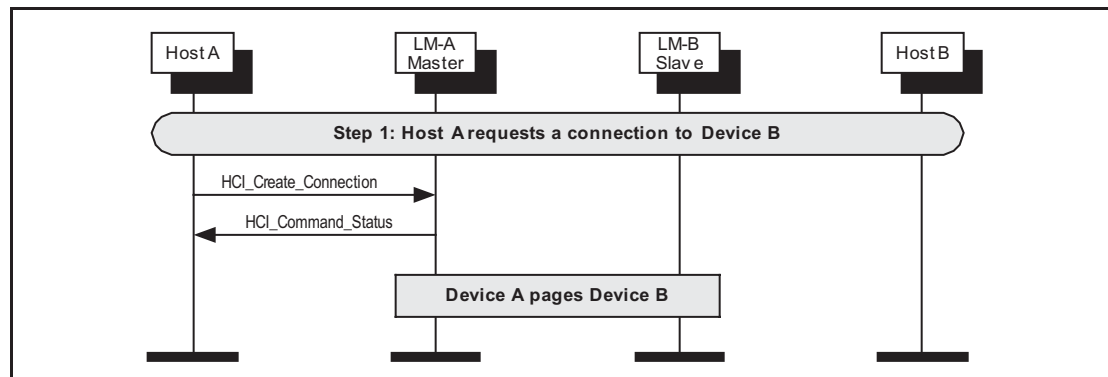


Figure 3.2: Host A requests connection with device B.

Step 2: Optionally, the LM may decide to exchange features. (See [Figure 3.3 on page 632](#))

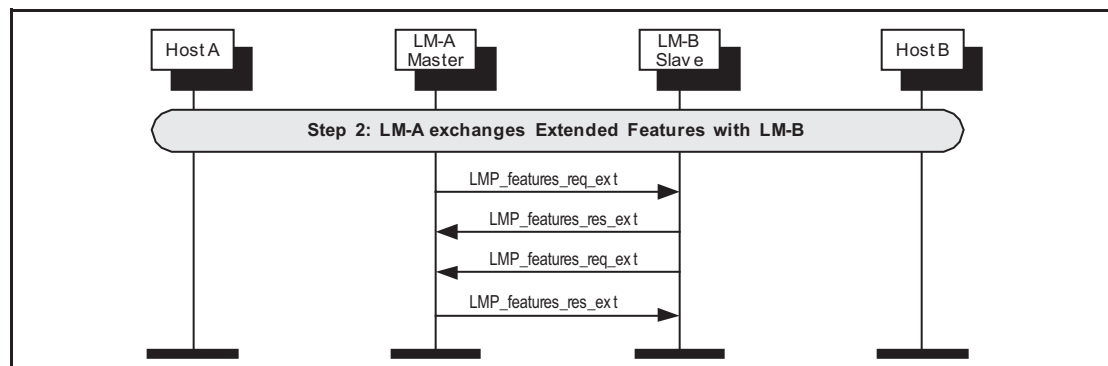


Figure 3.3: LM-A and LM-B exchange features.

Step 3: The LM on the master will request an LMP_host_connection_req PDU. The LM on the slave will then confirm that a connection is OK, and if so, what role is preferred. (See [Figure 3.4 on page 632](#))

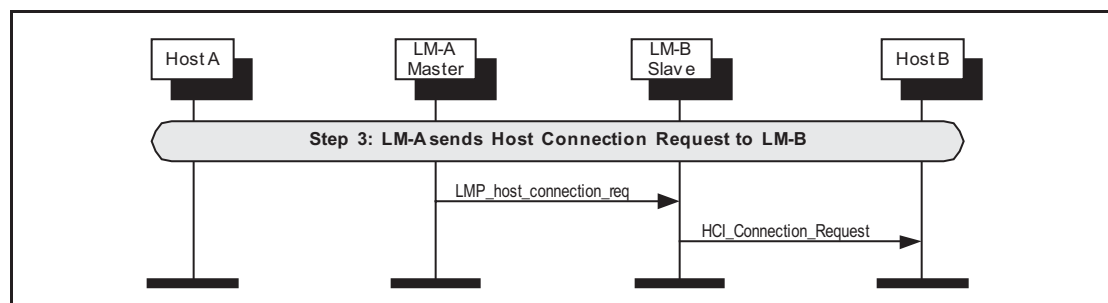


Figure 3.4: LM-A requests host connection.

Step 4a: The remote host rejects this connection, and the link is terminated.
(See [Figure 3.5 on page 633](#))

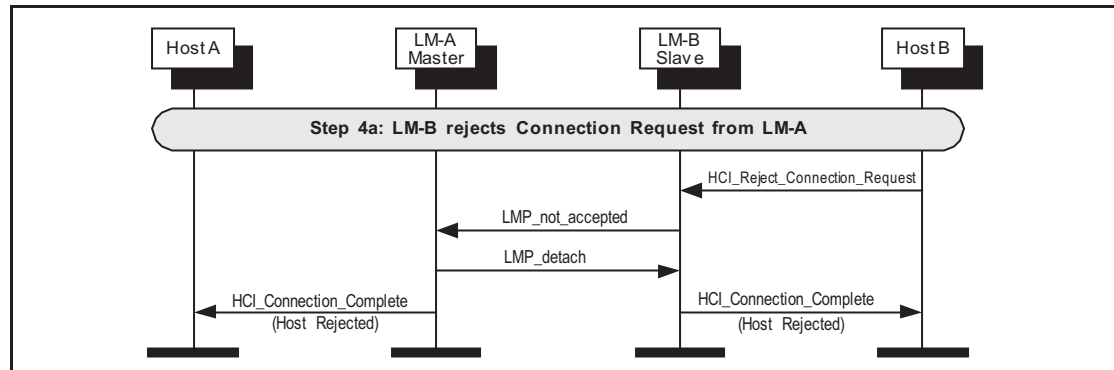


Figure 3.5: Device B rejects connection request.

Step 4b: The remote host accepts this connection. (See [Figure 3.6 on page 633](#))

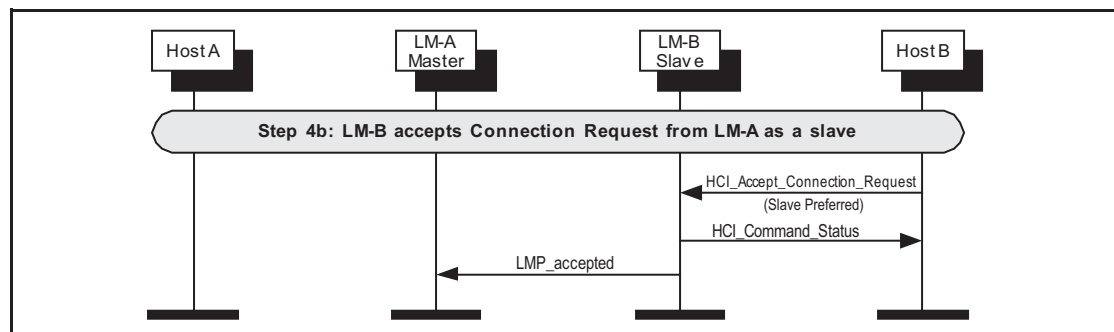


Figure 3.6: Device B accepts connection request.

Step 4c: The remote host accepts this connection but with the preference of being a master. This will cause a role switch to occur before the LMP_accepted for the LMP_host_connection_req PDU is sent. (See [Figure 3.7 on page 634](#))

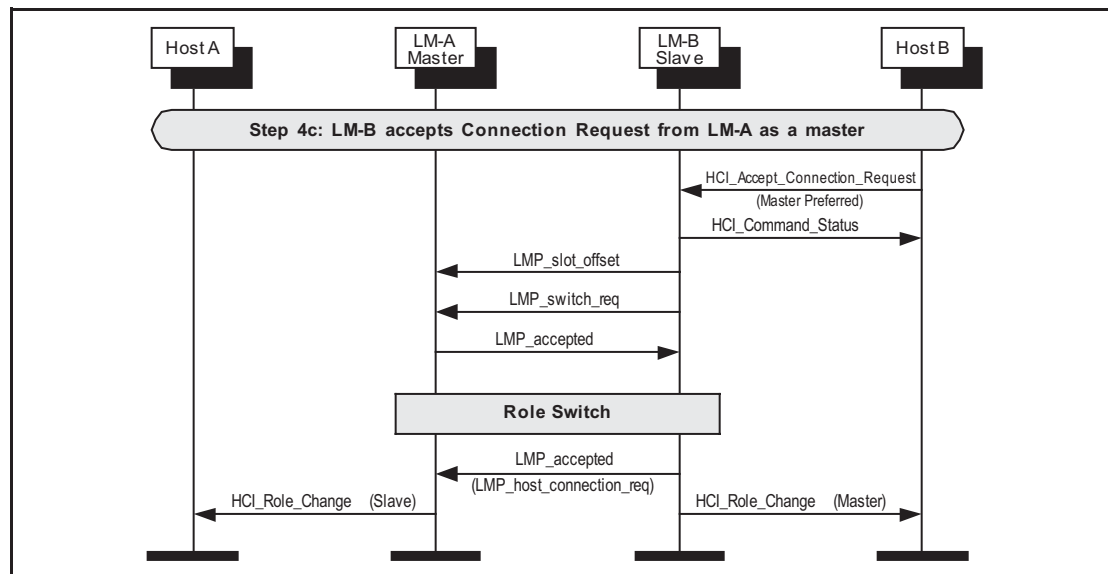


Figure 3.7: Device B accepts connection requests as master.

Step 5: After the features have been exchanged and AFH support is determined to be available, the master may at any time send an LMP_set_AFH and LMP_channel_classification_req PDU. (See [Figure 3.8 on page 634](#))

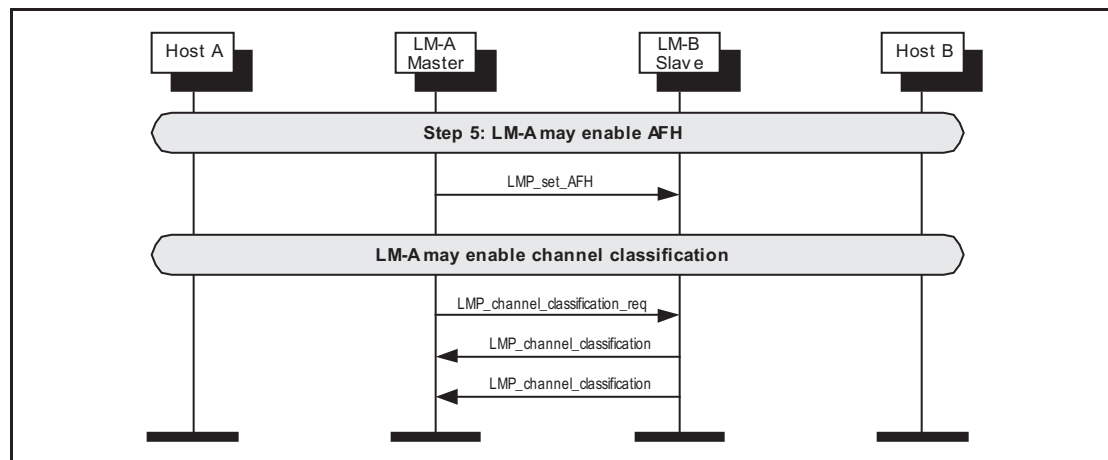


Figure 3.8: LM-A starts adaptive frequency hopping.

Step 6: The LM will request if authentication is required. It does this by requesting the Link Key for this connection from the Host. (See [Figure 3.9 on page 635](#))

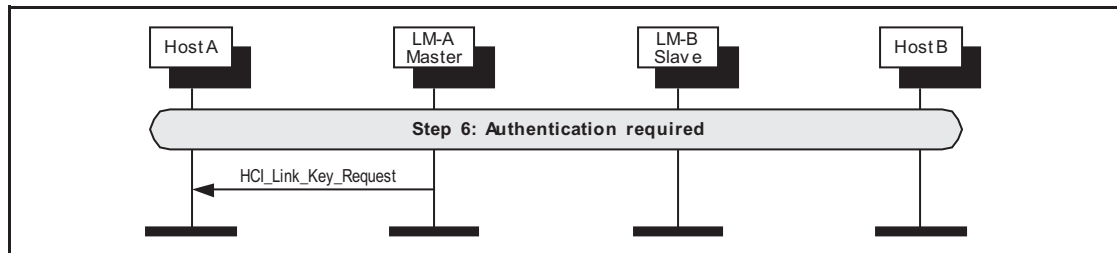


Figure 3.9: Authentication initiated.



Step 7a: If authentication is required by the higher layers and the devices to be connected do not have a common link key, a pairing procedure will be used. The LM will have requested a link key from the host for this connection. If there is a negative reply, then a PIN code will be requested. This PIN code will be requested on both sides of the connection, and authentication performed based on this PIN code. The last step is for the new link key for this connection to be passed to the host so that it may store it for future connections. (See [Figure 3.10 on page 636](#))

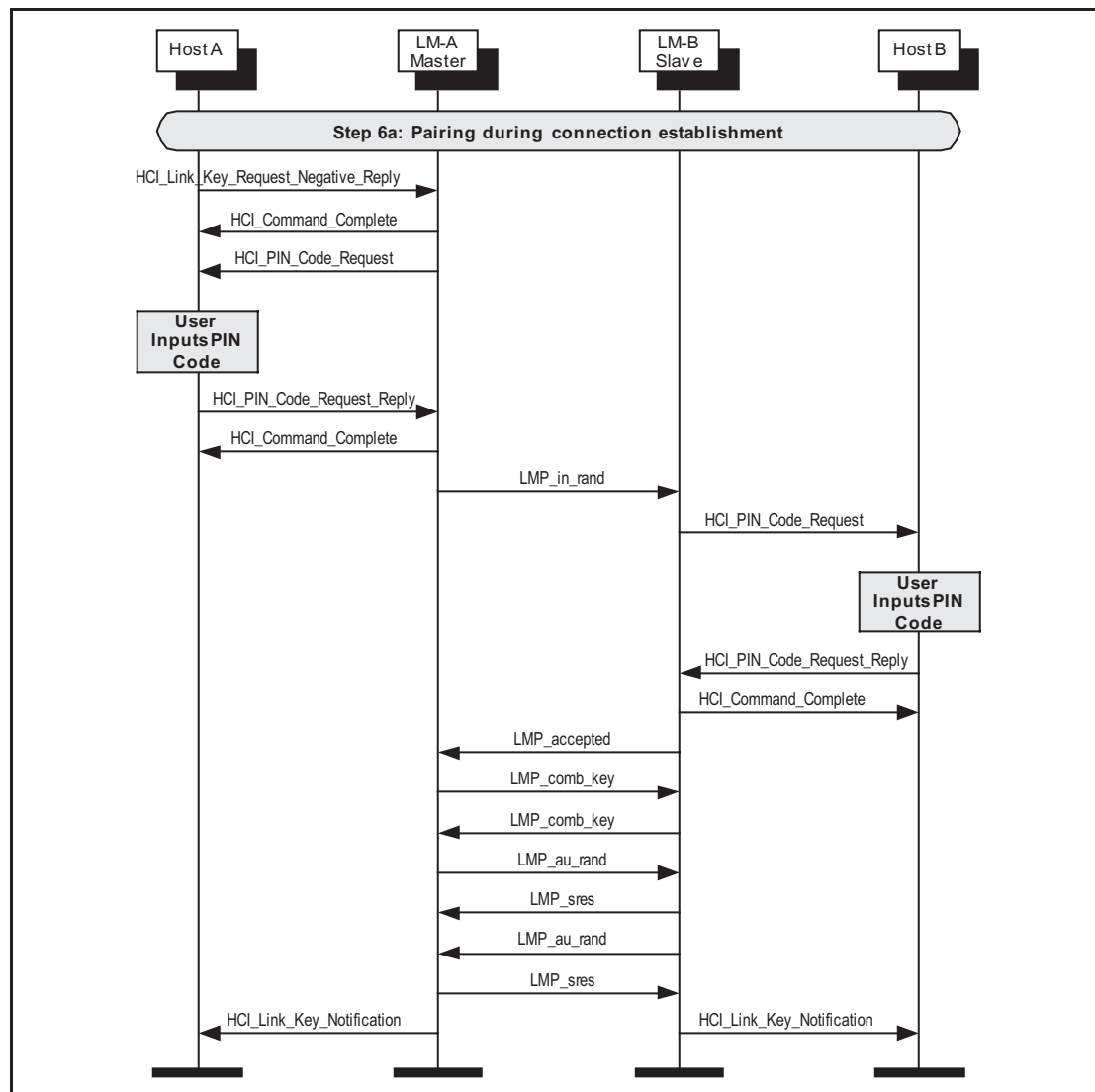


Figure 3.10: Pairing during connection setup.

Step 7b: If a common link key exists between the devices, then pairing is not needed. The LM will have asked for a link key from the host for this connection. If this is a positive reply, then the link key is used for authentication. If the configuration parameter `Authentication_Enable` is set, then the authentication procedure must be executed. This MSC only shows the case when `Authentication_Enable` is set on both sides. (See [Figure 3.11 on page 637](#))

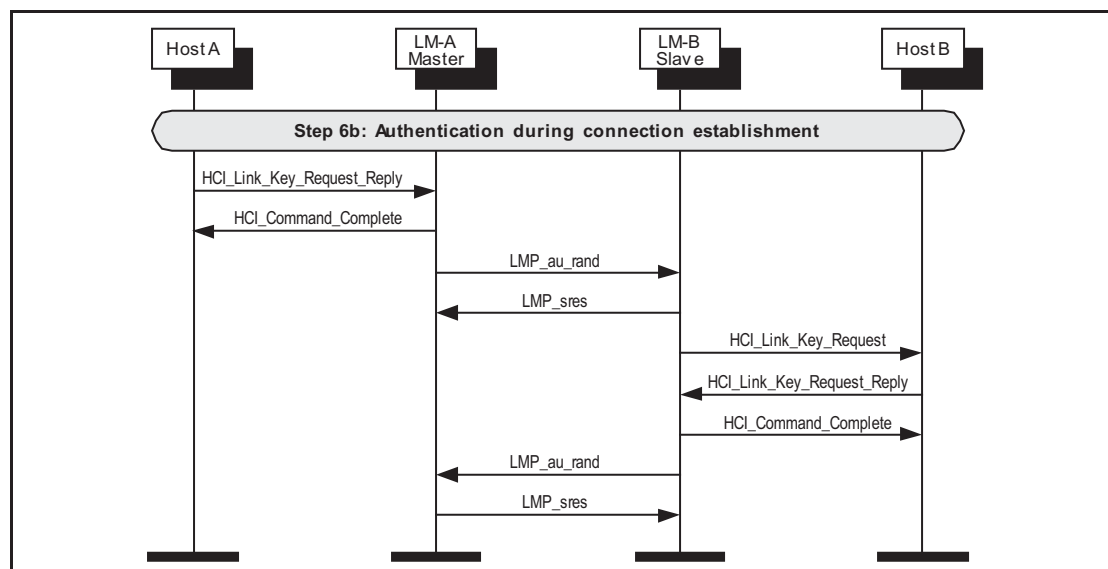


Figure 3.11: Authentication during connection setup.

Step 8: Once the pairing or authentication procedure is successful, the encryption procedure may be started. This MSC only shows the set up of an encrypted point-to-point connection. (See [Figure 3.12 on page 637](#))

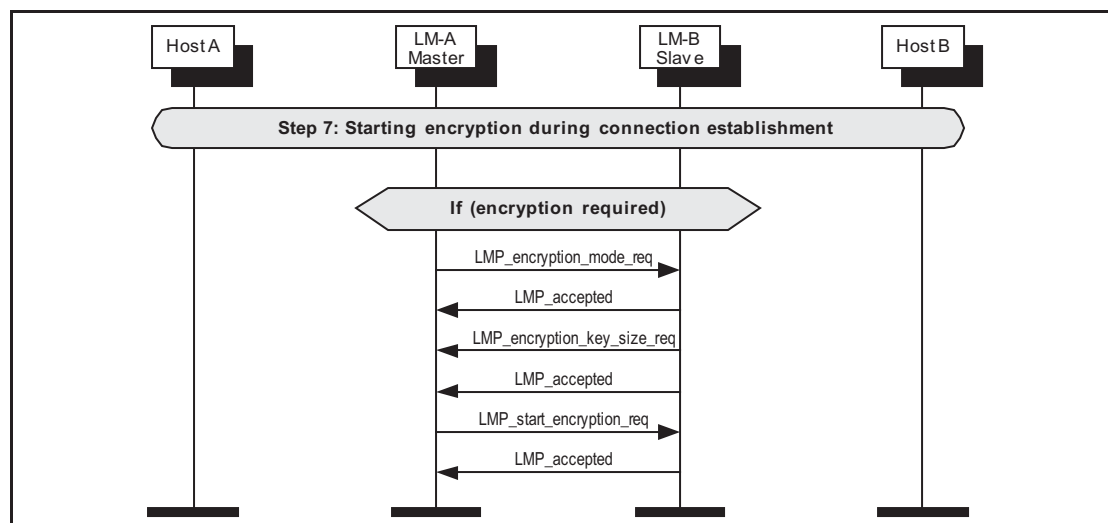


Figure 3.12: Starting encryption during connection setup.

Step 9: The LMs indicate that the connection is setup by sending LMP_setup_complete PDU. This will cause the Host to be notified of the new connection handle, and this connection may be used to send higher layer data such as L2CAP information. (See [Figure 3.13 on page 638](#))

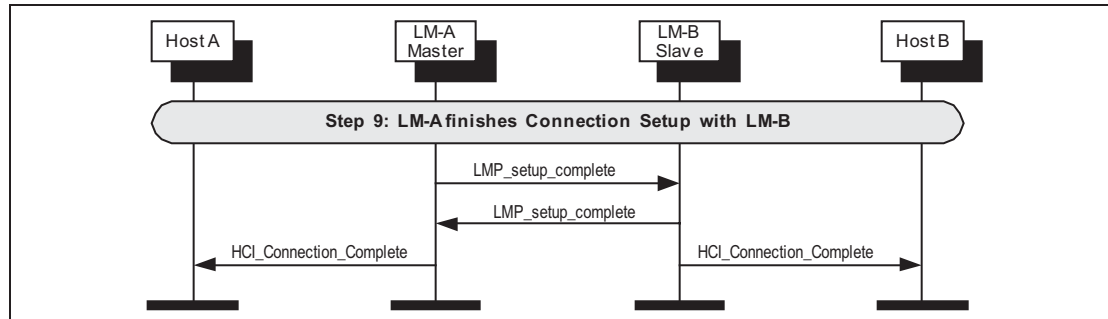


Figure 3.13: LM-A and LM-B finishes connection setup.

Step 10: Once the connection is no longer needed, either device may terminate the connection using the HCI_Disconnect command and LMP_detach message PDU. The disconnection procedure is one-sided and does not need an explicit acknowledgment from the remote LM. The use of ARQ Acknowledgment from the Baseband is needed to ensure that the remote LM has received the LMP_detach PDU. (See [Figure 3.13 on page 638](#))

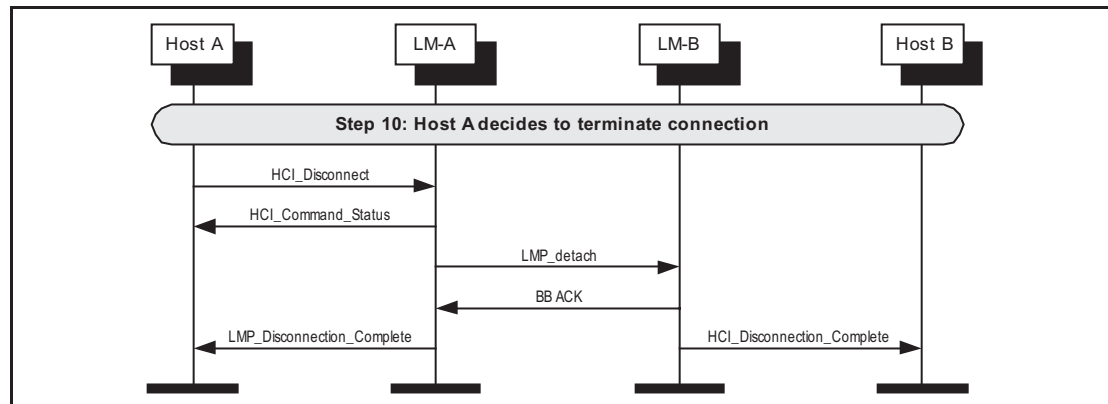


Figure 3.14: Host A decides to disconnect.

4 OPTIONAL ACTIVITIES AFTER ACL CONNECTION ESTABLISHMENT

4.1 AUTHENTICATION REQUESTED

Step 1: Authentication can be explicitly executed at any time after a connection has been established. If no Link Key is available then the Link Key is required from the Host. (See [Figure 4.1 on page 639](#))

Note: If the Controller or LM and the Host do not have the Link Key a PIN Code Request event will be sent to the Host to request a PIN Code for pairing. A procedure identical to that used during Connection Setup (Section 3.1, [Step 7a:](#)) will be used. (See [Figure 3.9 on page 635](#))

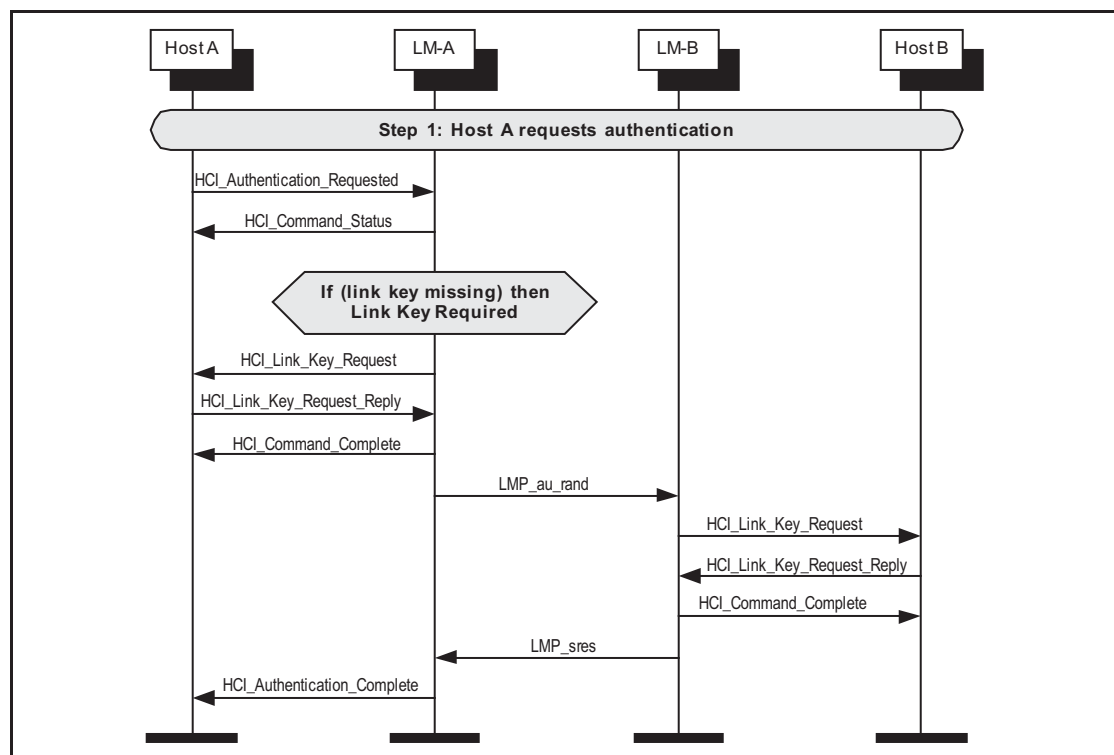


Figure 4.1: Authentication requested.

4.2 SET CONNECTION ENCRYPTION

Step 1: The host may at any time turn on encryption using the HCI_Set_Connection_Encryption command. This command can be originated from either the master or slave sides. Only the master side is shown in [Figure 4.2 on page 640](#). If this command is sent from a slave, the only difference is that the LMP_encryption_mode_req PDU will be sent from the slave. The LMP_encryption_key_size_req and LMP_start_encryption_req PDUs will always be requested from the master. (See [Figure 4.2 on page 640](#))

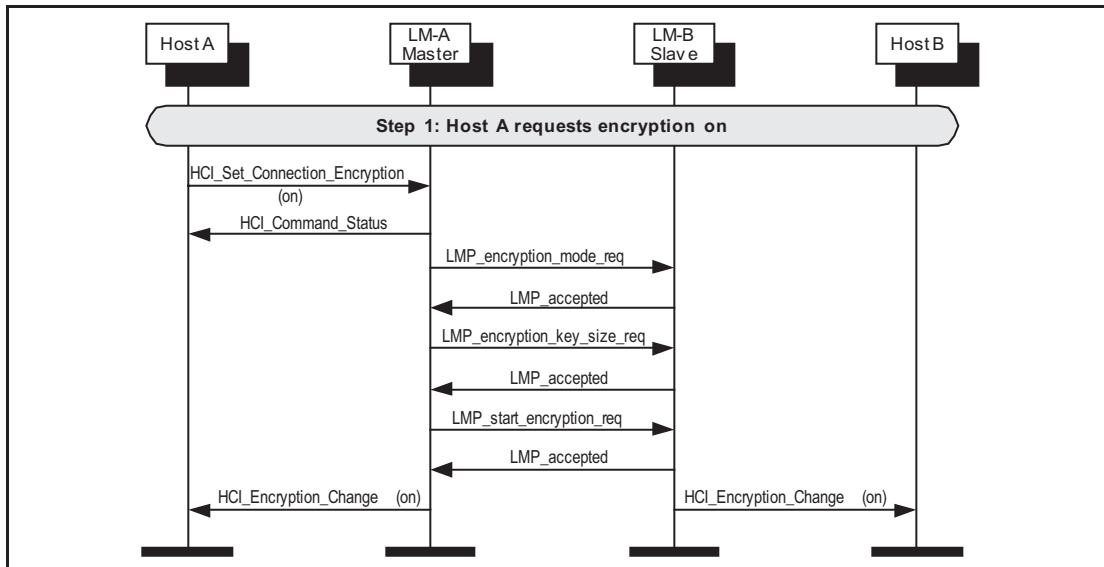


Figure 4.2: Encryption requested.

Step 2: To terminate the use of encryption, The HCI_Set_Connection_Encryption command is used. (See [Figure 4.3 on page 640](#))

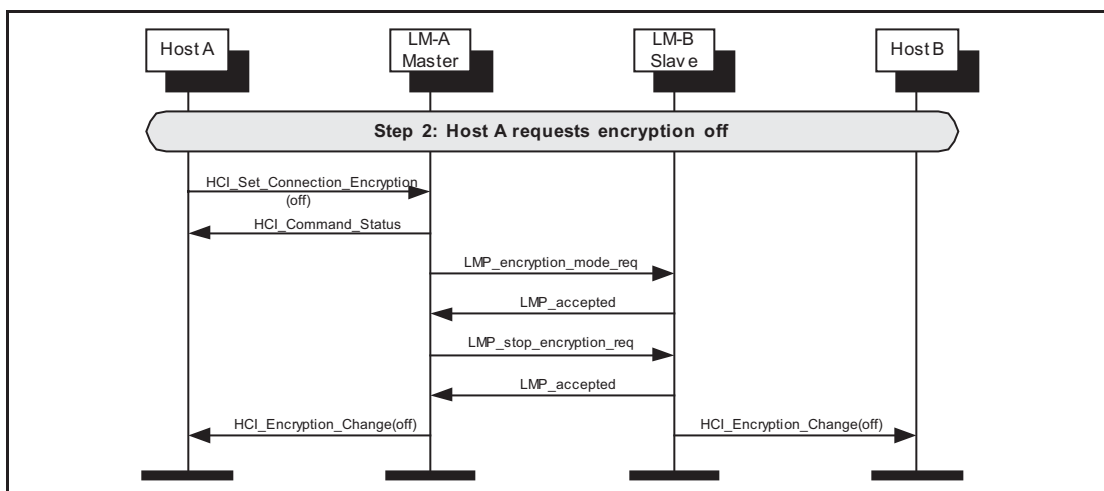


Figure 4.3: Encryption off requested.

4.3 CHANGE CONNECTION LINK KEY

Step 1: The master host (Host A) may change the connection link key using the HCI_Change_Connection_Link_Key command. A new link key will be generated and the hosts will be notified of this new link key. (See [Figure 4.4 on page 641](#)).

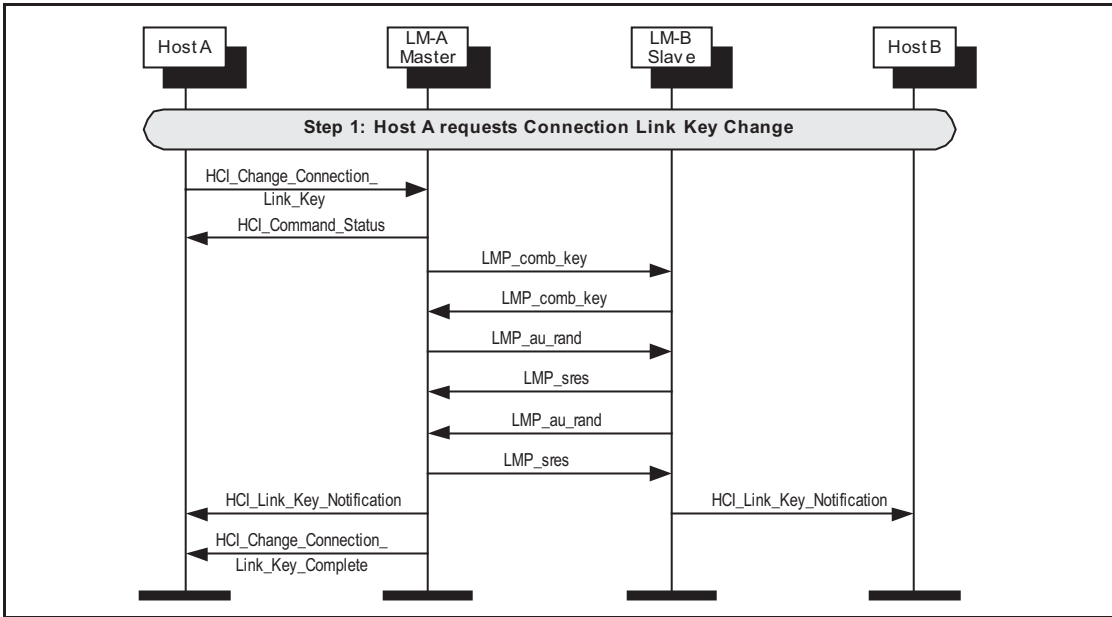


Figure 4.4: Change connection link key.

4.4 MASTER LINK KEY

Step 1: The host changes to a Master Link Key from a Semi-permanent Link Key using the HCI_Master_Link_Key command. (See [Figure 4.5 on page 642](#))

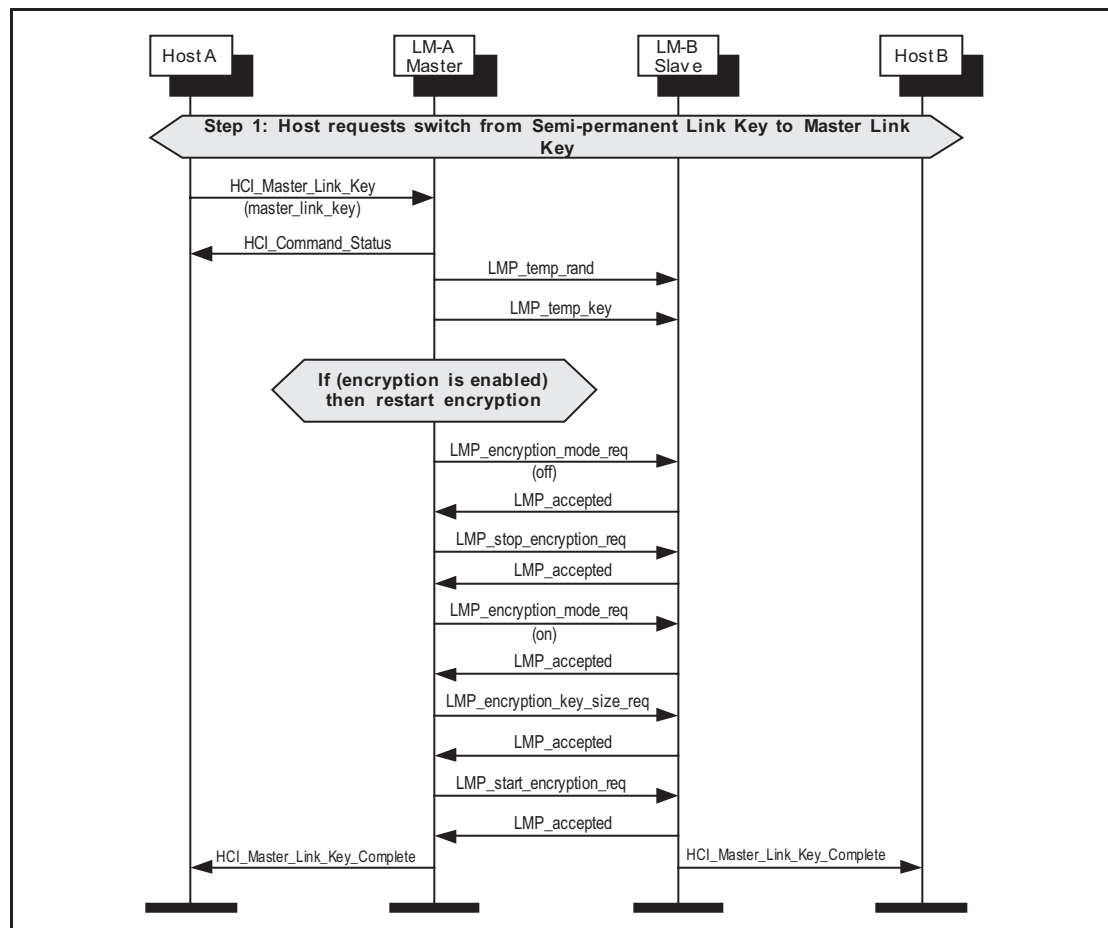


Figure 4.5: Change to master link key.

Step 2: The host changes to a Semi-permanent Link Key from a Master Link Key using the HCI_Master_Link_Key command. (See [Figure 4.6 on page 643](#))

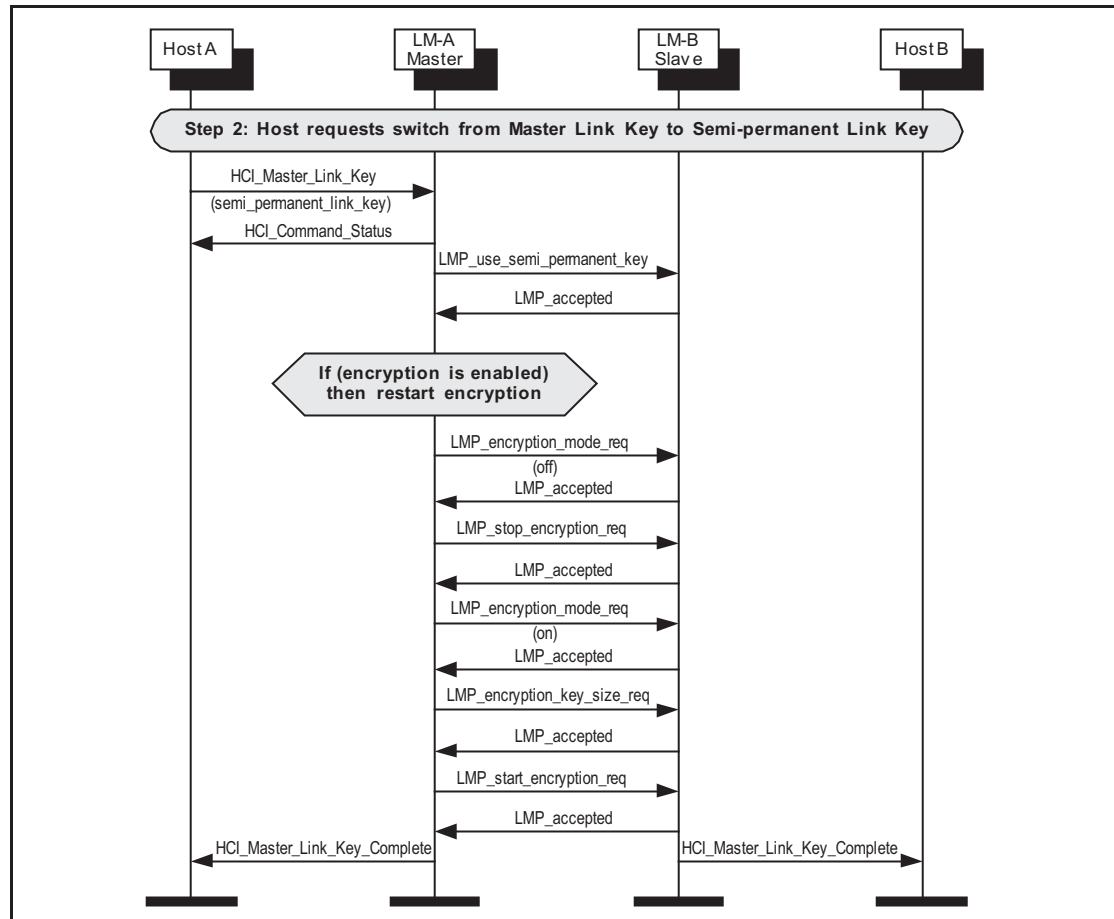


Figure 4.6: Change to semi permanent link key.

4.5 READ REMOTE SUPPORTED FEATURES

Using the `HCI_Read_Remote_Supported_Features` command the supported LMP Features of a remote device can be read. (See [Figure 4.7 on page 644](#))

If the remote supported features have been obtained previously then the Controller may return them without sending any LMP PDUs.

Step 1: The host requests the supported features of a remote device.

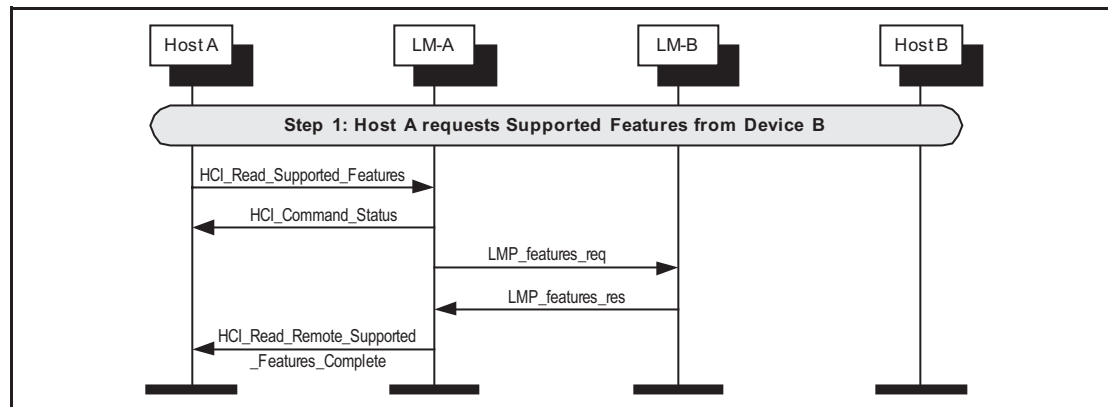


Figure 4.7: Read remote supported features.

4.6 READ REMOTE EXTENDED FEATURES

Using the `HCI_Read_Remote_Extended_Features` command the extended LMP features of a remote device can be read. (See [Figure 4.8 on page 644](#))

If the remote extended features have been obtained previously then the Controller may return them without sending any LMP PDUs.

Step 1: The host requests the extended features of a remote device.

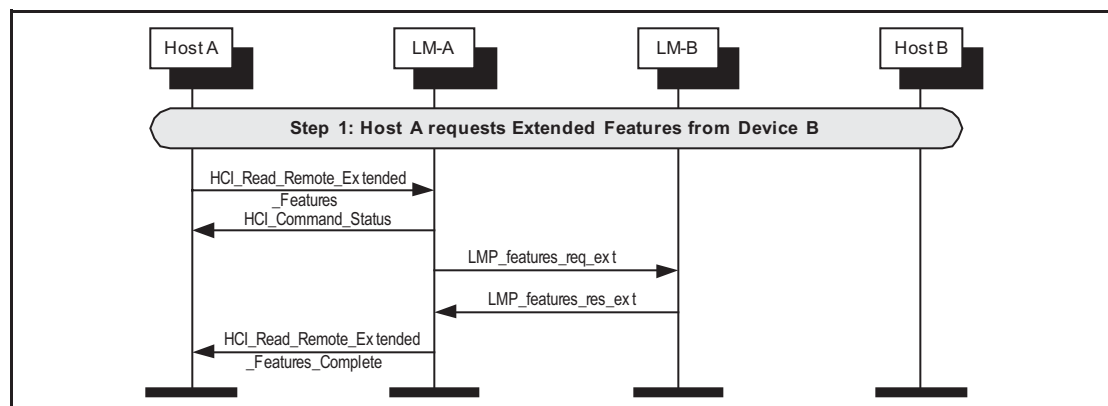


Figure 4.8: Read remote extended features.

4.7 READ CLOCK OFFSET

Using the `HCI_Read_Clock_Offset` command the device acting as the master can read the Clock Offset of a slave. The Clock Offset can be used to speed up the paging procedure in a later connection attempt. If the command is requested from the slave device, the Controller will directly return a Command Status event and a Read Clock Offset Complete event without sending any LMP PDUs. (See [Figure 4.9 on page 645](#))

Step 1: The host requests the clock offset of a remote device.

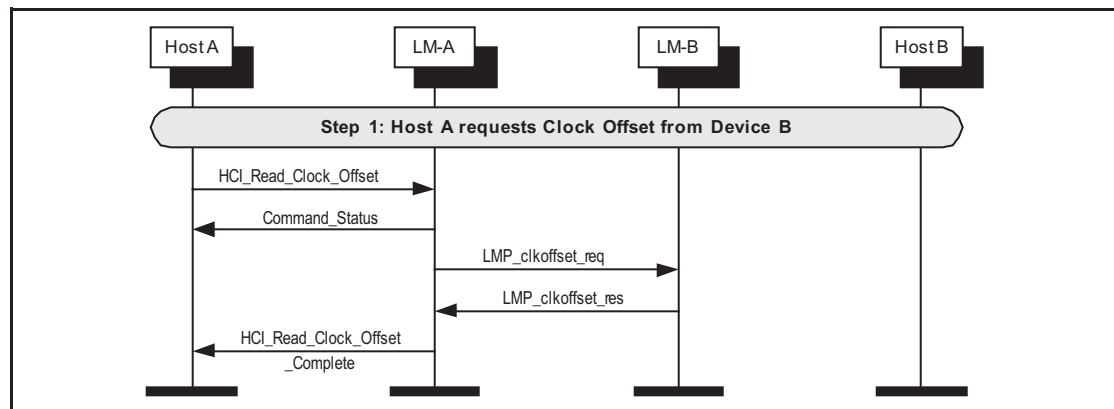


Figure 4.9: Read clock offset.

4.8 READ REMOTE VERSION INFORMATION

Using the `HCI_Read_Remote_Version_Information` command the version information of a remote device can be read. (See [Figure 4.10 on page 645](#))

If the remote version information has been obtained previously then the Controller may return them without sending any LMP PDUs.

Step 1: The host requests the version information of a remote device.

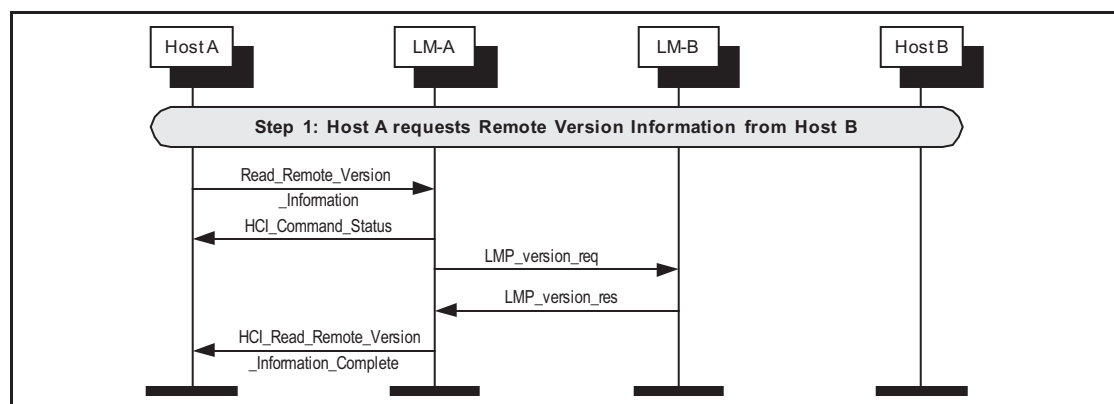


Figure 4.10: Read remote version information.

4.9 QOS SETUP

Using the `HCI_Flow_Specification` command the Quality of Service (QoS) and Flow Specification requirements of a connection can be notified to a Controller. The Controller may then change the quality of service parameters with a remote device. (See [Figure 4.11 on page 646](#))

Step 1: The host sends QoS parameters to a remote device.

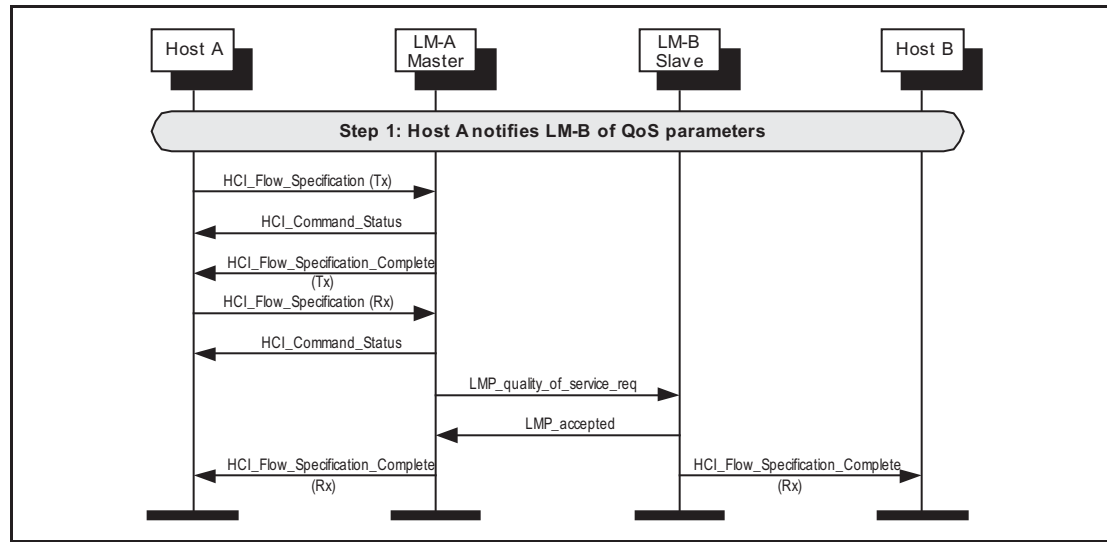


Figure 4.11: QoS flow specification.

4.10 SWITCH ROLE

The `HCI_Switch_Role` command can be used to explicitly switch the current master / slave role of the local device with the specified device.

Step 1a: The master host (A) requests a role switch with a slave. This will send the switch request, and the slave will respond with the slot offset and accepted. (See [Figure 4.12 on page 646](#))

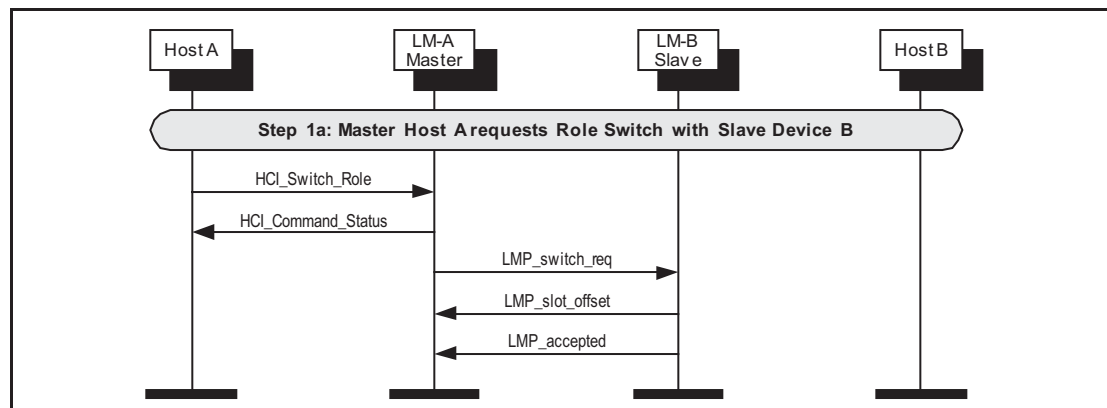


Figure 4.12: Master requests role switch.

Step 1b: The slave host (B) requests a role switch with a master. This will send the slot offset and the switch request, and the master will respond with a LMP_accepted PDU. (See [Figure 4.13 on page 647](#))

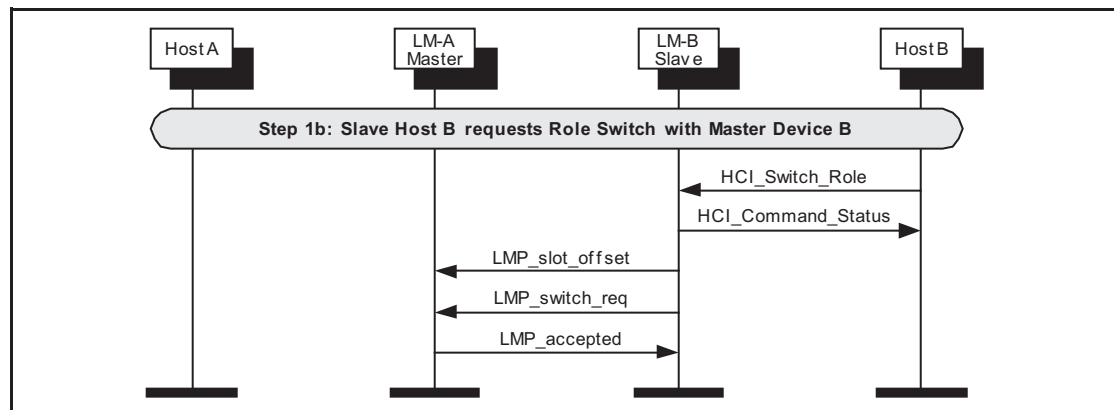


Figure 4.13: Slave requests role switch.

Step 2: The role switch is performed by doing the TDD switch and piconet switch. Finally an HCI_Role_Change event is sent on both sides. (See [Figure 4.14 on page 647](#))

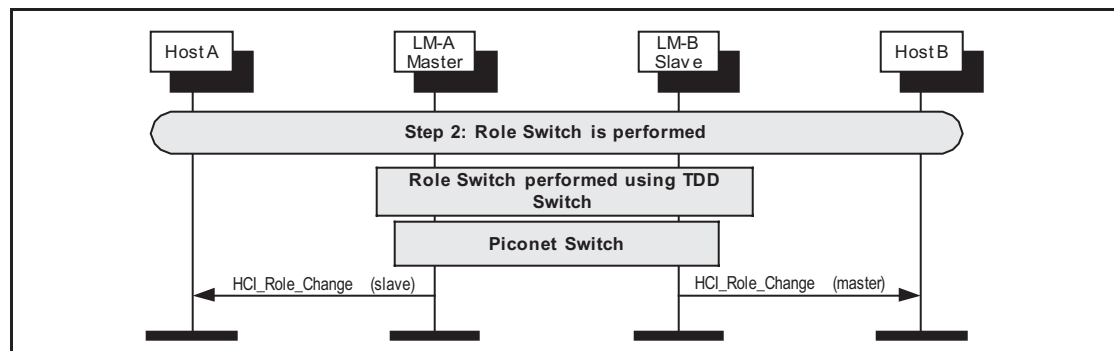


Figure 4.14: Role switch is performed.



5 SYNCHRONOUS CONNECTION ESTABLISHMENT AND DETACHMENT

5.1 SYNCHRONOUS CONNECTION SETUP

Using the `HCI_Setup_Synchronous_Connection` command, a host can add a synchronous logical channel to the link. A synchronous logical link can be provided by creating a SCO or an eSCO logical transport.

Note: An ACL Connection must be established before a synchronous connection can be created.

Step 1a: Master device requests a synchronous connection with a device.
(See [Figure 5.1 on page 649](#))

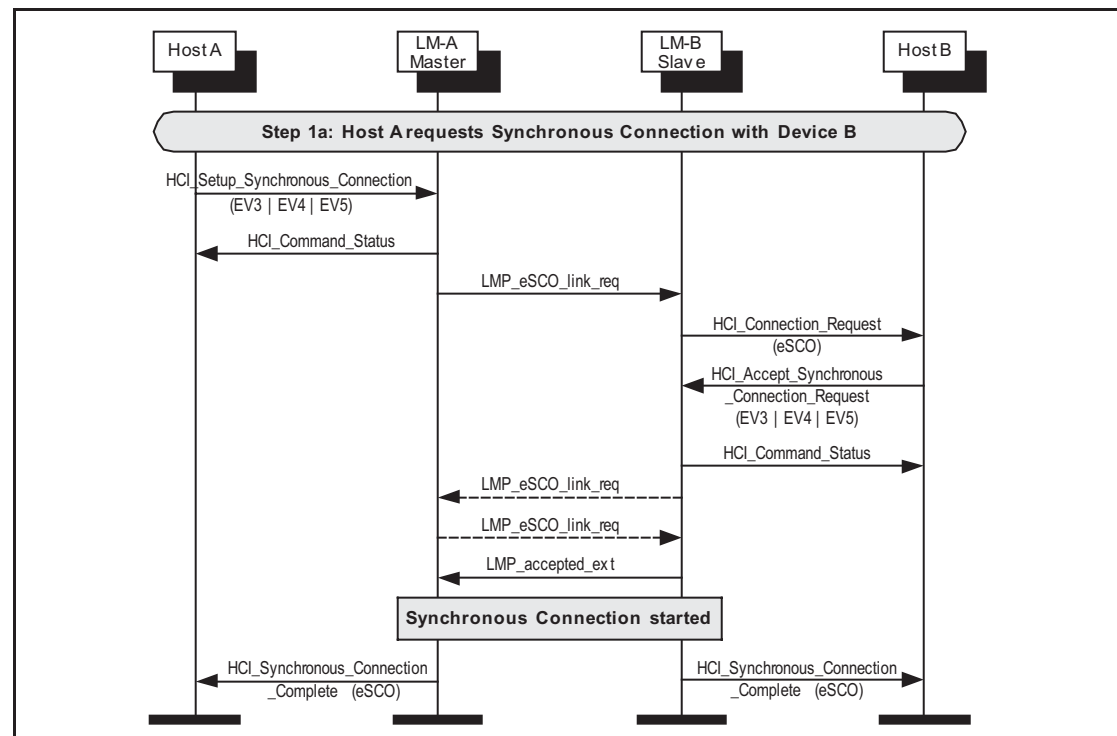


Figure 5.1: Master requests synchronous EV3, EV4 OR EV5 connection.

Step 1b: Slave device requests a synchronous connection with a device.
(See [Figure 5.2 on page 650](#))

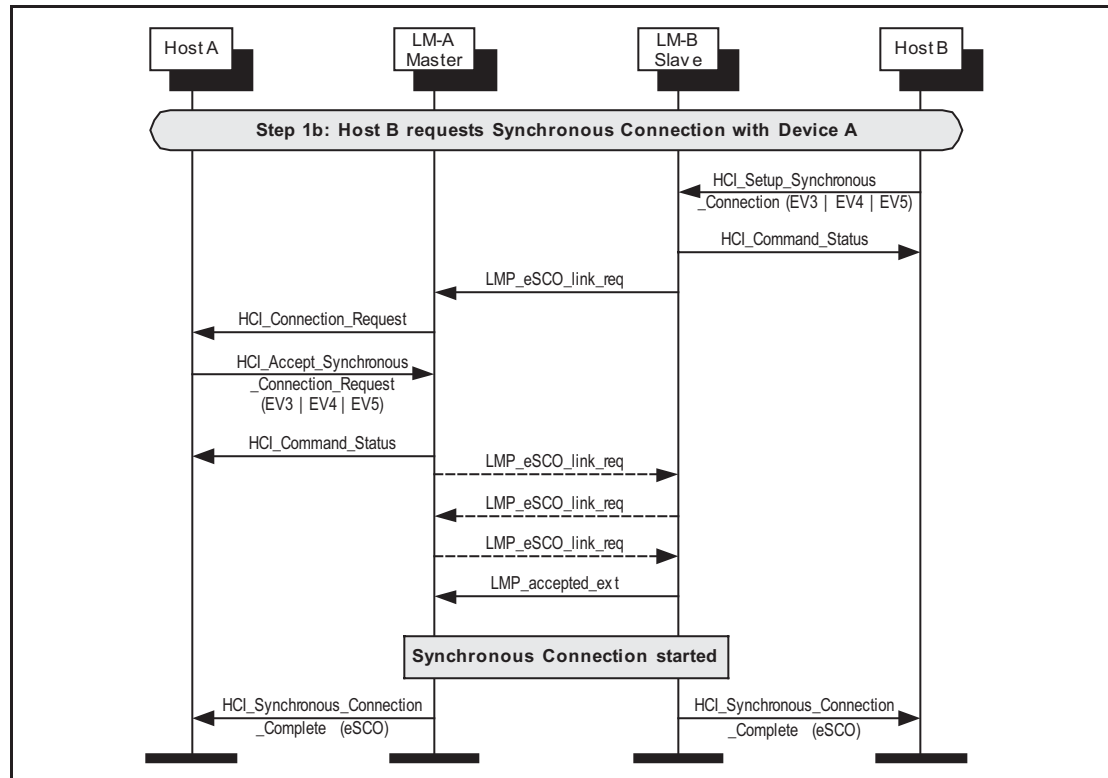


Figure 5.2: Slave requests synchronous EV3, EV4 OR EV5 connection.

Step 1c: Master device requests a SCO connection with a device.
(See [Figure 5.3 on page 650](#))

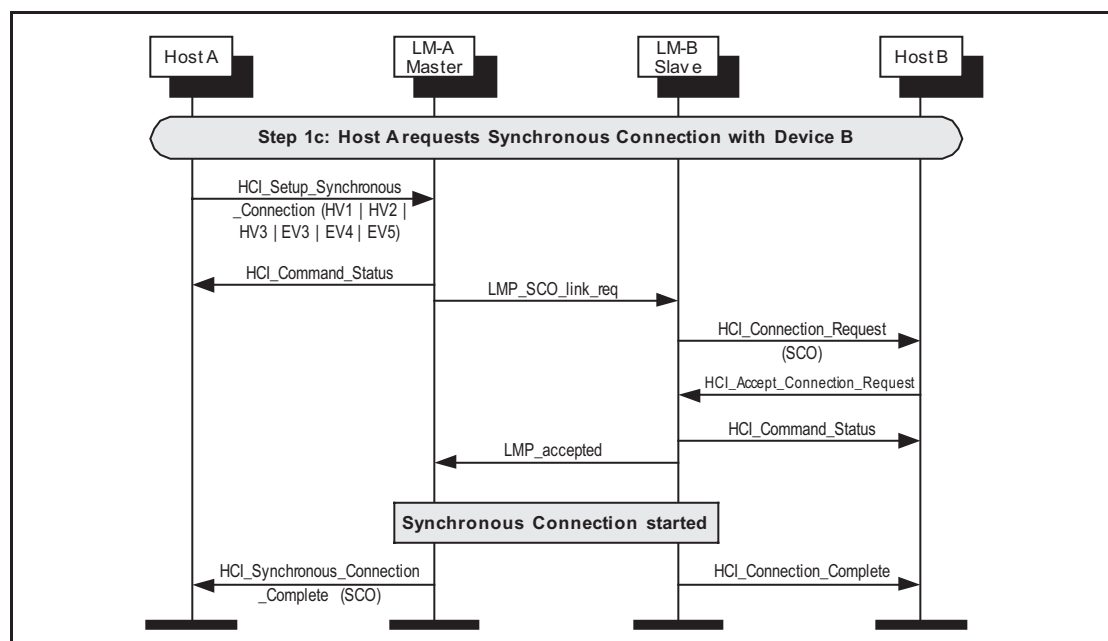


Figure 5.3: Master requests synchronous connection using SCO.

Step 1d: Master device requests a SCO connection with a device.
(See [Figure 5.4 on page 651](#))

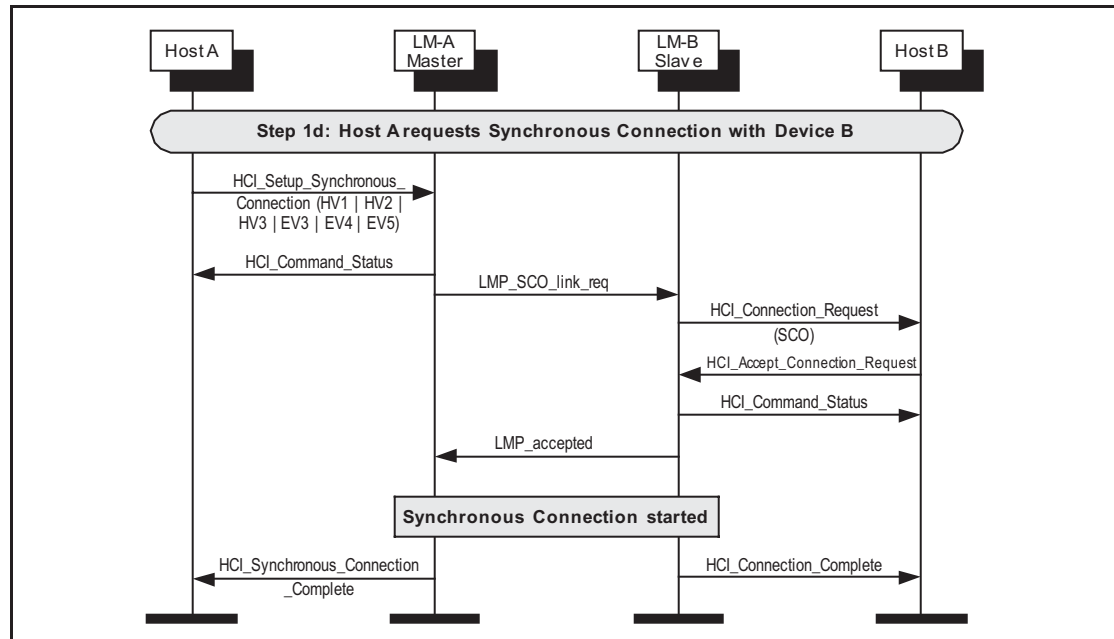


Figure 5.4: Master requests synchronous connection with legacy slave.

Step 1e: Host device requests a SCO connection with a device.
(See [Figure 5.5 on page 651](#))

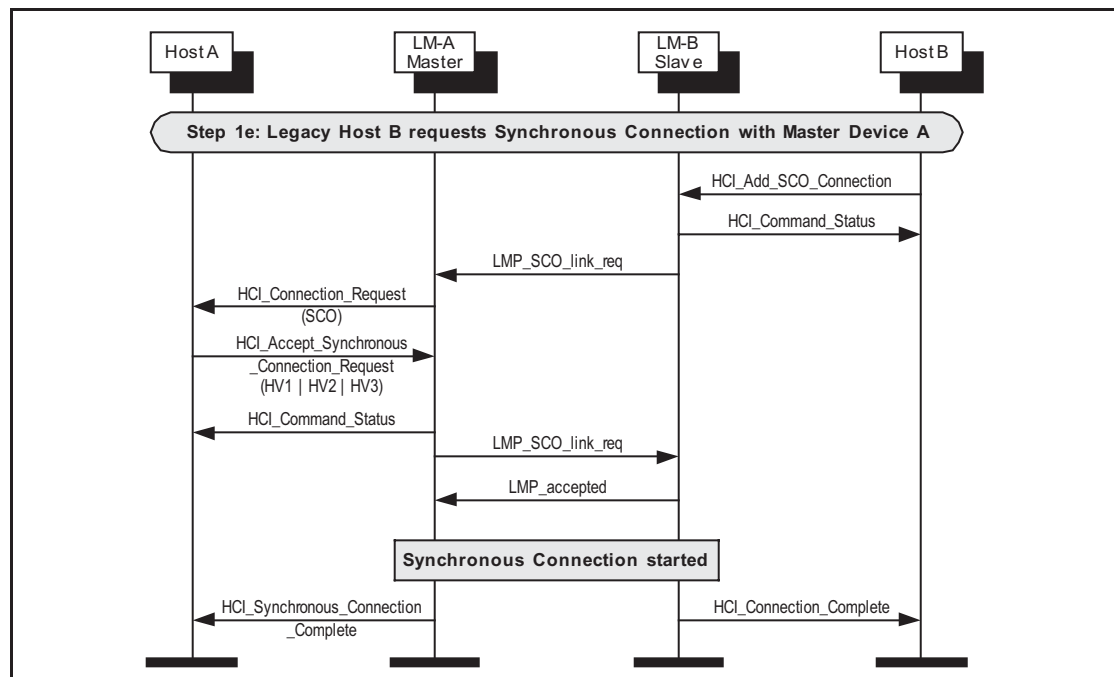


Figure 5.5: Any device that supports only SCO connections requests a synchronous connection with a device.

Step 2a: Master renegotiates eSCO connection (See [Figure 5.6 on page 652](#)).

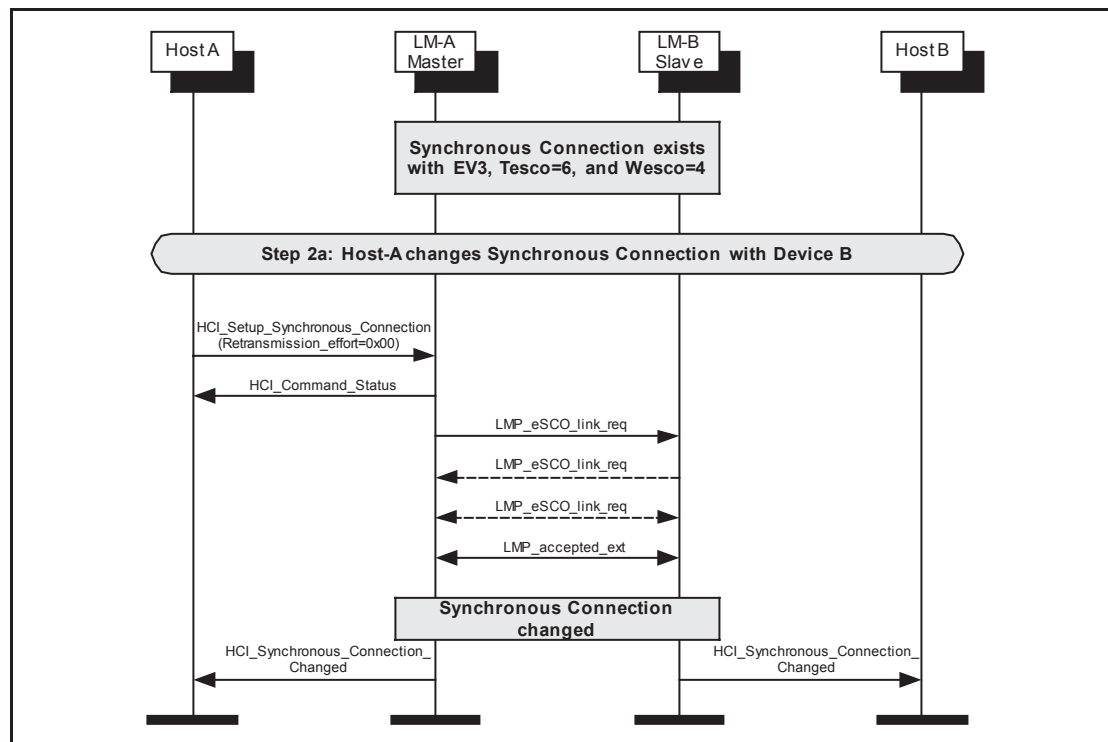


Figure 5.6: Master renegotiates eSCO connection.

Step 2b: Slave renegotiates eSCO connection (See [Figure 5.7 on page 652](#)).

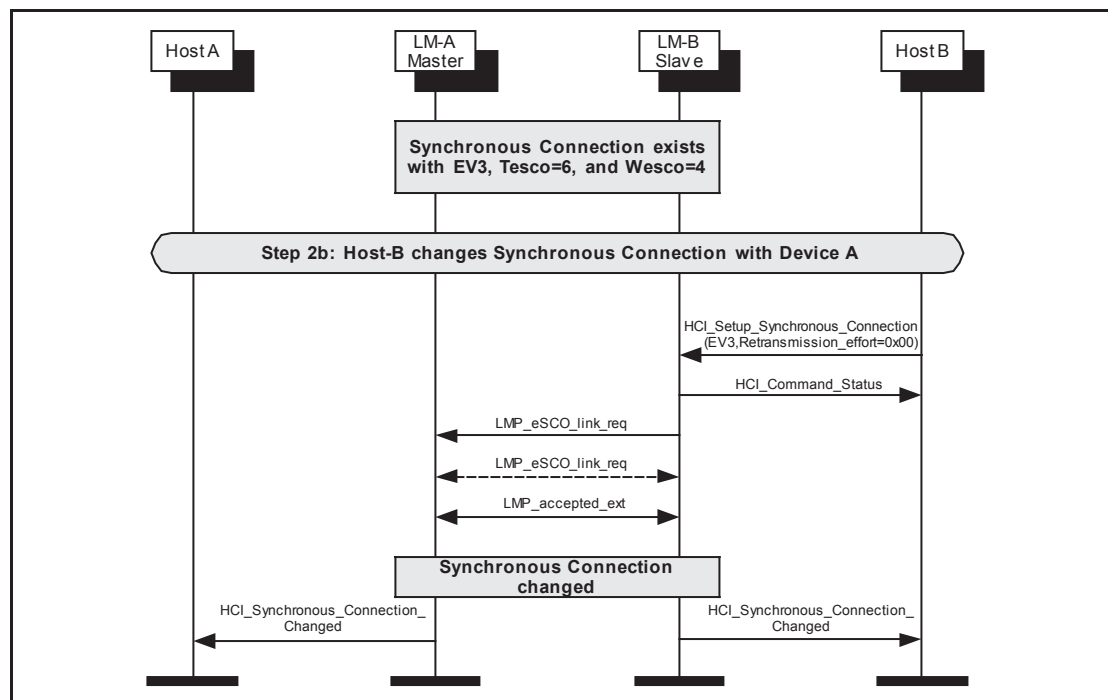


Figure 5.7: Slave renegotiates eSCO connection.

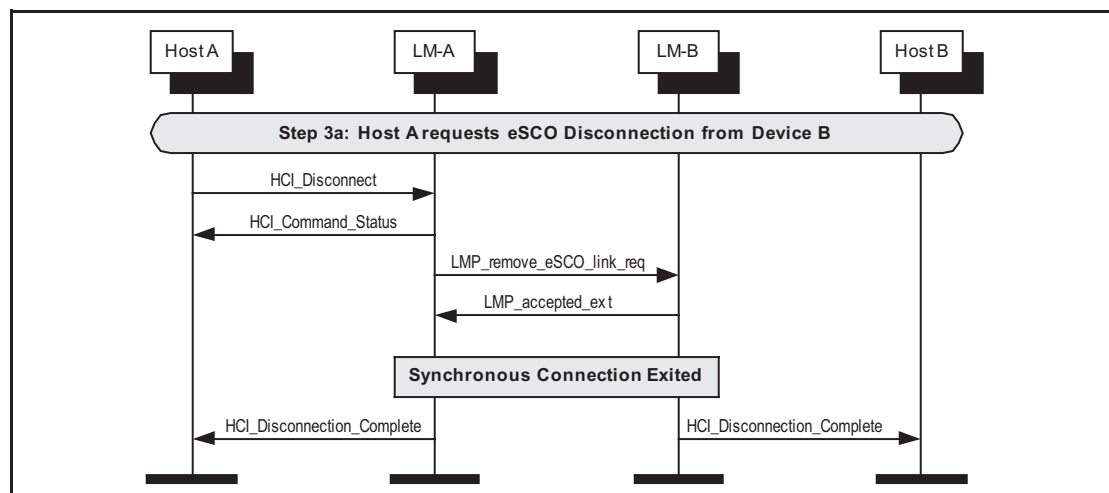
Step 3a: eSCO Disconnection. (See [Figure 5.8 on page 653](#))


Figure 5.8: Synchronous disconnection of eSCO connection.

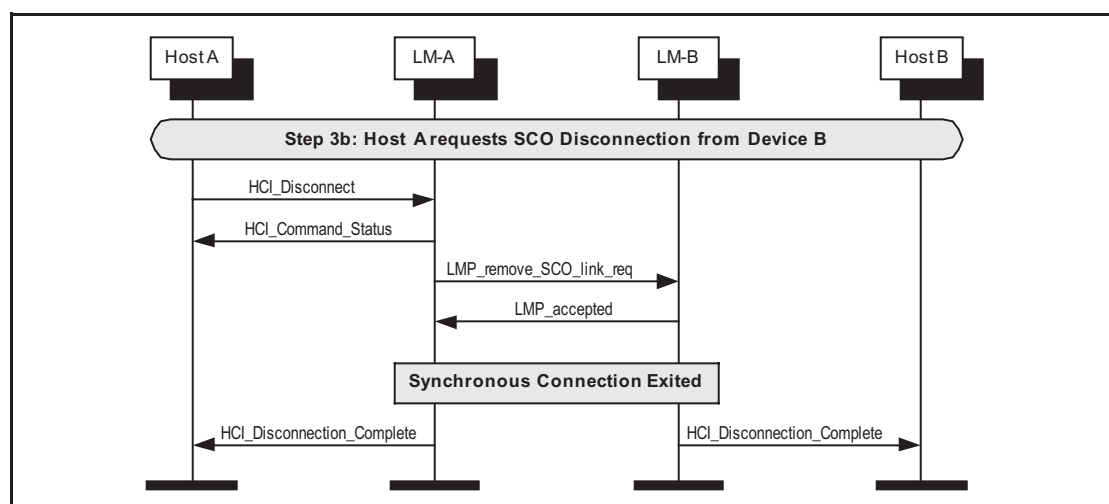
Step 3b: SCO Disconnection. (See [Figure 5.9 on page 653](#))


Figure 5.9: Synchronous disconnection of SCO connection.



6 SNIFF, HOLD AND PARK

Entry into sniff mode, hold mode or park state requires an established ACL Connection.

6.1 SNIFF MODE

The HCI_Sniff_Mode command is used to enter sniff mode. The HCI_Exit_Sniff_Mode command is used to exit sniff mode.

Step 1: Host requests to enter sniff mode. Multiple LMP_sniff_req PDUs may be sent as the parameters for sniff mode are negotiated. (See [Figure 6.1 on page 655](#))

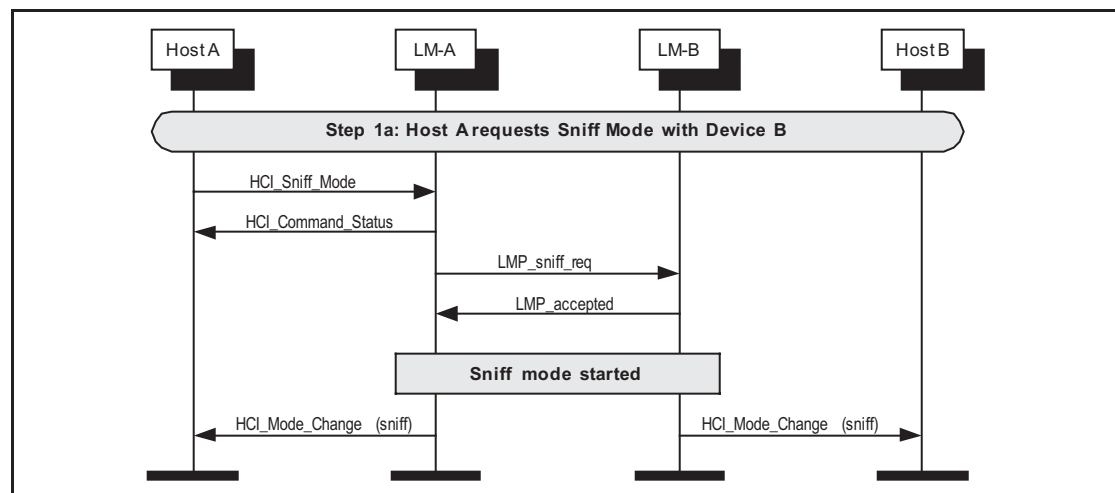


Figure 6.1: Sniff mode request.

Step 2: Host requests to exit sniff mode. (See [Figure 6.2 on page 655](#))

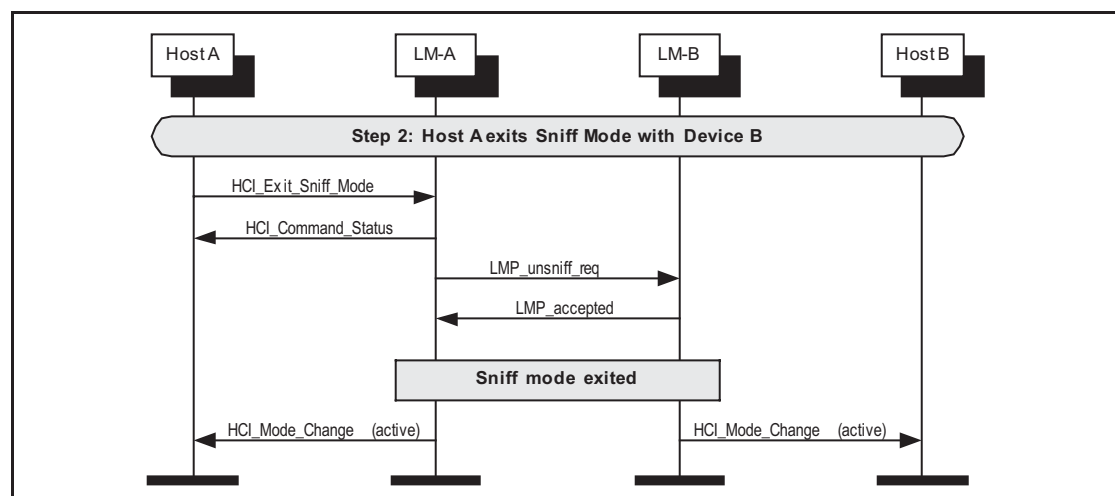


Figure 6.2: Exit sniff mode request.

6.2 HOLD MODE

The `HCI_Hold_Mode` command can be used to place a device into hold mode. The Controller may do this by either negotiating the hold mode parameters or forcing hold mode. Hold mode will automatically end after the negotiated length of time.

Step 1a: A host requests hold mode. (See [Figure 6.3 on page 656](#))

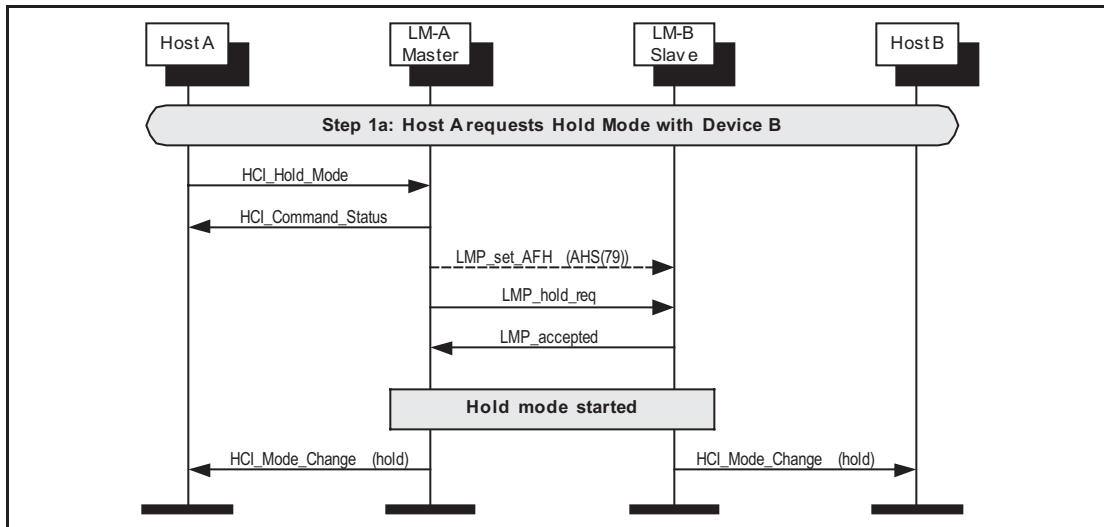


Figure 6.3: Hold request.

Step 1b: A host may force hold mode. (See [Figure 6.4 on page 656](#))

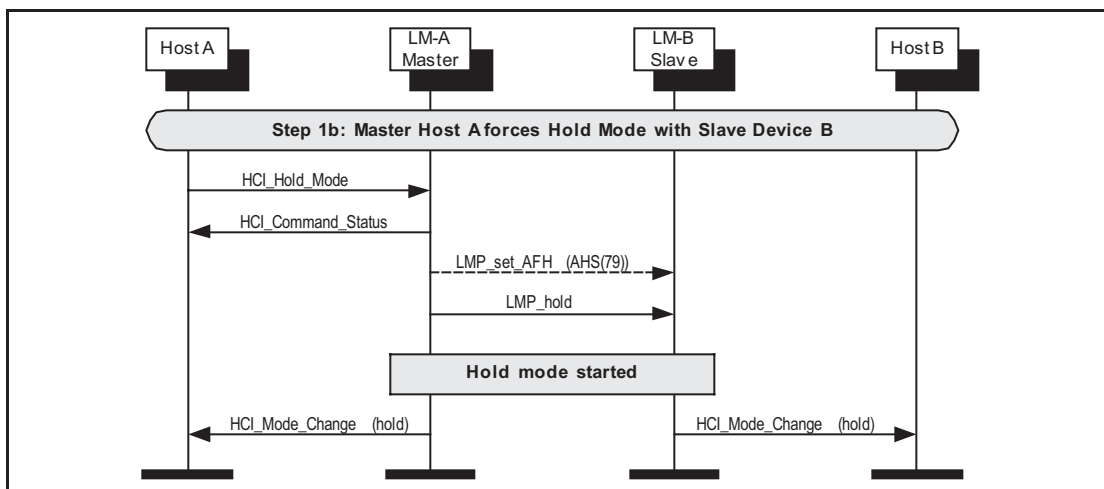


Figure 6.4: Master forces hold mode.

Step 1c: A slave device requests hold mode. (See [Figure 6.5 on page 657](#))

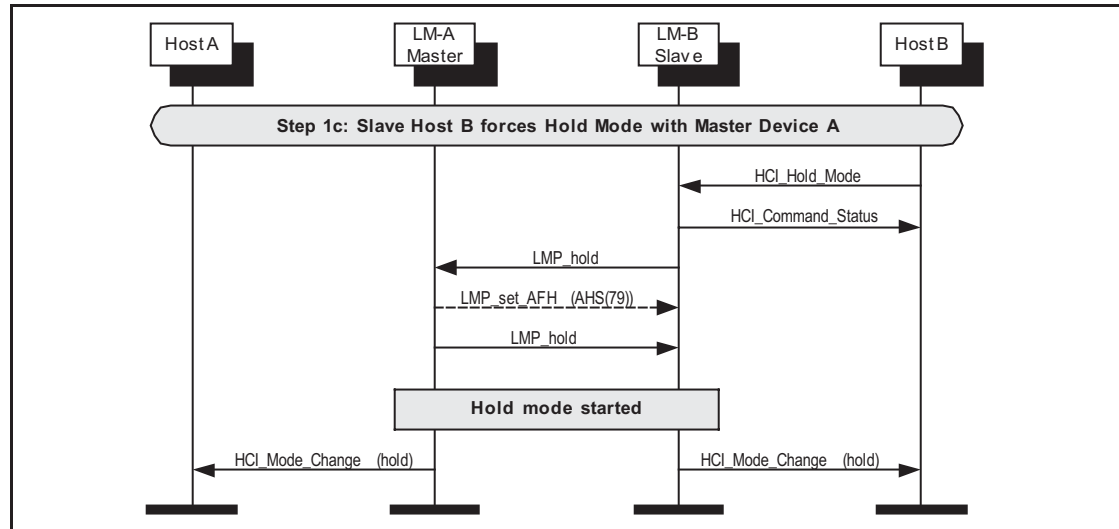


Figure 6.5: Slave forces hold mode.

Step 2: When hold mode completes the hosts are notified using the **HCI_Mode_Change** event. (See [Figure 6.6 on page 657](#))

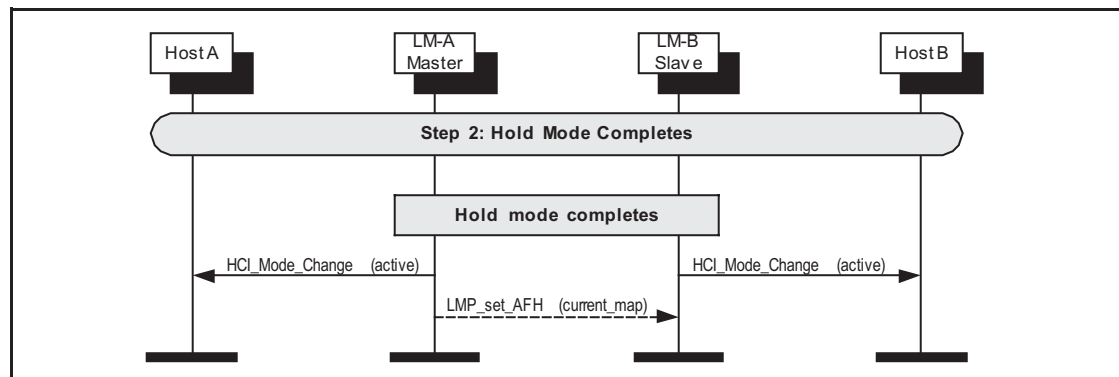


Figure 6.6: Hold mode completes.

6.3 PARK STATE

Park state can be entered by using the HCI_Park_State command.

Step 1a: The master requests to place the slave in the park state. Before sending the LMP_park_req PDU, the master may disable AFH by setting the connection into AHS(79). (See [Figure 6.7 on page 658](#))

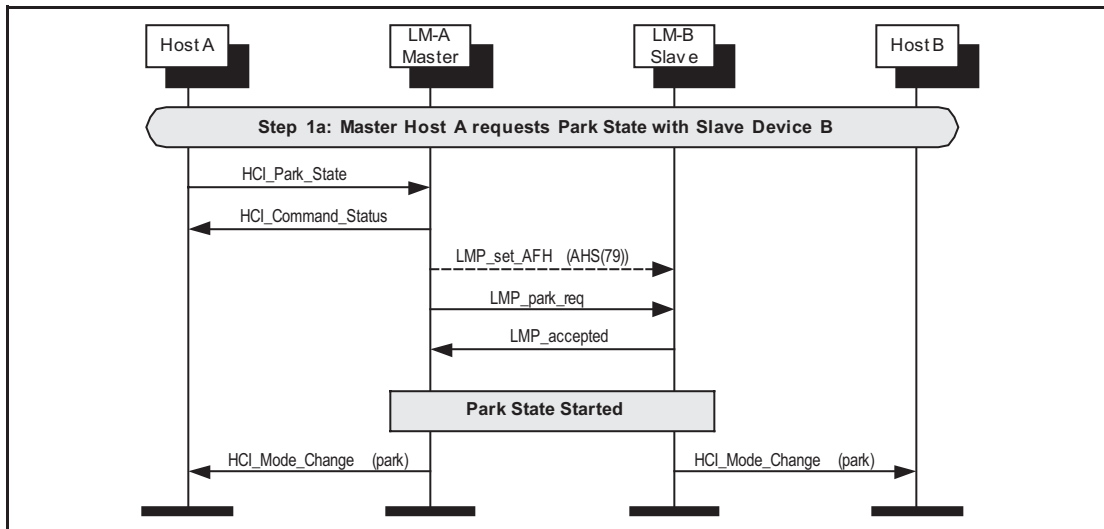


Figure 6.7: Park state request from master.

Step 1b: The slave requests to be placed in the park state. Before sending the LMP_park_req PDU back to the slave, the master may disable AFH by setting the connection into AHS(79). (See [Figure 6.8 on page 658](#))

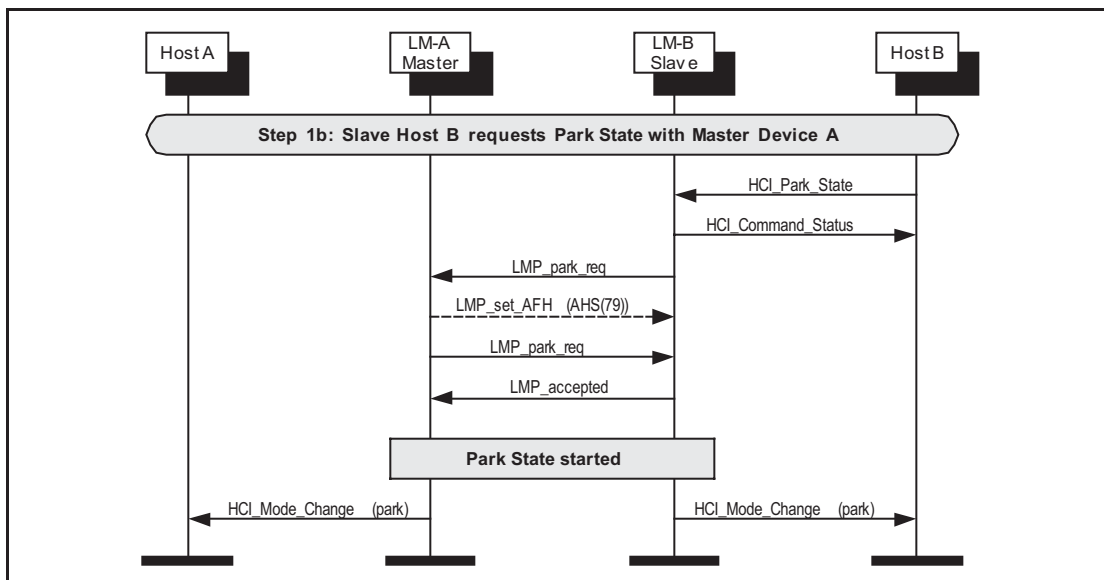


Figure 6.8: Park state request from slave.

Step 2: When in the park state, a slave still needs to be unparked for link supervision purposes. The master sends an LMP_unpark_PM_ADDR_req PDU or an LMP_unpark_BD_ADDR_req PDU to the slave during the beacon. Only the PM_ADDR version is illustrated in the figure. (See [Figure 6.9 on page 659](#))

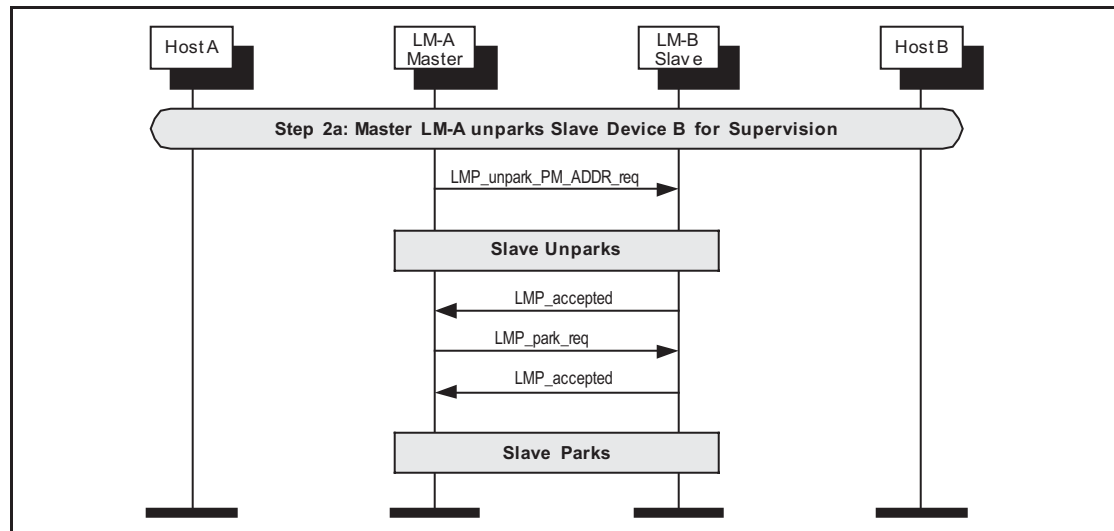


Figure 6.9: Master un parks slave for supervision.

Step 3a: A master may unpark a slave to exit park state. The master should re-enable AFH by setting the current AFH channel map to the unparked slave. (See [Figure 6.10 on page 659](#))

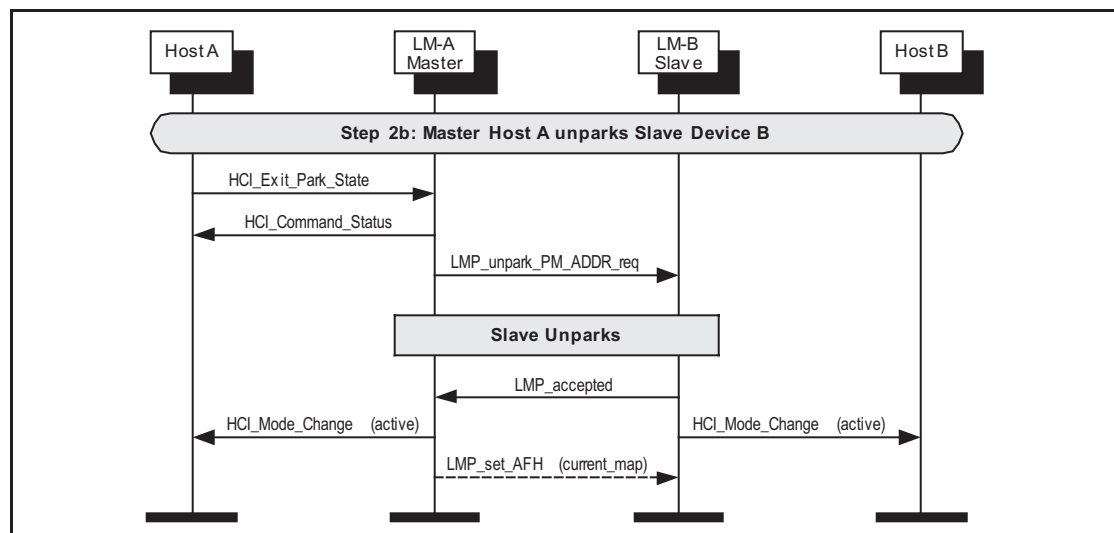


Figure 6.10: Master exits park state with slave.

Step 3b: A slave may request to be unparked by sending a message in an access window. It will then receive instructions from the master to unpark. The master should re-enable AFH by setting the current AFH channel map to the unparked slave. (See [Figure 6.11 on page 660](#))

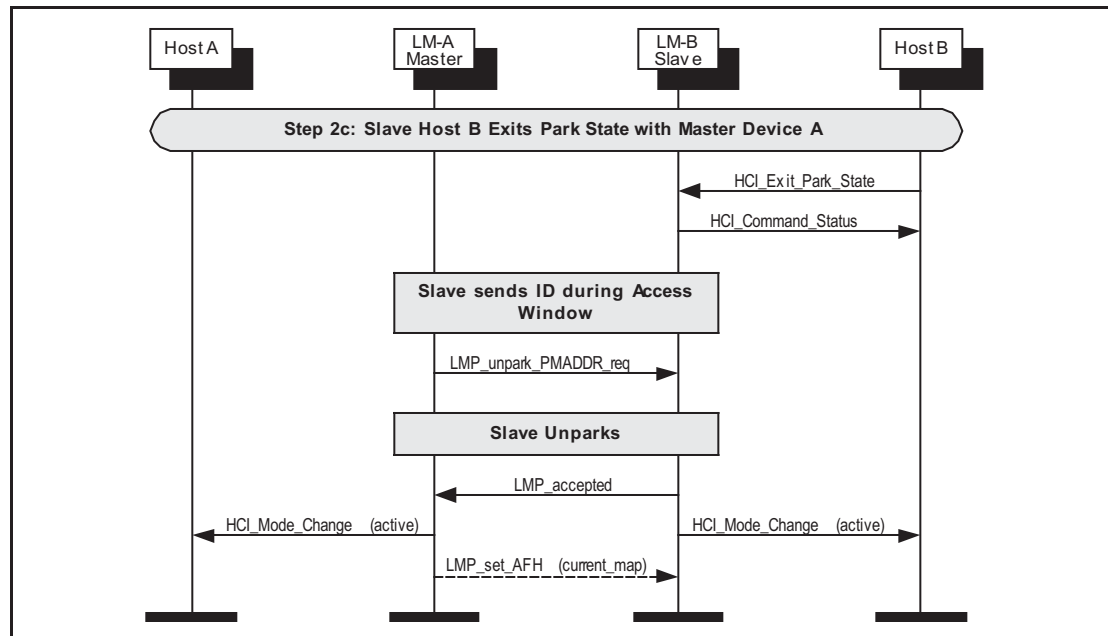


Figure 6.11: Slave exits park state with master.

7 BUFFER MANAGEMENT, FLOW CONTROL

Buffer management is very important for resource limited devices. This can be achieved on the Host Controller Interface using the HCI_Read_Buffer_Size command, and the HCI_Number_Of_Completed_Packets event, and the HCI_Set_Host_Controller_To_Host_Flow_Control, HCI_Host_Buffer_Size and HCI_Host_Number_Of_Completed_Packets commands.

Step 1: During initialization, the host reads the buffer sizes available in the Controller. When an HCI Data Packet has been transferred to the remote device, and a Baseband acknowledgement has been received for this data, then an HCI_Number_Of_Completed_Packets event will be generated. (See [Figure 7.1 on page 661](#))

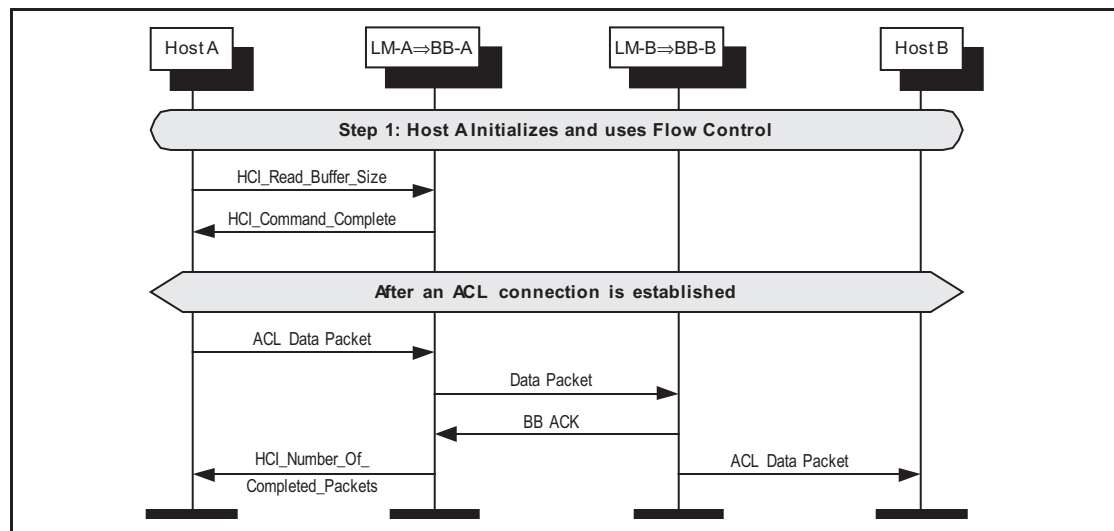


Figure 7.1: Host to Controller flow control.



Step 2: During initialization, the host notifies the Controller that host flow control shall be used, and then the host buffer sizes available. When a data packet has been received from a remote device, an HCI Data Packet is sent to the host from the Controller, and the host shall acknowledge its receipt by sending HCI_Host_Number_Of_Completed_Packets. (See [Figure 7.2 on page 662](#))

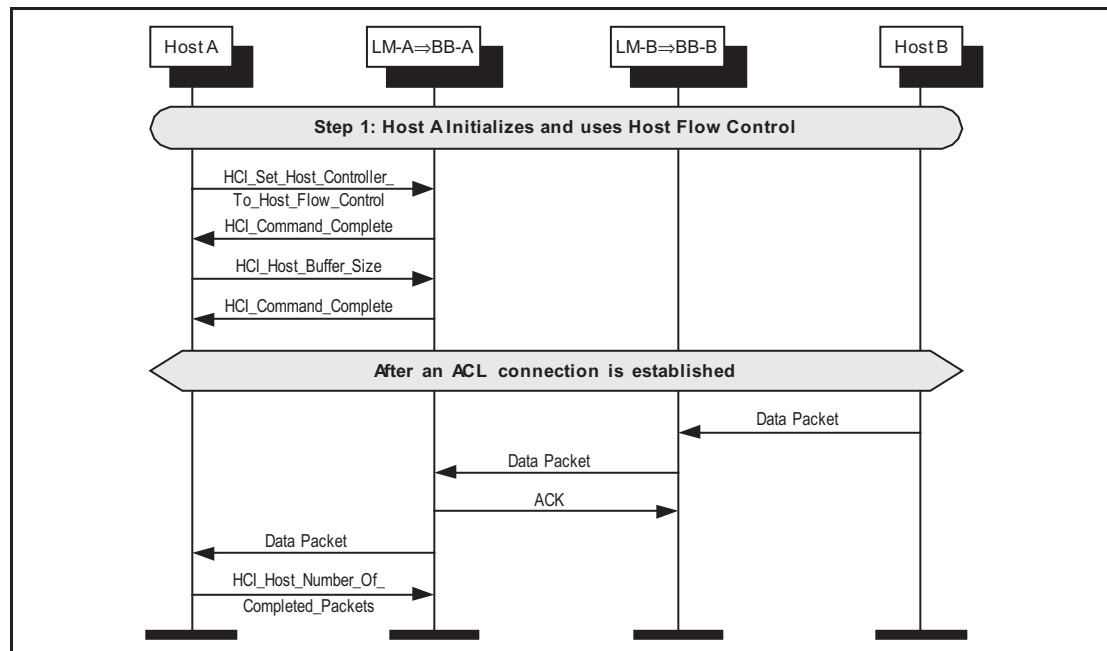


Figure 7.2: Controller to Host flow control.

8 LOOPBACK MODE

The loopback modes are used for testing of a device only.

8.1 LOCAL LOOPBACK MODE

The local loopback mode is used to loopback received HCI Commands, and HCI ACL and HCI Synchronous packets sent from the Host to the Controller.

Step 1: The host enters local loopback mode. Four connection complete events are generated and then a command complete event.
(See [Figure 8.1 on page 663](#))

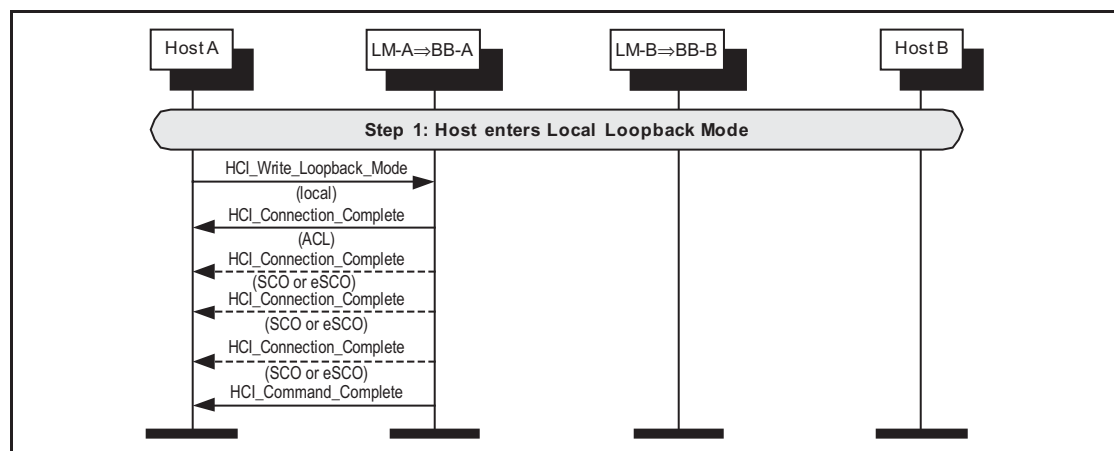


Figure 8.1: Entering local loopback mode.

Step 2a: The host sending HCI Data Packet will receive the exact same data back in HCI Data Packets from the Controller. (See [Figure 8.2 on page 663](#))

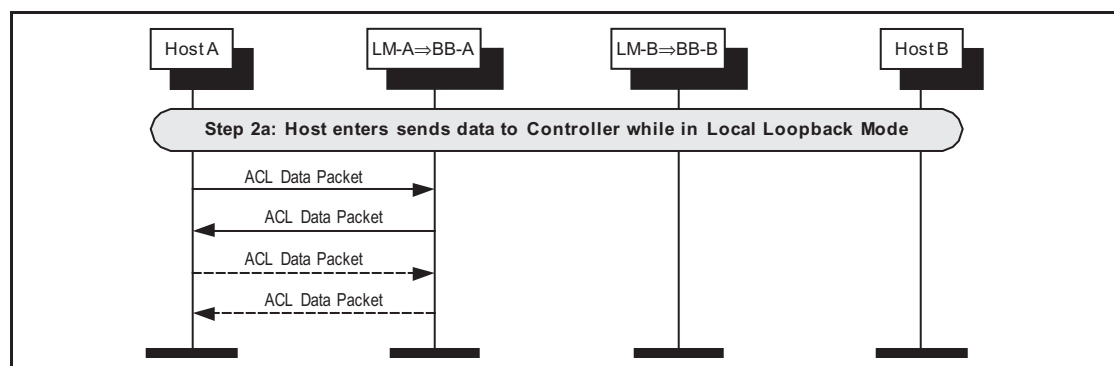


Figure 8.2: Looping back data in local loopback mode.

Step 2b: The host sending most HCI Command Packets to the Controller will receive an HCI_Loopback_Command event with the contents of the HCI Command Packet in the payload. (See [Figure 8.3 on page 664](#))

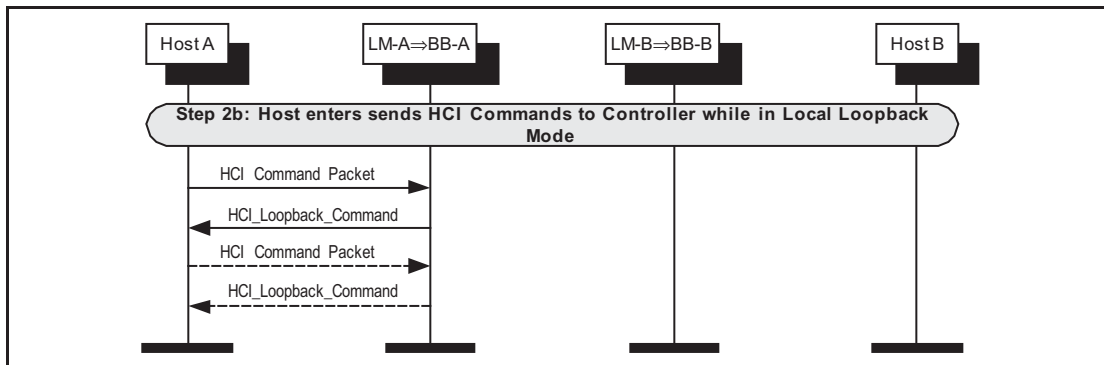


Figure 8.3: Looping back commands in local loopback mode.

Step 3: The host exits local loopback mode. Multiple disconnection complete events are generated before the command complete event. (See [Figure 8.4 on page 664](#))

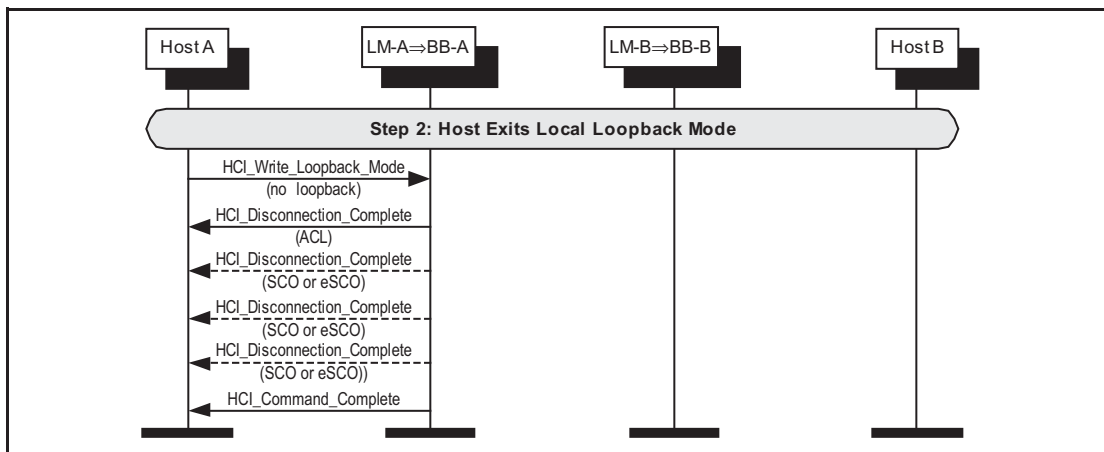


Figure 8.4: Exiting local loopback mode.

8.2 REMOTE LOOPBACK MODE

The remote loopback mode is used to lookback data to a remote device over the air.

Step 1: The remote host first sets up an connection to the local device. The local device then enables remote loopback. (See [Figure 8.5 on page 665](#))

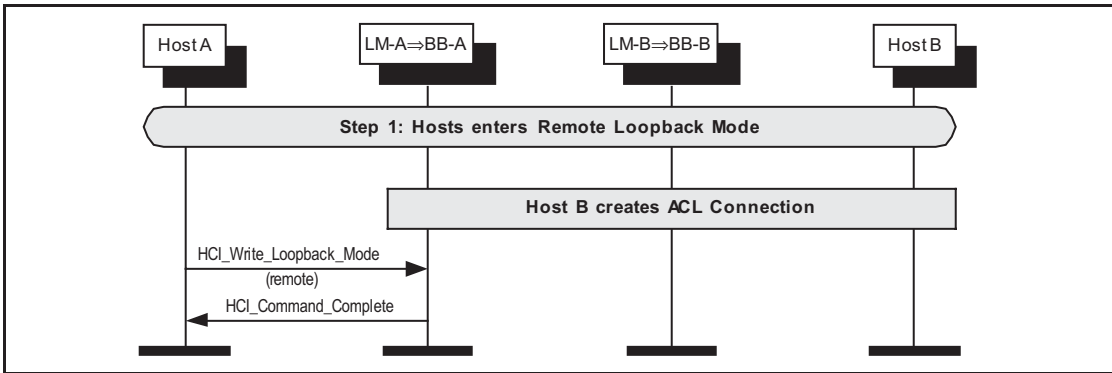


Figure 8.5: Entering remote loopback mode.

Step 2: Any data received from the remote host will be loopbacked in the Controller of the local device. (See [Figure 8.6 on page 665](#))

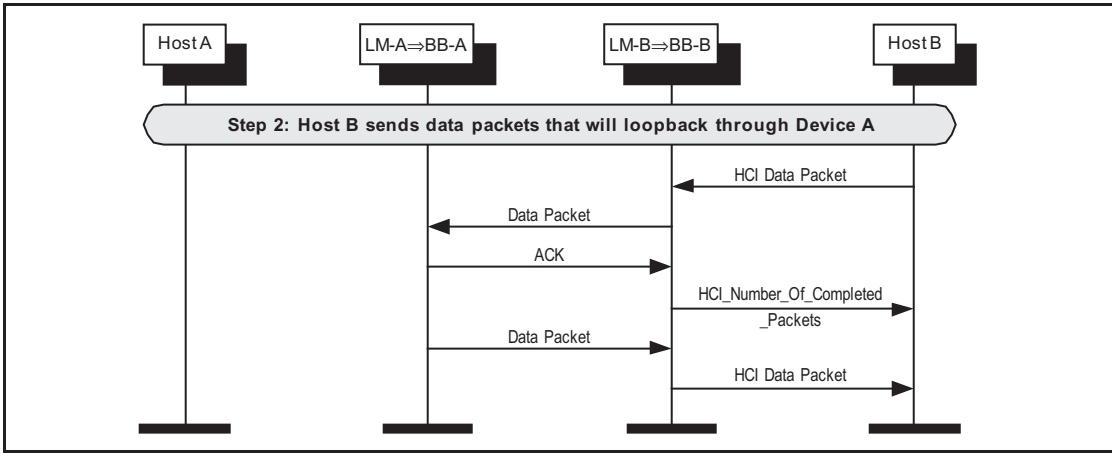


Figure 8.6: Looping back data in Remote Loopback Mode.



Step 3: The local host exits remote loopback mode. Any connections can then be disconnected by the remote device. (See [Figure 8.7 on page 666](#))

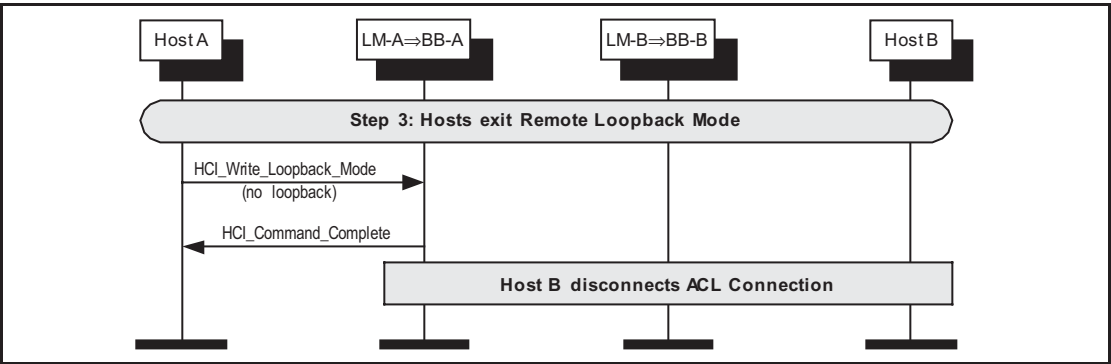


Figure 8.7: Exiting remote loopback mode.


9 LIST OF FIGURES

| | | |
|--------------|--|-----|
| Figure 1.1: | Example MSC. | 620 |
| Figure 2.1: | Remote name request. | 621 |
| Figure 2.2: | Remote name request if no current baseband connection. | 621 |
| Figure 2.3: | Remote name request with baseband connection. | 622 |
| Figure 2.4: | Host A starts inquiry procedure. | 622 |
| Figure 2.5: | LM-A performs inquiry and reports result. | 623 |
| Figure 2.6: | Host A cancels inquiry. | 623 |
| Figure 2.7: | LM-A terminates current inquiry. | 624 |
| Figure 2.8: | Host A starts periodic inquiry. | 624 |
| Figure 2.9: | LM-A periodically performs an inquiry and reports result. | 625 |
| Figure 2.10: | LM-A terminates current inquiry. | 625 |
| Figure 2.11: | Host A decides to exit periodic inquiry. | 625 |
| Figure 3.1: | Overview diagram for connection setup. | 627 |
| Figure 3.2: | Host A requests connection with device B. | 628 |
| Figure 3.3: | LM-A and LM-B exchange features. | 628 |
| Figure 3.4: | LM-A requests host connection. | 628 |
| Figure 3.5: | Device B rejects connection request. | 629 |
| Figure 3.6: | Device B accepts connection request. | 629 |
| Figure 3.7: | Device B accepts connection requests as master. | 630 |
| Figure 3.8: | LM-A starts adaptive frequency hopping. | 630 |
| Figure 3.9: | Authentication initiated. | 631 |
| Figure 3.10: | Pairing during connection setup. | 632 |
| Figure 3.11: | Authentication during connection setup. | 633 |
| Figure 3.12: | Starting encryption during connection setup. | 633 |
| Figure 3.13: | LM-A and LM-B finishes connection setup. | 634 |
| Figure 3.14: | Host A decides to disconnect. | 634 |
| Figure 4.1: | Authentication requested. | 635 |
| Figure 4.2: | Encryption requested. | 636 |
| Figure 4.3: | Encryption off requested. | 636 |
| Figure 4.4: | Change connection link key. | 637 |
| Figure 4.5: | Change to master link key. | 638 |
| Figure 4.6: | Change to semi permanent link key. | 639 |
| Figure 4.7: | Read remote supported features. | 640 |
| Figure 4.8: | Read remote extended features. | 640 |
| Figure 4.9: | Read clock offset. | 641 |
| Figure 4.10: | Read remote version information. | 641 |
| Figure 4.11: | QoS flow specification. | 642 |
| Figure 4.12: | Master requests role switch. | 642 |
| Figure 4.13: | Slave requests role switch. | 643 |
| Figure 4.14: | Role switch is performed. | 643 |



| | | |
|--------------|--|-----|
| Figure 5.1: | Master requests synchronous EV3, EV4 OR EV5 connection. | 645 |
| Figure 5.2: | Slave requests synchronous EV3, EV4 OR EV5 connection. . | 646 |
| Figure 5.3: | Master requests synchronous connection using SCO. | 646 |
| Figure 5.4: | Master requests synchronous connection with legacy slave. . | 647 |
| Figure 5.5: | Any device that supports only SCO connections requests a synchronous connection with a device. 647 | |
| Figure 5.6: | Master renegotiates eSCO connection. | 648 |
| Figure 5.7: | Slave renegotiates eSCO connection. | 648 |
| Figure 5.8: | Synchronous disconnection of eSCO connection. | 649 |
| Figure 5.9: | Synchronous disconnection of SCO connection. | 649 |
| Figure 6.1: | Sniff mode request. | 651 |
| Figure 6.2: | Exit sniff mode request. | 651 |
| Figure 6.3: | Hold request. | 652 |
| Figure 6.4: | Master forces hold mode. | 652 |
| Figure 6.5: | Slave forces hold mode. | 653 |
| Figure 6.6: | Hold mode completes. | 653 |
| Figure 6.7: | Park state request from master. | 654 |
| Figure 6.8: | Park state request from slave. | 654 |
| Figure 6.9: | Master unparks slave for supervision. | 655 |
| Figure 6.10: | Master exits park state with slave. | 655 |
| Figure 6.11: | Slave exits park state with master. | 656 |
| Figure 7.1: | Host to Controller flow control. | 657 |
| Figure 7.2: | Controller to Host flow control. | 658 |
| Figure 8.1: | Entering local loopback mode. | 659 |
| Figure 8.2: | Looping back data in local loopback mode. | 659 |
| Figure 8.3: | Looping back commands in local loopback mode. | 660 |
| Figure 8.4: | Exiting local loopback mode. | 660 |
| Figure 8.5: | Entering remote loopback mode. | 661 |
| Figure 8.6: | Looping back data in Remote Loopback Mode. | 661 |
| Figure 8.7: | Exiting remote loopback mode. | 662 |

SAMPLE DATA



This appendix contains sample data for various parts of the Bluetooth baseband specification. All sample data are provided for reference purpose only; they are intended as a complement to the definitions provided elsewhere in the specification. They can be used to check the behavior of an implementation and avoid misunderstandings. Fulfilling these sample data is a necessary but not sufficient condition for an implementation to be fully Bluetooth compliant.

Sample Data





CONTENTS

| | | |
|----------|--|------------|
| 1 | Encryption Sample Data | 673 |
| 1.1 | Generating Kc' from Kc, | 673 |
| 1 | Encryption Sample Data | 673 |
| 1.2 | First Set of Sample Data | 676 |
| 1.3 | Second Set of Sample Data | 684 |
| 1.4 | Third Set of Samples | 692 |
| 1.5 | Fourth Set of Samples | 700 |
| 2 | Frequency Hopping Sample Data | 709 |
| 2.1 | First set | 710 |
| 2.2 | Second set | 716 |
| 2.3 | Third set | 722 |
| 3 | Access Code Sample Data | 729 |
| 4 | HEC and Packet Header Sample Data | 733 |
| 5 | CRC Sample Data | 735 |
| 6 | Complete Sample Packets | 737 |
| 6.1 | Example of DH1 Packet | 737 |
| 6.2 | Example of DM1 Packet | 738 |
| 7 | Whitening Sequence Sample Data | 739 |
| 8 | FEC Sample Data | 743 |
| 9 | Encryption Key Sample Data | 745 |
| 9.1 | Four Tests of E1 | 745 |
| 9.2 | Four Tests of E21 | 750 |
| 9.3 | Three Tests of E22 | 752 |
| 9.4 | Tests of E22 With Pin Augmenting | 754 |
| 9.5 | Four Tests of E3 | 764 |

Sample Data





1 ENCRYPTION SAMPLE DATA

This section contains four sets of sample data for the encryption process.

With respect to the functional description of the encryption engine in the Bluetooth baseband specification, the contents of registers and resulting concurrent values are listed as well. This by no means excludes different implementations (as far as they produce the same encryption stream) but is intended to describe the functional behavior.

In case of misunderstandings or inconsistencies, these sample data form the normative reference.

1.1 GENERATING KC' FROM KC,

where $Kc'(x) = g2(x)(Kc(x) \bmod g1(x))$.

Note: All polynomials are in hexadecimal notation.

'L' is the effective key length in bytes.

The notation 'p: [m]' implies that $\deg(p(x)) = m$.

| | | MSB | LSB |
|----------------|-------|-------------------------------------|-----|
| L = 1 | | | |
| g1: | [8] | 00000000 00000000 00000000 0000011d | |
| g2: | [119] | 00e275a0 abd218d4 cf928b9b bf6cb08f | |
| Kc: | | a2b230a4 93f281bb 61a85b82 a9d4a30e | |
| Kc mod g1: | [7] | 00000000 00000000 00000000 0000009f | |
| g2(Kc mod g1): | [126] | 7aa16f39 59836ba3 22049a7b 87f1d8a5 | |
| ----- | | | |
| L = 2 | | | |
| g1: | [16] | 00000000 00000000 00000000 0001003f | |
| g2: | [112] | 0001e3f6 3d7659b3 7f18c258 cff6efef | |
| Kc: | | 64e7df78 bb7ccaa4 61433123 5b3222ad | |
| Kc mod g1: | [12] | 00000000 00000000 00000000 00001ff0 | |
| g2(Kc mod g1): | [124] | 142057bb 0bceac4c 58bd142e 1e710a50 | |
| ----- | | | |
| L = 3 | | | |
| g1: | [24] | 00000000 00000000 00000000 010000db | |
| g2: | [104] | 000001be f66c6c3a b1030a5a 1919808b | |
| Kc: | | 575e5156 ba685dc6 112124ac edb2c179 | |
| Kc mod g1: | [23] | 00000000 00000000 00000000 008ddbcb | |
| g2(Kc mod g1): | [127] | d56d0adb 8216cb39 7fe3c591 1ff95618 | |
| ----- | | | |
| L = 4 | | | |
| g1: | [32] | 00000000 00000000 00000001 000000af | |
| g2: | [96] | 00000001 6ab89969 de17467f d3736ad9 | |
| Kc: | | 8917b4fc 403b6db2 1596b86d 1cb8adab | |
| Kc mod g1: | [31] | 00000000 00000000 00000000 aa1e78aa | |
| g2(Kc mod g1): | [127] | 91910128 b0e2f5ed a132a03e af3d8cda | |
| ----- | | | |

Sample Data



```
L = 5
g1:          [40]          00000000 00000000 00000100 00000039
g2:          [88]          00000000 01630632 91da50ec 55715247
Kc:          785c915b dd25b9c6 0102ab00 b6cd2a68
Kc mod g1:   [38]          00000000 00000000 0000007f 13d44436
g2(Kc mod g1): [126]       6fb5651c cb80c8d7 ea1ee56d f1ec5d02
-----

L = 6
g1:          [48]          00000000 00000000 00010000 00000291
g2:          [77]          00000000 00002c93 52aa6cc0 54468311
Kc:          5e77d19f 55ccd7d5 798f9a32 3b83e5d8
Kc mod g1:   [47]          00000000 00000000 000082eb 4af213ed
g2(Kc mod g1): [124]       16096bcb afcf8def 1d226a1b 4d3f9a3d
-----
```


Sample Data

L = 7

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [56] | 00000000 | 00000000 | 01000000 | 00000095 |
| g2: | [71] | 00000000 | 000000b3 | f7fffce2 | 79f3a073 |
| Kc: | | 05454e03 | 8ddcfbe3 | ed024b2d | 92b7f54c |
| Kc mod g1: | [55] | 00000000 | 00000000 | 0095b8a4 | 8eb816da |
| g2(Kc mod g1): | [126] | 50f9c0d4 | e3178da9 | 4a09fe0d | 34f67b0e |

L = 8

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [64] | 00000000 | 00000001 | 00000000 | 0000001b |
| g2: | [63] | 00000000 | 00000000 | a1ab815b | c7ec8025 |
| Kc: | | 7ce149fc | f4b38ad7 | 2a5d8a41 | eb15ba31 |
| Kc mod g1: | [63] | 00000000 | 00000000 | 8660806c | 1865deec |
| g2(Kc mod g1): | [126] | 532c36d4 | 5d0954e0 | 922989b6 | 826f78dc |

L = 9

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [72] | 00000000 | 00000100 | 00000000 | 00000609 |
| g2: | [49] | 00000000 | 00000000 | 0002c980 | 11d8b04d |
| Kc: | | 5eef7ca | 84fc2782 | 9c051726 | 3df6f36e |
| Kc mod g1: | [71] | 00000000 | 00000083 | 58ccb7d0 | b95d3c71 |
| g2(Kc mod g1): | [120] | 016313f6 | 0d3771cf | 7f8e4bb9 | 4aa6827d |

L = 10

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [80] | 00000000 | 00010000 | 00000000 | 00000215 |
| g2: | [42] | 00000000 | 00000000 | 0000058e | 24f9a4bb |
| Kc: | | 7b13846e | 88beb4de | 34e7160a | fd44dc65 |
| Kc mod g1: | [79] | 00000000 | 0000b4de | 34171767 | f36981c3 |
| g2(Kc mod g1): | [121] | 023bc1ec | 34a0029e | f798dcfb | 618ba58d |

L = 11

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [88] | 00000000 | 01000000 | 00000000 | 0000013b |
| g2: | [35] | 00000000 | 00000000 | 0000000c | a76024d7 |
| Kc: | | bda6de6c | 6e7d757e | 8dfe2d49 | 9a181193 |
| Kc mod g1: | [86] | 00000000 | 007d757e | 8dfe88aa | 2fcee371 |
| g2(Kc mod g1): | [121] | 022e08a9 | 3aa51d8d | 2f93fa78 | 85cc1f87 |

L = 12

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [96] | 00000001 | 00000000 | 00000000 | 000000dd |
| g2: | [28] | 00000000 | 00000000 | 00000000 | 1c9c26b9 |
| Kc: | | e6483b1c | 2cdb1040 | 9a658f97 | c4efd90d |
| Kc mod g1: | [93] | 00000000 | 2cdb1040 | 9a658fd7 | 5b562e41 |
| g2(Kc mod g1): | [121] | 030d752b | 216fe29b | b880275c | d7e6f6f9 |

L = 13

| | | | | | |
|----------------|-------|----------|----------|----------|----------|
| g1: | [104] | 00000100 | 00000000 | 00000000 | 0000049d |
| g2: | [21] | 00000000 | 00000000 | 00000000 | 0026d9e3 |
| Kc: | | d79d281d | a2266847 | 6b223c46 | dc0ab9ee |
| Kc mod g1: | [100] | 0000001d | a2266847 | 6b223c45 | e1fc5fa6 |
| g2(Kc mod g1): | [121] | 03f11138 | 9cebf919 | 00b93808 | 4ac158aa |

Sample Data

L = 14

```

g1:          [112]      00010000 00000000 00000000 0000014f
g2:          [14]       00000000 00000000 00000000 00004377
Kc:          cad9a65b 9fca1c1d a2320fcf 7c4ae48e
Kc mod g1:   [111]      0000a65b 9fca1c1d a2320fcf 7cb6a909
g2(Kc mod g1): [125]    284840fd f1305f3c 529f5703 76adf7cf
-----

```

L = 15

```

g1:          [120]      01000000 00000000 00000000 000000e7
g2:          [7]        00000000 00000000 00000000 00000089
Kc:          21f0cc31 049b7163 d375e9e1 06029809
Kc mod g1:   [119]      00f0cc31 049b7163 d375e9e1 0602840e
g2(Kc mod g1): [126]    7f10b53b 6df84b94 f22e566a 3754a37e
-----

```

L = 16

```

g1:          [128]      00000001 00000000 00000000 00000000 00000000
g2:          [0]        00000000 00000000 00000000 00000001
Kc:          35ec8fc3 d50ccd32 5f2fd907 bde206de
Kc mod g1:   [125]      35ec8fc3 d50ccd32 5f2fd907 bde206de
g2(Kc mod g1): [125]    35ec8fc3 d50ccd32 5f2fd907 bde206de
-----

```

1.2 FIRST SET OF SAMPLE DATA

Initial values for the key, pan address and clock

```

K'c1[0] = 00  K'c1[1] = 00  K'c1[2] = 00  K'c1[3] = 00
K'c1[4] = 00  K'c1[5] = 00  K'c1[6] = 00  K'c1[7] = 00
K'c1[8] = 00  K'c1[9] = 00  K'c1[10] = 00  K'c1[11] = 00
K'c1[12] = 00  K'c1[13] = 00  K'c1[14] = 00  K'c1[15] = 00

```

```

Addr1[0] = 00  Addr1[1] = 00  Addr1[2] = 00
Addr1[3] = 00  Addr1[4] = 00  Addr1[5] = 00

```

```

CL1[0] = 00  CL1[1] = 00  CL1[2] = 00  CL1[3] = 00

```

```

=====
Fill LFSRs with initial data
=====

```

| t | clk# | LFSR1 | LFSR2 | LFSR3 | LFSR4 | X1 | X2 | X3 | X4 | Z | C[t+1] | C[t] | C[t-1] |
|---|------|----------|-----------|------------|-------------|----|----|----|----|---|--------|------|--------|
| 0 | 0 | 0000000* | 00000000* | 000000000* | 0000000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 1 | 1 | 0000000* | 00000001* | 000000000* | 0000000001* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 2 | 2 | 0000000* | 00000002* | 000000000* | 0000000003* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 3 | 3 | 0000000* | 00000004* | 000000000* | 0000000007* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 4 | 4 | 0000000* | 00000008* | 000000000* | 000000000E* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 5 | 5 | 0000000* | 00000010* | 000000000* | 000000001C* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 6 | 6 | 0000000* | 00000020* | 000000000* | 0000000038* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|----|----|----------|-----------|------------|-------------|---|---|---|---|---|----|----|----|
| 7 | 7 | 0000000* | 00000040* | 000000000* | 0000000070* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 8 | 8 | 0000000* | 00000080* | 000000000* | 00000000E0* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 9 | 9 | 0000000* | 00000100* | 000000000* | 00000001C0* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 10 | 10 | 0000000* | 00000200* | 000000000* | 0000000380* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 11 | 11 | 0000000* | 00000400* | 000000000* | 0000000700* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 12 | 12 | 0000000* | 00000800* | 000000000* | 0000000E00* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 13 | 13 | 0000000* | 00001000* | 000000000* | 0000001C00* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 14 | 14 | 0000000* | 00002000* | 000000000* | 0000003800* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 15 | 15 | 0000000* | 00004000* | 000000000* | 0000007000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 16 | 16 | 0000000* | 00008000* | 000000000* | 000000E000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 17 | 17 | 0000000* | 00010000* | 000000000* | 000001C000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 18 | 18 | 0000000* | 00020000* | 000000000* | 0000038000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 19 | 19 | 0000000* | 00040000* | 000000000* | 0000070000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 20 | 20 | 0000000* | 00080000* | 000000000* | 00000E0000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 21 | 21 | 0000000* | 00100000* | 000000000* | 00001C0000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 22 | 22 | 0000000* | 00200000* | 000000000* | 0000380000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 23 | 23 | 0000000* | 00400000* | 000000000* | 0000700000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 24 | 24 | 0000000* | 00800000* | 000000000* | 0000E00000* | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 25 | 25 | 0000000* | 01000000* | 000000000* | 0001C00000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 26 | 26 | 0000000 | 02000000* | 000000000* | 0003800000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 27 | 27 | 0000000 | 04000000* | 000000000* | 0007000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 28 | 28 | 0000000 | 08000000* | 000000000* | 000E000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 29 | 29 | 0000000 | 10000000* | 000000000* | 001C000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 30 | 30 | 0000000 | 20000000* | 000000000* | 0038000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 31 | 31 | 0000000 | 40000000* | 000000000* | 0070000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 32 | 32 | 0000000 | 00000001 | 000000000* | 00E0000000* | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 33 | 33 | 0000000 | 00000002 | 000000000* | 01C0000000* | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 34 | 34 | 0000000 | 00000004 | 000000000 | 0380000000* | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 35 | 35 | 0000000 | 00000008 | 000000000 | 0700000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 36 | 36 | 0000000 | 00000010 | 000000000 | 0E00000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 37 | 37 | 0000000 | 00000020 | 000000000 | 1C00000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 38 | 38 | 0000000 | 00000040 | 000000000 | 3800000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 39 | 39 | 0000000 | 00000080 | 000000000 | 7000000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |

Start clocking Summation Combiner

| | | | | | | | | | | | | | |
|----|----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 40 | 1 | 0000000 | 00000100 | 000000000 | 6000000001 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 41 | 2 | 0000000 | 00000200 | 000000000 | 4000000003 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 42 | 3 | 0000000 | 00000400 | 000000000 | 0000000007 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 43 | 4 | 0000000 | 00000800 | 000000000 | 000000000E | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 44 | 5 | 0000000 | 00001001 | 000000000 | 000000001D | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 45 | 6 | 0000000 | 00002002 | 000000000 | 000000003B | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 46 | 7 | 0000000 | 00004004 | 000000000 | 0000000077 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 47 | 8 | 0000000 | 00008008 | 000000000 | 00000000EE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 48 | 9 | 0000000 | 00010011 | 000000000 | 00000001DD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 49 | 10 | 0000000 | 00020022 | 000000000 | 00000003BB | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 50 | 11 | 0000000 | 00040044 | 000000000 | 0000000777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 51 | 12 | 0000000 | 00080088 | 000000000 | 0000000EEE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 52 | 13 | 0000000 | 00100110 | 000000000 | 0000001DDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 53 | 14 | 0000000 | 00200220 | 000000000 | 0000003BBB | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 54 | 15 | 0000000 | 00400440 | 000000000 | 0000007777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 55 | 16 | 0000000 | 00800880 | 000000000 | 000000EEEE | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 56 | 17 | 0000000 | 01001100 | 000000000 | 000001DDDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 57 | 18 | 0000000 | 02002200 | 000000000 | 000003BBBB | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 58 | 19 | 0000000 | 04004400 | 000000000 | 0000077777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 59 | 20 | 0000000 | 08008800 | 000000000 | 00000EEEE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 60 | 21 | 0000000 | 10011000 | 000000000 | 00001DDDDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|-----|----|----------|----------|------------|-------------|---|---|---|---|---|----|----|----|
| 61 | 22 | 00000000 | 20022000 | 0000000000 | 00003BBBBB | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 62 | 23 | 00000000 | 40044000 | 0000000000 | 0000777777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 63 | 24 | 00000000 | 00088001 | 0000000000 | 0000EEEEEE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 64 | 25 | 00000000 | 00110003 | 0000000000 | 0001DDDDDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 65 | 26 | 00000000 | 00220006 | 0000000000 | 0003BBBBBB | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 66 | 27 | 00000000 | 0044000C | 0000000000 | 0007777777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 67 | 28 | 00000000 | 00880018 | 0000000000 | 000EEEEEEE | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 68 | 29 | 00000000 | 01100031 | 0000000000 | 001DDDDDDC | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 69 | 30 | 00000000 | 02200062 | 0000000000 | 003BBBBBB8 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 70 | 31 | 00000000 | 044000C4 | 0000000000 | 0077777770 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 71 | 32 | 00000000 | 08800188 | 0000000000 | 00EEEEEE0 | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 72 | 33 | 00000000 | 11000311 | 0000000000 | 01DDDDDDC1 | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 73 | 34 | 00000000 | 22000622 | 0000000000 | 03BBBBBB83 | 0 | 0 | 0 | 1 | 1 | 11 | 00 | 01 |
| 74 | 35 | 00000000 | 44000C44 | 0000000000 | 0777777707 | 0 | 0 | 0 | 0 | 1 | 10 | 11 | 00 |
| 75 | 36 | 00000000 | 08001888 | 0000000000 | 0EEEEEEE0E | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 76 | 37 | 00000000 | 10003111 | 0000000000 | 1DDDDDDC1D | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 77 | 38 | 00000000 | 20006222 | 0000000000 | 3BBBBBB83B | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 78 | 39 | 00000000 | 4000C444 | 0000000000 | 7777777077 | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 79 | 40 | 00000000 | 00018888 | 0000000000 | 6EEEEEE0EF | 0 | 0 | 0 | 1 | 0 | 10 | 01 | 11 |
| 80 | 41 | 00000000 | 00031110 | 0000000000 | 5DDDDDC1DE | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 81 | 42 | 00000000 | 00062220 | 0000000000 | 3BBBBB83BC | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 82 | 43 | 00000000 | 000C4440 | 0000000000 | 7777770779 | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 83 | 44 | 00000000 | 00188880 | 0000000000 | 6EEEEEE0F2 | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 84 | 45 | 00000000 | 00311100 | 0000000000 | 5DDDDC1DE5 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 85 | 46 | 00000000 | 00622200 | 0000000000 | 3BBBB83BCB | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 86 | 47 | 00000000 | 00C44400 | 0000000000 | 7777707797 | 0 | 1 | 0 | 0 | 0 | 01 | 01 | 10 |
| 87 | 48 | 00000000 | 01888801 | 0000000000 | 6EEEE0EF2F | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 88 | 49 | 00000000 | 03111003 | 0000000000 | 5DDDC1DE5E | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 89 | 50 | 00000000 | 06222006 | 0000000000 | 3BBB83BCBC | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 90 | 51 | 00000000 | 0C44400C | 0000000000 | 7777077979 | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 91 | 52 | 00000000 | 18888018 | 0000000000 | 6EEEE0EF2F2 | 0 | 1 | 0 | 1 | 0 | 10 | 00 | 01 |
| 92 | 53 | 00000000 | 31110030 | 0000000000 | 5DDC1DE5E5 | 0 | 0 | 0 | 1 | 1 | 11 | 10 | 00 |
| 93 | 54 | 00000000 | 62220060 | 0000000000 | 3BB83BCBCB | 0 | 0 | 0 | 1 | 0 | 00 | 11 | 10 |
| 94 | 55 | 00000000 | 444400C1 | 0000000000 | 7770779797 | 0 | 0 | 0 | 0 | 0 | 10 | 00 | 11 |
| 95 | 56 | 00000000 | 08880183 | 0000000000 | 6EE0EF2F2F | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 96 | 57 | 00000000 | 11100307 | 0000000000 | 5DC1DE5E5F | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 97 | 58 | 00000000 | 2220060E | 0000000000 | 3B83BCBCBF | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 98 | 59 | 00000000 | 44400C1C | 0000000000 | 770779797E | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 99 | 60 | 00000000 | 08801838 | 0000000000 | 6E0EF2F2FC | 0 | 1 | 0 | 0 | 0 | 01 | 11 | 00 |
| 100 | 61 | 00000000 | 11003070 | 0000000000 | 5C1DE5E5F8 | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 101 | 62 | 00000000 | 220060E0 | 0000000000 | 383BCBCBF0 | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 102 | 63 | 00000000 | 4400C1C0 | 0000000000 | 70779797E0 | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 103 | 64 | 00000000 | 08018380 | 0000000000 | 60EF2F2FC1 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 104 | 65 | 00000000 | 10030701 | 0000000000 | 41DE5E5F82 | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 105 | 66 | 00000000 | 20060E02 | 0000000000 | 03BCBCBF04 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 106 | 67 | 00000000 | 400C1C05 | 0000000000 | 0779797E09 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 107 | 68 | 00000000 | 0018380A | 0000000000 | 0EF2F2FC12 | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 108 | 69 | 00000000 | 00307015 | 0000000000 | 1DE5E5F825 | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 109 | 70 | 00000000 | 0060E02A | 0000000000 | 3BCBCBF04B | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 110 | 71 | 00000000 | 00C1C055 | 0000000000 | 779797E097 | 0 | 1 | 0 | 1 | 0 | 10 | 00 | 01 |
| 111 | 72 | 00000000 | 018380AA | 0000000000 | 6F2F2FC12F | 0 | 1 | 0 | 0 | 1 | 11 | 10 | 00 |
| 112 | 73 | 00000000 | 03070154 | 0000000000 | 5E5E5F825E | 0 | 0 | 0 | 0 | 1 | 11 | 11 | 10 |
| 113 | 74 | 00000000 | 060E02A8 | 0000000000 | 3CBCBF04BC | 0 | 0 | 0 | 1 | 0 | 11 | 11 | 11 |
| 114 | 75 | 00000000 | 0C1C0550 | 0000000000 | 79797E0979 | 0 | 0 | 0 | 0 | 1 | 00 | 11 | 11 |
| 115 | 76 | 00000000 | 18380AA0 | 0000000000 | 72F2FC12F2 | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 116 | 77 | 00000000 | 30701541 | 0000000000 | 65E5F825E5 | 0 | 0 | 0 | 1 | 1 | 11 | 10 | 00 |
| 117 | 78 | 00000000 | 60E02A82 | 0000000000 | 4BCBF04BCB | 0 | 1 | 0 | 1 | 1 | 00 | 11 | 10 |

Sample Data

| | | | | | | | | | | | | | |
|-----|-----|----------|----------|------------|------------|---|---|---|---|---|----|----|----|
| 118 | 79 | 00000000 | 41C05505 | 0000000000 | 1797E09796 | 0 | 1 | 0 | 1 | 0 | 11 | 00 | 11 |
| 119 | 80 | 00000000 | 0380AA0A | 0000000000 | 2F2FC12F2C | 0 | 1 | 0 | 0 | 0 | 01 | 11 | 00 |
| 120 | 81 | 00000000 | 07015415 | 0000000000 | 5E5F825E59 | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 121 | 82 | 00000000 | 0E02A82A | 0000000000 | 3CBF04BCB2 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 122 | 83 | 00000000 | 1C055054 | 0000000000 | 797E097964 | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 123 | 84 | 00000000 | 380AA0A8 | 0000000000 | 72FC12F2C9 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 124 | 85 | 00000000 | 70154151 | 0000000000 | 65F825E593 | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 125 | 86 | 00000000 | 602A82A3 | 0000000000 | 4BF04BCB26 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 126 | 87 | 00000000 | 40550546 | 0000000000 | 17E097964C | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 127 | 88 | 00000000 | 00AA0A8D | 0000000000 | 2FC12F2C99 | 0 | 1 | 0 | 1 | 1 | 01 | 01 | 10 |
| 128 | 89 | 00000000 | 0154151A | 0000000000 | 5F825E5932 | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 129 | 90 | 00000000 | 02A82A34 | 0000000000 | 3F04BCB264 | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 130 | 91 | 00000000 | 05505468 | 0000000000 | 7E097964C9 | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 131 | 92 | 00000000 | 0AA0A8D0 | 0000000000 | 7C12F2C992 | 0 | 1 | 0 | 0 | 0 | 01 | 01 | 10 |
| 132 | 93 | 00000000 | 154151A1 | 0000000000 | 7825E59324 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 133 | 94 | 00000000 | 2A82A342 | 0000000000 | 704BCB2648 | 0 | 1 | 0 | 0 | 1 | 00 | 10 | 01 |
| 134 | 95 | 00000000 | 55054684 | 0000000000 | 6097964C91 | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 135 | 96 | 00000000 | 2A0A8D09 | 0000000000 | 412F2C9923 | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 136 | 97 | 00000000 | 54151A12 | 0000000000 | 025E593246 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 137 | 98 | 00000000 | 282A3424 | 0000000000 | 04BCB2648D | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 138 | 99 | 00000000 | 50546848 | 0000000000 | 097964C91A | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 139 | 100 | 00000000 | 20A8D090 | 0000000000 | 12F2C99235 | 0 | 1 | 0 | 1 | 1 | 00 | 01 | 00 |
| 140 | 101 | 00000000 | 4151A120 | 0000000000 | 25E593246A | 0 | 0 | 0 | 1 | 1 | 11 | 00 | 01 |
| 141 | 102 | 00000000 | 02A34240 | 0000000000 | 4BCB2648D5 | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 142 | 103 | 00000000 | 05468481 | 0000000000 | 17964C91AB | 0 | 0 | 0 | 1 | 0 | 10 | 01 | 11 |
| 143 | 104 | 00000000 | 0A8D0903 | 0000000000 | 2F2C992357 | 0 | 1 | 0 | 0 | 1 | 00 | 10 | 01 |
| 144 | 105 | 00000000 | 151A1206 | 0000000000 | 5E593246AE | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 145 | 106 | 00000000 | 2A34240C | 0000000000 | 3CB2648D5C | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 146 | 107 | 00000000 | 54684818 | 0000000000 | 7964C91AB8 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 147 | 108 | 00000000 | 28D09030 | 0000000000 | 72C9923571 | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 148 | 109 | 00000000 | 51A12060 | 0000000000 | 6593246AE2 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 149 | 110 | 00000000 | 234240C0 | 0000000000 | 4B2648D5C5 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 150 | 111 | 00000000 | 46848180 | 0000000000 | 164C91AB8A | 0 | 1 | 0 | 0 | 1 | 01 | 00 | 10 |
| 151 | 112 | 00000000 | 0D090301 | 0000000000 | 2C99235714 | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 152 | 113 | 00000000 | 1A120602 | 0000000000 | 593246AE28 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 153 | 114 | 00000000 | 34240C04 | 0000000000 | 32648D5C51 | 0 | 0 | 0 | 0 | 1 | 10 | 11 | 00 |
| 154 | 115 | 00000000 | 68481809 | 0000000000 | 64C91AB8A2 | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 155 | 116 | 00000000 | 50903012 | 0000000000 | 4992357144 | 0 | 1 | 0 | 1 | 1 | 01 | 01 | 10 |
| 156 | 117 | 00000000 | 21206024 | 0000000000 | 13246AE288 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 157 | 118 | 00000000 | 4240C048 | 0000000000 | 2648D5C511 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 158 | 119 | 00000000 | 04818090 | 0000000000 | 4C91AB8A23 | 0 | 1 | 0 | 1 | 0 | 00 | 00 | 10 |
| 159 | 120 | 00000000 | 09030120 | 0000000000 | 1923571446 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 160 | 121 | 00000000 | 12060240 | 0000000000 | 3246AE288D | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 161 | 122 | 00000000 | 240C0480 | 0000000000 | 648D5C511B | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 162 | 123 | 00000000 | 48180900 | 0000000000 | 491AB8A237 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 163 | 124 | 00000000 | 10301200 | 0000000000 | 123571446F | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 164 | 125 | 00000000 | 20602400 | 0000000000 | 246AE288DF | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 165 | 126 | 00000000 | 40C04800 | 0000000000 | 48D5C511BE | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 166 | 127 | 00000000 | 01809001 | 0000000000 | 11AB8A237D | 0 | 1 | 0 | 1 | 1 | 00 | 01 | 00 |
| 167 | 128 | 00000000 | 03012002 | 0000000000 | 23571446FA | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 168 | 129 | 00000000 | 06024004 | 0000000000 | 46AE288DF5 | 0 | 0 | 0 | 1 | 0 | 01 | 11 | 00 |
| 169 | 130 | 00000000 | 0C048008 | 0000000000 | 0D5C511BEA | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 170 | 131 | 00000000 | 18090011 | 0000000000 | 1AB8A237D5 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 171 | 132 | 00000000 | 30120022 | 0000000000 | 3571446FAA | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 172 | 133 | 00000000 | 60240044 | 0000000000 | 6AE288DF55 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 173 | 134 | 00000000 | 40480089 | 0000000000 | 55C511BEAA | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 174 | 135 | 00000000 | 00900113 | 0000000000 | 2B8A237D54 | 0 | 1 | 0 | 1 | 1 | 10 | 11 | 01 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|----------|----------|------------|------------|---|---|---|---|---|----|----|----|
| 175 | 136 | 00000000 | 01200227 | 0000000000 | 571446FAA8 | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 176 | 137 | 00000000 | 0240044E | 0000000000 | 2E288DF550 | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 177 | 138 | 00000000 | 0480089C | 0000000000 | 5C511BEAA0 | 0 | 1 | 0 | 0 | 1 | 11 | 00 | 01 |
| 178 | 139 | 00000000 | 09001138 | 0000000000 | 38A237D540 | 0 | 0 | 0 | 1 | 0 | 01 | 11 | 00 |
| 179 | 140 | 00000000 | 12002270 | 0000000000 | 71446FAA81 | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 180 | 141 | 00000000 | 240044E0 | 0000000000 | 6288DF5503 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 181 | 142 | 00000000 | 480089C0 | 0000000000 | 4511BEAA06 | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 182 | 143 | 00000000 | 10011381 | 0000000000 | 0A237D540D | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 183 | 144 | 00000000 | 20022702 | 0000000000 | 1446FAA81A | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 184 | 145 | 00000000 | 40044E04 | 0000000000 | 288DF55035 | 0 | 0 | 0 | 1 | 0 | 01 | 11 | 00 |
| 185 | 146 | 00000000 | 00089C08 | 0000000000 | 511BEAA06A | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 186 | 147 | 00000000 | 00113810 | 0000000000 | 2237D540D5 | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 187 | 148 | 00000000 | 00227021 | 0000000000 | 446FAA81AA | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 188 | 149 | 00000000 | 0044E042 | 0000000000 | 08DF550355 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 189 | 150 | 00000000 | 0089C085 | 0000000000 | 11BEAA06AA | 0 | 1 | 0 | 1 | 0 | 10 | 10 | 11 |
| 190 | 151 | 00000000 | 0113810A | 0000000000 | 237D540D54 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 191 | 152 | 00000000 | 02270215 | 0000000000 | 46FAA81AA9 | 0 | 0 | 0 | 1 | 1 | 10 | 10 | 10 |
| 192 | 153 | 00000000 | 044E042A | 0000000000 | 0DF5503553 | 0 | 0 | 0 | 1 | 1 | 10 | 10 | 10 |
| 193 | 154 | 00000000 | 089C0854 | 0000000000 | 1BEAA06AA7 | 0 | 1 | 0 | 1 | 0 | 01 | 10 | 10 |
| 194 | 155 | 00000000 | 113810A8 | 0000000000 | 37D540D54E | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 195 | 156 | 00000000 | 22702150 | 0000000000 | 6FAA81AA9D | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 196 | 157 | 00000000 | 44E042A0 | 0000000000 | 5F5503553A | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 197 | 158 | 00000000 | 09C08540 | 0000000000 | 3EAA06AA75 | 0 | 1 | 0 | 1 | 0 | 10 | 10 | 11 |
| 198 | 159 | 00000000 | 13810A80 | 0000000000 | 7D540D54EA | 0 | 1 | 0 | 0 | 1 | 10 | 10 | 10 |
| 199 | 160 | 00000000 | 27021500 | 0000000000 | 7AA81AA9D5 | 0 | 0 | 0 | 1 | 1 | 10 | 10 | 10 |
| 200 | 161 | 00000000 | 4E042A00 | 0000000000 | 75503553AB | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 201 | 162 | 00000000 | 1C085400 | 0000000000 | 6AA06AA756 | 0 | 0 | 0 | 1 | 1 | 10 | 10 | 10 |
| 202 | 163 | 00000000 | 3810A800 | 0000000000 | 5540D54EAC | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 203 | 164 | 00000000 | 70215000 | 0000000000 | 2A81AA9D58 | 0 | 0 | 0 | 1 | 1 | 10 | 10 | 10 |
| 204 | 165 | 00000000 | 6042A001 | 0000000000 | 5503553AB0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 205 | 166 | 00000000 | 40854002 | 0000000000 | 2A06AA7561 | 0 | 1 | 0 | 0 | 1 | 10 | 10 | 10 |
| 206 | 167 | 00000000 | 010A8004 | 0000000000 | 540D54EAC3 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 207 | 168 | 00000000 | 02150009 | 0000000000 | 281AA9D586 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 208 | 169 | 00000000 | 042A0012 | 0000000000 | 503553AB0C | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 209 | 170 | 00000000 | 08540024 | 0000000000 | 206AA75618 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 210 | 171 | 00000000 | 10A80048 | 0000000000 | 40D54EAC30 | 0 | 1 | 0 | 1 | 0 | 01 | 10 | 10 |
| 211 | 172 | 00000000 | 21500091 | 0000000000 | 01AA9D5861 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 212 | 173 | 00000000 | 42A00122 | 0000000000 | 03553AB0C3 | 0 | 1 | 0 | 0 | 0 | 11 | 01 | 01 |
| 213 | 174 | 00000000 | 05400244 | 0000000000 | 06AA756186 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 214 | 175 | 00000000 | 0A800488 | 0000000000 | 0D54EAC30D | 0 | 1 | 0 | 0 | 1 | 01 | 10 | 11 |
| 215 | 176 | 00000000 | 15000911 | 0000000000 | 1AA9D5861A | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 216 | 177 | 00000000 | 2A001223 | 0000000000 | 3553AB0C35 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 217 | 178 | 00000000 | 54002446 | 0000000000 | 6AA756186A | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 218 | 179 | 00000000 | 2800488D | 0000000000 | 554EAC30D5 | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 219 | 180 | 00000000 | 5000911B | 0000000000 | 2A9D5861AA | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 220 | 181 | 00000000 | 20012236 | 0000000000 | 553AB0C355 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 221 | 182 | 00000000 | 4002446C | 0000000000 | 2A756186AA | 0 | 0 | 0 | 0 | 1 | 10 | 11 | 00 |
| 222 | 183 | 00000000 | 000488D9 | 0000000000 | 54EAC30D54 | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 223 | 184 | 00000000 | 000911B2 | 0000000000 | 29D5861AA8 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 224 | 185 | 00000000 | 00122364 | 0000000000 | 53AB0C3550 | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 225 | 186 | 00000000 | 002446C8 | 0000000000 | 2756186AA0 | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 226 | 187 | 00000000 | 00488D90 | 0000000000 | 4EAC30D540 | 0 | 0 | 0 | 1 | 0 | 10 | 01 | 11 |
| 227 | 188 | 00000000 | 00911B20 | 0000000000 | 1D5861AA81 | 0 | 1 | 0 | 0 | 1 | 00 | 10 | 01 |
| 228 | 189 | 00000000 | 01223640 | 0000000000 | 3AB0C35502 | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 229 | 190 | 00000000 | 02446C80 | 0000000000 | 756186AA05 | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 230 | 191 | 00000000 | 0488D901 | 0000000000 | 6AC30D540B | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 231 | 192 | 00000000 | 0911B203 | 0000000000 | 55861AA817 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |

Sample Data

| | | | | | | | | | | | | | |
|-----|-----|----------|----------|------------|------------|---|---|---|---|---|----|----|----|
| 232 | 193 | 00000000 | 12236407 | 0000000000 | 2B0C35502F | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 233 | 194 | 00000000 | 2446C80E | 0000000000 | 56186AA05F | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 234 | 195 | 00000000 | 488D901C | 0000000000 | 2C30D540BF | 0 | 1 | 0 | 0 | 1 | 11 | 00 | 01 |
| 235 | 196 | 00000000 | 111B2039 | 0000000000 | 5861AA817E | 0 | 0 | 0 | 0 | 1 | 10 | 11 | 00 |
| 236 | 197 | 00000000 | 22364072 | 0000000000 | 30C35502FD | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 237 | 198 | 00000000 | 446C80E4 | 0000000000 | 6186AA05FB | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 238 | 199 | 00000000 | 08D901C8 | 0000000000 | 430D540BF6 | 0 | 1 | 0 | 0 | 0 | 11 | 01 | 01 |
| 239 | 200 | 00000000 | 11B20391 | 0000000000 | 061AA817EC | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |

Z[0] = 3D
 Z[1] = C1
 Z[2] = F0
 Z[3] = BB
 Z[4] = 58
 Z[5] = 1E
 Z[6] = 42
 Z[7] = 42
 Z[8] = 4B
 Z[9] = 8E
 Z[10] = C1
 Z[11] = 2A
 Z[12] = 40
 Z[13] = 63
 Z[14] = 7A
 Z[15] = 1E

Reload this pattern into the LFSRs

Hold content of Summation Combiner regs and calculate new C[t+1] and Z values

LFSR1 <= 04B583D
 LFSR2 <= 208E1EC1
 LFSR3 <= 063C142F0
 LFSR4 <= 0F7A2A42BB
 C[t+1] <= 10

Generating 125 key symbols (encryption/decryption sequence)

| | | | | | | | | | | | | | |
|-----|----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 240 | 1 | 04B583D | 208E1EC1 | 063C142F0 | 0F7A2A42BB | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 241 | 2 | 096B07A | 411C3D82 | 0C78285E1 | 1EF4548577 | 1 | 0 | 1 | 1 | 1 | 10 | 10 | 11 |
| 242 | 3 | 12D60F4 | 02387B04 | 18F050BC3 | 3DE8A90AEF | 0 | 0 | 1 | 1 | 0 | 01 | 10 | 10 |
| 243 | 4 | 05AC1B9 | 0470F609 | 11E0A1786 | 7BD15215DF | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 244 | 5 | 0B583D2 | 08E1EC13 | 03C142F0C | 77A2A42BBF | 1 | 1 | 0 | 1 | 0 | 00 | 01 | 01 |
| 245 | 6 | 16B07A5 | 11C3D827 | 078285E18 | 6F4548577E | 0 | 1 | 0 | 0 | 1 | 11 | 00 | 01 |
| 246 | 7 | 0D60F4B | 2387B04F | 0F050BC30 | 5E8A90AEFD | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 247 | 8 | 1AC1E97 | 470F609E | 1E0A17860 | 3D15215DFA | 1 | 0 | 1 | 0 | 0 | 11 | 00 | 11 |
| 248 | 9 | 1583D2E | 0E1EC13D | 1C142F0C0 | 7A2A42BBF4 | 0 | 0 | 1 | 0 | 0 | 01 | 11 | 00 |
| 249 | 10 | 0B07A5D | 1C3D827B | 18285E181 | 74548577E9 | 1 | 0 | 1 | 0 | 1 | 10 | 01 | 11 |
| 250 | 11 | 160F4BB | 387B04F7 | 1050BC302 | 68A90AEFD2 | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 251 | 12 | 0C1E976 | 70F609EE | 00A178605 | 515215DFA5 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 252 | 13 | 183D2ED | 61EC13DD | 0142F0C0B | 22A42BBF4B | 1 | 1 | 0 | 1 | 1 | 01 | 00 | 00 |
| 253 | 14 | 107A5DA | 43D827BA | 0285E1817 | 4548577E97 | 0 | 1 | 0 | 0 | 0 | 00 | 01 | 00 |
| 254 | 15 | 00F4BB4 | 07B04F74 | 050BC302F | 0A90AEFD2E | 0 | 1 | 0 | 1 | 0 | 10 | 00 | 01 |
| 255 | 16 | 01E9769 | 0F609EE8 | 0A178605E | 15215DFA5C | 0 | 0 | 1 | 0 | 1 | 11 | 10 | 00 |
| 256 | 17 | 03D2ED3 | 1EC13DD0 | 142F0C0BD | 2A42BBF4B9 | 0 | 1 | 0 | 0 | 0 | 00 | 11 | 10 |
| 257 | 18 | 07A5DA7 | 3D827BA0 | 085E1817B | 548577E972 | 0 | 1 | 1 | 1 | 1 | 11 | 00 | 11 |

Sample Data



| | | | | | | | | | | | | | |
|-----|----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 258 | 19 | 0F4BB4F | 7B04F740 | 10BC302F6 | 290AEFD2E5 | 1 | 0 | 0 | 0 | 0 | 01 | 11 | 00 |
| 259 | 20 | 1B9769F | 7609EE80 | 0178605ED | 5215DFA5CA | 1 | 0 | 0 | 0 | 0 | 10 | 01 | 11 |
| 260 | 21 | 1D2ED3F | 6C13DD01 | 02F0C0BDA | 242BBF4B94 | 1 | 0 | 0 | 0 | 1 | 00 | 10 | 01 |
| 261 | 22 | 1A5DA7E | 5827BA03 | 05E1817B4 | 48577E9729 | 1 | 0 | 0 | 0 | 1 | 01 | 00 | 10 |
| 262 | 23 | 14BB4FC | 304F7407 | 0BC302F69 | 10AEFD2E53 | 0 | 0 | 1 | 1 | 1 | 00 | 01 | 00 |
| 263 | 24 | 09769F9 | 609EE80E | 178605ED2 | 215DFA5CA7 | 1 | 1 | 0 | 0 | 0 | 10 | 00 | 01 |
| 264 | 25 | 12ED3F2 | 413DD01C | 0F0C0BDA4 | 42BBF4B94F | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 265 | 26 | 05DA7E5 | 027BA038 | 1E1817B49 | 0577E9729F | 0 | 0 | 1 | 0 | 1 | 01 | 00 | 10 |
| 266 | 27 | 0BB4FCA | 04F74071 | 1C302F693 | 0AEFD2E53F | 1 | 1 | 1 | 1 | 1 | 11 | 01 | 00 |
| 267 | 28 | 1769F95 | 09EE80E3 | 18605ED27 | 15DFA5CA7F | 0 | 1 | 1 | 1 | 0 | 11 | 11 | 01 |
| 268 | 29 | 0ED3F2B | 13DD01C6 | 10C0BDA4F | 2BBF4B94FE | 1 | 1 | 0 | 1 | 0 | 10 | 11 | 11 |
| 269 | 30 | 1DA7E56 | 27BA038D | 01817B49F | 577E9729FD | 1 | 1 | 0 | 0 | 0 | 10 | 10 | 11 |
| 270 | 31 | 1B4FCAD | 4F74071B | 0302F693E | 2EFD2E53FB | 1 | 0 | 0 | 1 | 0 | 01 | 10 | 10 |
| 271 | 32 | 169F95B | 1EE80E37 | 0605ED27D | 5DFA5CA7F7 | 0 | 1 | 0 | 1 | 1 | 01 | 01 | 10 |
| 272 | 33 | 0D3F2B7 | 3DD01C6E | 0C0BDA4FB | 3BF4B94FEF | 1 | 1 | 1 | 1 | 1 | 00 | 01 | 01 |
| 273 | 34 | 1A7E56F | 7BA038DC | 1817B49F6 | 77E9729FDE | 1 | 1 | 1 | 1 | 0 | 01 | 00 | 01 |
| 274 | 35 | 14FCADF | 774071B9 | 102F693ED | 6FD2E53FBD | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 275 | 36 | 09F95BE | 6E80E373 | 005ED27DB | 5FA5CA7F7B | 1 | 1 | 0 | 1 | 1 | 10 | 00 | 01 |
| 276 | 37 | 13F2B7C | 5D01C6E7 | 00BDA4FB6 | 3F4B94FEF7 | 0 | 0 | 0 | 0 | 0 | 11 | 10 | 00 |
| 277 | 38 | 07E56F9 | 3A038DCE | 017B49F6C | 7E9729FDEE | 0 | 0 | 0 | 1 | 0 | 00 | 11 | 10 |
| 278 | 39 | 0FCADF2 | 74071B9C | 02F693ED8 | 7D2E53FBDD | 1 | 0 | 0 | 0 | 1 | 10 | 00 | 11 |
| 279 | 40 | 1F95BE5 | 680E3738 | 05ED27DB0 | 7A5CA7F7BA | 1 | 0 | 0 | 0 | 1 | 11 | 10 | 00 |
| 280 | 41 | 1F2B7CA | 501C6E71 | 0BDA4FB60 | 74B94FEF74 | 1 | 0 | 1 | 1 | 0 | 01 | 11 | 10 |
| 281 | 42 | 1E56F94 | 2038DCE2 | 17B49F6C0 | 69729FDEE8 | 1 | 0 | 0 | 0 | 0 | 10 | 01 | 11 |
| 282 | 43 | 1CADF29 | 4071B9C4 | 0F693ED80 | 52E53FBDD1 | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 283 | 44 | 195BE53 | 00E37389 | 1ED27DB01 | 25CA7F7BA3 | 1 | 1 | 1 | 1 | 1 | 01 | 11 | 10 |
| 284 | 45 | 12B7CA6 | 01C6E713 | 1DA4FB602 | 4B94FEF747 | 0 | 1 | 1 | 1 | 0 | 01 | 01 | 11 |
| 285 | 46 | 056F94C | 038DCE26 | 1B49F6C04 | 1729FDEE8E | 0 | 1 | 1 | 0 | 1 | 11 | 01 | 01 |
| 286 | 47 | 0ADF299 | 071B9C4D | 1693ED808 | 2E53FBDD1C | 1 | 0 | 0 | 0 | 0 | 10 | 11 | 01 |
| 287 | 48 | 15BE532 | 0E37389A | 0D27DB011 | 5CA7F7BA38 | 0 | 0 | 1 | 1 | 0 | 10 | 10 | 11 |
| 288 | 49 | 0B7CA64 | 1C6E7135 | 1A4FB6022 | 394FEF7471 | 1 | 0 | 1 | 0 | 0 | 01 | 10 | 10 |
| 289 | 50 | 16F94C9 | 38DCE26A | 149F6C044 | 729FDEE8E2 | 0 | 1 | 0 | 1 | 1 | 01 | 01 | 10 |
| 290 | 51 | 0DF2993 | 71B9C4D4 | 093ED8089 | 653FBDD1C4 | 1 | 1 | 1 | 0 | 0 | 00 | 01 | 01 |
| 291 | 52 | 1BE5327 | 637389A9 | 127DB0112 | 4A7F7BA388 | 1 | 0 | 0 | 0 | 1 | 11 | 00 | 01 |
| 292 | 53 | 17CA64E | 46E71353 | 04FB60224 | 14FEF74710 | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 293 | 54 | 0F94C9C | 0DCE26A6 | 09F6C0448 | 29FDEE8E21 | 1 | 1 | 1 | 1 | 1 | 01 | 01 | 11 |
| 294 | 55 | 1F29939 | 1B9C4D4D | 13ED80890 | 53FBDD1C42 | 1 | 1 | 0 | 1 | 0 | 00 | 01 | 01 |
| 295 | 56 | 1E53272 | 37389A9A | 07DB01121 | 27F7BA3884 | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 296 | 57 | 1CA64E5 | 6E713534 | 0FB602242 | 4FEF747108 | 1 | 0 | 1 | 1 | 1 | 00 | 10 | 00 |
| 297 | 58 | 194C9CB | 5CE26A69 | 1F6C04485 | 1FDEE8E210 | 1 | 1 | 1 | 1 | 0 | 11 | 00 | 10 |
| 298 | 59 | 1299397 | 39C4D4D3 | 1ED80890A | 3FBDD1C420 | 0 | 1 | 1 | 1 | 0 | 00 | 11 | 00 |
| 299 | 60 | 053272F | 7389A9A6 | 1DB011214 | 7F7BA38840 | 0 | 1 | 1 | 0 | 0 | 11 | 00 | 11 |
| 300 | 61 | 0A64E5E | 6713534C | 1B6022428 | 7EF7471081 | 1 | 0 | 1 | 1 | 0 | 00 | 11 | 00 |
| 301 | 62 | 14C9CBD | 4E26A699 | 16C044850 | 7DEE8E2102 | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 302 | 63 | 099397A | 1C4D4D32 | 0D80890A0 | 7BDD1C4205 | 1 | 0 | 1 | 1 | 1 | 00 | 10 | 00 |
| 303 | 64 | 13272F4 | 389A9A65 | 1B0112141 | 77BA38840B | 0 | 1 | 1 | 1 | 1 | 00 | 00 | 10 |
| 304 | 65 | 064E5E8 | 713534CB | 160224283 | 6F74710817 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 305 | 66 | 0C9CBD1 | 626A6997 | 0C0448507 | 5EE8E2102E | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 306 | 67 | 19397A3 | 44D4D32E | 180890A0E | 3DD1C4205C | 1 | 1 | 1 | 1 | 1 | 11 | 01 | 00 |
| 307 | 68 | 1272F46 | 09A9A65D | 10112141D | 7BA38840B8 | 0 | 1 | 0 | 1 | 1 | 10 | 11 | 01 |
| 308 | 69 | 04E5E8C | 13534CBA | 00224283A | 7747108171 | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 309 | 70 | 09CBD19 | 26A69975 | 004485075 | 6E8E2102E3 | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 310 | 71 | 1397A32 | 4D4D32EB | 00890A0EA | 5D1C4205C7 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 311 | 72 | 072F465 | 1A9A65D7 | 0112141D5 | 3A38840B8F | 0 | 1 | 0 | 0 | 1 | 01 | 00 | 10 |
| 312 | 73 | 0E5E8CA | 3534CBAF | 0224283AA | 747108171F | 1 | 0 | 0 | 0 | 0 | 00 | 01 | 00 |
| 313 | 74 | 1CBD194 | 6A69975E | 044850755 | 68E2102E3E | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 314 | 75 | 197A329 | 54D32EBC | 0890A0EAB | 51C4205C7D | 1 | 1 | 1 | 1 | 0 | 01 | 10 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 315 | 76 | 12F4653 | 29A65D79 | 112141D56 | 238840B8FA | 0 | 1 | 0 | 1 | 1 | 01 | 01 | 10 |
| 316 | 77 | 05E8CA6 | 534CBAF2 | 024283AAD | 47108171F4 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 317 | 78 | 0BD194D | 269975E5 | 04850755B | 0E2102E3E9 | 1 | 1 | 0 | 0 | 0 | 11 | 10 | 01 |
| 318 | 79 | 17A329A | 4D32EBCB | 090A0EAB6 | 1C4205C7D2 | 0 | 0 | 1 | 0 | 0 | 00 | 11 | 10 |
| 319 | 80 | 0F46535 | 1A65D797 | 12141D56D | 38840B8FA5 | 1 | 0 | 0 | 1 | 0 | 11 | 00 | 11 |
| 320 | 81 | 1E8CA6A | 34CBAF2F | 04283AADA | 7108171F4B | 1 | 1 | 0 | 0 | 1 | 01 | 11 | 00 |
| 321 | 82 | 1D194D5 | 69975E5F | 0850755B4 | 62102E3E97 | 1 | 1 | 1 | 0 | 0 | 01 | 01 | 11 |
| 322 | 83 | 1A329AA | 532EBCBF | 10A0EAB68 | 44205C7D2F | 1 | 0 | 0 | 0 | 0 | 11 | 01 | 01 |
| 323 | 84 | 1465355 | 265D797F | 0141D56D1 | 0840B8FA5E | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 324 | 85 | 08CA6AB | 4CBAF2FF | 0283AADA2 | 108171F4BC | 1 | 1 | 0 | 1 | 0 | 01 | 01 | 11 |
| 325 | 86 | 1194D56 | 1975E5FF | 050755B45 | 2102E3E979 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 326 | 87 | 0329AAD | 32EBCBFF | 0A0EAB68A | 4205C7D2F3 | 0 | 1 | 1 | 0 | 0 | 11 | 10 | 01 |
| 327 | 88 | 065355A | 65D797FF | 141D56D14 | 040B8FA5E7 | 0 | 1 | 0 | 0 | 0 | 00 | 11 | 10 |
| 328 | 89 | 0CA6AB4 | 4BAF2FFF | 083AADA28 | 08171F4BCF | 1 | 1 | 1 | 0 | 1 | 11 | 00 | 11 |
| 329 | 90 | 194D569 | 175E5FFF | 10755B450 | 102E3E979E | 1 | 0 | 0 | 0 | 0 | 01 | 11 | 00 |
| 330 | 91 | 129AAD3 | 2EBCBFFF | 00EAB68A1 | 205C7D2F3C | 0 | 1 | 0 | 0 | 0 | 10 | 01 | 11 |
| 331 | 92 | 05355A6 | 5D797FFF | 01D56D142 | 40B8FA5E78 | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 332 | 93 | 0A6AB4D | 3AF2FFFE | 03AADA285 | 0171F4BCF1 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 333 | 94 | 14D569B | 75E5FFFD | 0755B450A | 02E3E979E2 | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 334 | 95 | 09AAD37 | 6BCBFFFA | 0EAB68A15 | 05C7D2F3C4 | 1 | 1 | 1 | 1 | 1 | 11 | 01 | 00 |
| 335 | 96 | 1355A6E | 5797FFF4 | 1D56D142A | 0B8FA5E788 | 0 | 1 | 1 | 1 | 0 | 11 | 11 | 01 |
| 336 | 97 | 06AB4DC | 2F2FFFE8 | 1AADA2854 | 171F4BCF11 | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 337 | 98 | 0D569B8 | 5E5FFFD0 | 155B450A9 | 2E3E979E23 | 1 | 0 | 0 | 0 | 0 | 11 | 11 | 11 |
| 338 | 99 | 1AAD370 | 3CBFFFA1 | 0AB68A153 | 5C7D2F3C46 | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 339 | 100 | 155A6E0 | 797FFF43 | 156D142A7 | 38FA5E788D | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 340 | 101 | 0AB4DC0 | 72FFFE87 | 0ADA2854E | 71F4BCF11B | 1 | 1 | 1 | 1 | 1 | 10 | 01 | 10 |
| 341 | 102 | 1569B81 | 65FFFD0E | 15B450A9D | 63E979E236 | 0 | 1 | 0 | 1 | 0 | 11 | 10 | 01 |
| 342 | 103 | 0AD3703 | 4BFFFA1C | 0B68A153B | 47D2F3C46C | 1 | 1 | 1 | 1 | 1 | 01 | 11 | 10 |
| 343 | 104 | 15A6E07 | 17FFF438 | 16D142A76 | 0FA5E788D8 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 344 | 105 | 0B4DC0F | 2FFFE870 | 0DA2854EC | 1F4BCF11B0 | 1 | 1 | 1 | 0 | 1 | 11 | 10 | 01 |
| 345 | 106 | 169B81F | 5FFFD0E1 | 1B450A9D8 | 3E979E2360 | 0 | 1 | 1 | 1 | 0 | 01 | 11 | 10 |
| 346 | 107 | 0D3703F | 3FFFA1C3 | 168A153B0 | 7D2F3C46C1 | 1 | 1 | 0 | 0 | 1 | 10 | 01 | 11 |
| 347 | 108 | 1A6E07E | 7FFF4386 | 0D142A761 | 7A5E788D83 | 1 | 1 | 1 | 0 | 1 | 11 | 10 | 01 |
| 348 | 109 | 14DC0FD | 7FFE870C | 1A2854EC2 | 74BCF11B07 | 0 | 1 | 1 | 1 | 0 | 01 | 11 | 10 |
| 349 | 110 | 09B81FB | 7FFD0E19 | 1450A9D84 | 6979E2360E | 1 | 1 | 0 | 0 | 1 | 10 | 01 | 11 |
| 350 | 111 | 13703F6 | 7FFA1C33 | 08A153B09 | 52F3C46C1C | 0 | 1 | 1 | 1 | 1 | 11 | 10 | 01 |
| 351 | 112 | 06E07EC | 7FF43867 | 1142A7612 | 25E788D838 | 0 | 1 | 0 | 1 | 1 | 00 | 11 | 10 |
| 352 | 113 | 0DC0FD8 | 7FE870CF | 02854EC25 | 4BCF11B071 | 1 | 1 | 0 | 1 | 1 | 11 | 00 | 11 |
| 353 | 114 | 1B81FB1 | 7FD0E19E | 050A9D84B | 179E2360E3 | 1 | 1 | 0 | 1 | 0 | 00 | 11 | 00 |
| 354 | 115 | 1703F62 | 7FA1C33D | 0A153B096 | 2F3C46C1C7 | 0 | 1 | 1 | 0 | 0 | 11 | 00 | 11 |
| 355 | 116 | 0E07EC4 | 7F43867B | 142A7612C | 5E788D838E | 1 | 0 | 0 | 0 | 0 | 01 | 11 | 00 |
| 356 | 117 | 1C0FD88 | 7E870CF6 | 0854EC259 | 3CF11B071C | 1 | 1 | 1 | 1 | 1 | 01 | 01 | 11 |
| 357 | 118 | 181FB11 | 7D0E19ED | 10A9D84B3 | 79E2360E38 | 1 | 0 | 0 | 1 | 1 | 11 | 01 | 01 |
| 358 | 119 | 103F622 | 7A1C33DA | 0153B0967 | 73C46C1C71 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 359 | 120 | 007EC45 | 743867B5 | 02A7612CE | 6788D838E3 | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 360 | 121 | 00FD88B | 6870CF6B | 054EC259C | 4F11B071C6 | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 361 | 122 | 01FB117 | 50E19ED7 | 0A9D84B38 | 1E2360E38C | 0 | 1 | 1 | 0 | 0 | 10 | 00 | 01 |
| 362 | 123 | 03F622F | 21C33DAE | 153B09671 | 3C46C1C718 | 0 | 1 | 0 | 0 | 1 | 11 | 10 | 00 |
| 363 | 124 | 07EC45F | 43867B5C | 0A7612CE2 | 788D838E30 | 0 | 1 | 1 | 1 | 0 | 01 | 11 | 10 |
| 364 | 125 | 0FD88BF | 070CF6B9 | 14EC259C4 | 711B071C61 | 1 | 0 | 0 | 0 | 0 | 10 | 01 | 11 |

Sample Data



1.3 SECOND SET OF SAMPLE DATA

Initial values for the key, BD_ADDR and clock

```
K'c2[0] = 00   K'c2[1] = 00   K'c2[2] = 00   K'c2[3] = 00
K'c2[4] = 00   K'c2[5] = 00   K'c2[6] = 00   K'c2[7] = 00
K'c2[8] = 00   K'c2[9] = 00   K'c2[10] = 00  K'c2[11] = 00
K'c2[12] = 00  K'c2[13] = 00   K'c2[14] = 00  K'c2[15] = 00
```

```
Addr2[0] = 00   Addr2[1] = 00   Addr2[2] = 00
Addr2[3] = 00   Addr2[4] = 00   Addr2[5] = 00
```

```
CL2[0] = 00   CL2[1] = 00   CL2[2] = 00   CL2[3] = 03
```

```
=====
Fill LFSRs with initial data
=====
```

| t | clk# | LFSR1 | LFSR2 | LFSR3 | LFSR4 | X1 | X2 | X3 | X4 | Z | C[t+1] | C[t] | C[t-1] |
|----|------|----------|-----------|------------|-------------|----|----|----|----|---|--------|------|--------|
| 0 | 0 | 0000000* | 00000000* | 000000000* | 0000000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 1 | 1 | 0000001* | 00000001* | 000000001* | 0000000001* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 2 | 2 | 0000002* | 00000002* | 000000002* | 0000000003* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 3 | 3 | 0000004* | 00000004* | 000000004* | 0000000007* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 4 | 4 | 0000008* | 00000008* | 000000008* | 000000000E* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 5 | 5 | 0000010* | 00000010* | 000000010* | 000000001C* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 6 | 6 | 0000020* | 00000020* | 000000020* | 0000000038* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 7 | 7 | 0000040* | 00000040* | 000000040* | 0000000070* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 8 | 8 | 0000080* | 00000080* | 000000080* | 00000000E0* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 9 | 9 | 0000100* | 00000100* | 000000100* | 00000001C0* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 10 | 10 | 0000200* | 00000200* | 000000200* | 0000000380* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 11 | 11 | 0000400* | 00000400* | 000000400* | 0000000700* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 12 | 12 | 0000800* | 00000800* | 000000800* | 0000000E00* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 13 | 13 | 0001000* | 00001000* | 000001000* | 0000001C00* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 14 | 14 | 0002000* | 00002000* | 000002000* | 0000003800* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 15 | 15 | 0004000* | 00004000* | 000004000* | 0000007000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 16 | 16 | 0008000* | 00008000* | 000008000* | 000000E000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 17 | 17 | 0010000* | 00010000* | 000010000* | 000001C000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 18 | 18 | 0020000* | 00020000* | 000020000* | 0000038000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 19 | 19 | 0040000* | 00040000* | 000040000* | 0000070000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 20 | 20 | 0080000* | 00080000* | 000080000* | 00000E0000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 21 | 21 | 0100000* | 00100000* | 000100000* | 00001C0000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 22 | 22 | 0200000* | 00200000* | 000200000* | 0000380000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 23 | 23 | 0400000* | 00400000* | 000400000* | 0000700000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 24 | 24 | 0800000* | 00800000* | 000800000* | 0000E00000* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 25 | 25 | 1000000* | 01000000* | 001000000* | 0001C00000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 26 | 26 | 0000001 | 02000000* | 002000000* | 0003800000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 27 | 27 | 0000002 | 04000000* | 004000000* | 0007000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 28 | 28 | 0000004 | 08000000* | 008000000* | 000E000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 29 | 29 | 0000008 | 10000000* | 010000000* | 001C000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 30 | 30 | 0000010 | 20000000* | 020000000* | 0038000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 31 | 31 | 0000020 | 40000000* | 040000000* | 0070000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 32 | 32 | 0000040 | 00000001 | 080000000* | 00E0000000* | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 33 | 33 | 0000080 | 00000002 | 100000000* | 01C0000000* | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 34 | 34 | 0000101 | 00000004 | 000000001 | 0380000000* | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|----|----|---------|----------|-----------|-------------|---|---|---|---|---|----|----|----|
| 35 | 35 | 0000202 | 00000008 | 000000002 | 0700000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 36 | 36 | 0000404 | 00000010 | 000000004 | 0E00000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 37 | 37 | 0000808 | 00000020 | 000000008 | 1C00000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 38 | 38 | 0001011 | 00000040 | 000000011 | 3800000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 39 | 39 | 0002022 | 00000080 | 000000022 | 7000000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |

Start clocking Summation Combiner

| | | | | | | | | | | | | | |
|----|----|---------|----------|-----------|-------------|---|---|---|---|---|----|----|----|
| 40 | 1 | 0004044 | 00000100 | 000000044 | 6000000001 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 41 | 2 | 0008088 | 00000200 | 000000088 | 4000000003 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 42 | 3 | 0010111 | 00000400 | 000000111 | 0000000007 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 43 | 4 | 0020222 | 00000800 | 000000222 | 000000000E | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 44 | 5 | 0040444 | 00001001 | 000000444 | 000000001D | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 45 | 6 | 0080888 | 00002002 | 000000888 | 000000003B | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 46 | 7 | 0101111 | 00004004 | 000001111 | 0000000077 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 47 | 8 | 0202222 | 00008008 | 000002222 | 00000000EE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 48 | 9 | 0404444 | 00010011 | 000004444 | 00000001DD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 49 | 10 | 0808888 | 00020022 | 000008888 | 00000003BB | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 50 | 11 | 1011110 | 00040044 | 000011111 | 0000000777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 51 | 12 | 0022221 | 00080088 | 000022222 | 0000000EEE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 52 | 13 | 0044442 | 00100110 | 000044444 | 0000001DDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 53 | 14 | 0088884 | 00200220 | 000088888 | 0000003BBB | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 54 | 15 | 0111109 | 00400440 | 000111111 | 0000007777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 55 | 16 | 0222212 | 00800880 | 000222222 | 000000EEEE | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 56 | 17 | 0444424 | 01001100 | 000444444 | 000001DDDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 57 | 18 | 0888848 | 02002200 | 000888888 | 000003BBBB | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 58 | 19 | 1111090 | 04004400 | 001111110 | 0000077777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 59 | 20 | 0222120 | 08008800 | 002222220 | 00000EEEE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 60 | 21 | 0444240 | 10011000 | 004444440 | 00001DDDDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 61 | 22 | 0888480 | 20022000 | 008888880 | 00003BBBBB | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 62 | 23 | 1110900 | 40044000 | 011111100 | 0000777777 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 63 | 24 | 0221200 | 00088001 | 022222200 | 0000EEEEEE | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 64 | 25 | 0442400 | 00110003 | 044444400 | 0001DDDDDD | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 65 | 26 | 0884800 | 00220006 | 088888800 | 0003BBBBBB | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 66 | 27 | 1109000 | 0044000C | 111111000 | 0007777777 | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 67 | 28 | 0212001 | 00880018 | 022222001 | 000EEEEEEE | 0 | 1 | 0 | 0 | 0 | 11 | 01 | 01 |
| 68 | 29 | 0424002 | 01100031 | 044444002 | 001DDDDDDC | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 69 | 30 | 0848004 | 02200062 | 088888004 | 003BBBBBB8 | 1 | 0 | 1 | 0 | 1 | 10 | 01 | 11 |
| 70 | 31 | 1090008 | 044000C4 | 111110008 | 0077777770 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 71 | 32 | 0120010 | 08800188 | 022220010 | 00EEEEEEE0 | 0 | 1 | 0 | 1 | 0 | 00 | 00 | 10 |
| 72 | 33 | 0240020 | 11000311 | 044440020 | 01DDDDDDC1 | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 73 | 34 | 0480040 | 22000622 | 088880040 | 03BBBBBB83 | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 74 | 35 | 0900081 | 44000C44 | 111100080 | 0777777707 | 1 | 0 | 0 | 0 | 0 | 00 | 01 | 00 |
| 75 | 36 | 1200103 | 08001888 | 022200101 | 0EEEEEEE0E | 0 | 0 | 0 | 1 | 1 | 11 | 00 | 01 |
| 76 | 37 | 0400207 | 10003111 | 044400202 | 1DDDDDDC1D | 0 | 0 | 0 | 1 | 0 | 01 | 11 | 00 |
| 77 | 38 | 080040E | 20006222 | 088800404 | 3BBBBBB83B | 1 | 0 | 1 | 1 | 0 | 01 | 01 | 11 |
| 78 | 39 | 100081C | 4000C444 | 111000808 | 7777777077 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 79 | 40 | 0001038 | 00018888 | 022001010 | 6EEEEEE0EF | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 80 | 41 | 0002070 | 00031110 | 044002020 | 5DDDDDC1DE | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 81 | 42 | 00040E0 | 00062220 | 088004040 | 3BBBBB83BC | 0 | 0 | 1 | 1 | 1 | 00 | 01 | 00 |
| 82 | 43 | 00081C1 | 000C4440 | 110008081 | 7777777079 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 83 | 44 | 0010383 | 00188880 | 020010103 | 6EEEEEE0EF2 | 0 | 0 | 0 | 1 | 0 | 01 | 11 | 00 |
| 84 | 45 | 0020707 | 00311100 | 040020206 | 5DDDDC1DE5 | 0 | 0 | 0 | 1 | 0 | 10 | 01 | 11 |
| 85 | 46 | 0040E0E | 00622200 | 08004040C | 3BBBB83BCB | 0 | 0 | 1 | 1 | 0 | 11 | 10 | 01 |
| 86 | 47 | 0081C1D | 00C44400 | 100080819 | 7777707797 | 0 | 1 | 0 | 0 | 0 | 00 | 11 | 10 |
| 87 | 48 | 010383A | 01888801 | 000101032 | 6EEEE0EF2F | 0 | 1 | 0 | 1 | 0 | 11 | 00 | 11 |
| 88 | 49 | 0207075 | 03111003 | 000202064 | 5DDDC1DE5E | 0 | 0 | 0 | 1 | 0 | 01 | 11 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 89 | 50 | 040E0EA | 06222006 | 0004040C8 | 3BBB83BCBC | 0 | 0 | 0 | 1 | 0 | 10 | 01 | 11 |
| 90 | 51 | 081C1D5 | 0C44400C | 000808191 | 7777077979 | 1 | 0 | 0 | 0 | 1 | 00 | 10 | 01 |
| 91 | 52 | 10383AB | 18888018 | 001010323 | 6EEE0EF2F2 | 0 | 1 | 0 | 1 | 0 | 00 | 00 | 10 |
| 92 | 53 | 0070756 | 31110030 | 002020646 | 5DDC1DE5E5 | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 93 | 54 | 00E0EAC | 62220060 | 004040C8C | 3BB83BCBCB | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 94 | 55 | 01C1D59 | 444400C1 | 008081919 | 7770779797 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 95 | 56 | 0383AB2 | 08880183 | 010103232 | 6EE0EF2F2F | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 96 | 57 | 0707565 | 11100307 | 020206464 | 5DC1DE5E5F | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 97 | 58 | 0E0EACA | 2220060E | 04040C8C8 | 3B83BCBCBF | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 98 | 59 | 1C1D594 | 44400C1C | 080819191 | 770779797E | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 99 | 60 | 183AB28 | 08801838 | 101032323 | 6E0EF2F2FC | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 100 | 61 | 1075650 | 11003070 | 002064647 | 5C1DE5E5F8 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 101 | 62 | 00EACA1 | 220060E0 | 0040C8C8E | 383BCBCBF0 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 102 | 63 | 01D5943 | 4400C1C0 | 00819191D | 70779797E0 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 103 | 64 | 03AB286 | 08018380 | 01032323A | 60EF2F2FC1 | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 104 | 65 | 075650C | 10030701 | 020646475 | 41DE5E5F82 | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 105 | 66 | 0EACA18 | 20060E02 | 040C8C8EA | 03BCBCBF04 | 1 | 0 | 0 | 1 | 0 | 01 | 00 | 00 |
| 106 | 67 | 1D59430 | 400C1C05 | 0819191D4 | 0779797E09 | 1 | 0 | 1 | 0 | 1 | 00 | 01 | 00 |
| 107 | 68 | 1AB2861 | 0018380A | 1032323A9 | 0EF2F2FC12 | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 108 | 69 | 15650C3 | 00307015 | 006464752 | 1DE5E5F825 | 0 | 0 | 0 | 1 | 1 | 11 | 10 | 00 |
| 109 | 70 | 0ACA186 | 0060E02A | 00C8C8EA4 | 3BCBCBF04B | 1 | 0 | 0 | 1 | 1 | 00 | 11 | 10 |
| 110 | 71 | 159430C | 00C1C055 | 019191D48 | 779797E097 | 0 | 1 | 0 | 1 | 0 | 11 | 00 | 11 |
| 111 | 72 | 0B28618 | 018380AA | 032323A90 | 6F2F2FC12F | 1 | 1 | 0 | 0 | 1 | 01 | 11 | 00 |
| 112 | 73 | 1650C30 | 03070154 | 064647520 | 5E5E5F825E | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 113 | 74 | 0CA1860 | 060E02A8 | 0C8C8EA40 | 3CBCBF04BC | 1 | 0 | 1 | 1 | 0 | 11 | 11 | 01 |
| 114 | 75 | 19430C0 | 0C1C0550 | 19191D480 | 79797E0979 | 1 | 0 | 1 | 0 | 1 | 11 | 11 | 11 |
| 115 | 76 | 1286180 | 18380AA0 | 12323A900 | 72F2FC12F2 | 0 | 0 | 0 | 1 | 0 | 11 | 11 | 11 |
| 116 | 77 | 050C301 | 30701541 | 046475201 | 65E5F825E5 | 0 | 0 | 0 | 1 | 0 | 11 | 11 | 11 |
| 117 | 78 | 0A18602 | 60E02A82 | 08C8EA402 | 4BCBF04BCB | 1 | 1 | 1 | 1 | 1 | 10 | 11 | 11 |
| 118 | 79 | 1430C04 | 41C05505 | 1191D4804 | 1797E09796 | 0 | 1 | 0 | 1 | 0 | 10 | 10 | 11 |
| 119 | 80 | 0861808 | 0380AA0A | 0323A9008 | 2F2FC12F2C | 1 | 1 | 0 | 0 | 0 | 01 | 10 | 10 |
| 120 | 81 | 10C3011 | 07015415 | 064752011 | 5E5F825E59 | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 121 | 82 | 0186022 | 0E02A82A | 0C8EA4022 | 3CBF04BCB2 | 0 | 0 | 1 | 1 | 0 | 10 | 00 | 01 |
| 122 | 83 | 030C045 | 1C055054 | 191D48044 | 797E097964 | 0 | 0 | 1 | 0 | 1 | 11 | 10 | 00 |
| 123 | 84 | 061808A | 380AA0A8 | 123A90088 | 72FC12F2C9 | 0 | 0 | 0 | 1 | 0 | 00 | 11 | 10 |
| 124 | 85 | 0C30115 | 70154151 | 047520111 | 65F825E593 | 1 | 0 | 0 | 1 | 0 | 11 | 00 | 11 |
| 125 | 86 | 186022A | 602A82A3 | 08EA40222 | 4BF04BCB26 | 1 | 0 | 1 | 1 | 0 | 00 | 11 | 00 |
| 126 | 87 | 10C0455 | 40550546 | 11D480444 | 17E097964C | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 127 | 88 | 01808AA | 00AA0A8D | 03A900888 | 2FC12F2C99 | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 128 | 89 | 0301155 | 0154151A | 075201111 | 5F825E5932 | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 129 | 90 | 06022AA | 02A82A34 | 0EA402222 | 3F04BCB264 | 0 | 1 | 1 | 0 | 1 | 00 | 01 | 00 |
| 130 | 91 | 0C04555 | 05505468 | 1D4804445 | 7E097964C9 | 1 | 0 | 1 | 0 | 0 | 10 | 00 | 01 |
| 131 | 92 | 1808AAA | 0AA0A8D0 | 1A900888A | 7C12F2C992 | 1 | 1 | 1 | 0 | 1 | 00 | 10 | 00 |
| 132 | 93 | 1011555 | 154151A1 | 152011115 | 7825E59324 | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 133 | 94 | 0022AAB | 2A82A342 | 0A402222B | 704BCB2648 | 0 | 1 | 1 | 0 | 1 | 00 | 01 | 00 |
| 134 | 95 | 0045556 | 55054684 | 148044457 | 6097964C91 | 0 | 0 | 0 | 1 | 1 | 11 | 00 | 01 |
| 135 | 96 | 008AAAC | 2A0A8D09 | 0900888AE | 412F2C9923 | 0 | 0 | 1 | 0 | 0 | 01 | 11 | 00 |
| 136 | 97 | 0115559 | 54151A12 | 12011115D | 025E593246 | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 137 | 98 | 022AAB2 | 282A3424 | 0402222BA | 04BCB2648D | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 138 | 99 | 0455564 | 50546848 | 080444575 | 097964C91A | 0 | 0 | 1 | 0 | 1 | 01 | 10 | 11 |
| 139 | 100 | 08AAAC8 | 20A8D090 | 100888AEA | 12F2C99235 | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 140 | 101 | 1155591 | 4151A120 | 0011115D5 | 25E593246A | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 141 | 102 | 02AAB22 | 02A34240 | 002222BAA | 4BCB2648D5 | 0 | 1 | 0 | 1 | 0 | 00 | 00 | 10 |
| 142 | 103 | 0555644 | 05468481 | 004445755 | 17964C91AB | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 143 | 104 | 0AAAC88 | 0A8D0903 | 00888AEAA | 2F2C992357 | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 144 | 105 | 1555911 | 151A1206 | 011115D55 | 5E593246AE | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 145 | 106 | 0AAB222 | 2A34240C | 02222BAAA | 3CB2648D5C | 1 | 0 | 0 | 1 | 1 | 11 | 01 | 01 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 146 | 107 | 1556445 | 54684818 | 044457555 | 7964C91AB8 | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 147 | 108 | 0AAC88B | 28D09030 | 0888AEAAA | 72C9923571 | 1 | 1 | 1 | 1 | 1 | 01 | 01 | 11 |
| 148 | 109 | 1559117 | 51A12060 | 11115D555 | 6593246AE2 | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 149 | 110 | 0AB222F | 234240C0 | 0222BAAAB | 4B2648D5C5 | 1 | 0 | 0 | 0 | 0 | 10 | 11 | 01 |
| 150 | 111 | 156445F | 46848180 | 044575557 | 164C91AB8A | 0 | 1 | 0 | 0 | 1 | 01 | 10 | 11 |
| 151 | 112 | 0AC88BF | 0D090301 | 088AEAAAE | 2C99235714 | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 152 | 113 | 159117F | 1A120602 | 1115D555D | 593246AE28 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 153 | 114 | 0B222FE | 34240C04 | 022BAAABA | 32648D5C51 | 1 | 0 | 0 | 0 | 1 | 01 | 00 | 10 |
| 154 | 115 | 16445FD | 68481809 | 045755574 | 64C91AB8A2 | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 155 | 116 | 0C88BFA | 50903012 | 08AEAAAE8 | 4992357144 | 1 | 1 | 1 | 1 | 0 | 01 | 00 | 01 |
| 156 | 117 | 19117F5 | 21206024 | 115D555D1 | 13246AE288 | 1 | 0 | 0 | 0 | 0 | 00 | 01 | 00 |
| 157 | 118 | 1222FEA | 4240C048 | 02BAAABA2 | 2648D5C511 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 158 | 119 | 0445FD5 | 04818090 | 057555744 | 4C91AB8A23 | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 159 | 120 | 088BFAA | 09030120 | 0AEAAAE88 | 1923571446 | 1 | 0 | 1 | 0 | 1 | 10 | 01 | 11 |
| 160 | 121 | 1117F55 | 12060240 | 15D555D11 | 3246AE288D | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 161 | 122 | 022FEAA | 240C0480 | 0BAAABA22 | 648D5C511B | 0 | 0 | 1 | 1 | 0 | 00 | 00 | 10 |
| 162 | 123 | 045FD54 | 48180900 | 175557444 | 491AB8A237 | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 163 | 124 | 08BFAA9 | 10301200 | 0EAAAE889 | 123571446F | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 164 | 125 | 117F553 | 20602400 | 1D555D113 | 246AE288DF | 0 | 0 | 1 | 0 | 0 | 00 | 01 | 00 |
| 165 | 126 | 02FEAA7 | 40C04800 | 1AAABA227 | 48D5C511BE | 0 | 1 | 1 | 1 | 1 | 10 | 00 | 01 |
| 166 | 127 | 05FD54F | 01809001 | 15557444F | 11AB8A237D | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 167 | 128 | 0BFAA9F | 03012002 | 0AAAE889E | 23571446FA | 1 | 0 | 1 | 0 | 0 | 00 | 00 | 10 |
| 168 | 129 | 17F553F | 06024004 | 1555D113D | 46AE288DF5 | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 169 | 130 | 0FEAA7E | 0C048008 | 0AABA227A | 0D5C511BEA | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 170 | 131 | 1FD54FC | 18090011 | 1557444F5 | 1AB8A237D5 | 1 | 0 | 0 | 1 | 1 | 00 | 01 | 00 |
| 171 | 132 | 1FAA9F9 | 30120022 | 0AAE889EB | 3571446FAA | 1 | 0 | 1 | 0 | 0 | 10 | 00 | 01 |
| 172 | 133 | 1F553F2 | 60240044 | 155D113D7 | 6AE288DF55 | 1 | 0 | 0 | 1 | 0 | 00 | 10 | 00 |
| 173 | 134 | 1EAA7E4 | 40480089 | 0ABA227AE | 55C511BEAA | 1 | 0 | 1 | 1 | 1 | 00 | 00 | 10 |
| 174 | 135 | 1D54FC9 | 00900113 | 157444F5D | 2B8A237D54 | 1 | 1 | 0 | 1 | 1 | 01 | 00 | 00 |
| 175 | 136 | 1AA9F93 | 01200227 | 0AE889EBA | 571446FAA8 | 1 | 0 | 1 | 0 | 1 | 00 | 01 | 00 |
| 176 | 137 | 1553F26 | 0240044E | 15D113D75 | 2E288DF550 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 177 | 138 | 0AA7E4C | 0480089C | 0BA227AEA | 5C511BEAA0 | 1 | 1 | 1 | 0 | 0 | 00 | 11 | 00 |
| 178 | 139 | 154FC98 | 09001138 | 17444F5D4 | 38A237D540 | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 179 | 140 | 0A9F931 | 12002270 | 0E889EBA9 | 71446FAA81 | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 180 | 141 | 153F262 | 240044E0 | 1D113D753 | 6288DF5503 | 0 | 0 | 1 | 1 | 0 | 00 | 00 | 10 |
| 181 | 142 | 0A7E4C5 | 480089C0 | 1A227AEA7 | 4511BEAA06 | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 182 | 143 | 14FC98B | 10011381 | 1444F5D4F | 0A237D540D | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 183 | 144 | 09F9316 | 20022702 | 0889EBA9E | 1446FAA81A | 1 | 0 | 1 | 0 | 1 | 11 | 01 | 01 |
| 184 | 145 | 13F262D | 40044E04 | 1113D753D | 288DF55035 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 185 | 146 | 07E4C5A | 00089C08 | 0227AEA7A | 511BEAA06A | 0 | 0 | 0 | 0 | 0 | 01 | 10 | 11 |
| 186 | 147 | 0FC98B4 | 00113810 | 044F5D4F5 | 2237D540D5 | 1 | 0 | 0 | 0 | 0 | 01 | 01 | 10 |
| 187 | 148 | 1F93169 | 00227021 | 089EBA9EB | 446FAA81AA | 1 | 0 | 1 | 0 | 1 | 11 | 01 | 01 |
| 188 | 149 | 1F262D2 | 0044E042 | 113D753D7 | 08DF550355 | 1 | 0 | 0 | 1 | 1 | 10 | 11 | 01 |
| 189 | 150 | 1E4C5A4 | 0089C085 | 027AEA7AE | 11BEAA06AA | 1 | 1 | 0 | 1 | 1 | 10 | 10 | 11 |
| 190 | 151 | 1C98B48 | 0113810A | 04F5D4F5C | 237D540D54 | 1 | 0 | 0 | 0 | 1 | 10 | 10 | 10 |
| 191 | 152 | 1931691 | 02270215 | 09EBA9EB8 | 46FAA81AA9 | 1 | 0 | 1 | 1 | 1 | 01 | 10 | 10 |
| 192 | 153 | 1262D22 | 044E042A | 13D753D71 | 0DF5503553 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 193 | 154 | 04C5A44 | 089C0854 | 07AEA7AE2 | 1BEAA06AA7 | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 194 | 155 | 098B488 | 113810A8 | 0F5D4F5C4 | 37D540D54E | 1 | 0 | 1 | 1 | 0 | 11 | 11 | 01 |
| 195 | 156 | 1316910 | 22702150 | 1EBA9EB89 | 6FAA81AA9D | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 196 | 157 | 062D220 | 44E042A0 | 1D753D712 | 5F5503553A | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 197 | 158 | 0C5A440 | 09C08540 | 1AEA7AE25 | 3EAA06AA75 | 1 | 1 | 1 | 1 | 1 | 10 | 11 | 11 |
| 198 | 159 | 18B4880 | 13810A80 | 15D4F5C4B | 7D540D54EA | 1 | 1 | 0 | 0 | 0 | 10 | 10 | 11 |
| 199 | 160 | 1169100 | 27021500 | 0BA9EB897 | 7AA81AA9D5 | 0 | 0 | 1 | 1 | 0 | 01 | 10 | 10 |
| 200 | 161 | 02D2201 | 4E042A00 | 1753D712E | 75503553AB | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 201 | 162 | 05A4403 | 1C085400 | 0EA7AE25C | 6AA06AA756 | 0 | 0 | 1 | 1 | 0 | 10 | 00 | 01 |
| 202 | 163 | 0B48807 | 3810A800 | 1D4F5C4B8 | 5540D54EAC | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |

Sample Data

| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 203 | 164 | 169100F | 70215000 | 1A9EB8971 | 2A81AA9D58 | 0 | 0 | 1 | 1 | 0 | 00 | 00 | 10 |
| 204 | 165 | 0D2201E | 6042A001 | 153D712E3 | 5503553AB0 | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 205 | 166 | 1A4403C | 40854002 | 0A7AE25C6 | 2A06AA7561 | 1 | 1 | 1 | 0 | 1 | 01 | 00 | 00 |
| 206 | 167 | 1488079 | 010A8004 | 14F5C4B8D | 540D54EAC3 | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 207 | 168 | 09100F2 | 02150009 | 09EB8971B | 281AA9D586 | 1 | 0 | 1 | 0 | 1 | 11 | 01 | 01 |
| 208 | 169 | 12201E5 | 042A0012 | 13D712E37 | 503553AB0C | 0 | 0 | 0 | 0 | 1 | 01 | 11 | 01 |
| 209 | 170 | 04403CA | 08540024 | 07AE25C6E | 206AA75618 | 0 | 0 | 0 | 0 | 1 | 11 | 01 | 11 |
| 210 | 171 | 0880795 | 10A80048 | 0F5C4B8DD | 40D54EAC30 | 1 | 1 | 1 | 1 | 1 | 11 | 11 | 01 |
| 211 | 172 | 1100F2A | 21500091 | 1EB8971BA | 01AA9D5861 | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 212 | 173 | 0201E54 | 42A00122 | 1D712E374 | 03553AB0C3 | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 213 | 174 | 0403CA9 | 05400244 | 1AE25C6E9 | 06AA756186 | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 214 | 175 | 0807952 | 0A800488 | 15C4B8DD3 | 0D54EAC30D | 1 | 1 | 0 | 0 | 1 | 11 | 11 | 11 |
| 215 | 176 | 100F2A5 | 15000911 | 0B8971BA6 | 1AA9D5861A | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 216 | 177 | 001E54A | 2A001223 | 1712E374C | 3553AB0C35 | 0 | 0 | 0 | 0 | 1 | 00 | 11 | 11 |
| 217 | 178 | 003CA94 | 54002446 | 0E25C6E98 | 6AA756186A | 0 | 0 | 1 | 1 | 0 | 11 | 00 | 11 |
| 218 | 179 | 0079528 | 2800488D | 1C4B8DD31 | 554EAC30D5 | 0 | 0 | 1 | 0 | 0 | 01 | 11 | 00 |
| 219 | 180 | 00F2A50 | 5000911B | 18971BA62 | 2A9D5861AA | 0 | 0 | 1 | 1 | 1 | 10 | 01 | 11 |
| 220 | 181 | 01E54A0 | 20012236 | 112E374C4 | 553AB0C355 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 221 | 182 | 03CA940 | 4002446C | 025C6E988 | 2A756186AA | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 222 | 183 | 0795280 | 000488D9 | 04B8DD310 | 54EAC30D54 | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 223 | 184 | 0F2A500 | 000911B2 | 0971BA620 | 29D5861AA8 | 1 | 0 | 1 | 1 | 1 | 10 | 00 | 01 |
| 224 | 185 | 1E54A00 | 00122364 | 12E374C40 | 53AB0C3550 | 1 | 0 | 0 | 1 | 0 | 00 | 10 | 00 |
| 225 | 186 | 1CA9400 | 002446C8 | 05C6E9880 | 2756186AA0 | 1 | 0 | 0 | 0 | 1 | 01 | 00 | 10 |
| 226 | 187 | 1952800 | 00488D90 | 0B8DD3101 | 4EAC30D540 | 1 | 0 | 1 | 1 | 0 | 11 | 01 | 00 |
| 227 | 188 | 12A5000 | 00911B20 | 171BA6202 | 1D5861AA81 | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 228 | 189 | 054A000 | 01223640 | 0E374C404 | 3AB0C35502 | 0 | 0 | 1 | 1 | 0 | 10 | 10 | 11 |
| 229 | 190 | 0A94000 | 02446C80 | 1C6E98808 | 756186AA05 | 1 | 0 | 1 | 0 | 0 | 01 | 10 | 10 |
| 230 | 191 | 1528001 | 0488D901 | 18DD31011 | 6AC30D540B | 0 | 1 | 1 | 1 | 0 | 10 | 01 | 10 |
| 231 | 192 | 0A50003 | 0911B203 | 11BA62023 | 55861AA817 | 1 | 0 | 0 | 1 | 0 | 11 | 10 | 01 |
| 232 | 193 | 14A0006 | 12236407 | 0374C4047 | 2B0C35502F | 0 | 0 | 0 | 0 | 1 | 11 | 11 | 10 |
| 233 | 194 | 094000C | 2446C80E | 06E98808E | 56186AA05F | 1 | 0 | 0 | 0 | 0 | 11 | 11 | 11 |
| 234 | 195 | 1280018 | 488D901C | 0DD31011D | 2C30D540BF | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 235 | 196 | 0500030 | 111B2039 | 1BA62023A | 5861AA817E | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 236 | 197 | 0A00060 | 22364072 | 174C40475 | 30C35502FD | 1 | 0 | 0 | 1 | 1 | 11 | 11 | 11 |
| 237 | 198 | 14000C0 | 446C80E4 | 0E98808EA | 6186AA05FB | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 238 | 199 | 0800180 | 08D901C8 | 1D31011D5 | 430D540BF6 | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 239 | 200 | 1000301 | 11B20391 | 1A62023AB | 061AA817EC | 0 | 1 | 1 | 0 | 0 | 10 | 10 | 11 |

Z[0] = 25

Z[1] = 45

Z[2] = 6B

Z[3] = 55

Z[4] = 5F

Z[5] = C2

Z[6] = 20

Z[7] = E5

Z[8] = C4

Z[9] = F8

Z[10] = 3A

Z[11] = F1

Z[12] = FF

Z[13] = 89

Z[14] = 02

Z[15] = 35

=====

Reload this pattern into the LFSRs

Sample Data



Hold content of Summation Combiner regs and calculate new C[t+1] and Z values

```
=====
LFSR1  <= 1C45F25
LFSR2  <= 7FF8C245
LFSR3  <= 1893A206B
LFSR4  <= 1A02F1E555
C[t+1] <= 10
=====
```

Generating 125 key symbols (encryption/decryption sequence)

```
=====
240  1  1C45F25 7FF8C245 1893A206B 1A02F1E555  1 1 1 0  1 10  10 11
241  2  188BE4A 7FF1848B 1127440D7 3405E3CAAB  1 1 0 0  0 01  10 10
242  3  1117C95 7FE30917 024E881AF 680BC79557  0 1 0 0  0 01  01 10
243  4  022F92B 7FC6122F 049D1035E 50178F2AAF  0 1 0 0  0 11  01 01
244  5  045F257 7F8C245E 093A206BD 202F1E555E  0 1 1 0  1 10  11 01
245  6  08BE4AE 7F1848BC 127440D7A 405E3CAABC  1 0 0 0  1 01  10 11
246  7  117C95C 7E309178 04E881AF4 00BC795579  0 0 0 1  0 01  01 10
247  8  02F92B8 7C6122F0 09D1035E8 0178F2AAF2  0 0 1 0  0 11  01 01
248  9  05F2570 78C245E1 13A206BD0 02F1E555E5  0 1 0 1  1 10  11 01
249 10  0BE4AE1 71848BC2 07440D7A0 05E3CAABCA  1 1 0 1  1 10  10 11
250 11  17C95C3 63091784 0E881AF40 0BC7955795  0 0 1 1  0 01  10 10
251 12  0F92B87 46122F09 1D1035E80 178F2AAF2B  1 0 1 1  0 10  01 10
252 13  1F2570F 0C245E12 1A206BD01 2F1E555E56  1 0 1 0  0 11  10 01
253 14  1E4AE1F 1848BC25 1440D7A03 5E3CAABCAC  1 0 0 0  0 00  11 10
254 15  1C95C3E 3091784A 0881AF407 3C79557958  1 1 1 0  1 11  00 11
255 16  192B87D 6122F094 11035E80F 78F2AAF2B1  1 0 0 1  1 01  11 00
256 17  12570FA 4245E128 0206BD01E 71E555E562  0 0 0 1  0 10  01 11
257 18  04AE1F4 048BC250 040D7A03D 63CAABCAC5  0 1 0 1  0 11  10 01
258 19  095C3E8 091784A0 081AF407A 479557958A  1 0 1 1  0 01  11 10
259 20  12B87D1 122F0941 1035E80F4 0F2AAF2B14  0 0 0 0  1 11  01 11
260 21  0570FA3 245E1283 006BD01E9 1E555E5628  0 0 0 0  1 01  11 01
261 22  0AE1F46 48BC2506 00D7A03D2 3CAABCAC50  1 1 0 1  0 01  01 11
262 23  15C3E8C 11784A0C 01AF407A5 79557958A0  0 0 0 0  1 10  01 01
263 24  0B87D18 22F09419 035E80F4A 72AAF2B140  1 1 0 1  1 11  10 01
264 25  170FA30 45E12832 06BD01E94 6555E56280  0 1 0 0  0 00  11 10
265 26  0E1F460 0BC25065 0D7A03D28 4AABCAC501  1 1 1 1  0 00  00 11
266 27  1C3E8C0 1784A0CB 1AF407A50 1557958A03  1 1 1 0  1 01  00 00
267 28  187D181 2F094196 15E80F4A0 2AAF2B1406  1 0 0 1  1 00  01 00
268 29  10FA302 5E12832C 0BD01E941 555E56280C  0 0 1 0  1 11  00 01
269 30  01F4604 3C250658 17A03D283 2ABCAC5019  0 0 0 1  0 01  11 00
270 31  03E8C09 784A0CB0 0F407A506 557958A033  0 0 1 0  0 10  01 11
271 32  07D1812 70941960 1E80F4A0C 2AF2B14066  0 1 1 1  1 11  10 01
272 33  0FA3024 612832C1 1D01E9419 55E56280CD  1 0 1 1  0 01  11 10
273 34  1F46049 42506583 1A03D2832 2BCAC5019A  1 0 1 1  0 01  01 11
274 35  1E8C093 04A0CB07 1407A5065 57958A0335  1 1 0 1  0 00  01 01
275 36  1D18127 0941960F 080F4A0CB 2F2B14066B  1 0 1 0  0 10  00 01
276 37  1A3024F 12832C1F 101E94196 5E56280CD7  1 1 0 0  0 00  10 00
277 38  146049F 2506583E 003D2832C 3CAC5019AE  0 0 0 1  1 01  00 10
278 39  08C093E 4A0CB07D 007A50658 7958A0335D  1 0 0 0  0 00  01 00
279 40  118127C 141960FA 00F4A0CB0 72B14066BA  0 0 0 1  1 11  00 01
280 41  03024F8 2832C1F4 01E941961 656280CD74  0 0 0 0  1 10  11 00
281 42  06049F1 506583E9 03D2832C2 4AC5019AE9  0 0 0 1  1 01  10 11
282 43  0C093E2 20CB07D2 07A506585 158A0335D3  1 1 0 1  0 10  01 10
283 44  18127C5 41960FA5 0F4A0CB0B 2B14066BA7  1 1 1 0  1 11  10 01
284 45  1024F8A 032C1F4B 1E9419616 56280CD74F  0 0 1 0  0 00  11 10
285 46  0049F15 06583E97 1D2832C2C 2C5019AE9F  0 0 1 0  1 10  00 11
=====
```

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 286 | 47 | 0093E2B | 0CB07D2F | 1A5065859 | 58A0335D3E | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 287 | 48 | 0127C56 | 1960FA5E | 14A0CB0B2 | 314066BA7D | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 288 | 49 | 024F8AD | 32C1F4BC | 094196164 | 6280CD74FB | 0 | 1 | 1 | 1 | 0 | 11 | 01 | 00 |
| 289 | 50 | 049F15A | 6583E978 | 12832C2C8 | 45019AE9F6 | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 290 | 51 | 093E2B5 | 4B07D2F0 | 050658591 | 0A0335D3ED | 1 | 0 | 0 | 0 | 1 | 01 | 10 | 11 |
| 291 | 52 | 127C56B | 160FA5E0 | 0A0CB0B22 | 14066BA7DA | 0 | 0 | 1 | 0 | 0 | 01 | 01 | 10 |
| 292 | 53 | 04F8AD7 | 2C1F4BC1 | 141961645 | 280CD74FB5 | 0 | 0 | 0 | 0 | 1 | 10 | 01 | 01 |
| 293 | 54 | 09F15AF | 583E9783 | 0832C2C8A | 5019AE9F6A | 1 | 0 | 1 | 0 | 0 | 11 | 10 | 01 |
| 294 | 55 | 13E2B5E | 307D2F06 | 106585915 | 20335D3ED5 | 0 | 0 | 0 | 0 | 1 | 11 | 11 | 10 |
| 295 | 56 | 07C56BD | 60FA5E0D | 00CB0B22B | 4066BA7DAA | 0 | 1 | 0 | 0 | 0 | 11 | 11 | 11 |
| 296 | 57 | 0F8AD7A | 41F4BC1B | 019616457 | 00CD74FB54 | 1 | 1 | 0 | 1 | 0 | 10 | 11 | 11 |
| 297 | 58 | 1F15AF4 | 03E97836 | 032C2C8AF | 019AE9F6A9 | 1 | 1 | 0 | 1 | 1 | 10 | 10 | 11 |
| 298 | 59 | 1E2B5E9 | 07D2F06C | 06585915E | 0335D3ED52 | 1 | 1 | 0 | 0 | 0 | 01 | 10 | 10 |
| 299 | 60 | 1C56BD2 | 0FA5E0D8 | 0CB0B22BC | 066BA7DAA4 | 1 | 1 | 1 | 0 | 0 | 10 | 01 | 10 |
| 300 | 61 | 18AD7A5 | 1F4BC1B0 | 196164578 | 0CD74FB549 | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 301 | 62 | 115AF4B | 3E978361 | 12C2C8AF0 | 19AE9F6A92 | 0 | 1 | 0 | 1 | 1 | 00 | 11 | 10 |
| 302 | 63 | 02B5E96 | 7D2F06C2 | 0585915E0 | 335D3ED524 | 0 | 0 | 0 | 0 | 0 | 10 | 00 | 11 |
| 303 | 64 | 056BD2D | 7A5E0D85 | 0B0B22BC1 | 66BA7DAA49 | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 304 | 65 | 0AD7A5B | 74BC1B0A | 161645783 | 4D74FB5493 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 305 | 66 | 15AF4B6 | 69783615 | 0C2C8AF07 | 1AE9F6A926 | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 306 | 67 | 0B5E96D | 52F06C2B | 185915E0F | 35D3ED524C | 1 | 1 | 1 | 1 | 1 | 11 | 01 | 00 |
| 307 | 68 | 16BD2DB | 25E0D857 | 10B22BC1F | 6BA7DAA499 | 0 | 1 | 0 | 1 | 1 | 10 | 11 | 01 |
| 308 | 69 | 0D7A5B7 | 4BC1B0AF | 01645783F | 574FB54933 | 1 | 1 | 0 | 0 | 0 | 10 | 10 | 11 |
| 309 | 70 | 1AF4B6F | 1783615F | 02C8AF07F | 2E9F6A9266 | 1 | 1 | 0 | 1 | 1 | 01 | 10 | 10 |
| 310 | 71 | 15E96DF | 2F06C2BF | 05915E0FF | 5D3ED524CC | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 311 | 72 | 0BD2DBF | 5E0D857F | 0B22BC1FE | 3A7DAA4998 | 1 | 0 | 1 | 0 | 0 | 10 | 00 | 01 |
| 312 | 73 | 17A5B7F | 3C1B0AFE | 1645783FD | 74FB549331 | 0 | 0 | 0 | 1 | 1 | 11 | 10 | 00 |
| 313 | 74 | 0F4B6FF | 783615FD | 0C8AF07FA | 69F6A92662 | 1 | 0 | 1 | 1 | 0 | 01 | 11 | 10 |
| 314 | 75 | 1E96DFF | 706C2BFB | 1915E0FF5 | 53ED524CC4 | 1 | 0 | 1 | 1 | 0 | 01 | 01 | 11 |
| 315 | 76 | 1D2DBFE | 60D857F6 | 122BC1FEB | 27DAA49988 | 1 | 1 | 0 | 1 | 0 | 00 | 01 | 01 |
| 316 | 77 | 1A5B7FD | 41B0AFEC | 045783FD7 | 4FB5493310 | 1 | 1 | 0 | 1 | 1 | 10 | 00 | 01 |
| 317 | 78 | 14B6FFA | 03615FD8 | 08AF07FAE | 1F6A926620 | 0 | 0 | 1 | 0 | 1 | 11 | 10 | 00 |
| 318 | 79 | 096DFF4 | 06C2BFB1 | 115E0FF5D | 3ED524CC40 | 1 | 1 | 0 | 1 | 0 | 01 | 11 | 10 |
| 319 | 80 | 12DBFE8 | 0D857F63 | 02BC1FEBB | 7DAA499881 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 320 | 81 | 05B7FD0 | 1B0AFEC6 | 05783FD77 | 7B54933103 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 321 | 82 | 0B6FFA1 | 3615FD8C | 0AF07FAEF | 76A9266206 | 1 | 0 | 1 | 1 | 1 | 00 | 00 | 10 |
| 322 | 83 | 16DFF42 | 6C2BFB18 | 15E0FF5DE | 6D524CC40C | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 323 | 84 | 0DBFE85 | 5857F631 | 0BC1FEBBD | 5AA4998819 | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 324 | 85 | 1B7FD0B | 30AFEC62 | 1783FD77A | 3549331033 | 1 | 1 | 0 | 0 | 1 | 00 | 01 | 00 |
| 325 | 86 | 16FFA16 | 615FD8C5 | 0F07FAEF5 | 6A92662067 | 0 | 0 | 1 | 1 | 0 | 10 | 00 | 01 |
| 326 | 87 | 0DFF42D | 42BFB18B | 1E0FF5DEA | 5524CC40CE | 1 | 1 | 1 | 0 | 1 | 00 | 10 | 00 |
| 327 | 88 | 1BFE85B | 057F6317 | 1C1FEBBD5 | 2A4998819C | 1 | 0 | 1 | 0 | 0 | 00 | 00 | 10 |
| 328 | 89 | 17FD0B7 | 0AFEC62E | 183FD77AA | 5493310339 | 0 | 1 | 1 | 1 | 1 | 01 | 00 | 00 |
| 329 | 90 | 0FFA16F | 15FD8C5C | 107FAEF55 | 2926620672 | 1 | 1 | 0 | 0 | 1 | 00 | 01 | 00 |
| 330 | 91 | 1FF42DF | 2BFB18B9 | 00FF5DEAA | 524CC40CE5 | 1 | 1 | 0 | 0 | 0 | 10 | 00 | 01 |
| 331 | 92 | 1FE85BF | 57F63172 | 01FEBBD55 | 24998819CA | 1 | 1 | 0 | 1 | 1 | 00 | 10 | 00 |
| 332 | 93 | 1FD0B7F | 2FEC62E4 | 03FD77AAA | 4933103394 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 333 | 94 | 1FA16FF | 5FD8C5C9 | 07FAEF555 | 1266206728 | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 334 | 95 | 1F42DFF | 3FB18B93 | 0FF5DEAAA | 24CC40CE51 | 1 | 1 | 1 | 1 | 1 | 11 | 01 | 00 |
| 335 | 96 | 1E85BFF | 7F631727 | 1FEBBD554 | 4998819CA3 | 1 | 0 | 1 | 1 | 0 | 11 | 11 | 01 |
| 336 | 97 | 1D0B7FE | 7EC62E4F | 1FD77AAA9 | 1331033947 | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 337 | 98 | 1A16FFC | 7D8C5C9F | 1FAEF5553 | 266206728E | 1 | 1 | 1 | 0 | 1 | 10 | 10 | 11 |
| 338 | 99 | 142DFF9 | 7B18B93F | 1F5DEAAA7 | 4CC40CE51D | 0 | 0 | 1 | 1 | 0 | 01 | 10 | 10 |
| 339 | 100 | 085BFF3 | 7631727F | 1EBBD554E | 198819CA3B | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 340 | 101 | 10B7FE6 | 6C62E4FF | 1D77AAA9C | 3310339477 | 0 | 0 | 1 | 0 | 1 | 00 | 10 | 01 |
| 341 | 102 | 016FFCC | 58C5C9FE | 1AEF55538 | 66206728EE | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 342 | 103 | 02DFF98 | 318B93FC | 15DEAAA70 | 4C40CE51DC | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |

Sample Data

| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 343 | 104 | 05BFF31 | 631727F8 | 0BBD554E1 | 18819CA3B9 | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 344 | 105 | 0B7FE62 | 462E4FF1 | 177AAA9C2 | 3103394772 | 1 | 0 | 0 | 0 | 0 | 00 | 01 | 00 |
| 345 | 106 | 16FFCC5 | 0C5C9FE2 | 0EF555384 | 6206728EE4 | 0 | 0 | 1 | 0 | 1 | 11 | 00 | 01 |
| 346 | 107 | 0DFF98A | 18B93FC4 | 1DEAAA709 | 440CE51DC9 | 1 | 1 | 1 | 0 | 0 | 00 | 11 | 00 |
| 347 | 108 | 1BFF315 | 31727F88 | 1BD554E12 | 0819CA3B93 | 1 | 0 | 1 | 0 | 0 | 11 | 00 | 11 |
| 348 | 109 | 17FE62A | 62E4FF11 | 17AAA9C24 | 1033947726 | 0 | 1 | 0 | 0 | 0 | 01 | 11 | 00 |
| 349 | 110 | 0FFCC54 | 45C9FE22 | 0F5553849 | 206728EE4C | 1 | 1 | 1 | 0 | 0 | 01 | 01 | 11 |
| 350 | 111 | 1FF98A8 | 0B93FC44 | 1EAAA7093 | 40CE51DC99 | 1 | 1 | 1 | 1 | 1 | 00 | 01 | 01 |
| 351 | 112 | 1FF3150 | 1727F889 | 1D554E127 | 019CA3B933 | 1 | 0 | 1 | 1 | 1 | 10 | 00 | 01 |
| 352 | 113 | 1FE62A0 | 2E4FF112 | 1AAA9C24F | 0339477267 | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 353 | 114 | 1FCC541 | 5C9FE225 | 15553849E | 06728EE4CF | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 354 | 115 | 1F98A82 | 393FC44B | 0AAA7093C | 0CE51DC99F | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 355 | 116 | 1F31504 | 727F8897 | 1554E1279 | 19CA3B933E | 1 | 0 | 0 | 1 | 1 | 00 | 01 | 00 |
| 356 | 117 | 1E62A09 | 64FF112F | 0AA9C24F2 | 339477267D | 1 | 1 | 1 | 1 | 0 | 01 | 00 | 01 |
| 357 | 118 | 1CC5412 | 49FE225E | 1553849E4 | 6728EE4CFB | 1 | 1 | 0 | 0 | 1 | 00 | 01 | 00 |
| 358 | 119 | 198A824 | 13FC44BC | 0AA7093C9 | 4E51DC99F7 | 1 | 1 | 1 | 0 | 1 | 10 | 00 | 01 |
| 359 | 120 | 1315049 | 27F88979 | 154E12792 | 1CA3B933EE | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 360 | 121 | 062A093 | 4FF112F3 | 0A9C24F24 | 39477267DC | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 361 | 122 | 0C54127 | 1FE225E6 | 153849E48 | 728EE4CFB8 | 1 | 1 | 0 | 1 | 1 | 01 | 00 | 00 |
| 362 | 123 | 18A824E | 3FC44BCD | 0A7093C91 | 651DC99F71 | 1 | 1 | 1 | 0 | 0 | 11 | 01 | 00 |
| 363 | 124 | 115049C | 7F88979A | 14E127922 | 4A3B933EE2 | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 364 | 125 | 02A0938 | 7F112F35 | 09C24F244 | 1477267DC5 | 0 | 0 | 1 | 0 | 1 | 01 | 10 | 11 |

Sample Data



1.4 THIRD SET OF SAMPLES

Initial values for the key, pan address and clock

```

K'c3[0]  = FF  K'c3[1]  = FF  K'c3[2]  = FF  K'c3[3]  = FF
K'c3[4]  = FF  K'c3[5]  = FF  K'c3[6]  = FF  K'c3[7]  = FF
K'c3[8]  = FF  K'c3[9]  = FF  K'c3[10] = FF  K'c3[11] = FF
K'c3[12] = FF  K'c3[13] = FF  K'c3[14] = FF  K'c3[15] = FF

```

```

Addr3[0] = FF  Addr3[1] = FF  Addr3[2] = FF
Addr3[3] = FF  Addr3[4] = FF  Addr3[5] = FF

```

```

CL3[0]  = FF  CL3[1]  = FF  CL3[2]  = FF  CL3[3]  = 03

```

```

=====
Fill LFSRs with initial data
=====

```

| t | clk# | LFSR1 | LFSR2 | LFSR3 | LFSR4 | X1 | X2 | X3 | X4 | Z | C[t+1] | C[t] | C[t-1] |
|----|------|-----------|-----------|-------------|--------------|----|----|----|----|---|--------|------|--------|
| 0 | 0 | 0000000* | 00000000* | 000000000* | 0000000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 1 | 1 | 0000001* | 00000001* | 000000001* | 0000000001* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 2 | 2 | 0000003* | 00000002* | 000000003* | 0000000003* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 3 | 3 | 0000007* | 00000004* | 000000007* | 0000000007* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 4 | 4 | 000000F* | 00000009* | 00000000F* | 000000000F* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 5 | 5 | 000001F* | 00000013* | 00000001F* | 000000001F* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 6 | 6 | 000003F* | 00000027* | 00000003F* | 000000003F* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 7 | 7 | 000007F* | 0000004F* | 00000007F* | 000000007F* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 8 | 8 | 00000FF* | 0000009F* | 0000000FF* | 00000000FF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 9 | 9 | 00001FF* | 0000013F* | 0000001FF* | 00000001FF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 10 | 10 | 00003FF* | 0000027F* | 0000003FF* | 00000003FF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 11 | 11 | 00007FF* | 000004FF* | 0000007FF* | 00000007FF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 12 | 12 | 0000FFF* | 000009FF* | 000000FFF* | 0000000FFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 13 | 13 | 0001FFF* | 000013FF* | 000001FFF* | 0000001FFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 14 | 14 | 0003FFF* | 000027FF* | 000003FFF* | 0000003FFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 15 | 15 | 0007FFF* | 00004FFF* | 000007FFF* | 0000007FFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 16 | 16 | 000FFFF* | 00009FFF* | 00000FFFF* | 000000FFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 17 | 17 | 001FFFF* | 00013FFF* | 00001FFFF* | 000001FFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 18 | 18 | 003FFFF* | 00027FFF* | 00003FFFF* | 000003FFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 19 | 19 | 007FFFF* | 0004FFF* | 00007FFFF* | 000007FFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 20 | 20 | 00FFFFFF* | 0009FFF* | 0000FFFFFF* | 00000FFFFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 21 | 21 | 01FFFFFF* | 0013FFF* | 0001FFFFFF* | 00001FFFFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 22 | 22 | 03FFFFFF* | 0027FFF* | 0003FFFFFF* | 00003FFFFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 23 | 23 | 07FFFFFF* | 004FFF* | 0007FFFFFF* | 00007FFFFFF* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 24 | 24 | 0FFFFFF* | 009FFF* | 000FFFFFF* | 0000FFFFFF* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 25 | 25 | 1FFFFFF* | 013FFF* | 001FFFFFF* | 0001FFFFFF* | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 26 | 26 | 1FFFFFF* | 027FFF* | 003FFFFFF* | 0003FFFFFF* | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 27 | 27 | 1FFFFFF* | 04FFF* | 007FFFFFF* | 0007FFFFFF* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 28 | 28 | 1FFFFFF* | 09FFF* | 00FFFFFF* | 000FFFFFF* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 29 | 29 | 1FFFFFF* | 13FFF* | 01FFFFFF* | 001FFFFFF* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 30 | 30 | 1FFFFFF* | 27FFF* | 03FFFFFF* | 003FFFFFF* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 31 | 31 | 1FFFFFF* | 4FFF* | 07FFFFFF* | 007FFFFFF* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 32 | 32 | 1FFFFFF* | 1FFFFFF* | 0FFFFFF* | 00FFFFFF* | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 33 | 33 | 1FFFFFF* | 3FFFFFF* | 1FFFFFF* | 01FFFFFF* | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 34 | 34 | 1FFFFFF* | 7FFFFFF* | 1FFFFFF* | 03FFFFFF* | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|----|----|----------|-----------|------------|-------------|---|---|---|---|---|----|----|----|
| 35 | 35 | 1FFFFFFF | 7FFFFFFF9 | 1FFFFFFFFF | 07FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 36 | 36 | 1FFFFFFF | 7FFFFFFF3 | 1FFFFFFFFF | 0FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 37 | 37 | 1FFFFFFF | 7FFFFFFE7 | 1FFFFFFFFF | 1FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 38 | 38 | 1FFFFFFF | 7FFFFFFCF | 1FFFFFFFFF | 3FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 39 | 39 | 1FFFFFFF | 7FFFFFF9F | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |

Start clocking Summation Combiner

| | | | | | | | | | | | | | |
|----|----|----------|------------|-------------|---------------|---|---|---|---|---|----|----|----|
| 40 | 1 | 1FFFFFFF | 7FFFFFF3F | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 01 | 10 | 00 |
| 41 | 2 | 1FFFFFFF | 7FFFFFFE7F | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 1 | 10 | 01 | 10 |
| 42 | 3 | 1FFFFFFF | 7FFFCFF | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 10 | 01 |
| 43 | 4 | 1FFFFFFF | 7FFFF9FF | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 00 | 10 | 10 |
| 44 | 5 | 1FFFFFFF | 7FFFF3FF | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 11 | 00 | 10 |
| 45 | 6 | 1FFFFFFF | 7FFE7FE | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 46 | 7 | 1FFFFFFF | 7FFCFFC | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 00 | 00 | 11 |
| 47 | 8 | 1FFFFFFF | 7FF9FF9 | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 48 | 9 | 1FFFFFFF | 7FF3FF3 | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 01 | 10 | 00 |
| 49 | 10 | 1FFFFFFF | 7FE7FE6 | 1FFFFFFFFF | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 1 | 10 | 01 | 10 |
| 50 | 11 | 1FFFFFFE | 7FCFFCC | 1FFFFFFFE | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 10 | 01 |
| 51 | 12 | 1FFFFFC | 7F9FF99 | 1FFFFF*FC | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 00 | 10 | 10 |
| 52 | 13 | 1FFFFF8 | 7FF3FF33 | 1FFFFF*F8 | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 11 | 00 | 10 |
| 53 | 14 | 1FFFFF0 | 7FE7FE67 | 1FFFFF*F0 | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 54 | 15 | 1FFFFE0 | 7CF*CCF | 1FFFFF*E1 | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 00 | 00 | 11 |
| 55 | 16 | 1FFFFC0 | 7F9FF99F | 1FFFFF*FC3 | 7FFFFFFF*F | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 56 | 17 | 1FFFF80 | 7F3FF33E | 1FFFFF*F87 | 7FFFFFFF*E | 1 | 0 | 1 | 1 | 1 | 00 | 10 | 00 |
| 57 | 18 | 1FFFF00 | 7E7FE67C | 1FFFFF*F0F | 7FFFFFFF*FC | 1 | 0 | 1 | 1 | 1 | 00 | 00 | 10 |
| 58 | 19 | 1FFFE01 | 7CF*CCF8 | 1FFFE1E1E | 7FFFFFFF*F8 | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 59 | 20 | 1FFFC03 | 79FF99F0 | 1FFFC3C3C | 7FFFFFFF*F0 | 1 | 1 | 1 | 1 | 0 | 01 | 10 | 00 |
| 60 | 21 | 1FFF807 | 73FF33E0 | 1FFFFF878 | 7FFFFFFF*E1 | 1 | 1 | 1 | 1 | 1 | 10 | 01 | 10 |
| 61 | 22 | 1FFF00F | 67FE67C0 | 1FFFFF0F0 | 7FFFFFFF*FC3 | 1 | 1 | 1 | 1 | 0 | 10 | 10 | 01 |
| 62 | 23 | 1FFE01E | 4FF*CCF80 | 1FFFE1E1E1 | 7FFFFFFF*F87 | 1 | 1 | 1 | 1 | 0 | 00 | 10 | 10 |
| 63 | 24 | 1FFC03C | 1FF99F00 | 1FFFC3C3C3 | 7FFFFFFF*F0F | 1 | 1 | 1 | 1 | 0 | 11 | 00 | 10 |
| 64 | 25 | 1FF8078 | 3FF33E01 | 1FFFFF8787 | 7FFFFFFF*E1E | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 65 | 26 | 1FF00F0 | 7FE67C02 | 1FFFFF0F0F | 7FFFFFFF*FC3C | 1 | 1 | 1 | 1 | 0 | 00 | 00 | 11 |
| 66 | 27 | 1FE01E1 | 7CC*F805 | 1FFFE1E1E1E | 7FFFFFFF*F878 | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 67 | 28 | 1FC03C3 | 7F99F00A | 1FFFC3C3C3C | 7FFFFFFF*F0F0 | 1 | 1 | 1 | 1 | 0 | 01 | 10 | 00 |
| 68 | 29 | 1F80787 | 7F33E015 | 1FFF87878 | 7FFFFFFF*E1E1 | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 69 | 30 | 1F00F0F | 7E67C02A | 1FFF0F0F0 | 7FFFFFC3C3C3 | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 70 | 31 | 1E01E1E | 7CC*F8054 | 1FFE1E1E1E1 | 7FFFFF8787 | 1 | 1 | 1 | 1 | 1 | 01 | 11 | 10 |
| 71 | 32 | 1C03C3C | 799F00A9 | 1FFC3C3C3C3 | 7FFFFF0F0F | 1 | 1 | 1 | 1 | 1 | 01 | 01 | 11 |
| 72 | 33 | 1807878 | 733E0152 | 1FF878787 | 7FFFE1E1E1E | 1 | 0 | 1 | 1 | 0 | 00 | 01 | 01 |
| 73 | 34 | 100F0F0 | 667C02A5 | 1FF0F0F0F | 7FFFC3C3C3C | 0 | 0 | 1 | 1 | 0 | 10 | 00 | 01 |
| 74 | 35 | 001E1E0 | 4CF8054B | 1FE1E1E1F | 7FFF87878 | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 75 | 36 | 003C3C1 | 19F00A96 | 1FC3C3C3F | 7FFF0F0F0 | 0 | 1 | 1 | 1 | 1 | 00 | 00 | 10 |
| 76 | 37 | 0078783 | 33E0152C | 1F878787F | 7FFE1E1E1E1 | 0 | 1 | 1 | 1 | 1 | 01 | 00 | 00 |
| 77 | 38 | 00F0F07 | 67C02A59 | 1F0F0F0FF | 7FFC3C3C3C3 | 0 | 1 | 1 | 1 | 0 | 11 | 01 | 00 |
| 78 | 39 | 01E1E0E | 4F8054B3 | 1E1E1E1FF | 7FFF878787 | 0 | 1 | 1 | 1 | 0 | 11 | 11 | 01 |
| 79 | 40 | 03C3C1C | 1F00A966 | 1C3C3C3FF | 7FFF0F0F0F | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 80 | 41 | 0787838 | 3E0152CC | 1878787FF | 7FE1E1E1E1E | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 81 | 42 | 0F0F070 | 7C02A598 | 10F0F0FFF | 7FFC3C3C3C3C | 1 | 0 | 0 | 1 | 1 | 11 | 11 | 11 |
| 82 | 43 | 1E1E0E0 | 78054B30 | 01E1E1FFF | 7FF8787878 | 1 | 0 | 0 | 1 | 1 | 11 | 11 | 11 |
| 83 | 44 | 1C3C1C0 | 700A9660 | 03C3C3FFE | 7FF0F0F0F0 | 1 | 0 | 0 | 1 | 1 | 11 | 11 | 11 |
| 84 | 45 | 1878380 | 60152CC0 | 078787FFC | 7FE1E1E1E0 | 1 | 0 | 0 | 1 | 1 | 11 | 11 | 11 |
| 85 | 46 | 10F0700 | 402A5980 | 0F0F0FFF8 | 7FC3C3C3C0 | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 86 | 47 | 01E0E00 | 0054B300 | 1E1E1FFF0 | 7F87878780 | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 87 | 48 | 03C1C00 | 00A96601 | 1C3C3FFE0 | 7F0F0F0F00 | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 88 | 49 | 0783800 | 0152CC03 | 18787FFC0 | 7E1E1E1E01 | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 89 | 50 | 0F07000 | 02A59806 | 10F0FFF80 | 7C3C3C3C03 | 1 | 1 | 0 | 0 | 1 | 11 | 11 | 11 |
| 90 | 51 | 1E0E000 | 054B300D | 01E1FFF00 | 7878787807 | 1 | 0 | 0 | 0 | 0 | 11 | 11 | 11 |
| 91 | 52 | 1C1C001 | 0A96601A | 03C3FFE01 | 70F0F0F00F | 1 | 1 | 0 | 1 | 0 | 10 | 11 | 11 |
| 92 | 53 | 1838003 | 152CC035 | 0787FFC03 | 61E1E1E01E | 1 | 0 | 0 | 1 | 0 | 10 | 10 | 11 |
| 93 | 54 | 1070007 | 2A59806B | 0F0FFF807 | 43C3C3C03C | 0 | 0 | 1 | 1 | 0 | 01 | 10 | 10 |
| 94 | 55 | 00E000F | 54B300D7 | 1E1FFF00F | 0787878078 | 0 | 1 | 1 | 1 | 0 | 10 | 01 | 10 |
| 95 | 56 | 01C001F | 296601AE | 1C3FFE01F | 0F0F0F00F1 | 0 | 0 | 1 | 0 | 1 | 00 | 10 | 01 |
| 96 | 57 | 038003F | 52CC035C | 187FFC03F | 1E1E1E01E2 | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 97 | 58 | 070007F | 259806B8 | 10FFF807F | 3C3C3C03C4 | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 98 | 59 | 0E000FE | 4B300D71 | 01FFF00FE | 7878780788 | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 99 | 60 | 1C001FD | 16601AE2 | 03FFE01FD | 70F0F00F10 | 1 | 0 | 0 | 1 | 0 | 01 | 00 | 00 |
| 100 | 61 | 18003FA | 2CC035C5 | 07FFC03FB | 61E1E01E21 | 1 | 1 | 0 | 1 | 0 | 11 | 01 | 00 |
| 101 | 62 | 10007F4 | 59806B8B | 0FFF807F7 | 43C3C03C43 | 0 | 1 | 1 | 1 | 0 | 11 | 11 | 01 |
| 102 | 63 | 0000FE8 | 3300D717 | 1FFF00FEE | 0787807887 | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 103 | 64 | 0001FD0 | 6601AE2F | 1FFE01FDC | 0F0F00F10E | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 104 | 65 | 0003FA0 | 4C035C5F | 1FFC03FB8 | 1E1E01E21D | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 105 | 66 | 0007F40 | 1806B8BE | 1FF807F70 | 3C3C03C43B | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 106 | 67 | 000FE81 | 300D717C | 1FF00FEE1 | 7878078877 | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 107 | 68 | 001FD02 | 601AE2F8 | 1FE01FDC2 | 70F00F10EF | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 108 | 69 | 003FA05 | 4035C5F0 | 1FC03FB84 | 61E01E21DE | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 109 | 70 | 007F40B | 006B8BE0 | 1F807F708 | 43C03C43BC | 0 | 0 | 1 | 1 | 1 | 11 | 11 | 11 |
| 110 | 71 | 00FE816 | 00D717C0 | 1F00FEE11 | 0780788778 | 0 | 1 | 1 | 1 | 0 | 10 | 11 | 11 |
| 111 | 72 | 01FD02C | 01AE2F81 | 1E01FDC23 | 0F00F10EF1 | 0 | 1 | 1 | 0 | 0 | 10 | 10 | 11 |
| 112 | 73 | 03FA059 | 035C5F02 | 1C03FB847 | 1E01E21DE3 | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 113 | 74 | 07F40B3 | 06B8BE05 | 1807F708F | 3C03C43BC7 | 0 | 1 | 1 | 0 | 0 | 01 | 10 | 10 |
| 114 | 75 | 0FE8166 | 0D717C0B | 100FEE11E | 780788778F | 1 | 0 | 0 | 0 | 0 | 01 | 01 | 10 |
| 115 | 76 | 1FD02CD | 1AE2F817 | 001FDC23D | 700F10EF1F | 1 | 1 | 0 | 0 | 1 | 11 | 01 | 01 |
| 116 | 77 | 1FA059B | 35C5F02F | 003FB847A | 601E21DE3F | 1 | 1 | 0 | 0 | 1 | 10 | 11 | 01 |
| 117 | 78 | 1F40B37 | 6B8BE05E | 007F708F4 | 403C43BC7F | 1 | 1 | 0 | 0 | 0 | 10 | 10 | 11 |
| 118 | 79 | 1E8166E | 5717C0BD | 00FEE11E9 | 00788778FF | 1 | 0 | 0 | 0 | 1 | 10 | 10 | 10 |
| 119 | 80 | 1D02CDC | 2E2F817A | 01FDC23D3 | 00F10EF1FE | 1 | 0 | 0 | 1 | 0 | 01 | 10 | 10 |
| 120 | 81 | 1A059B9 | 5C5F02F5 | 03FB847A6 | 01E21DE3FD | 1 | 0 | 0 | 1 | 1 | 01 | 01 | 10 |
| 121 | 82 | 140B373 | 38BE05EB | 07F708F4C | 03C43BC7FB | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 122 | 83 | 08166E7 | 717C0BD7 | 0FEE11E98 | 0788778FF7 | 1 | 0 | 1 | 1 | 0 | 11 | 11 | 01 |
| 123 | 84 | 102CDCF | 62F817AE | 1FDC23D31 | 0F10EF1FEF | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 124 | 85 | 0059B9F | 45F02F5C | 1FB847A63 | 1E21DE3FDE | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 125 | 86 | 00B373E | 0BE05EB9 | 1F708F4C7 | 3C43BC7FBC | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 126 | 87 | 0166E7D | 17C0BD72 | 1EB11E98F | 788778FF78 | 0 | 1 | 1 | 1 | 0 | 10 | 11 | 11 |
| 127 | 88 | 02CDCFB | 2F817AE5 | 1DC23D31F | 710EF1FEF1 | 0 | 1 | 1 | 0 | 0 | 10 | 10 | 11 |
| 128 | 89 | 059B9F7 | 5F02F5CA | 1B847A63F | 621DE3FDE2 | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 129 | 90 | 0B373EF | 3E05EB94 | 1708F4C7F | 443BC7FBC4 | 1 | 0 | 0 | 0 | 1 | 10 | 10 | 10 |
| 130 | 91 | 166E7DF | 7C0BD728 | 0E11E98FF | 08778FF788 | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 131 | 92 | 0CDCFBE | 7817AE50 | 1C23D31FF | 10EF1FEF10 | 1 | 0 | 1 | 1 | 1 | 01 | 10 | 10 |
| 132 | 93 | 19B9F7D | 702F5CA1 | 1847A63FE | 21DE3FDE21 | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 133 | 94 | 1373EFB | 605EB942 | 108F4C7FC | 43BC7FBC43 | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 134 | 95 | 06E7DF7 | 40BD7285 | 011E98FF8 | 0778FF7886 | 0 | 1 | 0 | 0 | 1 | 01 | 00 | 10 |
| 135 | 96 | 0DCFBEF | 017AE50A | 023D31FF0 | 0EF1FEF10D | 1 | 0 | 0 | 1 | 1 | 00 | 01 | 00 |
| 136 | 97 | 1B9F7DF | 02F5CA15 | 047A63FE1 | 1DE3FDE21A | 1 | 1 | 0 | 1 | 1 | 10 | 00 | 01 |
| 137 | 98 | 173EFBF | 05EB942B | 08F4C7FC3 | 3BC7FBC434 | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 138 | 99 | 0E7DF7F | 0BD72856 | 11E98FF87 | 778FF78869 | 1 | 1 | 0 | 1 | 1 | 00 | 00 | 10 |
| 139 | 100 | 1CFBEFF | 17AE50AC | 03D31FF0F | 6F1FEF10D3 | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 140 | 101 | 19F7DFE | 2F5CA159 | 07A63FE1E | 5B3FDE21A7 | 1 | 0 | 0 | 0 | 0 | 00 | 01 | 00 |
| 141 | 102 | 13EFBFC | 5EB942B3 | 0F4C7FC3C | 3C7FBC434F | 0 | 1 | 1 | 0 | 0 | 10 | 00 | 01 |
| 142 | 103 | 07DF7F8 | 3D728566 | 1E98FF878 | 78FF78869F | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 143 | 104 | 0FBEFF0 | 7AE50ACD | 1D31FF0F0 | 71FEF10D3E | 1 | 1 | 1 | 1 | 0 | 11 | 00 | 10 |
| 144 | 105 | 1F7DFE1 | 75CA159B | 1A63FE1E1 | 63FDE21A7D | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 145 | 106 | 1EFBFC3 | 6B942B36 | 14C7FC3C3 | 47FBC434FB | 1 | 1 | 0 | 1 | 1 | 11 | 00 | 11 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 146 | 107 | 1DF7F86 | 5728566D | 098FF8786 | 0FF78869F7 | 1 | 0 | 1 | 1 | 0 | 00 | 11 | 00 |
| 147 | 108 | 1BEFF0C | 2E50ACDB | 131FF0F0C | 1FEF10D3EF | 1 | 0 | 0 | 1 | 0 | 11 | 00 | 11 |
| 148 | 109 | 17DFE19 | 5CA159B6 | 063FE1E19 | 3FDE21A7DF | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 149 | 110 | 0FBFC33 | 3942B36D | 0C7FC3C32 | 7FBC434FBF | 1 | 0 | 1 | 1 | 0 | 01 | 01 | 11 |
| 150 | 111 | 1F7F866 | 728566DB | 18FF87865 | 7F78869F7E | 1 | 1 | 1 | 0 | 0 | 00 | 01 | 01 |
| 151 | 112 | 1EFF0CC | 650ACDB6 | 11FF0F0CB | 7EF10D3EFC | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 152 | 113 | 1DFE199 | 4A159B6D | 03FE1E196 | 7DE21A7DF9 | 1 | 0 | 0 | 1 | 0 | 00 | 10 | 00 |
| 153 | 114 | 1BFC333 | 142B36DB | 07FC3C32C | 7BC434FBF3 | 1 | 0 | 0 | 1 | 0 | 00 | 00 | 10 |
| 154 | 115 | 17F8666 | 28566DB6 | 0FF878659 | 778869F7E6 | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 155 | 116 | 0FF0CCC | 50ACDB6D | 1FF0F0CB3 | 6F10D3EFCC | 1 | 1 | 1 | 0 | 0 | 11 | 01 | 00 |
| 156 | 117 | 1FE1999 | 2159B6DA | 1FE1E1966 | 5E21A7DF99 | 1 | 0 | 1 | 0 | 1 | 10 | 11 | 01 |
| 157 | 118 | 1FC3332 | 42B36DB5 | 1FC3C32CC | 3C434FBF33 | 1 | 1 | 1 | 0 | 1 | 10 | 10 | 11 |
| 158 | 119 | 1F86664 | 0566DB6B | 1F8786599 | 78869F7E67 | 1 | 0 | 1 | 1 | 1 | 01 | 10 | 10 |
| 159 | 120 | 1F0CCC8 | 0ACDB6D6 | 1F0F0CB33 | 710D3EFCCE | 1 | 1 | 1 | 0 | 0 | 10 | 01 | 10 |
| 160 | 121 | 1E19991 | 159B6DAC | 1E1E19666 | 621A7DF99D | 1 | 1 | 1 | 0 | 1 | 11 | 10 | 01 |
| 161 | 122 | 1C33323 | 2B36DB58 | 1C3C32CCC | 4434FBF33B | 1 | 0 | 1 | 0 | 1 | 00 | 11 | 10 |
| 162 | 123 | 1866647 | 566DB6B0 | 187865999 | 0869F7E676 | 1 | 0 | 1 | 0 | 0 | 11 | 00 | 11 |
| 163 | 124 | 10CCC8F | 2CDB6D60 | 10F0CB333 | 10D3EFCCEC | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 164 | 125 | 019991E | 59B6DAC0 | 01E196666 | 21A7DF99D9 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 165 | 126 | 033323C | 336DB580 | 03C32CCCD | 434FBF33B3 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 166 | 127 | 0666478 | 66DB6B01 | 07865999A | 069F7E6766 | 0 | 1 | 0 | 1 | 0 | 00 | 00 | 10 |
| 167 | 128 | 0CCC8F0 | 4DB6D603 | 0F0CB3334 | 0D3EFCCECD | 1 | 1 | 1 | 0 | 1 | 01 | 00 | 00 |
| 168 | 129 | 19991E1 | 1B6DAC07 | 1E1966669 | 1A7DF99D9B | 1 | 0 | 1 | 0 | 1 | 00 | 01 | 00 |
| 169 | 130 | 13323C3 | 36DB580E | 1C32CCCD3 | 34FBF33B37 | 0 | 1 | 1 | 1 | 1 | 10 | 00 | 01 |
| 170 | 131 | 0664786 | 6DB6B01C | 1865999A7 | 69F7E6766F | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 171 | 132 | 0CC8F0D | 5B6D6039 | 10CB3334F | 53EFCCECDF | 1 | 0 | 0 | 1 | 0 | 00 | 00 | 10 |
| 172 | 133 | 1991E1A | 36DAC073 | 01966669E | 27DF99D9BF | 1 | 1 | 0 | 1 | 1 | 01 | 00 | 00 |
| 173 | 134 | 1323C35 | 6DB580E6 | 032CCCD3C | 4FBF33B37E | 0 | 1 | 0 | 1 | 1 | 00 | 01 | 00 |
| 174 | 135 | 064786A | 5B6B01CD | 065999A78 | 1F7E6766FC | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 175 | 136 | 0C8F0D5 | 36D6039B | 0CB3334F0 | 3EFCCECDF9 | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 176 | 137 | 191E1AA | 6DAC0737 | 1966669E1 | 7DF99D9BF3 | 1 | 1 | 1 | 1 | 0 | 00 | 00 | 11 |
| 177 | 138 | 123C354 | 5B580E6E | 12CCCD3C3 | 7BF33B37E7 | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 178 | 139 | 04786A9 | 36B01CDC | 05999A787 | 77E6766FCE | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 179 | 140 | 08F0D53 | 6D6039B8 | 0B3334F0E | 6FCCECDF9C | 1 | 0 | 1 | 1 | 0 | 11 | 01 | 00 |
| 180 | 141 | 11E1AA6 | 5AC07370 | 166669E1D | 5F99D9BF38 | 0 | 1 | 0 | 1 | 1 | 10 | 11 | 01 |
| 181 | 142 | 03C354C | 3580E6E0 | 0CCCD3C3A | 3F33B37E70 | 0 | 1 | 1 | 0 | 0 | 10 | 10 | 11 |
| 182 | 143 | 0786A99 | 6B01CDC0 | 1999A7875 | 7E6766FCE1 | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 183 | 144 | 0F0D533 | 56039B81 | 13334F0EB | 7CCECDF9C2 | 1 | 0 | 0 | 1 | 0 | 01 | 10 | 10 |
| 184 | 145 | 1E1AA66 | 2C073703 | 06669E1D6 | 799D9BF385 | 1 | 0 | 0 | 1 | 1 | 01 | 01 | 10 |
| 185 | 146 | 1C354CC | 580E6E06 | 0CCD3C3AC | 733B37E70B | 1 | 0 | 1 | 0 | 1 | 11 | 01 | 01 |
| 186 | 147 | 186A998 | 301CDC0C | 199A78759 | 66766FCE17 | 1 | 0 | 1 | 0 | 1 | 10 | 11 | 01 |
| 187 | 148 | 10D5331 | 6039B818 | 1334F0EB2 | 4CECDF9C2F | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 188 | 149 | 01AA662 | 40737031 | 0669E1D65 | 19D9BF385E | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 189 | 150 | 0354CC5 | 00E6E063 | 0CD3C3ACB | 33B37E70BD | 0 | 1 | 1 | 1 | 0 | 00 | 01 | 01 |
| 190 | 151 | 06A998A | 01CDC0C6 | 19A787596 | 6766FCE17B | 0 | 1 | 1 | 0 | 0 | 10 | 00 | 01 |
| 191 | 152 | 0D53315 | 039B818C | 134F0EB2C | 4ECDF9C2F6 | 1 | 1 | 0 | 1 | 1 | 00 | 10 | 00 |
| 192 | 153 | 1AA662A | 07370318 | 069E1D659 | 1D9BF385ED | 1 | 0 | 0 | 1 | 0 | 00 | 00 | 10 |
| 193 | 154 | 154CC54 | 0E6E0630 | 0D3C3ACB3 | 3B37E70BDB | 0 | 0 | 1 | 0 | 1 | 00 | 00 | 00 |
| 194 | 155 | 0A998A8 | 1CDC0C60 | 1A7875967 | 766FCE17B6 | 1 | 1 | 1 | 0 | 1 | 01 | 00 | 00 |
| 195 | 156 | 1533151 | 39B818C0 | 14F0EB2CE | 6CDF9C2F6C | 0 | 1 | 0 | 1 | 1 | 00 | 01 | 00 |
| 196 | 157 | 0A662A3 | 73703180 | 09E1D659D | 59BF385ED8 | 1 | 0 | 1 | 1 | 1 | 10 | 00 | 01 |
| 197 | 158 | 14CC547 | 66E06301 | 13C3ACB3A | 337E70BDB0 | 0 | 1 | 0 | 0 | 1 | 11 | 10 | 00 |
| 198 | 159 | 0998A8E | 4DC0C602 | 078759675 | 66FCE17B61 | 1 | 1 | 0 | 1 | 0 | 01 | 11 | 10 |
| 199 | 160 | 133151D | 1B818C05 | 0F0EB2CEB | 4DF9C2F6C2 | 0 | 1 | 1 | 1 | 0 | 01 | 01 | 11 |
| 200 | 161 | 0662A3B | 3703180B | 1E1D659D6 | 1BF385ED85 | 0 | 0 | 1 | 1 | 1 | 11 | 01 | 01 |
| 201 | 162 | 0CC5477 | 6E063017 | 1C3ACB3AC | 37E70BDB0B | 1 | 0 | 1 | 1 | 0 | 11 | 11 | 01 |
| 202 | 163 | 198A8EF | 5C0C602F | 187596759 | 6FCE17B617 | 1 | 0 | 1 | 1 | 0 | 10 | 11 | 11 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 203 | 164 | 13151DE | 3818C05F | 10EB2CEB2 | 5F9C2F6C2F | 0 | 0 | 0 | 1 | 1 | 01 | 10 | 11 |
| 204 | 165 | 062A3BC | 703180BF | 01D659D65 | 3F385ED85E | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 205 | 166 | 0C54779 | 6063017E | 03ACB3ACB | 7E70BDB0BD | 1 | 0 | 0 | 0 | 1 | 11 | 00 | 01 |
| 206 | 167 | 18A8EF2 | 40C602FD | 075967597 | 7CE17B617B | 1 | 1 | 0 | 1 | 0 | 00 | 11 | 00 |
| 207 | 168 | 1151DE4 | 018C05FA | 0EB2CEB2F | 79C2F6C2F7 | 0 | 1 | 1 | 1 | 1 | 11 | 00 | 11 |
| 208 | 169 | 02A3BC9 | 03180BF5 | 1D659D65E | 7385ED85EE | 0 | 0 | 1 | 1 | 1 | 01 | 11 | 00 |
| 209 | 170 | 0547793 | 063017EB | 1ACB3ACBC | 670BDB0BDC | 0 | 0 | 1 | 0 | 0 | 10 | 01 | 11 |
| 210 | 171 | 0A8EF27 | 0C602FD6 | 159675978 | 4E17B617B9 | 1 | 0 | 0 | 0 | 1 | 00 | 10 | 01 |
| 211 | 172 | 151DE4E | 18C05FAD | 0B2CEB2F1 | 1C2F6C2F73 | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 212 | 173 | 0A3BC9C | 3180BF5A | 1659D65E3 | 385ED85EE6 | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 213 | 174 | 1477938 | 63017EB5 | 0CB3ACBC6 | 70BDB0BDCC | 0 | 0 | 1 | 1 | 1 | 00 | 01 | 00 |
| 214 | 175 | 08EF270 | 4602FD6A | 19675978D | 617B617B99 | 1 | 0 | 1 | 0 | 0 | 10 | 00 | 01 |
| 215 | 176 | 11DE4E1 | 0C05FAD5 | 12CEB2F1A | 42F6C2F733 | 0 | 0 | 0 | 1 | 1 | 11 | 10 | 00 |
| 216 | 177 | 03BC9C3 | 180BF5AA | 059D65E34 | 05ED85EE67 | 0 | 0 | 0 | 1 | 0 | 00 | 11 | 10 |
| 217 | 178 | 0779387 | 3017EB55 | 0B3ACBC68 | 0BDB0BDCCF | 0 | 0 | 1 | 1 | 0 | 11 | 00 | 11 |
| 218 | 179 | 0EF270F | 602FD6AA | 1675978D0 | 17B617B99F | 1 | 0 | 0 | 1 | 1 | 01 | 11 | 00 |
| 219 | 180 | 1DE4E1F | 405FAD54 | 0CEB2F1A1 | 2F6C2F733F | 1 | 0 | 1 | 0 | 1 | 10 | 01 | 11 |
| 220 | 181 | 1BC9C3F | 00BF5AA9 | 19D65E342 | 5ED85EE67F | 1 | 1 | 1 | 1 | 0 | 10 | 10 | 01 |
| 221 | 182 | 179387F | 017EB552 | 13ACBC684 | 3DB0BDCCFE | 0 | 0 | 0 | 1 | 1 | 10 | 10 | 10 |
| 222 | 183 | 0F270FF | 02FD6AA5 | 075978D09 | 7B617B99FC | 1 | 1 | 0 | 0 | 0 | 01 | 10 | 10 |
| 223 | 184 | 1E4E1FF | 05FAD54A | 0EB2F1A12 | 76C2F733F9 | 1 | 1 | 1 | 1 | 1 | 10 | 01 | 10 |
| 224 | 185 | 1C9C3FE | 0BF5AA94 | 1D65E3425 | 6D85EE67F2 | 1 | 1 | 1 | 1 | 0 | 10 | 10 | 01 |
| 225 | 186 | 19387FD | 17EB5529 | 1ACBC684B | 5B0BDCCFE4 | 1 | 1 | 1 | 0 | 1 | 01 | 10 | 10 |
| 226 | 187 | 1270FFA | 2FD6AA53 | 15978D096 | 3617B99FC9 | 0 | 1 | 0 | 0 | 0 | 01 | 01 | 10 |
| 227 | 188 | 04E1FF5 | 5FAD54A7 | 0B2F1A12C | 6C2F733F93 | 0 | 1 | 1 | 0 | 1 | 11 | 01 | 01 |
| 228 | 189 | 09C3FEB | 3F5AA94E | 165E34258 | 585EE67F27 | 1 | 0 | 0 | 0 | 0 | 10 | 11 | 01 |
| 229 | 190 | 1387FD7 | 7EB5529C | 0CBC684B1 | 30BDCCFE4F | 0 | 1 | 1 | 1 | 1 | 10 | 10 | 11 |
| 230 | 191 | 070FFAE | 7D6AA538 | 1978D0962 | 617B99FC9E | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 231 | 192 | 0E1FF5C | 7AD54A70 | 12F1A12C4 | 42F733F93D | 1 | 1 | 0 | 1 | 1 | 01 | 10 | 10 |
| 232 | 193 | 1C3FEB9 | 75AA94E1 | 05E342588 | 05EE67F27A | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 233 | 194 | 187FD73 | 6B5529C3 | 0BC684B10 | 0BDCCFE4F4 | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 234 | 195 | 10FFAE6 | 56AA5386 | 178D09621 | 17B99FC9E8 | 0 | 1 | 0 | 1 | 1 | 00 | 11 | 10 |
| 235 | 196 | 01FF5CC | 2D54A70C | 0F1A12C43 | 2F733F93D0 | 0 | 0 | 1 | 0 | 1 | 10 | 00 | 11 |
| 236 | 197 | 03FEB98 | 5AA94E19 | 1E3425887 | 5EE67F27A1 | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 237 | 198 | 07FD731 | 35529C33 | 1C684B10F | 3DCCFE4F42 | 0 | 0 | 1 | 1 | 0 | 00 | 00 | 10 |
| 238 | 199 | 0FFAE63 | 6AA53866 | 18D09621F | 7B99FC9E84 | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 239 | 200 | 1FF5CC6 | 554A70CD | 11A12C43F | 7733F93D09 | 1 | 0 | 0 | 0 | 1 | 11 | 10 | 00 |

Z[0] = 59

Z[1] = 3B

Z[2] = EF

Z[3] = 07

Z[4] = 13

Z[5] = 70

Z[6] = 9B

Z[7] = B7

Z[8] = 52

Z[9] = 8F

Z[10] = 3E

Z[11] = B9

Z[12] = A5

Z[13] = AC

Z[14] = EA

Z[15] = 9E

Sample Data



```

=====
Reload this pattern into the LFSRs
Hold content of Summation Combiner regs and calculate new C[t+1] and Z values
=====

LFSR1  <= 1521359
LFSR2  <= 528F703B
LFSR3  <= 0AC3E9BEF
LFSR4  <= 4FEAB9B707
C[t+1] <= 00

=====
Generating 125 key symbols (encryption/decryption sequence)
=====
240  1  1521359  528F703B  0AC3E9BEF  4FEAB9B707  0 1 1 1 1 00 10 00
241  2  0A426B3  251EE076  1587D37DE  1FD5736E0F  1 0 0 1 0 00 00 10
242  3  1484D67  4A3DC0ED  0B0FA6FBD  3FAAE6DC1E  0 0 1 1 0 01 00 00
243  4  0909ACF  147B81DA  161F4DF7A  7F55CDB83D  1 0 0 0 0 00 01 00
244  5  121359E  28F703B5  0C3E9BEF5  7EAB9B707B  0 1 1 1 1 10 00 01
245  6  0426B3C  51EE076B  187D37DEB  7D5736E0F6  0 1 1 0 0 00 10 00
246  7  084D679  23DC0ED6  10FA6FBD7  7AAE6DC1EC  1 1 0 1 1 00 00 10
247  8  109ACF2  47B81DAC  01F4DF7AF  755CDB83D8  0 1 0 0 1 00 00 00
248  9  01359E4  0F703B59  03E9BEF5E  6AB9B707B1  0 0 0 1 1 00 00 00
249  10 026B3C8  1EE076B3  07D37DEBD  55736E0F63  0 1 0 0 1 00 00 00
250  11 04D6791  3DC0ED67  0FA6FBD7A  2AE6DC1EC7  0 1 1 1 1 01 00 00
251  12 09ACF22  7B81DACF  1F4DF7AF4  55CDB83D8F  1 1 1 1 1 11 01 00
252  13 1359E44  7703B59E  1E9BEF5E8  2B9B707B1F  0 0 1 1 1 10 11 01
253  14 06B3C88  6E076B3C  1D37DEBD0  5736E0F63F  0 0 1 0 1 01 10 11
254  15 0D67911  5C0ED678  1A6FBD7A1  2E6DC1EC7E  1 0 1 0 1 01 01 10
255  16 1ACF223  381DACF0  14DF7AF42  5CDB83D8FD  1 0 0 1 1 11 01 01
256  17 159E446  703B59E0  09BEF5E85  39B707B1FA  0 0 1 1 1 10 11 01
257  18 0B3C88C  6076B3C0  137DEBD0A  736E0F63F4  1 0 0 0 1 01 10 11
258  19 1679118  40ED6780  06FBD7A15  66DC1EC7E8  0 1 0 1 1 01 01 10
259  20 0CF2231  01DACF00  0DF7AF42A  4DB83D8FD1  1 1 1 1 1 00 01 01
260  21 19E4463  03B59E01  1BEF5E854  1B707B1FA3  1 1 1 0 1 10 00 01
261  22 13C88C6  076B3C03  17DEBD0A9  36E0F63F47  0 0 0 1 1 11 10 00
262  23 079118C  0ED67807  0FBD7A152  6DC1EC7E8E  0 1 1 1 0 01 11 10
263  24 0F22318  1DACF00E  1F7AF42A4  5B83D8FD1D  1 1 1 1 1 01 01 11
264  25 1E44630  3B59E01C  1EF5E8548  3707B1FA3B  1 0 1 0 1 11 01 01
265  26 1C88C61  76B3C039  1DEBD0A91  6E0F63F477  1 1 1 0 0 11 11 01
266  27 19118C3  6D678073  1BD7A1523  5C1EC7E8EF  1 0 1 0 1 11 11 11
267  28 1223187  5ACF00E6  17AF42A46  383D8FD1DE  0 1 0 0 0 11 11 11
268  29 044630E  359E01CC  0F5E8548D  707B1FA3BD  0 1 1 0 1 11 11 11
269  30 088C61C  6B3C0399  1EBD0A91A  60F63F477B  1 0 1 1 0 10 11 11
270  31 1118C39  56780733  1D7A15234  41EC7E8EF6  0 0 1 1 0 10 10 11
271  32 0231872  2CF00E67  1AF42A468  03D8FD1DEC  0 1 1 1 1 01 10 10
272  33 04630E5  59E01CCE  15E8548D1  07B1FA3BD8  0 1 0 1 1 01 01 10
273  34 08C61CB  33C0399D  0BD0A91A3  0F63F477B1  1 1 1 0 0 00 01 01
274  35 118C396  6780733A  17A152347  1BC7E8EF63  0 1 0 1 0 10 00 01
275  36 031872D  4F00E674  0F42A468E  3D8FD1DEC7  0 0 1 1 0 00 10 00
276  37 0630E5A  1E01CCE8  1E8548D1D  7B1FA3BD8E  0 0 1 0 1 01 00 10
277  38 0C61CB5  3C0399D0  1D0A91A3B  763F477B1C  1 0 1 0 1 00 01 00
278  39 18C396A  780733A0  1A1523477  6C7E8EF639  1 0 1 0 0 10 00 01
279  40 11872D5  700E6741  142A468EF  58FD1DEC72  0 0 0 1 1 11 10 00
280  41 030E5AB  601CCE83  08548D1DF  31FA3BD8E5  0 0 1 1 1 00 11 10
281  42 061CB57  40399D07  10A91A3BF  63F477B1CB  0 0 0 1 1 10 00 11
282  43 0C396AF  00733A0F  01523477E  47E8EF6396  1 0 0 1 0 00 10 00
283  44 1872D5F  00E6741F  02A468EFD  0FD1DEC72C  1 1 0 1 1 00 00 10

```

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|-----------|-----------|------------|---|---|---|---|---|----|----|----|
| 284 | 45 | 10E5ABE | 01CCE83F | 0548D1DFA | 1FA3BD8E58 | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 285 | 46 | 01CB57C | 0399D07F | 0A91A3BF4 | 3F477B1CB0 | 0 | 1 | 1 | 0 | 1 | 00 | 01 | 00 |
| 286 | 47 | 0396AF9 | 0733A0FE | 1523477E9 | 7E8EF63961 | 0 | 0 | 0 | 1 | 1 | 11 | 00 | 01 |
| 287 | 48 | 072D5F3 | 0E6741FD | 0A468EFD2 | 7D1DEC72C3 | 0 | 0 | 1 | 0 | 0 | 01 | 11 | 00 |
| 288 | 49 | 0E5ABE7 | 1CCE83FA | 148D1DFA4 | 7A3BD8E587 | 1 | 1 | 0 | 0 | 1 | 10 | 01 | 11 |
| 289 | 50 | 1CB57CE | 399D07F4 | 091A3BF49 | 7477B1CB0F | 1 | 1 | 1 | 0 | 1 | 11 | 10 | 01 |
| 290 | 51 | 196AF9D | 733A0FE9 | 123477E92 | 68EF63961E | 1 | 0 | 0 | 1 | 1 | 00 | 11 | 10 |
| 291 | 52 | 12D5F3B | 66741FD2 | 0468EFD25 | 51DEC72C3C | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 292 | 53 | 05ABE77 | 4CE83FA4 | 08D1DFA4B | 23BD8E5879 | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 293 | 54 | 0B57CEE | 19D07F49 | 11A3BF496 | 477B1CB0F2 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 294 | 55 | 16AF9DC | 33A0FE92 | 03477E92C | 0EF63961E4 | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 295 | 56 | 0D5F3B8 | 6741FD25 | 068EFD259 | 1DEC72C3C9 | 1 | 0 | 0 | 1 | 1 | 00 | 01 | 00 |
| 296 | 57 | 1ABE771 | 4E83FA4B | 0D1DFA4B3 | 3BD8E58793 | 1 | 1 | 1 | 1 | 0 | 01 | 00 | 01 |
| 297 | 58 | 157CEE2 | 1D07F496 | 1A3BF4967 | 77B1CB0F26 | 0 | 0 | 1 | 1 | 1 | 00 | 01 | 00 |
| 298 | 59 | 0AF9DC5 | 3A0FE92D | 1477E92CE | 6F63961E4D | 1 | 0 | 0 | 0 | 1 | 11 | 00 | 01 |
| 299 | 60 | 15F3B8B | 741FD25A | 08EFD259C | 5EC72C3C9B | 0 | 0 | 1 | 1 | 1 | 01 | 11 | 00 |
| 300 | 61 | 0BE7716 | 683FA4B4 | 11DFA4B39 | 3D8E587937 | 1 | 0 | 0 | 1 | 1 | 10 | 01 | 11 |
| 301 | 62 | 17CEE2D | 507F4968 | 03BF49672 | 7B1CB0F26E | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 302 | 63 | 0F9DC5B | 20FE92D0 | 077E92CE4 | 763961E4DC | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 303 | 64 | 1F3B8B6 | 41FD25A0 | 0EFD259C9 | 6C72C3C9B9 | 1 | 1 | 1 | 0 | 1 | 01 | 00 | 00 |
| 304 | 65 | 1E7716D | 03FA4B40 | 1DFA4B393 | 58E5879373 | 1 | 1 | 1 | 1 | 1 | 11 | 01 | 00 |
| 305 | 66 | 1CEE2DB | 07F49680 | 1BF496727 | 31CB0F26E6 | 1 | 1 | 1 | 1 | 1 | 11 | 11 | 01 |
| 306 | 67 | 19DC5B7 | 0FE92D00 | 17E92CE4E | 63961E4DCD | 1 | 1 | 0 | 1 | 0 | 10 | 11 | 11 |
| 307 | 68 | 13B8B6F | 1FD25A00 | 0FD259C9C | 472C3C9B9A | 0 | 1 | 1 | 0 | 0 | 10 | 10 | 11 |
| 308 | 69 | 07716DF | 3FA4B400 | 1FA4B3938 | 0E58793735 | 0 | 1 | 1 | 0 | 0 | 01 | 10 | 10 |
| 309 | 70 | 0EE2DBF | 7F496800 | 1F4967271 | 1CB0F26E6A | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 310 | 71 | 1DC5B7F | 7E92D000 | 1E92CE4E2 | 3961E4DCD4 | 1 | 1 | 1 | 0 | 1 | 11 | 10 | 01 |
| 311 | 72 | 1B8B6FF | 7D25A001 | 1D259C9C4 | 72C3C9B9A9 | 1 | 0 | 1 | 1 | 0 | 01 | 11 | 10 |
| 312 | 73 | 1716DFF | 7A4B4002 | 1A4B39389 | 6587937352 | 0 | 0 | 1 | 1 | 1 | 10 | 01 | 11 |
| 313 | 74 | 0E2DBFF | 74968005 | 149672713 | 4B0F26E6A5 | 1 | 1 | 0 | 0 | 0 | 11 | 10 | 01 |
| 314 | 75 | 1C5B7FE | 692D000B | 092CE4E26 | 161E4DCD4B | 1 | 0 | 1 | 0 | 1 | 00 | 11 | 10 |
| 315 | 76 | 18B6FFC | 525A0017 | 1259C9C4D | 2C3C9B9A96 | 1 | 0 | 0 | 0 | 1 | 10 | 00 | 11 |
| 316 | 77 | 116DFF8 | 24B4002F | 04B39389B | 587937352C | 0 | 1 | 0 | 0 | 1 | 11 | 10 | 00 |
| 317 | 78 | 02DBFF1 | 4968005F | 096727136 | 30F26E6A58 | 0 | 0 | 1 | 1 | 1 | 00 | 11 | 10 |
| 318 | 79 | 05B7FE3 | 12D000BF | 12CE4E26C | 61E4DCD4B1 | 0 | 1 | 0 | 1 | 0 | 11 | 00 | 11 |
| 319 | 80 | 0B6FFC7 | 25A0017F | 059C9C4D8 | 43C9B9A963 | 1 | 1 | 0 | 1 | 0 | 00 | 11 | 00 |
| 320 | 81 | 16DFF8E | 4B4002FF | 0B39389B1 | 07937352C6 | 0 | 0 | 1 | 1 | 0 | 11 | 00 | 11 |
| 321 | 82 | 0DBFF1C | 168005FF | 167271363 | 0F26E6A58C | 1 | 1 | 0 | 0 | 1 | 01 | 11 | 00 |
| 322 | 83 | 1B7FE38 | 2D000BFF | 0CE4E26C7 | 1E4DCD4B18 | 1 | 0 | 1 | 0 | 1 | 10 | 01 | 11 |
| 323 | 84 | 16FFC70 | 5A0017FF | 19C9C4D8F | 3C9B9A9631 | 0 | 0 | 1 | 1 | 0 | 11 | 10 | 01 |
| 324 | 85 | 0DFF8E1 | 34002FFF | 139389B1E | 7937352C62 | 1 | 0 | 0 | 0 | 0 | 00 | 11 | 10 |
| 325 | 86 | 1BFF1C3 | 68005FFF | 07271363D | 726E6A58C4 | 1 | 0 | 0 | 0 | 1 | 10 | 00 | 11 |
| 326 | 87 | 17FE387 | 5000BFFE | 0E4E26C7B | 64DCD4B188 | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 327 | 88 | 0FFC70F | 20017FFD | 1C9C4D8F6 | 49B9A96311 | 1 | 0 | 1 | 1 | 1 | 00 | 00 | 10 |
| 328 | 89 | 1FF8E1F | 4002FFFF | 19389B1ED | 137352C623 | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 329 | 90 | 1FF1C3F | 0005FFFF | 1271363DB | 26E6A58C46 | 1 | 0 | 0 | 1 | 1 | 00 | 01 | 00 |
| 330 | 91 | 1FE387F | 000BFFEE | 04E26C7B6 | 4DCD4B188C | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 331 | 92 | 1FC70FF | 0017FFDC | 09C4D8F6D | 1B9A963118 | 1 | 0 | 1 | 1 | 1 | 00 | 10 | 00 |
| 332 | 93 | 1F8E1FF | 002FFFFB | 1389B1EDA | 37352C6231 | 1 | 0 | 0 | 0 | 1 | 01 | 00 | 10 |
| 333 | 94 | 1F1C3FF | 005FFFF7 | 071363DB4 | 6E6A58C462 | 1 | 0 | 0 | 0 | 0 | 00 | 01 | 00 |
| 334 | 95 | 1B387FE | 00BFFEE0 | 0E26C7B68 | 5CD4B188C5 | 1 | 1 | 1 | 1 | 0 | 01 | 00 | 01 |
| 335 | 96 | 1C70FFC | 017FFDC1 | 1C4D8F6D1 | 39A963118A | 1 | 0 | 1 | 1 | 0 | 11 | 01 | 00 |
| 336 | 97 | 18E1FF9 | 02FFFFB8 | 189B1EDA2 | 7352C62315 | 1 | 1 | 1 | 0 | 0 | 11 | 11 | 01 |
| 337 | 98 | 11C3FF2 | 05FFF705 | 11363DB45 | 66A58C462B | 0 | 1 | 0 | 1 | 1 | 11 | 11 | 11 |
| 338 | 99 | 0387FE4 | 0BFFEE0A | 026C7B68B | 4D4B188C56 | 0 | 1 | 0 | 0 | 0 | 11 | 11 | 11 |
| 339 | 100 | 070FFC9 | 17FFDC15 | 04D8F6D16 | 1A963118AD | 0 | 1 | 0 | 1 | 1 | 11 | 11 | 11 |
| 340 | 101 | 0E1FF92 | 2FFFFB82B | 09B1EDA2C | 352C62315A | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |

Sample Data

| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 341 | 102 | 1C3FF24 | 5FFF7057 | 1363DB458 | 6A58C462B4 | 1 | 1 | 0 | 0 | 0 | 10 | 10 | 11 |
| 342 | 103 | 187FE48 | 3FFEE0AE | 06C7B68B0 | 54B188C569 | 1 | 1 | 0 | 1 | 1 | 01 | 10 | 10 |
| 343 | 104 | 10FFC90 | 7FFDC15C | 0D8F6D161 | 2963118AD2 | 0 | 1 | 1 | 0 | 1 | 01 | 01 | 10 |
| 344 | 105 | 01FF920 | 7FFB82B9 | 1B1EDA2C2 | 52C62315A5 | 0 | 1 | 1 | 1 | 0 | 00 | 01 | 01 |
| 345 | 106 | 03FF240 | 7FF70573 | 163DB4584 | 258C462B4B | 0 | 1 | 0 | 1 | 0 | 10 | 00 | 01 |
| 346 | 107 | 07FE481 | 7FEE0AE6 | 0C7B68B08 | 4B188C5696 | 0 | 1 | 1 | 0 | 0 | 00 | 10 | 00 |
| 347 | 108 | 0FFC902 | 7FDC15CD | 18F6D1610 | 163118AD2D | 1 | 1 | 1 | 0 | 1 | 00 | 00 | 10 |
| 348 | 109 | 1FF9204 | 7FB82B9A | 11EDA2C20 | 2C62315A5B | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 349 | 110 | 1FF2408 | 7F705735 | 03DB45841 | 58C462B4B6 | 1 | 0 | 0 | 1 | 1 | 00 | 01 | 00 |
| 350 | 111 | 1FE4810 | 7EE0AE6B | 07B68B082 | 3188C5696C | 1 | 1 | 0 | 1 | 1 | 10 | 00 | 01 |
| 351 | 112 | 1FC9021 | 7DC15CD6 | 0F6D16105 | 63118AD2D8 | 1 | 1 | 1 | 0 | 1 | 00 | 10 | 00 |
| 352 | 113 | 1F92042 | 7B82B9AD | 1EDA2C20B | 462315A5B0 | 1 | 1 | 1 | 0 | 1 | 00 | 00 | 10 |
| 353 | 114 | 1F24084 | 7705735A | 1DB458416 | 0C462B4B61 | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 354 | 115 | 1E48108 | 6E0AE6B5 | 1B68B082C | 188C5696C3 | 1 | 0 | 1 | 1 | 0 | 11 | 01 | 00 |
| 355 | 116 | 1C90211 | 5C15CD6A | 16D161059 | 3118AD2D86 | 1 | 0 | 0 | 0 | 0 | 10 | 11 | 01 |
| 356 | 117 | 1920422 | 382B9AD5 | 0DA2C20B3 | 62315A5B0D | 1 | 0 | 1 | 0 | 0 | 10 | 10 | 11 |
| 357 | 118 | 1240845 | 705735AA | 1B4584167 | 4462B4B61A | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 358 | 119 | 048108A | 60AE6B55 | 168B082CF | 08C5696C34 | 0 | 1 | 0 | 1 | 0 | 01 | 10 | 10 |
| 359 | 120 | 0902114 | 415CD6AB | 0D161059E | 118AD2D869 | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 360 | 121 | 1204228 | 02B9AD56 | 1A2C20B3D | 2315A5B0D2 | 0 | 1 | 1 | 0 | 0 | 11 | 10 | 01 |
| 361 | 122 | 0408451 | 05735AAD | 14584167B | 462B4B61A4 | 0 | 0 | 0 | 0 | 1 | 11 | 11 | 10 |
| 362 | 123 | 08108A2 | 0AE6B55B | 08B082CF7 | 0C5696C348 | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 363 | 124 | 1021144 | 15CD6AB6 | 1161059EF | 18AD2D8690 | 0 | 1 | 0 | 1 | 0 | 10 | 10 | 11 |
| 364 | 125 | 0042289 | 2B9AD56C | 02C20B3DE | 315A5B0D20 | 0 | 1 | 0 | 0 | 1 | 10 | 10 | 10 |

Sample Data



1.5 FOURTH SET OF SAMPLES

Initial values for the key, pan address and clock

K'c4[0] = 21 K'c4[1] = 87 K'c4[2] = F0 K'c4[3] = 4A
 K'c4[4] = BA K'c4[5] = 90 K'c4[6] = 31 K'c4[7] = D0
 K'c4[8] = 78 K'c4[9] = 0D K'c4[10] = 4C K'c4[11] = 53
 K'c4[12] = E0 K'c4[13] = 15 K'c4[14] = 3A K'c4[15] = 63

Addr4[0] = 2C Addr4[1] = 7F Addr4[2] = 94
 Addr4[3] = 56 Addr4[4] = 0F Addr4[5] = 1B

CL4[0] = 5F CL4[1] = 1A CL4[2] = 00 CL4[3] = 02

=====

Fill LFSRs with initial data

=====

| t | clk# | LFSR1 | LFSR2 | LFSR3 | LFSR4 | X1 | X2 | X3 | X4 | Z | C[t+1] | C[t] | C[t-1] |
|----|------|-----------|-----------|------------|-------------|----|----|----|----|---|--------|------|--------|
| 0 | 0 | 00000000* | 00000000* | 000000000* | 0000000000* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 1 | 1 | 00000000* | 00000001* | 000000001* | 0000000001* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 2 | 2 | 0000001* | 00000002* | 000000002* | 0000000003* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 3 | 3 | 0000002* | 00000004* | 000000004* | 0000000007* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 4 | 4 | 0000004* | 00000009* | 000000008* | 000000000F* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 5 | 5 | 0000008* | 00000013* | 000000010* | 000000001E* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 6 | 6 | 0000010* | 00000027* | 000000021* | 000000003D* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 7 | 7 | 0000021* | 0000004F* | 000000043* | 000000007A* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 8 | 8 | 0000042* | 0000009F* | 000000087* | 00000000F4* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 9 | 9 | 0000084* | 0000013F* | 00000010F* | 00000001E9* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 10 | 10 | 0000108* | 0000027F* | 00000021F* | 00000003D2* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 11 | 11 | 0000211* | 000004FE* | 00000043E* | 00000007A5* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 12 | 12 | 0000422* | 000009FC* | 00000087C* | 0000000F4A* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 13 | 13 | 0000845* | 000013F8* | 0000010F8* | 0000001E94* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 14 | 14 | 000108B* | 000027F0* | 0000021F1* | 0000003D29* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 15 | 15 | 0002117* | 00004FE1* | 0000043E3* | 0000007A52* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 16 | 16 | 000422E* | 00009FC2* | 0000087C6* | 000000F4A4* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 17 | 17 | 000845D* | 00013F84* | 000010F8C* | 000001E948* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 18 | 18 | 00108BA* | 00027F08* | 000021F18* | 000003D290* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 19 | 19 | 0021174* | 0004FE10* | 000043E30* | 000007A520* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 20 | 20 | 00422E8* | 0009FC21* | 000087C61* | 00000F4A41* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 21 | 21 | 00845D1* | 0013F842* | 00010F8C3* | 00001E9482* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 22 | 22 | 0108BA3* | 0027F084* | 00021F186* | 00003D2905* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 23 | 23 | 0211747* | 004FE109* | 00043E30C* | 00007A520B* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 24 | 24 | 0422E8F* | 009FC213* | 00087C619* | 0000F4A417* | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 25 | 25 | 0845D1E* | 013F8426* | 0010F8C32* | 0001E9482F* | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 26 | 26 | 108BA3D | 027F084D* | 0021F1864* | 0003D2905E* | 0 | 0 | 0 | 0 | 0 | 00 | 00 | 00 |
| 27 | 27 | 011747B | 04FE109B* | 0043E30C9* | 0007A520BC* | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 28 | 28 | 022E8F6 | 09FC2136* | 0087C6192* | 000F4A4179* | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 29 | 29 | 045D1EC | 13F8426C* | 010F8C325* | 001E9482F2* | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 30 | 30 | 08BA3D9 | 27F084D8* | 021F1864B* | 003D2905E5* | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 31 | 31 | 11747B3 | 4FE109B0* | 043E30C97* | 007A520BCA* | 0 | 1 | 0 | 0 | 1 | 00 | 00 | 00 |
| 32 | 32 | 02E8F67 | 1FC21360 | 087C6192E* | 00F4A41795* | 0 | 1 | 1 | 1 | 1 | 01 | 00 | 00 |
| 33 | 33 | 05D1ECF | 3F8426C1 | 10F8C325C* | 01E9482F2B* | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 34 | 34 | 0BA3D9F | 7F084D82 | 01F1864B8 | 03D2905E56* | 1 | 0 | 0 | 1 | 0 | 01 | 00 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|----|----|---------|----------|-----------|-------------|---|---|---|---|---|----|----|----|
| 35 | 35 | 1747B3E | 7E109B04 | 03E30C970 | 07A520BCAC* | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 36 | 36 | 0E8F67C | 7C213608 | 07C6192E1 | 0F4A417958* | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 37 | 37 | 1D1ECF8 | 78426C11 | 0F8C325C3 | 1E9482F2B1* | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 38 | 38 | 1A3D9F0 | 7084D822 | 1F1864B86 | 3D2905E563* | 1 | 1 | 1 | 0 | 1 | 01 | 00 | 00 |
| 39 | 39 | 147B3E1 | 6109B044 | 1E30C970C | 7A520BCAC6* | 0 | 0 | 1 | 0 | 1 | 00 | 00 | 00 |

Start clocking Summation Combiner

| | | | | | | | | | | | | | |
|----|----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 40 | 1 | 08F67C2 | 42136088 | 1C6192E18 | 74A417958D | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 41 | 2 | 11ECF84 | 0426C111 | 18C325C30 | 69482F2B1B | 0 | 0 | 1 | 0 | 0 | 00 | 01 | 00 |
| 42 | 3 | 03D9F08 | 084D8222 | 11864B861 | 52905E5637 | 0 | 0 | 0 | 1 | 1 | 11 | 00 | 01 |
| 43 | 4 | 07B3E10 | 109B0444 | 030C970C3 | 2520BCAC6E | 0 | 1 | 0 | 0 | 0 | 01 | 11 | 00 |
| 44 | 5 | 0F67C21 | 21360889 | 06192E186 | 4A417958DC | 1 | 0 | 0 | 0 | 0 | 10 | 01 | 11 |
| 45 | 6 | 1ECF843 | 426C1112 | 0C325C30C | 1482F2B1B8 | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 46 | 7 | 1D9F086 | 04D82225 | 1864B8619 | 2905E56370 | 1 | 1 | 1 | 0 | 0 | 01 | 11 | 10 |
| 47 | 8 | 1B3E10D | 09B0444B | 10C970C32 | 520BCAC6E1 | 1 | 1 | 0 | 0 | 1 | 10 | 01 | 11 |
| 48 | 9 | 167C21B | 13608897 | 0192E1865 | 2417958DC3 | 0 | 0 | 0 | 0 | 0 | 00 | 10 | 01 |
| 49 | 10 | 0CF8436 | 26C1112F | 0325C30CB | 482F2B1B87 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 50 | 11 | 19F086D | 4D82225E | 064B86197 | 105E56370F | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 51 | 12 | 13E10DB | 1B0444BC | 0C970C32F | 20BCAC6E1F | 0 | 0 | 1 | 1 | 1 | 00 | 01 | 00 |
| 52 | 13 | 07C21B7 | 36088979 | 192E1865E | 417958DC3F | 0 | 0 | 1 | 0 | 1 | 11 | 00 | 01 |
| 53 | 14 | 0F8436E | 6C1112F2 | 125C30CBD | 02F2B1B87F | 1 | 0 | 0 | 1 | 1 | 01 | 11 | 00 |
| 54 | 15 | 1F086DD | 582225E4 | 04B86197B | 05E56370FF | 1 | 0 | 0 | 1 | 1 | 10 | 01 | 11 |
| 55 | 16 | 1E10DBA | 30444BC9 | 0970C32F7 | 0BCAC6E1FF | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 56 | 17 | 1C21B75 | 60889793 | 12E1865EE | 17958DC3FF | 1 | 1 | 0 | 1 | 0 | 01 | 11 | 10 |
| 57 | 18 | 18436EA | 41112F27 | 05C30CBDD | 2F2B1B87FF | 1 | 0 | 0 | 0 | 0 | 10 | 01 | 11 |
| 58 | 19 | 1086DD4 | 02225E4E | 0B86197BA | 5E56370FFF | 0 | 0 | 1 | 0 | 1 | 00 | 10 | 01 |
| 59 | 20 | 010DBA8 | 0444BC9D | 170C32F74 | 3CAC6E1FFF | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 60 | 21 | 021B750 | 0889793A | 0E1865EE8 | 7958DC3FFF | 0 | 1 | 1 | 0 | 1 | 00 | 01 | 00 |
| 61 | 22 | 0436EA0 | 1112F274 | 1C30CBDD0 | 72B1B87FFE | 0 | 0 | 1 | 1 | 0 | 10 | 00 | 01 |
| 62 | 23 | 086DD40 | 2225E4E9 | 186197BA1 | 656370FFFC | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 63 | 24 | 10DBA81 | 444BC9D3 | 10C32F743 | 4AC6E1FFF8 | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 64 | 25 | 01B7502 | 089793A7 | 01865EE86 | 158DC3FFF1 | 0 | 1 | 0 | 1 | 1 | 00 | 01 | 00 |
| 65 | 26 | 036EA05 | 112F274E | 030CBDD0D | 2B1B87FFE3 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 66 | 27 | 06DD40B | 225E4E9C | 06197BA1A | 56370FFFC6 | 0 | 0 | 0 | 0 | 1 | 10 | 11 | 00 |
| 67 | 28 | 0DBA817 | 44BC9D39 | 0C32F7434 | 2C6E1FFF8D | 1 | 1 | 1 | 0 | 1 | 10 | 10 | 11 |
| 68 | 29 | 1B7502E | 09793A72 | 1865EE868 | 58DC3FFF1B | 1 | 0 | 1 | 1 | 1 | 01 | 10 | 10 |
| 69 | 30 | 16EA05D | 12F274E5 | 10CBDD0D0 | 31B87FFE36 | 0 | 1 | 0 | 1 | 1 | 01 | 01 | 10 |
| 70 | 31 | 0DD40BA | 25E4E9CB | 0197BA1A1 | 6370FFFC6D | 1 | 1 | 0 | 0 | 1 | 11 | 01 | 01 |
| 71 | 32 | 1BA8174 | 4BC9D397 | 032F74343 | 46E1FFF8DA | 1 | 1 | 0 | 1 | 0 | 11 | 11 | 01 |
| 72 | 33 | 17502E8 | 1793A72F | 065EE8687 | 0DC3FFF1B4 | 0 | 1 | 0 | 1 | 1 | 11 | 11 | 11 |
| 73 | 34 | 0EA05D0 | 2F274E5E | 0CBDD0D0F | 1B87FFE369 | 1 | 0 | 1 | 1 | 0 | 10 | 11 | 11 |
| 74 | 35 | 1D40BA0 | 5E4E9CBD | 197BA1A1F | 370FFFC6D2 | 1 | 0 | 1 | 0 | 0 | 10 | 10 | 11 |
| 75 | 36 | 1A81741 | 3C9D397B | 12F74343F | 6E1FFF8DA5 | 1 | 1 | 0 | 0 | 0 | 01 | 10 | 10 |
| 76 | 37 | 1502E82 | 793A72F6 | 05EE8687F | 5C3FFF1B4B | 0 | 0 | 0 | 0 | 1 | 00 | 01 | 10 |
| 77 | 38 | 0A05D05 | 7274E5ED | 0BDD0D0FF | 387FFE3696 | 1 | 0 | 1 | 0 | 0 | 10 | 00 | 01 |
| 78 | 39 | 140BA0B | 64E9CBDA | 17BA1A1FF | 70FFFC6D2C | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 79 | 40 | 0817416 | 49D397B4 | 0F74343FE | 61FFF8DA59 | 1 | 1 | 1 | 1 | 0 | 11 | 00 | 10 |
| 80 | 41 | 102E82C | 13A72F69 | 1EE8687FD | 43FFF1B4B3 | 0 | 1 | 1 | 1 | 0 | 00 | 11 | 00 |
| 81 | 42 | 005D058 | 274E5ED2 | 1DD0D0FFA | 07FFE36966 | 0 | 0 | 1 | 1 | 0 | 11 | 00 | 11 |
| 82 | 43 | 00BA0B0 | 4E9CBDA5 | 1BA1A1FF5 | 0FFFC6D2CD | 0 | 1 | 1 | 1 | 0 | 00 | 11 | 00 |
| 83 | 44 | 0174160 | 1D397B4A | 174343FEA | 1FFF8DA59B | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 84 | 45 | 02E82C0 | 3A72F695 | 0E8687FD4 | 3FFF1B4B37 | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 85 | 46 | 05D0580 | 74E5ED2B | 1D0D0FFA9 | 7FFE36966E | 0 | 1 | 1 | 1 | 1 | 00 | 00 | 10 |
| 86 | 47 | 0BA0B00 | 69CBDA56 | 1A1A1FF53 | 7FFC6D2CDC | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 87 | 48 | 1741600 | 5397B4AC | 14343FEA6 | 7FF8DA59B8 | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 88 | 49 | 0E82C01 | 272F6959 | 08687FD4D | 7FF1B4B370 | 1 | 0 | 1 | 1 | 1 | 00 | 00 | 10 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 89 | 50 | 1D05802 | 4E5ED2B3 | 10D0FFA9A | 7FE36966E0 | 1 | 0 | 0 | 1 | 0 | 01 | 00 | 00 |
| 90 | 51 | 1A0B004 | 1CBDA566 | 01A1FF535 | 7FC6D2CDC0 | 1 | 1 | 0 | 1 | 0 | 11 | 01 | 00 |
| 91 | 52 | 1416009 | 397B4ACC | 0343FEA6B | 7F8DA59B80 | 0 | 0 | 0 | 1 | 0 | 10 | 11 | 01 |
| 92 | 53 | 082C013 | 72F69599 | 0687FD4D7 | 7F1B4B3701 | 1 | 1 | 0 | 0 | 0 | 10 | 10 | 11 |
| 93 | 54 | 1058026 | 65ED2B33 | 0D0FFA9AF | 7E36966E03 | 0 | 1 | 1 | 0 | 0 | 01 | 10 | 10 |
| 94 | 55 | 00B004D | 4BDA5667 | 1A1FF535E | 7C6D2CDC06 | 0 | 1 | 1 | 0 | 1 | 01 | 01 | 10 |
| 95 | 56 | 016009B | 17B4ACCE | 143FEA6BD | 78DA59B80D | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 96 | 57 | 02C0137 | 2F69599D | 087FD4D7B | 71B4B3701A | 0 | 0 | 1 | 1 | 1 | 10 | 11 | 01 |
| 97 | 58 | 058026F | 5ED2B33B | 10FFA9AF6 | 636966E034 | 0 | 1 | 0 | 0 | 1 | 01 | 10 | 11 |
| 98 | 59 | 0B004DF | 3DA56677 | 01FF535ED | 46D2CDC068 | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 99 | 60 | 16009BF | 7B4ACCEF | 03FEA6BDB | 0DA59B80D0 | 0 | 0 | 0 | 1 | 1 | 00 | 10 | 01 |
| 100 | 61 | 0C0137F | 769599DF | 07FD4D7B7 | 1B4B3701A1 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 101 | 62 | 18026FE | 6D2B33BE | 0FFA9AF6E | 36966E0342 | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 102 | 63 | 1004DFC | 5A56677D | 1FF535EDD | 6D2CDC0684 | 0 | 0 | 1 | 0 | 0 | 00 | 01 | 00 |
| 103 | 64 | 0009BF9 | 34ACCEFB | 1FEA6BDBB | 5A59B80D09 | 0 | 1 | 1 | 0 | 0 | 10 | 00 | 01 |
| 104 | 65 | 00137F2 | 69599DF7 | 1FD4D7B76 | 34B3701A12 | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 105 | 66 | 0026FE5 | 52B33BEF | 1FA9AF6EC | 6966E03424 | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 106 | 67 | 004DFCA | 256677DF | 1F535EDD8 | 52CDC06848 | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 107 | 68 | 009BF94 | 4ACCEFBE | 1EA6BDBB0 | 259B80D091 | 0 | 1 | 1 | 1 | 0 | 11 | 01 | 00 |
| 108 | 69 | 0137F29 | 1599DF7C | 1D4D7B760 | 4B3701A123 | 0 | 1 | 1 | 0 | 1 | 10 | 11 | 01 |
| 109 | 70 | 026FE53 | 2B33BEF9 | 1A9AF6EC0 | 166E034246 | 0 | 0 | 1 | 0 | 1 | 01 | 10 | 11 |
| 110 | 71 | 04DFCA7 | 56677DF2 | 1535EDD81 | 2CDC06848D | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 111 | 72 | 09BF94F | 2CCEFBE4 | 0A6BDBB03 | 59B80D091B | 1 | 1 | 1 | 1 | 1 | 00 | 01 | 01 |
| 112 | 73 | 137F29E | 599DF7C9 | 14D7B7607 | 33701A1236 | 0 | 1 | 0 | 0 | 1 | 11 | 00 | 01 |
| 113 | 74 | 06FE53C | 333BEF93 | 09AF6EC0E | 66E034246C | 0 | 0 | 1 | 1 | 1 | 01 | 11 | 00 |
| 114 | 75 | 0DFCA79 | 6677DF26 | 135EDD81D | 4DC06848D8 | 1 | 0 | 0 | 1 | 1 | 10 | 01 | 11 |
| 115 | 76 | 1BF94F2 | 4CEFBE4D | 06BDBB03B | 1B80D091B1 | 1 | 1 | 0 | 1 | 1 | 11 | 10 | 01 |
| 116 | 77 | 17F29E5 | 19DF7C9A | 0D7B76077 | 3701A12363 | 0 | 1 | 1 | 0 | 1 | 00 | 11 | 10 |
| 117 | 78 | 0FE53CA | 33BEF934 | 1AF6EC0EF | 6E034246C6 | 1 | 1 | 1 | 0 | 1 | 11 | 00 | 11 |
| 118 | 79 | 1FCA794 | 677DF269 | 15EDD81DF | 5C06848D8C | 1 | 0 | 0 | 0 | 0 | 01 | 11 | 00 |
| 119 | 80 | 1F94F29 | 4EFBE4D2 | 0BDBB03BE | 380D091B19 | 1 | 1 | 1 | 0 | 0 | 01 | 01 | 11 |
| 120 | 81 | 1F29E53 | 1DF7C9A5 | 17B76077D | 701A123633 | 1 | 1 | 0 | 0 | 1 | 11 | 01 | 01 |
| 121 | 82 | 1E53CA6 | 3BEF934B | 0F6EC0EFB | 6034246C66 | 1 | 1 | 1 | 0 | 0 | 11 | 11 | 01 |
| 122 | 83 | 1CA794D | 77DF2696 | 1EDD81DF6 | 406848D8CD | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 123 | 84 | 194F29B | 6FBE4D2C | 1DBB03BED | 00D091B19B | 1 | 1 | 1 | 1 | 0 | 11 | 10 | 11 |
| 124 | 85 | 129E536 | 5F7C9A59 | 1B76077DA | 01A1236337 | 0 | 0 | 1 | 1 | 1 | 00 | 11 | 10 |
| 125 | 86 | 053CA6C | 3EF934B3 | 16EC0EFB4 | 034246C66E | 0 | 1 | 0 | 0 | 1 | 10 | 00 | 11 |
| 126 | 87 | 0A794D9 | 7DF26967 | 0DD81DF69 | 06848D8CDD | 1 | 1 | 1 | 1 | 0 | 01 | 10 | 00 |
| 127 | 88 | 14F29B3 | 7BE4D2CF | 1BB03BED3 | 0D091B19BB | 0 | 1 | 1 | 0 | 1 | 01 | 01 | 10 |
| 128 | 89 | 09E5366 | 77C9A59F | 176077DA6 | 1A12363377 | 1 | 1 | 0 | 0 | 1 | 11 | 01 | 01 |
| 129 | 90 | 13CA6CD | 6F934B3F | 0EC0EFB4D | 34246C66EF | 0 | 1 | 1 | 0 | 1 | 10 | 11 | 01 |
| 130 | 91 | 0794D9B | 5F26967F | 1D81DF69A | 6848D8CDDF | 0 | 0 | 1 | 0 | 1 | 01 | 10 | 11 |
| 131 | 92 | 0F29B37 | 3E4D2CFE | 1B03BED35 | 5091B19BBE | 1 | 0 | 1 | 1 | 0 | 10 | 01 | 10 |
| 132 | 93 | 1E5366F | 7C9A59FD | 16077DA6B | 212363377C | 1 | 1 | 0 | 0 | 0 | 11 | 10 | 01 |
| 133 | 94 | 1CA6CDF | 7934B3FB | 0C0EFB4D6 | 4246C66EF9 | 1 | 0 | 1 | 0 | 1 | 00 | 11 | 10 |
| 134 | 95 | 194D9BE | 726967F6 | 181DF69AD | 048D8CDDF2 | 1 | 0 | 1 | 1 | 1 | 11 | 00 | 11 |
| 135 | 96 | 129B37D | 64D2CFED | 103BED35B | 091B19BBE5 | 0 | 1 | 0 | 0 | 0 | 01 | 11 | 00 |
| 136 | 97 | 05366FA | 49A59FDA | 0077DA6B7 | 12363377CA | 0 | 1 | 0 | 0 | 0 | 10 | 01 | 11 |
| 137 | 98 | 0A6CDF5 | 134B3FB4 | 00EFB4D6E | 246C66EF95 | 1 | 0 | 0 | 0 | 1 | 00 | 10 | 01 |
| 138 | 99 | 14D9BEA | 26967F69 | 01DF69ADD | 48D8CDDF2B | 0 | 1 | 0 | 1 | 0 | 00 | 00 | 10 |
| 139 | 100 | 09B37D4 | 4D2CFED2 | 03BED35BB | 11B19BBE56 | 1 | 0 | 0 | 1 | 0 | 01 | 00 | 00 |
| 140 | 101 | 1366FA8 | 1A59FDA5 | 077DA6B77 | 2363377CAC | 0 | 0 | 0 | 0 | 1 | 01 | 01 | 00 |
| 141 | 102 | 06CDF51 | 34B3FB4A | 0EFB4D6EF | 46C66EF959 | 0 | 1 | 1 | 1 | 0 | 00 | 01 | 01 |
| 142 | 103 | 0D9BEA2 | 6967F695 | 1DF69ADDF | 0D8CDDF2B2 | 1 | 0 | 1 | 1 | 1 | 10 | 00 | 01 |
| 143 | 104 | 1B37D45 | 52CFED2A | 1BED35BBF | 1B19BBE564 | 1 | 1 | 1 | 0 | 1 | 00 | 10 | 00 |
| 144 | 105 | 166FA8A | 259FDA54 | 17DA6B77E | 363377CAC8 | 0 | 1 | 0 | 0 | 1 | 01 | 00 | 10 |
| 145 | 106 | 0CDF515 | 4B3FB4A9 | 0FB4D6EFC | 6C66EF9591 | 1 | 0 | 1 | 0 | 1 | 00 | 01 | 00 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 146 | 107 | 19BEA2B | 167F6952 | 1F69ADDF8 | 58CDDF2B22 | 1 | 0 | 1 | 1 | 1 | 10 | 00 | 01 |
| 147 | 108 | 137D457 | 2CFED2A5 | 1ED35BBF1 | 319BBE5645 | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 148 | 109 | 06FA8AF | 59FDA54A | 1DA6B77E2 | 63377CAC8B | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 149 | 110 | 0DF515F | 33FB4A95 | 1B4D6EFC4 | 466EF95916 | 1 | 1 | 1 | 0 | 1 | 01 | 00 | 00 |
| 150 | 111 | 1BEA2BF | 67F6952A | 169ADDF88 | 0CDDF2B22C | 1 | 1 | 0 | 1 | 0 | 11 | 01 | 00 |
| 151 | 112 | 17D457F | 4FED2A55 | 0D35BBF10 | 19BBE56459 | 0 | 1 | 1 | 1 | 0 | 11 | 11 | 01 |
| 152 | 113 | 0FA8AFE | 1FDA54AB | 1A6B77E20 | 3377CAC8B3 | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 153 | 114 | 1F515FD | 3FB4A957 | 14D6EFC40 | 66EF959166 | 1 | 1 | 0 | 1 | 1 | 10 | 10 | 11 |
| 154 | 115 | 1EA2BFA | 7F6952AF | 09ADDF880 | 4DDF2B22CC | 1 | 0 | 1 | 1 | 1 | 01 | 10 | 10 |
| 155 | 116 | 1D457F4 | 7ED2A55F | 135BBF100 | 1BBE564598 | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 156 | 117 | 1A8AFE8 | 7DA54ABF | 06B77E200 | 377CAC8B31 | 1 | 1 | 0 | 0 | 0 | 11 | 10 | 01 |
| 157 | 118 | 1515FD0 | 7B4A957F | 0D6EFC401 | 6EF9591663 | 0 | 0 | 1 | 1 | 1 | 00 | 11 | 10 |
| 158 | 119 | 0A2BFA1 | 76952AFE | 1ADDF8803 | 5DF2B22CC7 | 1 | 1 | 1 | 1 | 0 | 00 | 00 | 11 |
| 159 | 120 | 1457F42 | 6D2A55FD | 15BBF1007 | 3BE564598E | 0 | 0 | 0 | 1 | 1 | 00 | 00 | 00 |
| 160 | 121 | 08AFE84 | 5A54ABFB | 0B77E200F | 77CAC8B31C | 1 | 0 | 1 | 1 | 1 | 01 | 00 | 00 |
| 161 | 122 | 115FD09 | 34A957F7 | 16EFC401F | 6F95916639 | 0 | 1 | 0 | 1 | 1 | 00 | 01 | 00 |
| 162 | 123 | 02BFA12 | 6952AFEF | 0DDF8803E | 5F2B22CC73 | 0 | 0 | 1 | 0 | 1 | 11 | 00 | 01 |
| 163 | 124 | 057F424 | 52A55FDF | 1BBF1007D | 3E564598E7 | 0 | 1 | 1 | 0 | 1 | 01 | 11 | 00 |
| 164 | 125 | 0AFE848 | 254ABFBF | 177E200FA | 7CAC8B31CF | 1 | 0 | 0 | 1 | 1 | 10 | 01 | 11 |
| 165 | 126 | 15FD090 | 4A957F7E | 0EFC401F5 | 795916639E | 0 | 1 | 1 | 0 | 0 | 11 | 10 | 01 |
| 166 | 127 | 0BFA121 | 152AFefd | 1DF8803EA | 72B22CC73C | 1 | 0 | 1 | 1 | 0 | 01 | 11 | 10 |
| 167 | 128 | 17F4243 | 2A55FDFA | 1BF1007D4 | 6564598E78 | 0 | 0 | 1 | 0 | 0 | 10 | 01 | 11 |
| 168 | 129 | 0FE8486 | 54ABFBF4 | 17E200FA8 | 4AC8B31CF0 | 1 | 1 | 0 | 1 | 1 | 11 | 10 | 01 |
| 169 | 130 | 1FD090C | 2957F7E8 | 0FC401F51 | 15916639E1 | 1 | 0 | 1 | 1 | 0 | 01 | 11 | 10 |
| 170 | 131 | 1FA1219 | 52AFefd1 | 1F8803EA3 | 2B22CC73C2 | 1 | 1 | 1 | 0 | 0 | 01 | 01 | 11 |
| 171 | 132 | 1F42432 | 255FDFA2 | 1F1007D47 | 564598E785 | 1 | 0 | 1 | 0 | 1 | 11 | 01 | 01 |
| 172 | 133 | 1E84865 | 4ABFBF44 | 1E200FA8F | 2C8B31CF0B | 1 | 1 | 1 | 1 | 1 | 11 | 11 | 01 |
| 173 | 134 | 1D090CB | 157F7E88 | 1C401F51E | 5916639E17 | 1 | 0 | 1 | 0 | 1 | 11 | 11 | 11 |
| 174 | 135 | 1A12196 | 2AFefd11 | 18803EA3C | 322CC73C2E | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 175 | 136 | 142432C | 55FDFA23 | 11007D479 | 64598E785C | 0 | 1 | 0 | 0 | 1 | 01 | 10 | 11 |
| 176 | 137 | 0848659 | 2BFBF446 | 0200FA8F2 | 48B31CF0B9 | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 177 | 138 | 1090CB2 | 57F7E88C | 0401F51E4 | 116639E173 | 0 | 1 | 0 | 0 | 1 | 00 | 10 | 01 |
| 178 | 139 | 0121964 | 2FEFD118 | 0803EA3C8 | 22CC73C2E6 | 0 | 1 | 1 | 1 | 1 | 00 | 00 | 10 |
| 179 | 140 | 02432C9 | 5FDFA230 | 1007D4791 | 4598E785CD | 0 | 1 | 0 | 1 | 0 | 01 | 00 | 00 |
| 180 | 141 | 0486593 | 3FBF4461 | 000FA8F23 | 0B31CF0B9B | 0 | 1 | 0 | 0 | 0 | 00 | 01 | 00 |
| 181 | 142 | 090CB26 | 7F7E88C3 | 001F51E47 | 16639E1736 | 1 | 0 | 0 | 0 | 1 | 11 | 00 | 01 |
| 182 | 143 | 121964D | 7EFD1187 | 003EA3C8F | 2CC73C2E6C | 0 | 1 | 0 | 1 | 1 | 01 | 11 | 00 |
| 183 | 144 | 0432C9B | 7DFA230E | 007D4791E | 598E785CD8 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 184 | 145 | 0865936 | 7BF4461C | 00FA8F23C | 331CF0B9B0 | 1 | 1 | 0 | 0 | 0 | 11 | 10 | 01 |
| 185 | 146 | 10CB26D | 77E88C38 | 01F51E479 | 6639E17361 | 0 | 1 | 0 | 0 | 0 | 00 | 11 | 10 |
| 186 | 147 | 01964DA | 6FD11870 | 03EA3C8F2 | 4C73C2E6C2 | 0 | 1 | 0 | 0 | 1 | 10 | 00 | 11 |
| 187 | 148 | 032C9B4 | 5FA230E1 | 07D4791E4 | 18E785CD84 | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 188 | 149 | 0659368 | 3F4461C2 | 0FA8F23C9 | 31CF0B9B09 | 0 | 0 | 1 | 1 | 0 | 00 | 00 | 10 |
| 189 | 150 | 0CB26D0 | 7E88C384 | 1F51E4793 | 639E173612 | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 190 | 151 | 1964DA0 | 7D118709 | 1EA3C8F27 | 473C2E6C24 | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 191 | 152 | 12C9B41 | 7A230E12 | 1D4791E4E | 0E785CD848 | 0 | 0 | 1 | 0 | 1 | 01 | 00 | 10 |
| 192 | 153 | 0593683 | 74461C24 | 1A8F23C9C | 1CF0B9B091 | 0 | 0 | 1 | 1 | 1 | 00 | 01 | 00 |
| 193 | 154 | 0B26D06 | 688C3848 | 151E47938 | 39E1736123 | 1 | 1 | 0 | 1 | 1 | 10 | 00 | 01 |
| 194 | 155 | 164DA0D | 51187091 | 0A3C8F271 | 73C2E6C247 | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 195 | 156 | 0C9B41A | 2230E123 | 14791E4E3 | 6785CD848F | 1 | 0 | 0 | 1 | 0 | 00 | 00 | 10 |
| 196 | 157 | 1936835 | 4461C247 | 08F23C9C6 | 4F0B9B091E | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 197 | 158 | 126D06A | 08C3848E | 11E47938D | 1E1736123C | 0 | 1 | 0 | 0 | 0 | 00 | 01 | 00 |
| 198 | 159 | 04DA0D5 | 1187091C | 03C8F271B | 3C2E6C2478 | 0 | 1 | 0 | 0 | 1 | 11 | 00 | 01 |
| 199 | 160 | 09B41AA | 230E1238 | 0791E4E37 | 785CD848F1 | 1 | 0 | 0 | 0 | 0 | 01 | 11 | 00 |
| 200 | 161 | 1368354 | 461C2470 | 0F23C9C6F | 70B9B091E3 | 0 | 0 | 1 | 1 | 1 | 10 | 01 | 11 |
| 201 | 162 | 06D06A9 | 0C3848E1 | 1E47938DF | 61736123C6 | 0 | 0 | 1 | 0 | 1 | 00 | 10 | 01 |
| 202 | 163 | 0DA0D52 | 187091C3 | 1C8F271BE | 42E6C2478D | 1 | 0 | 1 | 1 | 1 | 00 | 00 | 10 |

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 203 | 164 | 1B41AA4 | 30E12387 | 191E4E37C | 05CD848F1A | 1 | 1 | 1 | 1 | 0 | 10 | 00 | 00 |
| 204 | 165 | 1683549 | 61C2470F | 123C9C6F9 | 0B9B091E34 | 0 | 1 | 0 | 1 | 0 | 00 | 10 | 00 |
| 205 | 166 | 0D06A92 | 43848E1E | 047938DF3 | 1736123C68 | 1 | 1 | 0 | 0 | 0 | 00 | 00 | 10 |
| 206 | 167 | 1A0D524 | 07091C3C | 08F271BE7 | 2E6C2478D1 | 1 | 0 | 1 | 0 | 0 | 01 | 00 | 00 |
| 207 | 168 | 141AA49 | 0E123879 | 11E4E37CF | 5CD848F1A2 | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 208 | 169 | 0835492 | 1C2470F3 | 03C9C6F9F | 39B091E345 | 1 | 0 | 0 | 1 | 0 | 10 | 00 | 01 |
| 209 | 170 | 106A925 | 3848E1E6 | 07938DF3F | 736123C68B | 0 | 0 | 0 | 0 | 0 | 11 | 10 | 00 |
| 210 | 171 | 00D524A | 7091C3CD | 0F271BE7E | 66C2478D16 | 0 | 1 | 1 | 1 | 0 | 01 | 11 | 10 |
| 211 | 172 | 01AA495 | 6123879B | 1E4E37CFD | 4D848F1A2D | 0 | 0 | 1 | 1 | 1 | 10 | 01 | 11 |
| 212 | 173 | 035492A | 42470F36 | 1C9C6F9FB | 1B091E345B | 0 | 0 | 1 | 0 | 1 | 00 | 10 | 01 |
| 213 | 174 | 06A9255 | 048E1E6C | 1938DF3F6 | 36123C68B7 | 0 | 1 | 1 | 0 | 0 | 00 | 00 | 10 |
| 214 | 175 | 0D524AB | 091C3CD8 | 1271BE7EC | 6C2478D16E | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 215 | 176 | 1AA4957 | 123879B1 | 04E37CFD8 | 5848F1A2DD | 1 | 0 | 0 | 0 | 1 | 00 | 00 | 00 |
| 216 | 177 | 15492AF | 2470F363 | 09C6F9FB0 | 3091E345BA | 0 | 0 | 1 | 1 | 0 | 01 | 00 | 00 |
| 217 | 178 | 0A9255E | 48E1E6C7 | 138DF3F61 | 6123C68B75 | 1 | 1 | 0 | 0 | 1 | 00 | 01 | 00 |
| 218 | 179 | 1524ABD | 11C3CD8F | 071BE7EC3 | 42478D16EB | 0 | 1 | 0 | 0 | 1 | 11 | 00 | 01 |
| 219 | 180 | 0A4957B | 23879B1F | 0E37CFD87 | 048F1A2DD6 | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 220 | 181 | 1492AF6 | 470F363F | 1C6F9FB0E | 091E345BAD | 0 | 0 | 1 | 0 | 1 | 10 | 00 | 11 |
| 221 | 182 | 09255EC | 0E1E6C7F | 18DF3F61D | 123C68B75B | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 222 | 183 | 124ABD9 | 1C3CD8FF | 11BE7EC3A | 2478D16EB6 | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 223 | 184 | 04957B3 | 3879B1FE | 037CFD874 | 48F1A2DD6D | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 224 | 185 | 092AF66 | 70F363FD | 06F9FB0E9 | 11E345BADB | 1 | 1 | 0 | 1 | 1 | 10 | 00 | 01 |
| 225 | 186 | 1255ECD | 61E6C7FA | 0DF3F61D3 | 23C68B75B7 | 0 | 1 | 1 | 1 | 1 | 00 | 10 | 00 |
| 226 | 187 | 04ABD9B | 43CD8FF5 | 1BE7EC3A7 | 478D16EB6E | 0 | 1 | 1 | 1 | 1 | 00 | 00 | 10 |
| 227 | 188 | 0957B37 | 079B1FEA | 17CFD874E | 0F1A2DD6DD | 1 | 1 | 0 | 0 | 0 | 01 | 00 | 00 |
| 228 | 189 | 12AF66F | 0F363FD4 | 0F9FB0E9C | 1E345BADBB | 0 | 0 | 1 | 0 | 0 | 00 | 01 | 00 |
| 229 | 190 | 055ECDE | 1E6C7FA9 | 1F3F61D39 | 3C68B75B76 | 0 | 0 | 1 | 0 | 1 | 11 | 00 | 01 |
| 230 | 191 | 0ABD9BC | 3CD8FF53 | 1E7EC3A73 | 78D16EB6EC | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 231 | 192 | 157B379 | 79B1FEA7 | 1CFD874E6 | 71A2DD6DD9 | 0 | 1 | 1 | 1 | 1 | 11 | 00 | 11 |
| 232 | 193 | 0AF66F3 | 7363FD4E | 19FB0E9CD | 6345BADBB2 | 1 | 0 | 1 | 0 | 1 | 01 | 11 | 00 |
| 233 | 194 | 15ECDE6 | 66C7FA9D | 13F61D39A | 468B75B765 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 234 | 195 | 0BD9BCC | 4D8FF53A | 07EC3A735 | 0D16EB6ECA | 1 | 1 | 0 | 0 | 0 | 11 | 10 | 01 |
| 235 | 196 | 17B3799 | 1B1FEA75 | 0FD874E6A | 1A2DD6DD94 | 0 | 0 | 1 | 0 | 0 | 00 | 11 | 10 |
| 236 | 197 | 0F66F33 | 363FD4EA | 1FB0E9CD5 | 345BADBB28 | 1 | 0 | 1 | 0 | 0 | 11 | 00 | 11 |
| 237 | 198 | 1ECDE67 | 6C7FA9D5 | 1F61D39AA | 68B75B7650 | 1 | 0 | 1 | 1 | 0 | 00 | 11 | 00 |
| 238 | 199 | 1D9BCCF | 58FF53AB | 1EC3A7354 | 516EB6ECA0 | 1 | 1 | 1 | 0 | 1 | 11 | 00 | 11 |
| 239 | 200 | 1B3799E | 31FEA756 | 1D874E6A8 | 22DD6DD940 | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |

Z[0] = 3F

Z[1] = B1

Z[2] = 67

Z[3] = D2

Z[4] = 2F

Z[5] = A6

Z[6] = 1F

Z[7] = B9

Z[8] = E6

Z[9] = 84

Z[10] = 43

Z[11] = 07

Z[12] = D8

Z[13] = 1E

Z[14] = E7

Z[15] = C3

Sample Data



```

=====
Reload this pattern into the LFSRs
Hold content of Summation Combiner regs and calculate new C[t+1] and Z values
=====

LFSR1  <= 0E62F3F
LFSR2  <= 6C84A6B1
LFSR3  <= 11E431F67
LFSR4  <= 61E707B9D2
C[t+1] <= 00

=====
Generating 125 key symbols (encryption/decryption sequence)
=====
240  1  0E62F3F  6C84A6B1  11E431F67  61E707B9D2  1  1  0  1  0  00  11  00
241  2  1CC5E7F  59094D63  03C863ECE  43CE0F73A5  1  0  0  1  0  11  00  11
242  3  198BCFF  32129AC6  0790C7D9D  079C1EE74A  1  0  0  1  1  01  11  00
243  4  13179FE  6425358C  0F218FB3A  0F383DCE94  0  0  1  0  0  10  01  11
244  5  062F3FD  484A6B19  1E431F675  1E707B9D28  0  0  1  0  1  00  10  01
245  6  0C5E7FB  1094D632  1C863ECEB  3CE0F73A50  1  1  1  1  0  11  00  10
246  7  18BCFF7  2129AC64  190C7D9D7  79C1EE74A1  1  0  1  1  0  00  11  00
247  8  1179FEE  425358C8  1218FB3AE  7383DCE942  0  0  0  1  1  10  00  11
248  9  02F3FDD  04A6B190  0431F675D  6707B9D285  0  1  0  0  1  11  10  00
249  10 05E7FBB  094D6320  0863ECEBB  4E0F73A50B  0  0  1  0  0  00  11  10
250  11 0BCFF77  129AC640  10C7D9D77  1C1EE74A16  1  1  0  0  0  11  00  11
251  12 179FEEE  25358C80  018FB3AEE  383DCE942C  0  0  0  0  1  10  11  00
252  13 0F3FDDC  4A6B1900  031F675DD  707B9D2859  1  0  0  0  1  01  10  11
253  14 1E7FBB8  14D63200  063ECEBBA  60F73A50B3  1  1  0  1  0  10  01  10
254  15 1CFF771  29AC6401  0C7D9D774  41EE74A167  1  1  1  1  0  10  10  01
255  16 19FEEE2  5358C803  18FB3AEE9  03DCE942CE  1  0  1  1  1  01  10  10
256  17 13FDDC4  26B19007  11F675DD2  07B9D2859C  0  1  0  1  1  01  01  10
257  18 07FBB88  4D63200E  03ECEBBA4  0F73A50B38  0  0  0  0  1  10  01  01
258  19 0FF7711  1AC6401D  07D9D7748  1EE74A1670  1  1  0  1  1  11  10  01
259  20 1FEEE23  358C803B  0FB3AEE91  3DCE942CE1  1  1  1  1  1  01  11  10
260  21 1FDCC47  6B190076  1F675DD23  7B9D2859C2  1  0  1  1  0  01  01  11
261  22 1FBB88F  563200ED  1ECEBBA47  773A50B385  1  0  1  0  1  11  01  01
262  23 1F7711E  2C6401DB  1D9D7748F  6E74A1670A  1  0  1  0  1  10  11  01
263  24 1EEE23D  58C803B6  1B3AEE91E  5CE942CE15  1  1  1  1  0  11  10  11
264  25 1DDC47A  3190076C  1675DD23D  39D2859C2B  1  1  0  1  0  01  11  10
265  26 1BB88F4  63200ED9  0CEBBA47A  73A50B3856  1  0  1  1  0  01  01  11
266  27 17711E8  46401DB2  19D7748F5  674A1670AD  0  0  1  0  0  11  01  01
267  28 0EE23D0  0C803B64  13AEE91EA  4E942CE15B  1  1  0  1  0  11  11  01
268  29 1DC47A0  190076C8  075DD23D4  1D2859C2B7  1  0  0  0  0  11  11  11
269  30 1B88F41  3200ED90  0EBBA47A9  3A50B3856E  1  0  1  0  1  11  11  11
270  31 1711E83  6401DB20  1D7748F53  74A1670ADC  0  0  1  1  1  11  11  11
271  32 0E23D07  4803B641  1AEE91EA7  6942CE15B8  1  0  1  0  1  11  11  11
272  33 1C47A0F  10076C82  15DD23D4F  52859C2B71  1  0  0  1  1  11  11  11
273  34 188F41E  200ED905  0BBA47A9E  250B3856E3  1  0  1  0  1  11  11  11
274  35 111E83C  401DB20A  17748F53D  4A1670ADC7  0  0  0  0  1  00  11  11
275  36 023D078  003B6414  0EE91EA7A  142CE15B8E  0  0  1  0  1  10  00  11
276  37 047A0F0  0076C828  1DD23D4F5  2859C2B71C  0  0  1  0  1  11  10  00
277  38 08F41E1  00ED9050  1BA47A9EA  50B3856E39  1  1  1  1  1  01  11  10
278  39 11E83C2  01DB20A0  1748F53D5  21670ADC72  0  1  0  0  0  10  01  11
279  40 03D0785  03B64141  0E91EA7AA  42CE15B8E4  0  1  1  1  1  11  10  01
280  41 07A0F0A  076C8283  1D23D4F54  059C2B71C8  0  0  1  1  1  00  11  10
281  42 0F41E14  0ED90507  1A47A9EA9  0B3856E390  1  1  1  0  1  11  00  11
282  43 1E83C29  1DB20A0F  148F53D52  1670ADC720  1  1  0  0  1  01  11  00
283  44 1D07853  3B64141E  091EA7AA5  2CE15B8E40  1  0  1  1  0  01  01  11

```

Sample Data



| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 284 | 45 | 1A0F0A6 | 76C8283C | 123D4F54B | 59C2B71C81 | 1 | 1 | 0 | 1 | 0 | 00 | 01 | 01 |
| 285 | 46 | 141E14C | 6D905079 | 047A9EA97 | 33856E3902 | 0 | 1 | 0 | 1 | 0 | 10 | 00 | 01 |
| 286 | 47 | 083C299 | 5B20A0F2 | 08F53D52F | 670ADC7204 | 1 | 0 | 1 | 0 | 0 | 00 | 10 | 00 |
| 287 | 48 | 1078533 | 364141E4 | 11EA7AA5E | 4E15B8E408 | 0 | 0 | 0 | 0 | 0 | 01 | 00 | 10 |
| 288 | 49 | 00F0A67 | 6C8283C8 | 03D4F54BC | 1C2B71C811 | 0 | 1 | 0 | 0 | 0 | 00 | 01 | 00 |
| 289 | 50 | 01E14CE | 59050791 | 07A9EA978 | 3856E39022 | 0 | 0 | 0 | 0 | 0 | 11 | 00 | 01 |
| 290 | 51 | 03C299C | 320A0F23 | 0F53D52F1 | 70ADC72045 | 0 | 0 | 1 | 1 | 1 | 01 | 11 | 00 |
| 291 | 52 | 0785339 | 64141E47 | 1EA7AA5E2 | 615B8E408A | 0 | 0 | 1 | 0 | 0 | 10 | 01 | 11 |
| 292 | 53 | 0F0A673 | 48283C8E | 1D4F54BC4 | 42B71C8115 | 1 | 0 | 1 | 1 | 1 | 11 | 10 | 01 |
| 293 | 54 | 1B14CE6 | 1050791C | 1A9EA9788 | 056E39022B | 1 | 0 | 1 | 0 | 1 | 00 | 11 | 10 |
| 294 | 55 | 1C299CD | 20A0F239 | 153D52F10 | 0ADC720456 | 1 | 1 | 0 | 1 | 1 | 11 | 00 | 11 |
| 295 | 56 | 185339B | 4141E472 | 0A7AA5E20 | 15B8E408AC | 1 | 0 | 1 | 1 | 0 | 00 | 11 | 00 |
| 296 | 57 | 10A6736 | 0283C8E4 | 14F54BC41 | 2B71C81158 | 0 | 1 | 0 | 0 | 1 | 10 | 00 | 11 |
| 297 | 58 | 014CE6C | 050791C9 | 09EA97882 | 56E39022B0 | 0 | 0 | 1 | 1 | 0 | 00 | 10 | 00 |
| 298 | 59 | 0299CD9 | 0A0F2393 | 13D52F104 | 2DC7204561 | 0 | 0 | 0 | 1 | 1 | 01 | 00 | 10 |
| 299 | 60 | 05339B3 | 141E4726 | 07AA5E208 | 5B8E408AC3 | 0 | 0 | 0 | 1 | 0 | 00 | 01 | 00 |
| 300 | 61 | 0A67366 | 283C8E4C | 0F54BC411 | 371C811587 | 1 | 0 | 1 | 0 | 0 | 10 | 00 | 01 |
| 301 | 62 | 14CE6CC | 50791C98 | 1EA978822 | 6E39022B0F | 0 | 0 | 1 | 0 | 1 | 11 | 10 | 00 |
| 302 | 63 | 099CD99 | 20F23930 | 1D52F1045 | 5C7204561E | 1 | 1 | 1 | 0 | 0 | 01 | 11 | 10 |
| 303 | 64 | 1339B33 | 41E47260 | 1AA5E208B | 38E408AC3D | 0 | 1 | 1 | 1 | 0 | 01 | 01 | 11 |
| 304 | 65 | 0673666 | 03C8E4C0 | 154BC4117 | 71C811587A | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |
| 305 | 66 | 0CE6CCC | 0791C980 | 0A978822E | 639022B0F5 | 1 | 1 | 1 | 1 | 1 | 11 | 11 | 01 |
| 306 | 67 | 19CD999 | 0F239301 | 152F1045C | 47204561EB | 1 | 0 | 0 | 0 | 0 | 11 | 11 | 11 |
| 307 | 68 | 139B332 | 1E472603 | 0A5E208B9 | 0E408AC3D6 | 0 | 0 | 1 | 0 | 0 | 11 | 11 | 11 |
| 308 | 69 | 0736664 | 3C8E4C06 | 14BC41172 | 1C811587AD | 0 | 1 | 0 | 1 | 1 | 11 | 11 | 11 |
| 309 | 70 | 0E6CCC8 | 791C980C | 0978822E5 | 39022B0F5A | 1 | 0 | 1 | 0 | 1 | 11 | 11 | 11 |
| 310 | 71 | 1CD9990 | 72393019 | 12F1045CB | 7204561EB4 | 1 | 0 | 0 | 0 | 0 | 11 | 11 | 11 |
| 311 | 72 | 19B3320 | 64726033 | 05E208B97 | 6408AC3D69 | 1 | 0 | 0 | 0 | 0 | 11 | 11 | 11 |
| 312 | 73 | 1366640 | 48E4C067 | 0BC41172F | 4811587AD3 | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 313 | 74 | 06CCC81 | 11C980CF | 178822E5E | 1022B0F5A6 | 0 | 1 | 0 | 0 | 0 | 11 | 11 | 11 |
| 314 | 75 | 0D99903 | 2393019E | 0F1045CBC | 204561EB4C | 1 | 1 | 1 | 0 | 0 | 10 | 11 | 11 |
| 315 | 76 | 1B33206 | 4726033D | 1E208B979 | 408AC3D699 | 1 | 0 | 1 | 1 | 1 | 10 | 10 | 11 |
| 316 | 77 | 166640D | 0E4C067B | 1C41172F2 | 011587AD33 | 0 | 0 | 1 | 0 | 1 | 10 | 10 | 10 |
| 317 | 78 | 0CCC81B | 1C980CF6 | 18822E5E5 | 022B0F5A66 | 1 | 1 | 1 | 0 | 1 | 01 | 10 | 10 |
| 318 | 79 | 1999036 | 393019EC | 11045CBCA | 04561EB4CD | 1 | 0 | 0 | 0 | 0 | 01 | 01 | 10 |
| 319 | 80 | 133206C | 726033D9 | 0208B9794 | 08AC3D699B | 0 | 0 | 0 | 1 | 0 | 11 | 01 | 01 |
| 320 | 81 | 06640D9 | 64C067B3 | 041172F29 | 11587AD337 | 0 | 1 | 0 | 0 | 0 | 10 | 11 | 01 |
| 321 | 82 | 0CC81B3 | 4980CF66 | 0822E5E53 | 22B0F5A66F | 1 | 1 | 1 | 1 | 0 | 11 | 10 | 11 |
| 322 | 83 | 1990366 | 13019ECC | 1045CBCA6 | 4561EB4CDF | 1 | 0 | 0 | 0 | 0 | 00 | 11 | 10 |
| 323 | 84 | 13206CC | 26033D98 | 008B9794D | 0AC3D699BE | 0 | 0 | 0 | 1 | 1 | 10 | 00 | 11 |
| 324 | 85 | 0640D98 | 4C067B31 | 01172F29B | 1587AD337C | 0 | 0 | 0 | 1 | 1 | 11 | 10 | 00 |
| 325 | 86 | 0C81B30 | 180CF662 | 022E5E537 | 2B0F5A66F9 | 1 | 0 | 0 | 0 | 0 | 00 | 11 | 10 |
| 326 | 87 | 1903660 | 3019ECC5 | 045CBCA6F | 561EB4CDF3 | 1 | 0 | 0 | 0 | 1 | 10 | 00 | 11 |
| 327 | 88 | 1206CC1 | 6033D98A | 08B9794DE | 2C3D699BE6 | 0 | 0 | 1 | 0 | 1 | 11 | 10 | 00 |
| 328 | 89 | 040D983 | 4067B315 | 1172F29BD | 587AD337CC | 0 | 0 | 0 | 0 | 1 | 11 | 11 | 10 |
| 329 | 90 | 081B306 | 00CF662A | 02E5E537A | 30F5A66F98 | 1 | 1 | 0 | 1 | 0 | 10 | 11 | 11 |
| 330 | 91 | 103660C | 019ECC55 | 05CBCA6F4 | 61EB4CDF31 | 0 | 1 | 0 | 1 | 0 | 10 | 10 | 11 |
| 331 | 92 | 006CC19 | 033D98AB | 0B9794DE8 | 43D699BE62 | 0 | 0 | 1 | 1 | 0 | 01 | 10 | 10 |
| 332 | 93 | 00D9833 | 067B3156 | 172F29BD0 | 07AD337CC5 | 0 | 0 | 0 | 1 | 0 | 01 | 01 | 10 |
| 333 | 94 | 01B3066 | 0CF662AC | 0E5E537A0 | 0F5A66F98B | 0 | 1 | 1 | 0 | 1 | 11 | 01 | 01 |
| 334 | 95 | 03660CD | 19ECC559 | 1CBCA6F41 | 1EB4CDF317 | 0 | 1 | 1 | 1 | 0 | 11 | 11 | 01 |
| 335 | 96 | 06CC19B | 33D98AB2 | 19794DE83 | 3D699BE62F | 0 | 1 | 1 | 0 | 1 | 11 | 11 | 11 |
| 336 | 97 | 0D98336 | 67B31565 | 12F29BD06 | 7AD337CC5F | 1 | 1 | 0 | 1 | 0 | 10 | 11 | 11 |
| 337 | 98 | 1B3066D | 4F662ACA | 05E537A0C | 75A66F98BF | 1 | 0 | 0 | 1 | 0 | 10 | 10 | 11 |
| 338 | 99 | 1660CDB | 1ECC5594 | 0BCA6F418 | 6B4CDF317E | 0 | 1 | 1 | 0 | 0 | 01 | 10 | 10 |
| 339 | 100 | 0CC19B7 | 3D98AB29 | 1794DE831 | 5699BE62FC | 1 | 1 | 0 | 1 | 0 | 10 | 01 | 10 |
| 340 | 101 | 198336F | 7B315653 | 0F29BD062 | 2D337CC5F9 | 1 | 0 | 1 | 0 | 0 | 11 | 10 | 01 |

Sample Data

| | | | | | | | | | | | | | |
|-----|-----|---------|----------|-----------|------------|---|---|---|---|---|----|----|----|
| 341 | 102 | 13066DE | 7662ACA7 | 1E537A0C5 | 5A66F98BF2 | 0 | 0 | 1 | 0 | 0 | 00 | 11 | 10 |
| 342 | 103 | 060CDBC | 6CC5594F | 1CA6F418B | 34CDF317E4 | 0 | 1 | 1 | 1 | 1 | 11 | 00 | 11 |
| 343 | 104 | 0C19B78 | 598AB29F | 194DE8317 | 699BE62FC9 | 1 | 1 | 1 | 1 | 1 | 00 | 11 | 00 |
| 344 | 105 | 18336F1 | 3315653F | 129BD062E | 5337CC5F92 | 1 | 0 | 0 | 0 | 1 | 10 | 00 | 11 |
| 345 | 106 | 1066DE2 | 662ACA7E | 0537A0C5C | 266F98BF25 | 0 | 0 | 0 | 0 | 0 | 11 | 10 | 00 |
| 346 | 107 | 00CDBC5 | 4C5594FD | 0A6F418B9 | 4CDF317E4B | 0 | 0 | 1 | 1 | 1 | 00 | 11 | 10 |
| 347 | 108 | 019B78B | 18AB29FA | 14DE83172 | 19BE62FC96 | 0 | 1 | 0 | 1 | 0 | 11 | 00 | 11 |
| 348 | 109 | 0336F16 | 315653F4 | 09BD062E5 | 337CC5F92C | 0 | 0 | 1 | 0 | 0 | 01 | 11 | 00 |
| 349 | 110 | 066DE2D | 62ACA7E8 | 137A0C5CA | 66F98BF258 | 0 | 1 | 0 | 1 | 1 | 10 | 01 | 11 |
| 350 | 111 | 0CDBC5B | 45594FD1 | 06F418B95 | 4DF317E4B1 | 1 | 0 | 0 | 1 | 0 | 11 | 10 | 01 |
| 351 | 112 | 19B78B6 | 0AB29FA2 | 0DE83172B | 1BE62FC962 | 1 | 1 | 1 | 1 | 1 | 01 | 11 | 10 |
| 352 | 113 | 136F16C | 15653F45 | 1BD062E57 | 37CC5F92C5 | 0 | 0 | 1 | 1 | 1 | 10 | 01 | 11 |
| 353 | 114 | 06DE2D9 | 2ACA7E8B | 17A0C5CAE | 6F98BF258B | 0 | 1 | 0 | 1 | 0 | 11 | 10 | 01 |
| 354 | 115 | 0DBC5B2 | 5594FD16 | 0F418B95D | 5F317E4B16 | 1 | 1 | 1 | 0 | 0 | 01 | 11 | 10 |
| 355 | 116 | 1B78B64 | 2B29FA2C | 1E83172BB | 3E62FC962C | 1 | 0 | 1 | 0 | 1 | 10 | 01 | 11 |
| 356 | 117 | 16F16C8 | 5653F458 | 1D062E577 | 7CC5F92C58 | 0 | 0 | 1 | 1 | 0 | 11 | 10 | 01 |
| 357 | 118 | 0DE2D91 | 2CA7E8B0 | 1A0C5CAEF | 798BF258B1 | 1 | 1 | 1 | 1 | 1 | 01 | 11 | 10 |
| 358 | 119 | 1BC5B23 | 594FD161 | 1418B95DF | 7317E4B163 | 1 | 0 | 0 | 0 | 0 | 10 | 01 | 11 |
| 359 | 120 | 178B647 | 329FA2C2 | 083172BBF | 662FC962C7 | 0 | 1 | 1 | 0 | 0 | 11 | 10 | 01 |
| 360 | 121 | 0F16C8E | 653F4584 | 1062E577F | 4C5F92C58E | 1 | 0 | 0 | 0 | 0 | 00 | 11 | 10 |
| 361 | 122 | 1E2D91C | 4A7E8B09 | 00C5CAEFE | 18BF258B1C | 1 | 0 | 0 | 1 | 0 | 11 | 00 | 11 |
| 362 | 123 | 1C5B238 | 14FD1613 | 018B95DFC | 317E4B1639 | 1 | 1 | 0 | 0 | 1 | 01 | 11 | 00 |
| 363 | 124 | 18B6471 | 29FA2C27 | 03172BBF9 | 62FC962C72 | 1 | 1 | 0 | 1 | 0 | 01 | 01 | 11 |
| 364 | 125 | 116C8E2 | 53F4584E | 062E577F3 | 45F92C58E4 | 0 | 1 | 0 | 1 | 1 | 11 | 01 | 01 |





2 FREQUENCY HOPPING SAMPLE DATA

The section contains three sets of sample data showing the basic and adapted hopping schemes for different combinations of addresses and initial clock values.

Sample Data



2.1 FIRST SET

Hop sequence {k} for PAGE SCAN/INQUIRY SCAN SUBSTATE:

| | | | | | | | | |
|-------------|------------|------|------|------|------|------|------|------|
| CLKN start: | 0x00000000 | | | | | | | |
| UAP / LAP: | 0x00000000 | | | | | | | |
| #ticks: | 0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
| 0x00000000: | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 |
| 0x00080000: | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| 0x00100000: | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 |
| 0x00180000: | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 |
| 0x00200000: | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 |
| 0x00280000: | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| 0x00300000: | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 |
| 0x00380000: | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 |

Hop sequence {k} for PAGE STATE/INQUIRY SUBSTATE:

| | | | | | | | | | | | | | | | | |
|-------------|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| CLKE start: | 0x00000000 | | | | | | | | | | | | | | | |
| UAP / LAP: | 0x00000000 | | | | | | | | | | | | | | | |
| #ticks: | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 0a | 0b | 0c | 0d | 0e | 0f |
| 0x00000000: | 48 | 50 | 09 | 13 | 52 | 54 | 41 | 45 | 56 | 58 | 11 | 15 | 60 | 62 | 43 | 47 |
| 0x00000010: | 00 | 02 | 64 | 68 | 04 | 06 | 17 | 21 | 08 | 10 | 66 | 70 | 12 | 14 | 19 | 23 |
| 0x00000020: | 48 | 50 | 09 | 13 | 52 | 54 | 41 | 45 | 56 | 58 | 11 | 15 | 60 | 62 | 43 | 47 |
| 0x00000030: | 00 | 02 | 64 | 68 | 04 | 06 | 17 | 21 | 08 | 10 | 66 | 70 | 12 | 14 | 19 | 23 |
| ... | | | | | | | | | | | | | | | | |
| 0x00010000: | 48 | 18 | 09 | 05 | 20 | 22 | 33 | 37 | 24 | 26 | 03 | 07 | 28 | 30 | 35 | 39 |
| 0x00010010: | 32 | 34 | 72 | 76 | 36 | 38 | 25 | 29 | 40 | 42 | 74 | 78 | 44 | 46 | 27 | 31 |
| 0x00010020: | 48 | 18 | 09 | 05 | 20 | 22 | 33 | 37 | 24 | 26 | 03 | 07 | 28 | 30 | 35 | 39 |
| 0x00010030: | 32 | 34 | 72 | 76 | 36 | 38 | 25 | 29 | 40 | 42 | 74 | 78 | 44 | 46 | 27 | 31 |
| ... | | | | | | | | | | | | | | | | |
| 0x00020000: | 16 | 18 | 01 | 05 | 52 | 54 | 41 | 45 | 56 | 58 | 11 | 15 | 60 | 62 | 43 | 47 |
| 0x00020010: | 00 | 02 | 64 | 68 | 04 | 06 | 17 | 21 | 08 | 10 | 66 | 70 | 12 | 14 | 19 | 23 |
| 0x00020020: | 16 | 18 | 01 | 05 | 52 | 54 | 41 | 45 | 56 | 58 | 11 | 15 | 60 | 62 | 43 | 47 |
| 0x00020030: | 00 | 02 | 64 | 68 | 04 | 06 | 17 | 21 | 08 | 10 | 66 | 70 | 12 | 14 | 19 | 23 |
| ... | | | | | | | | | | | | | | | | |
| 0x00030000: | 48 | 50 | 09 | 13 | 52 | 22 | 41 | 37 | 24 | 26 | 03 | 07 | 28 | 30 | 35 | 39 |
| 0x00030010: | 32 | 34 | 72 | 76 | 36 | 38 | 25 | 29 | 40 | 42 | 74 | 78 | 44 | 46 | 27 | 31 |
| 0x00030020: | 48 | 50 | 09 | 13 | 52 | 22 | 41 | 37 | 24 | 26 | 03 | 07 | 28 | 30 | 35 | 39 |
| 0x00030030: | 32 | 34 | 72 | 76 | 36 | 38 | 25 | 29 | 40 | 42 | 74 | 78 | 44 | 46 | 27 | 31 |

Hop sequence {k} for SLAVE PAGE RESPONSE SUBSTATE:

| | | | | | | | | | | | | | | | | |
|-------------|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| CLKN* = | 0x00000010 | | | | | | | | | | | | | | | |
| UAP / LAP: | 0x00000000 | | | | | | | | | | | | | | | |
| #ticks: | 00 | 02 | 04 | 06 | 08 | 0a | 0c | 0e | 10 | 12 | 14 | 16 | 18 | 1a | 1c | 1e |
| 0x00000012: | 64 | 02 | 68 | 04 | 17 | 06 | 21 | 08 | 66 | 10 | 70 | 12 | 19 | 14 | 23 | 16 |
| 0x00000032: | 01 | 18 | 05 | 20 | 33 | 22 | 37 | 24 | 03 | 26 | 07 | 28 | 35 | 30 | 39 | 32 |
| 0x00000052: | 72 | 34 | 76 | 36 | 25 | 38 | 29 | 40 | 74 | 42 | 78 | 44 | 27 | 46 | 31 | 48 |
| 0x00000072: | 09 | 50 | 13 | 52 | 41 | 54 | 45 | 56 | 11 | 58 | 15 | 60 | 43 | 62 | 47 | 00 |

Hop sequence {k} for MASTER PAGE RESPONSE SUBSTATE:

| | | | | | | | | | | | | | | | | |
|---------------|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Offset value: | 24 | | | | | | | | | | | | | | | |
| CLKE* = | 0x00000012 | | | | | | | | | | | | | | | |
| UAP / LAP: | 0x00000000 | | | | | | | | | | | | | | | |
| #ticks: | 00 | 02 | 04 | 06 | 08 | 0a | 0c | 0e | 10 | 12 | 14 | 16 | 18 | 1a | 1c | 1e |
| 0x00000014: | 02 | 68 | 04 | 17 | 06 | 21 | 08 | 66 | 10 | 70 | 12 | 19 | 14 | 23 | 16 | 01 |
| 0x00000034: | 18 | 05 | 20 | 33 | 22 | 37 | 24 | 03 | 26 | 07 | 28 | 35 | 30 | 39 | 32 | 72 |
| 0x00000054: | 34 | 76 | 36 | 25 | 38 | 29 | 40 | 74 | 42 | 78 | 44 | 27 | 46 | 31 | 48 | 09 |
| 0x00000074: | 50 | 13 | 52 | 41 | 54 | 45 | 56 | 11 | 58 | 15 | 60 | 43 | 62 | 47 | 00 | 64 |

Sample Data



Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence; ie, non-AFH):

CLK start: 0x0000010

UAP/LAP: 0x00000000

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0x0000010: | 08 66 | 10 70 | 12 19 | 14 23 | 16 01 | 18 05 | 20 33 | 22 37 |
| 0x0000030: | 24 03 | 26 07 | 28 35 | 30 39 | 32 72 | 34 76 | 36 25 | 38 29 |
| 0x0000050: | 40 74 | 42 78 | 44 27 | 46 31 | 48 09 | 50 13 | 52 41 | 54 45 |
| 0x0000070: | 56 11 | 58 15 | 60 43 | 62 47 | 32 17 | 36 19 | 34 49 | 38 51 |
| 0x0000090: | 40 21 | 44 23 | 42 53 | 46 55 | 48 33 | 52 35 | 50 65 | 54 67 |
| 0x00000b0: | 56 37 | 60 39 | 58 69 | 62 71 | 64 25 | 68 27 | 66 57 | 70 59 |
| 0x00000d0: | 72 29 | 76 31 | 74 61 | 78 63 | 01 41 | 05 43 | 03 73 | 07 75 |
| 0x00000f0: | 09 45 | 13 47 | 11 77 | 15 00 | 64 49 | 66 53 | 68 02 | 70 06 |
| 0x0000110: | 01 51 | 03 55 | 05 04 | 07 08 | 72 57 | 74 61 | 76 10 | 78 14 |
| 0x0000130: | 09 59 | 11 63 | 13 12 | 15 16 | 17 65 | 19 69 | 21 18 | 23 22 |
| 0x0000150: | 33 67 | 35 71 | 37 20 | 39 24 | 25 73 | 27 77 | 29 26 | 31 30 |
| 0x0000170: | 41 75 | 43 00 | 45 28 | 47 32 | 17 02 | 21 04 | 19 34 | 23 36 |
| 0x0000190: | 33 06 | 37 08 | 35 38 | 39 40 | 25 10 | 29 12 | 27 42 | 31 44 |
| 0x00001b0: | 41 14 | 45 16 | 43 46 | 47 48 | 49 18 | 53 20 | 51 50 | 55 52 |
| 0x00001d0: | 65 22 | 69 24 | 67 54 | 71 56 | 57 26 | 61 28 | 59 58 | 63 60 |
| 0x00001f0: | 73 30 | 77 32 | 75 62 | 00 64 | 49 34 | 51 42 | 57 66 | 59 74 |
| 0x0000210: | 53 36 | 55 44 | 61 68 | 63 76 | 65 50 | 67 58 | 73 03 | 75 11 |
| 0x0000230: | 69 52 | 71 60 | 77 05 | 00 13 | 02 38 | 04 46 | 10 70 | 12 78 |
| 0x0000250: | 06 40 | 08 48 | 14 72 | 16 01 | 18 54 | 20 62 | 26 07 | 28 15 |
| 0x0000270: | 22 56 | 24 64 | 30 09 | 32 17 | 02 66 | 06 74 | 10 19 | 14 27 |
| 0x0000290: | 04 70 | 08 78 | 12 23 | 16 31 | 18 03 | 22 11 | 26 35 | 30 43 |
| 0x00002b0: | 20 07 | 24 15 | 28 39 | 32 47 | 34 68 | 38 76 | 42 21 | 46 29 |
| 0x00002d0: | 36 72 | 40 01 | 44 25 | 48 33 | 50 05 | 54 13 | 58 37 | 62 45 |
| 0x00002f0: | 52 09 | 56 17 | 60 41 | 64 49 | 34 19 | 36 35 | 50 51 | 52 67 |
| 0x0000310: | 38 21 | 40 37 | 54 53 | 56 69 | 42 27 | 44 43 | 58 59 | 60 75 |
| 0x0000330: | 46 29 | 48 45 | 62 61 | 64 77 | 66 23 | 68 39 | 03 55 | 05 71 |
| 0x0000350: | 70 25 | 72 41 | 07 57 | 09 73 | 74 31 | 76 47 | 11 63 | 13 00 |
| 0x0000370: | 78 33 | 01 49 | 15 65 | 17 02 | 66 51 | 70 67 | 03 04 | 07 20 |
| 0x0000390: | 68 55 | 72 71 | 05 08 | 09 24 | 74 59 | 78 75 | 11 12 | 15 28 |
| 0x00003b0: | 76 63 | 01 00 | 13 16 | 17 32 | 19 53 | 23 69 | 35 06 | 39 22 |
| 0x00003d0: | 21 57 | 25 73 | 37 10 | 41 26 | 27 61 | 31 77 | 43 14 | 47 30 |
| 0x00003f0: | 29 65 | 33 02 | 45 18 | 49 34 | 19 04 | 21 08 | 23 20 | 25 24 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with all channel used; ie, AFH(79)):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels: 0x7fffffffffffffffffff

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 08 08 | 10 10 | 12 12 | 14 14 | 16 16 | 18 18 | 20 20 | 22 22 |
| 0x0000030 | 24 24 | 26 26 | 28 28 | 30 30 | 32 32 | 34 34 | 36 36 | 38 38 |
| 0x0000050 | 40 40 | 42 42 | 44 44 | 46 46 | 48 48 | 50 50 | 52 52 | 54 54 |
| 0x0000070 | 56 56 | 58 58 | 60 60 | 62 62 | 32 32 | 36 36 | 34 34 | 38 38 |
| 0x0000090 | 40 40 | 44 44 | 42 42 | 46 46 | 48 48 | 52 52 | 50 50 | 54 54 |
| 0x00000b0 | 56 56 | 60 60 | 58 58 | 62 62 | 64 64 | 68 68 | 66 66 | 70 70 |
| 0x00000d0 | 72 72 | 76 76 | 74 74 | 78 78 | 01 01 | 05 05 | 03 03 | 07 07 |
| 0x00000f0 | 09 09 | 13 13 | 11 11 | 15 15 | 64 64 | 66 66 | 68 68 | 70 70 |
| 0x0000110 | 01 01 | 03 03 | 05 05 | 07 07 | 72 72 | 74 74 | 76 76 | 78 78 |
| 0x0000130 | 09 09 | 11 11 | 13 13 | 15 15 | 17 17 | 19 19 | 21 21 | 23 23 |
| 0x0000150 | 33 33 | 35 35 | 37 37 | 39 39 | 25 25 | 27 27 | 29 29 | 31 31 |
| 0x0000170 | 41 41 | 43 43 | 45 45 | 47 47 | 17 17 | 21 21 | 19 19 | 23 23 |
| 0x0000190 | 33 33 | 37 37 | 35 35 | 39 39 | 25 25 | 29 29 | 27 27 | 31 31 |
| 0x00001b0 | 41 41 | 45 45 | 43 43 | 47 47 | 49 49 | 53 53 | 51 51 | 55 55 |
| 0x00001d0 | 65 65 | 69 69 | 67 67 | 71 71 | 57 57 | 61 61 | 59 59 | 63 63 |
| 0x00001f0 | 73 73 | 77 77 | 75 75 | 00 00 | 49 49 | 51 51 | 57 57 | 59 59 |
| 0x0000210 | 53 53 | 55 55 | 61 61 | 63 63 | 65 65 | 67 67 | 73 73 | 75 75 |
| 0x0000230 | 69 69 | 71 71 | 77 77 | 00 00 | 02 02 | 04 04 | 10 10 | 12 12 |
| 0x0000250 | 06 06 | 08 08 | 14 14 | 16 16 | 18 18 | 20 20 | 26 26 | 28 28 |
| 0x0000270 | 22 22 | 24 24 | 30 30 | 32 32 | 02 02 | 06 06 | 10 10 | 14 14 |
| 0x0000290 | 04 04 | 08 08 | 12 12 | 16 16 | 18 18 | 22 22 | 26 26 | 30 30 |
| 0x00002b0 | 20 20 | 24 24 | 28 28 | 32 32 | 34 34 | 38 38 | 42 42 | 46 46 |
| 0x00002d0 | 36 36 | 40 40 | 44 44 | 48 48 | 50 50 | 54 54 | 58 58 | 62 62 |
| 0x00002f0 | 52 52 | 56 56 | 60 60 | 64 64 | 34 34 | 36 36 | 50 50 | 52 52 |
| 0x0000310 | 38 38 | 40 40 | 54 54 | 56 56 | 42 42 | 44 44 | 58 58 | 60 60 |
| 0x0000330 | 46 46 | 48 48 | 62 62 | 64 64 | 66 66 | 68 68 | 03 03 | 05 05 |
| 0x0000350 | 70 70 | 72 72 | 07 07 | 09 09 | 74 74 | 76 76 | 11 11 | 13 13 |
| 0x0000370 | 78 78 | 01 01 | 15 15 | 17 17 | 66 66 | 70 70 | 03 03 | 07 07 |
| 0x0000390 | 68 68 | 72 72 | 05 05 | 09 09 | 74 74 | 78 78 | 11 11 | 15 15 |
| 0x00003b0 | 76 76 | 01 01 | 13 13 | 17 17 | 19 19 | 23 23 | 35 35 | 39 39 |
| 0x00003d0 | 21 21 | 25 25 | 37 37 | 41 41 | 27 27 | 31 31 | 43 43 | 47 47 |
| 0x00003f0 | 29 29 | 33 33 | 45 45 | 49 49 | 19 19 | 21 21 | 23 23 | 25 25 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with channels 0 to 21 unused):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels: 0x7fffffffffffffc00000

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 30 30 | 32 32 | 34 34 | 36 36 | 38 38 | 40 40 | 42 42 | 22 22 |
| 0x0000030 | 24 24 | 26 26 | 28 28 | 30 30 | 32 32 | 34 34 | 36 36 | 38 38 |
| 0x0000050 | 40 40 | 42 42 | 44 44 | 46 46 | 48 48 | 50 50 | 52 52 | 54 54 |
| 0x0000070 | 56 56 | 58 58 | 60 60 | 62 62 | 32 32 | 36 36 | 34 34 | 38 38 |
| 0x0000090 | 40 40 | 44 44 | 42 42 | 46 46 | 48 48 | 52 52 | 50 50 | 54 54 |
| 0x00000b0 | 56 56 | 60 60 | 58 58 | 62 62 | 64 64 | 68 68 | 66 66 | 70 70 |
| 0x00000d0 | 72 72 | 76 76 | 74 74 | 78 78 | 45 45 | 49 49 | 47 47 | 51 51 |
| 0x00000f0 | 53 53 | 57 57 | 55 55 | 59 59 | 64 64 | 66 66 | 68 68 | 70 70 |
| 0x0000110 | 45 45 | 47 47 | 49 49 | 51 51 | 72 72 | 74 74 | 76 76 | 78 78 |
| 0x0000130 | 53 53 | 55 55 | 57 57 | 59 59 | 61 61 | 63 63 | 65 65 | 23 23 |
| 0x0000150 | 33 33 | 35 35 | 37 37 | 39 39 | 25 25 | 27 27 | 29 29 | 31 31 |
| 0x0000170 | 41 41 | 43 43 | 45 45 | 47 47 | 61 61 | 65 65 | 63 63 | 23 23 |
| 0x0000190 | 33 33 | 37 37 | 35 35 | 39 39 | 25 25 | 29 29 | 27 27 | 31 31 |
| 0x00001b0 | 41 41 | 45 45 | 43 43 | 47 47 | 49 49 | 53 53 | 51 51 | 55 55 |
| 0x00001d0 | 65 65 | 69 69 | 67 67 | 71 71 | 57 57 | 61 61 | 59 59 | 63 63 |
| 0x00001f0 | 73 73 | 77 77 | 75 75 | 66 66 | 49 49 | 51 51 | 57 57 | 59 59 |
| 0x0000210 | 53 53 | 55 55 | 61 61 | 63 63 | 65 65 | 67 67 | 73 73 | 75 75 |
| 0x0000230 | 69 69 | 71 71 | 77 77 | 66 66 | 68 68 | 70 70 | 76 76 | 78 78 |
| 0x0000250 | 72 72 | 74 74 | 23 23 | 25 25 | 27 27 | 29 29 | 26 26 | 28 28 |
| 0x0000270 | 22 22 | 24 24 | 30 30 | 32 32 | 68 68 | 72 72 | 76 76 | 23 23 |
| 0x0000290 | 70 70 | 74 74 | 78 78 | 25 25 | 27 27 | 22 22 | 26 26 | 30 30 |
| 0x00002b0 | 29 29 | 24 24 | 28 28 | 32 32 | 34 34 | 38 38 | 42 42 | 46 46 |
| 0x00002d0 | 36 36 | 40 40 | 44 44 | 48 48 | 50 50 | 54 54 | 58 58 | 62 62 |
| 0x00002f0 | 52 52 | 56 56 | 60 60 | 64 64 | 34 34 | 36 36 | 50 50 | 52 52 |
| 0x0000310 | 38 38 | 40 40 | 54 54 | 56 56 | 42 42 | 44 44 | 58 58 | 60 60 |
| 0x0000330 | 46 46 | 48 48 | 62 62 | 64 64 | 66 66 | 68 68 | 34 34 | 36 36 |
| 0x0000350 | 70 70 | 72 72 | 38 38 | 40 40 | 74 74 | 76 76 | 42 42 | 44 44 |
| 0x0000370 | 78 78 | 32 32 | 46 46 | 48 48 | 66 66 | 70 70 | 34 34 | 38 38 |
| 0x0000390 | 68 68 | 72 72 | 36 36 | 40 40 | 74 74 | 78 78 | 42 42 | 46 46 |
| 0x00003b0 | 76 76 | 32 32 | 44 44 | 48 48 | 50 50 | 23 23 | 35 35 | 39 39 |
| 0x00003d0 | 52 52 | 25 25 | 37 37 | 41 41 | 27 27 | 31 31 | 43 43 | 47 47 |
| 0x00003f0 | 29 29 | 33 33 | 45 45 | 49 49 | 50 50 | 52 52 | 23 23 | 25 25 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with even channels used):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels: 0x555555555555555555555555

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 08 08 | 10 10 | 12 12 | 14 14 | 16 16 | 18 18 | 20 20 | 22 22 |
| 0x0000030 | 24 24 | 26 26 | 28 28 | 30 30 | 32 32 | 34 34 | 36 36 | 38 38 |
| 0x0000050 | 40 40 | 42 42 | 44 44 | 46 46 | 48 48 | 50 50 | 52 52 | 54 54 |
| 0x0000070 | 56 56 | 58 58 | 60 60 | 62 62 | 32 32 | 36 36 | 34 34 | 38 38 |
| 0x0000090 | 40 40 | 44 44 | 42 42 | 46 46 | 48 48 | 52 52 | 50 50 | 54 54 |
| 0x00000b0 | 56 56 | 60 60 | 58 58 | 62 62 | 64 64 | 68 68 | 66 66 | 70 70 |
| 0x00000d0 | 72 72 | 76 76 | 74 74 | 78 78 | 00 00 | 04 04 | 02 02 | 06 06 |
| 0x00000f0 | 08 08 | 12 12 | 10 10 | 14 14 | 64 64 | 66 66 | 68 68 | 70 70 |
| 0x0000110 | 00 00 | 02 02 | 04 04 | 06 06 | 72 72 | 74 74 | 76 76 | 78 78 |
| 0x0000130 | 08 08 | 10 10 | 12 12 | 14 14 | 16 16 | 18 18 | 20 20 | 22 22 |
| 0x0000150 | 32 32 | 34 34 | 36 36 | 38 38 | 24 24 | 26 26 | 28 28 | 30 30 |
| 0x0000170 | 40 40 | 42 42 | 44 44 | 46 46 | 16 16 | 20 20 | 18 18 | 22 22 |
| 0x0000190 | 32 32 | 36 36 | 34 34 | 38 38 | 24 24 | 28 28 | 26 26 | 30 30 |
| 0x00001b0 | 40 40 | 44 44 | 42 42 | 46 46 | 48 48 | 52 52 | 50 50 | 54 54 |
| 0x00001d0 | 64 64 | 68 68 | 66 66 | 70 70 | 56 56 | 60 60 | 58 58 | 62 62 |
| 0x00001f0 | 72 72 | 76 76 | 74 74 | 00 00 | 48 48 | 50 50 | 56 56 | 58 58 |
| 0x0000210 | 52 52 | 54 54 | 60 60 | 62 62 | 64 64 | 66 66 | 72 72 | 74 74 |
| 0x0000230 | 68 68 | 70 70 | 76 76 | 00 00 | 02 02 | 04 04 | 10 10 | 12 12 |
| 0x0000250 | 06 06 | 08 08 | 14 14 | 16 16 | 18 18 | 20 20 | 26 26 | 28 28 |
| 0x0000270 | 22 22 | 24 24 | 30 30 | 32 32 | 02 02 | 06 06 | 10 10 | 14 14 |
| 0x0000290 | 04 04 | 08 08 | 12 12 | 16 16 | 18 18 | 22 22 | 26 26 | 30 30 |
| 0x00002b0 | 20 20 | 24 24 | 28 28 | 32 32 | 34 34 | 38 38 | 42 42 | 46 46 |
| 0x00002d0 | 36 36 | 40 40 | 44 44 | 48 48 | 50 50 | 54 54 | 58 58 | 62 62 |
| 0x00002f0 | 52 52 | 56 56 | 60 60 | 64 64 | 34 34 | 36 36 | 50 50 | 52 52 |
| 0x0000310 | 38 38 | 40 40 | 54 54 | 56 56 | 42 42 | 44 44 | 58 58 | 60 60 |
| 0x0000330 | 46 46 | 48 48 | 62 62 | 64 64 | 66 66 | 68 68 | 00 00 | 02 02 |
| 0x0000350 | 70 70 | 72 72 | 04 04 | 06 06 | 74 74 | 76 76 | 08 08 | 10 10 |
| 0x0000370 | 78 78 | 78 78 | 12 12 | 14 14 | 66 66 | 70 70 | 00 00 | 04 04 |
| 0x0000390 | 68 68 | 72 72 | 02 02 | 06 06 | 74 74 | 78 78 | 08 08 | 12 12 |
| 0x00003b0 | 76 76 | 78 78 | 10 10 | 14 14 | 16 16 | 20 20 | 32 32 | 36 36 |
| 0x00003d0 | 18 18 | 22 22 | 34 34 | 38 38 | 24 24 | 28 28 | 40 40 | 44 44 |
| 0x00003f0 | 26 26 | 30 30 | 42 42 | 46 46 | 16 16 | 18 18 | 20 20 | 22 22 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with odd channels used):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels: 0x2aaaaaaaaaaaaaaaaaaaa

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 09 09 | 11 11 | 13 13 | 15 15 | 17 17 | 19 19 | 21 21 | 23 23 |
| 0x0000030 | 25 25 | 27 27 | 29 29 | 31 31 | 33 33 | 35 35 | 37 37 | 39 39 |
| 0x0000050 | 41 41 | 43 43 | 45 45 | 47 47 | 49 49 | 51 51 | 53 53 | 55 55 |
| 0x0000070 | 57 57 | 59 59 | 61 61 | 63 63 | 33 33 | 37 37 | 35 35 | 39 39 |
| 0x0000090 | 41 41 | 45 45 | 43 43 | 47 47 | 49 49 | 53 53 | 51 51 | 55 55 |
| 0x00000b0 | 57 57 | 61 61 | 59 59 | 63 63 | 65 65 | 69 69 | 67 67 | 71 71 |
| 0x00000d0 | 73 73 | 77 77 | 75 75 | 01 01 | 01 01 | 05 05 | 03 03 | 07 07 |
| 0x00000f0 | 09 09 | 13 13 | 11 11 | 15 15 | 65 65 | 67 67 | 69 69 | 71 71 |
| 0x0000110 | 01 01 | 03 03 | 05 05 | 07 07 | 73 73 | 75 75 | 77 77 | 01 01 |
| 0x0000130 | 09 09 | 11 11 | 13 13 | 15 15 | 17 17 | 19 19 | 21 21 | 23 23 |
| 0x0000150 | 33 33 | 35 35 | 37 37 | 39 39 | 25 25 | 27 27 | 29 29 | 31 31 |
| 0x0000170 | 41 41 | 43 43 | 45 45 | 47 47 | 17 17 | 21 21 | 19 19 | 23 23 |
| 0x0000190 | 33 33 | 37 37 | 35 35 | 39 39 | 25 25 | 29 29 | 27 27 | 31 31 |
| 0x00001b0 | 41 41 | 45 45 | 43 43 | 47 47 | 49 49 | 53 53 | 51 51 | 55 55 |
| 0x00001d0 | 65 65 | 69 69 | 67 67 | 71 71 | 57 57 | 61 61 | 59 59 | 63 63 |
| 0x00001f0 | 73 73 | 77 77 | 75 75 | 03 03 | 49 49 | 51 51 | 57 57 | 59 59 |
| 0x0000210 | 53 53 | 55 55 | 61 61 | 63 63 | 65 65 | 67 67 | 73 73 | 75 75 |
| 0x0000230 | 69 69 | 71 71 | 77 77 | 03 03 | 05 05 | 07 07 | 13 13 | 15 15 |
| 0x0000250 | 09 09 | 11 11 | 17 17 | 19 19 | 21 21 | 23 23 | 29 29 | 31 31 |
| 0x0000270 | 25 25 | 27 27 | 33 33 | 35 35 | 05 05 | 09 09 | 13 13 | 17 17 |
| 0x0000290 | 07 07 | 11 11 | 15 15 | 19 19 | 21 21 | 25 25 | 29 29 | 33 33 |
| 0x00002b0 | 23 23 | 27 27 | 31 31 | 35 35 | 37 37 | 41 41 | 45 45 | 49 49 |
| 0x00002d0 | 39 39 | 43 43 | 47 47 | 51 51 | 53 53 | 57 57 | 61 61 | 65 65 |
| 0x00002f0 | 55 55 | 59 59 | 63 63 | 67 67 | 37 37 | 39 39 | 53 53 | 55 55 |
| 0x0000310 | 41 41 | 43 43 | 57 57 | 59 59 | 45 45 | 47 47 | 61 61 | 63 63 |
| 0x0000330 | 49 49 | 51 51 | 65 65 | 67 67 | 69 69 | 71 71 | 03 03 | 05 05 |
| 0x0000350 | 73 73 | 75 75 | 07 07 | 09 09 | 77 77 | 01 01 | 11 11 | 13 13 |
| 0x0000370 | 03 03 | 01 01 | 15 15 | 17 17 | 69 69 | 73 73 | 03 03 | 07 07 |
| 0x0000390 | 71 71 | 75 75 | 05 05 | 09 09 | 77 77 | 03 03 | 11 11 | 15 15 |
| 0x00003b0 | 01 01 | 01 01 | 13 13 | 17 17 | 19 19 | 23 23 | 35 35 | 39 39 |
| 0x00003d0 | 21 21 | 25 25 | 37 37 | 41 41 | 27 27 | 31 31 | 43 43 | 47 47 |
| 0x00003f0 | 29 29 | 33 33 | 45 45 | 49 49 | 19 19 | 21 21 | 23 23 | 25 25 |

Sample Data



2.2 SECOND SET

Hop sequence {k} for PAGE SCAN/INQUIRY SCAN SUBSTATE:

CLKN start: 0x00000000

ULAP: 0x2a96ef25

| #ticks: | 0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
|-------------|------|------|------|------|------|------|------|------|
| 0x00000000: | 49 | 13 | 17 | 51 | 55 | 19 | 23 | 53 |
| 0x00080000: | 57 | 21 | 25 | 27 | 31 | 74 | 78 | 29 |
| 0x00100000: | 33 | 76 | 1 | 35 | 39 | 3 | 7 | 37 |
| 0x00180000: | 41 | 5 | 9 | 43 | 47 | 11 | 15 | 45 |
| 0x00200000: | 49 | 13 | 17 | 51 | 55 | 19 | 23 | 53 |
| 0x00280000: | 57 | 21 | 25 | 27 | 31 | 74 | 78 | 29 |
| 0x00300000: | 33 | 76 | 1 | 35 | 39 | 3 | 7 | 37 |
| 0x00380000: | 41 | 5 | 9 | 43 | 47 | 11 | 15 | 45 |

Hop sequence {k} for PAGE STATE/INQUIRY SUBSTATE:

CLKE start: 0x00000000

ULAP: 0x2a96ef25

| #ticks: | 00 01 02 03 | 04 05 06 07 | 08 09 0a 0b | 0c 0d 0e 0f |
|-------------|-------------|-------------|-------------|-------------|
| 0x00000000: | 41 05 10 04 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
| 0x00000010: | 49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
| 0x00000020: | 41 05 10 04 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
| 0x00000030: | 49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
| ... | | | | |
| 0x00010000: | 41 21 10 36 | 25 27 38 63 | 31 74 65 59 | 78 29 61 00 |
| 0x00010100: | 33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |
| 0x00010200: | 41 21 10 36 | 25 27 38 63 | 31 74 65 59 | 78 29 61 00 |
| 0x00010300: | 33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |
| ... | | | | |
| 0x00020000: | 57 21 42 36 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
| 0x00020100: | 49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
| 0x00020200: | 57 21 42 36 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
| 0x00020300: | 49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
| ... | | | | |
| 0x00030000: | 41 05 10 04 | 09 27 06 63 | 31 74 65 59 | 78 29 61 00 |
| 0x00030100: | 33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |
| 0x00030200: | 41 05 10 04 | 09 27 06 63 | 31 74 65 59 | 78 29 61 00 |
| 0x00030300: | 33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |

Hop sequence {k} for SLAVE PAGE RESPONSE SUBSTATE:

CLKN* = 0x00000010

ULAP: 0x2a96ef25

| #ticks: | 00 | 02 04 | 06 08 | 0a 0c | 0e 10 | 12 14 | 16 18 | 1a 1c | 1e |
|-------------|----|-------|-------|-------|-------|-------|-------|-------|----|
| 0x00000012: | 34 | 13 28 | 17 30 | 51 24 | 55 26 | 19 20 | 23 22 | 53 40 | 57 |
| 0x00000032: | 42 | 21 36 | 25 38 | 27 63 | 31 65 | 74 59 | 78 61 | 29 00 | 33 |
| 0x00000052: | 02 | 76 75 | 01 77 | 35 71 | 39 73 | 03 67 | 07 69 | 37 08 | 41 |
| 0x00000072: | 10 | 05 04 | 09 06 | 43 16 | 47 18 | 11 12 | 15 14 | 45 32 | 49 |

Hop sequence {k} for MASTER PAGE RESPONSE SUBSTATE:

Offset value: 24

CLKE* = 0x00000012

ULAP: 0x2a96ef25

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0x00000014: | 13 28 | 17 30 | 51 24 | 55 26 | 19 20 | 23 22 | 53 40 | 57 42 |
| 0x00000034: | 21 36 | 25 38 | 27 63 | 31 65 | 74 59 | 78 61 | 29 00 | 33 02 |
| 0x00000054: | 76 75 | 01 77 | 35 71 | 39 73 | 03 67 | 07 69 | 37 08 | 41 10 |
| 0x00000074: | 05 04 | 09 06 | 43 16 | 47 18 | 11 12 | 15 14 | 45 32 | 49 34 |

Sample Data



Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence; ie, non-AFH):

CLK start: 0x0000010

ULAP: 0x2a96ef25

#ticks: 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |

| | | | | | | | | |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0x0000010: | 55 26 | 19 20 | 23 22 | 53 40 | 57 42 | 21 36 | 25 38 | 27 63 |
| 0x0000030: | 31 65 | 74 59 | 78 61 | 29 00 | 33 02 | 76 75 | 01 77 | 35 71 |
| 0x0000050: | 39 73 | 03 67 | 07 69 | 37 08 | 41 10 | 05 04 | 09 06 | 43 16 |
| 0x0000070: | 47 18 | 11 12 | 15 14 | 45 32 | 02 66 | 47 60 | 49 64 | 04 54 |
| 0x0000090: | 06 58 | 51 52 | 53 56 | 08 70 | 10 74 | 55 68 | 57 72 | 59 14 |
| 0x00000b0: | 61 18 | 27 12 | 29 16 | 63 30 | 65 34 | 31 28 | 33 32 | 67 22 |
| 0x00000d0: | 69 26 | 35 20 | 37 24 | 71 38 | 73 42 | 39 36 | 41 40 | 75 46 |
| 0x00000f0: | 77 50 | 43 44 | 45 48 | 00 62 | 26 11 | 69 05 | 73 07 | 36 17 |
| 0x0000110: | 40 19 | 04 13 | 08 15 | 38 25 | 42 27 | 06 21 | 10 23 | 12 48 |
| 0x0000130: | 16 50 | 59 44 | 63 46 | 14 56 | 18 58 | 61 52 | 65 54 | 28 64 |
| 0x0000150: | 32 66 | 75 60 | 00 62 | 30 72 | 34 74 | 77 68 | 02 70 | 20 01 |
| 0x0000170: | 24 03 | 67 76 | 71 78 | 22 09 | 58 43 | 24 37 | 26 41 | 68 47 |
| 0x0000190: | 70 51 | 36 45 | 38 49 | 72 55 | 74 59 | 40 53 | 42 57 | 44 78 |
| 0x00001b0: | 46 03 | 12 76 | 14 01 | 48 07 | 50 11 | 16 05 | 18 09 | 60 15 |
| 0x00001d0: | 62 19 | 28 13 | 30 17 | 64 23 | 66 27 | 32 21 | 34 25 | 52 31 |
| 0x00001f0: | 54 35 | 20 29 | 22 33 | 56 39 | 19 04 | 62 63 | 66 00 | 07 73 |
| 0x0000210: | 11 10 | 54 69 | 58 06 | 23 75 | 27 12 | 70 71 | 74 08 | 76 33 |
| 0x0000230: | 01 49 | 44 29 | 48 45 | 13 35 | 17 51 | 60 31 | 64 47 | 05 41 |
| 0x0000250: | 09 57 | 52 37 | 56 53 | 21 43 | 25 59 | 68 39 | 72 55 | 78 65 |
| 0x0000270: | 03 02 | 46 61 | 50 77 | 15 67 | 51 36 | 17 18 | 19 34 | 41 24 |
| 0x0000290: | 43 40 | 09 22 | 11 38 | 57 28 | 59 44 | 25 26 | 27 42 | 29 63 |
| 0x00002b0: | 31 00 | 76 61 | 78 77 | 45 67 | 47 04 | 13 65 | 15 02 | 37 71 |
| 0x00002d0: | 39 08 | 05 69 | 07 06 | 53 75 | 55 12 | 21 73 | 23 10 | 33 16 |
| 0x00002f0: | 35 32 | 01 14 | 03 30 | 49 20 | 75 60 | 39 48 | 43 56 | 00 66 |
| 0x0000310: | 04 74 | 47 62 | 51 70 | 08 68 | 12 76 | 55 64 | 59 72 | 61 18 |
| 0x0000330: | 65 26 | 29 14 | 33 22 | 69 20 | 73 28 | 37 16 | 41 24 | 77 34 |
| 0x0000350: | 02 42 | 45 30 | 49 38 | 06 36 | 10 44 | 53 32 | 57 40 | 63 50 |
| 0x0000370: | 67 58 | 31 46 | 35 54 | 71 52 | 28 13 | 73 03 | 75 11 | 34 17 |
| 0x0000390: | 36 25 | 02 15 | 04 23 | 42 21 | 44 29 | 10 19 | 12 27 | 14 48 |
| 0x00003b0: | 16 56 | 61 46 | 63 54 | 22 52 | 24 60 | 69 50 | 71 58 | 30 64 |
| 0x00003d0: | 32 72 | 77 62 | 00 70 | 38 68 | 40 76 | 06 66 | 08 74 | 18 01 |
| 0x00003f0: | 20 09 | 65 78 | 67 07 | 26 05 | 44 29 | 32 23 | 36 25 | 70 43 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with all channel used; ie, AFH(79)):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels: 0x7fffffffffffffffffffff

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 55 55 | 19 19 | 23 23 | 53 53 | 57 57 | 21 21 | 25 25 | 27 27 |
| 0x0000030 | 31 31 | 74 74 | 78 78 | 29 29 | 33 33 | 76 76 | 01 01 | 35 35 |
| 0x0000050 | 39 39 | 03 03 | 07 07 | 37 37 | 41 41 | 05 05 | 09 09 | 43 43 |
| 0x0000070 | 47 47 | 11 11 | 15 15 | 45 45 | 02 02 | 47 47 | 49 49 | 04 04 |
| 0x0000090 | 06 06 | 51 51 | 53 53 | 08 08 | 10 10 | 55 55 | 57 57 | 59 59 |
| 0x00000b0 | 61 61 | 27 27 | 29 29 | 63 63 | 65 65 | 31 31 | 33 33 | 67 67 |
| 0x00000d0 | 69 69 | 35 35 | 37 37 | 71 71 | 73 73 | 39 39 | 41 41 | 75 75 |
| 0x00000f0 | 77 77 | 43 43 | 45 45 | 00 00 | 26 26 | 69 69 | 73 73 | 36 36 |
| 0x0000110 | 40 40 | 04 04 | 08 08 | 38 38 | 42 42 | 06 06 | 10 10 | 12 12 |
| 0x0000130 | 16 16 | 59 59 | 63 63 | 14 14 | 18 18 | 61 61 | 65 65 | 28 28 |
| 0x0000150 | 32 32 | 75 75 | 00 00 | 30 30 | 34 34 | 77 77 | 02 02 | 20 20 |
| 0x0000170 | 24 24 | 67 67 | 71 71 | 22 22 | 58 58 | 24 24 | 26 26 | 68 68 |
| 0x0000190 | 70 70 | 36 36 | 38 38 | 72 72 | 74 74 | 40 40 | 42 42 | 44 44 |
| 0x00001b0 | 46 46 | 12 12 | 14 14 | 48 48 | 50 50 | 16 16 | 18 18 | 60 60 |
| 0x00001d0 | 62 62 | 28 28 | 30 30 | 64 64 | 66 66 | 32 32 | 34 34 | 52 52 |
| 0x00001f0 | 54 54 | 20 20 | 22 22 | 56 56 | 19 19 | 62 62 | 66 66 | 07 07 |
| 0x0000210 | 11 11 | 54 54 | 58 58 | 23 23 | 27 27 | 70 70 | 74 74 | 76 76 |
| 0x0000230 | 01 01 | 44 44 | 48 48 | 13 13 | 17 17 | 60 60 | 64 64 | 05 05 |
| 0x0000250 | 09 09 | 52 52 | 56 56 | 21 21 | 25 25 | 68 68 | 72 72 | 78 78 |
| 0x0000270 | 03 03 | 46 46 | 50 50 | 15 15 | 51 51 | 17 17 | 19 19 | 41 41 |
| 0x0000290 | 43 43 | 09 09 | 11 11 | 57 57 | 59 59 | 25 25 | 27 27 | 29 29 |
| 0x00002b0 | 31 31 | 76 76 | 78 78 | 45 45 | 47 47 | 13 13 | 15 15 | 37 37 |
| 0x00002d0 | 39 39 | 05 05 | 07 07 | 53 53 | 55 55 | 21 21 | 23 23 | 33 33 |
| 0x00002f0 | 35 35 | 01 01 | 03 03 | 49 49 | 75 75 | 39 39 | 43 43 | 00 00 |
| 0x0000310 | 04 04 | 47 47 | 51 51 | 08 08 | 12 12 | 55 55 | 59 59 | 61 61 |
| 0x0000330 | 65 65 | 29 29 | 33 33 | 69 69 | 73 73 | 37 37 | 41 41 | 77 77 |
| 0x0000350 | 02 02 | 45 45 | 49 49 | 06 06 | 10 10 | 53 53 | 57 57 | 63 63 |
| 0x0000370 | 67 67 | 31 31 | 35 35 | 71 71 | 28 28 | 73 73 | 75 75 | 34 34 |
| 0x0000390 | 36 36 | 02 02 | 04 04 | 42 42 | 44 44 | 10 10 | 12 12 | 14 14 |
| 0x00003b0 | 16 16 | 61 61 | 63 63 | 22 22 | 24 24 | 69 69 | 71 71 | 30 30 |
| 0x00003d0 | 32 32 | 77 77 | 00 00 | 38 38 | 40 40 | 06 06 | 08 08 | 18 18 |
| 0x00003f0 | 20 20 | 65 65 | 67 67 | 26 26 | 44 44 | 32 32 | 36 36 | 70 70 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with channels 0 to 21 unused):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels: 0x7fffffffffffffc00000

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 55 55 | 50 50 | 23 23 | 53 53 | 57 57 | 52 52 | 25 25 | 27 27 |
| 0x0000030 | 31 31 | 74 74 | 78 78 | 29 29 | 33 33 | 76 76 | 32 32 | 35 35 |
| 0x0000050 | 39 39 | 34 34 | 38 38 | 37 37 | 41 41 | 36 36 | 40 40 | 43 43 |
| 0x0000070 | 47 47 | 42 42 | 46 46 | 45 45 | 55 55 | 47 47 | 49 49 | 57 57 |
| 0x0000090 | 59 59 | 51 51 | 53 53 | 61 61 | 63 63 | 55 55 | 57 57 | 59 59 |
| 0x00000b0 | 61 61 | 27 27 | 29 29 | 63 63 | 65 65 | 31 31 | 33 33 | 67 67 |
| 0x00000d0 | 69 69 | 35 35 | 37 37 | 71 71 | 73 73 | 39 39 | 41 41 | 75 75 |
| 0x00000f0 | 77 77 | 43 43 | 45 45 | 53 53 | 26 26 | 69 69 | 73 73 | 36 36 |
| 0x0000110 | 40 40 | 57 57 | 61 61 | 38 38 | 42 42 | 59 59 | 63 63 | 65 65 |
| 0x0000130 | 69 69 | 59 59 | 63 63 | 67 67 | 71 71 | 61 61 | 65 65 | 28 28 |
| 0x0000150 | 32 32 | 75 75 | 53 53 | 30 30 | 34 34 | 77 77 | 55 55 | 73 73 |
| 0x0000170 | 24 24 | 67 67 | 71 71 | 22 22 | 58 58 | 24 24 | 26 26 | 68 68 |
| 0x0000190 | 70 70 | 36 36 | 38 38 | 72 72 | 74 74 | 40 40 | 42 42 | 44 44 |
| 0x00001b0 | 46 46 | 65 65 | 67 67 | 48 48 | 50 50 | 69 69 | 71 71 | 60 60 |
| 0x00001d0 | 62 62 | 28 28 | 30 30 | 64 64 | 66 66 | 32 32 | 34 34 | 52 52 |
| 0x00001f0 | 54 54 | 73 73 | 22 22 | 56 56 | 37 37 | 62 62 | 66 66 | 25 25 |
| 0x0000210 | 29 29 | 54 54 | 58 58 | 23 23 | 27 27 | 70 70 | 74 74 | 76 76 |
| 0x0000230 | 76 76 | 44 44 | 48 48 | 31 31 | 35 35 | 60 60 | 64 64 | 23 23 |
| 0x0000250 | 27 27 | 52 52 | 56 56 | 39 39 | 25 25 | 68 68 | 72 72 | 78 78 |
| 0x0000270 | 78 78 | 46 46 | 50 50 | 33 33 | 51 51 | 35 35 | 37 37 | 41 41 |
| 0x0000290 | 43 43 | 27 27 | 29 29 | 57 57 | 59 59 | 25 25 | 27 27 | 29 29 |
| 0x00002b0 | 31 31 | 76 76 | 78 78 | 45 45 | 47 47 | 31 31 | 33 33 | 37 37 |
| 0x00002d0 | 39 39 | 23 23 | 25 25 | 53 53 | 55 55 | 39 39 | 23 23 | 33 33 |
| 0x00002f0 | 35 35 | 76 76 | 78 78 | 49 49 | 75 75 | 39 39 | 43 43 | 40 40 |
| 0x0000310 | 44 44 | 47 47 | 51 51 | 48 48 | 52 52 | 55 55 | 59 59 | 61 61 |
| 0x0000330 | 65 65 | 29 29 | 33 33 | 69 69 | 73 73 | 37 37 | 41 41 | 77 77 |
| 0x0000350 | 42 42 | 45 45 | 49 49 | 46 46 | 50 50 | 53 53 | 57 57 | 63 63 |
| 0x0000370 | 67 67 | 31 31 | 35 35 | 71 71 | 28 28 | 73 73 | 75 75 | 34 34 |
| 0x0000390 | 36 36 | 42 42 | 44 44 | 42 42 | 44 44 | 50 50 | 52 52 | 54 54 |
| 0x00003b0 | 56 56 | 61 61 | 63 63 | 22 22 | 24 24 | 69 69 | 71 71 | 30 30 |
| 0x00003d0 | 32 32 | 77 77 | 40 40 | 38 38 | 40 40 | 46 46 | 48 48 | 58 58 |
| 0x00003f0 | 60 60 | 65 65 | 67 67 | 26 26 | 44 44 | 32 32 | 36 36 | 70 70 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with even channels used):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels: 0x555555555555555555555555

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 52 52 | 16 16 | 20 20 | 50 50 | 54 54 | 18 18 | 22 22 | 24 24 |
| 0x0000030 | 28 28 | 74 74 | 78 78 | 26 26 | 30 30 | 76 76 | 78 78 | 32 32 |
| 0x0000050 | 36 36 | 00 00 | 04 04 | 34 34 | 38 38 | 02 02 | 06 06 | 40 40 |
| 0x0000070 | 44 44 | 08 08 | 12 12 | 42 42 | 02 02 | 44 44 | 46 46 | 04 04 |
| 0x0000090 | 06 06 | 48 48 | 50 50 | 08 08 | 10 10 | 52 52 | 54 54 | 56 56 |
| 0x00000b0 | 58 58 | 24 24 | 26 26 | 60 60 | 62 62 | 28 28 | 30 30 | 64 64 |
| 0x00000d0 | 66 66 | 32 32 | 34 34 | 68 68 | 70 70 | 36 36 | 38 38 | 72 72 |
| 0x00000f0 | 74 74 | 40 40 | 42 42 | 00 00 | 26 26 | 66 66 | 70 70 | 36 36 |
| 0x0000110 | 40 40 | 04 04 | 08 08 | 38 38 | 42 42 | 06 06 | 10 10 | 12 12 |
| 0x0000130 | 16 16 | 56 56 | 60 60 | 14 14 | 18 18 | 58 58 | 62 62 | 28 28 |
| 0x0000150 | 32 32 | 72 72 | 00 00 | 30 30 | 34 34 | 74 74 | 02 02 | 20 20 |
| 0x0000170 | 24 24 | 64 64 | 68 68 | 22 22 | 58 58 | 24 24 | 26 26 | 68 68 |
| 0x0000190 | 70 70 | 36 36 | 38 38 | 72 72 | 74 74 | 40 40 | 42 42 | 44 44 |
| 0x00001b0 | 46 46 | 12 12 | 14 14 | 48 48 | 50 50 | 16 16 | 18 18 | 60 60 |
| 0x00001d0 | 62 62 | 28 28 | 30 30 | 64 64 | 66 66 | 32 32 | 34 34 | 52 52 |
| 0x00001f0 | 54 54 | 20 20 | 22 22 | 56 56 | 14 14 | 62 62 | 66 66 | 02 02 |
| 0x0000210 | 06 06 | 54 54 | 58 58 | 18 18 | 22 22 | 70 70 | 74 74 | 76 76 |
| 0x0000230 | 76 76 | 44 44 | 48 48 | 08 08 | 12 12 | 60 60 | 64 64 | 00 00 |
| 0x0000250 | 04 04 | 52 52 | 56 56 | 16 16 | 20 20 | 68 68 | 72 72 | 78 78 |
| 0x0000270 | 78 78 | 46 46 | 50 50 | 10 10 | 46 46 | 12 12 | 14 14 | 36 36 |
| 0x0000290 | 38 38 | 04 04 | 06 06 | 52 52 | 54 54 | 20 20 | 22 22 | 24 24 |
| 0x00002b0 | 26 26 | 76 76 | 78 78 | 40 40 | 42 42 | 08 08 | 10 10 | 32 32 |
| 0x00002d0 | 34 34 | 00 00 | 02 02 | 48 48 | 50 50 | 16 16 | 18 18 | 28 28 |
| 0x00002f0 | 30 30 | 76 76 | 78 78 | 44 44 | 70 70 | 34 34 | 38 38 | 00 00 |
| 0x0000310 | 04 04 | 42 42 | 46 46 | 08 08 | 12 12 | 50 50 | 54 54 | 56 56 |
| 0x0000330 | 60 60 | 24 24 | 28 28 | 64 64 | 68 68 | 32 32 | 36 36 | 72 72 |
| 0x0000350 | 02 02 | 40 40 | 44 44 | 06 06 | 10 10 | 48 48 | 52 52 | 58 58 |
| 0x0000370 | 62 62 | 26 26 | 30 30 | 66 66 | 28 28 | 68 68 | 70 70 | 34 34 |
| 0x0000390 | 36 36 | 02 02 | 04 04 | 42 42 | 44 44 | 10 10 | 12 12 | 14 14 |
| 0x00003b0 | 16 16 | 56 56 | 58 58 | 22 22 | 24 24 | 64 64 | 66 66 | 30 30 |
| 0x00003d0 | 32 32 | 72 72 | 00 00 | 38 38 | 40 40 | 06 06 | 08 08 | 18 18 |
| 0x00003f0 | 20 20 | 60 60 | 62 62 | 26 26 | 44 44 | 32 32 | 36 36 | 70 70 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with odd channels used):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels: 0x2aaaaaaaaaaaaaaaaaaaa

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 55 55 | 19 19 | 23 23 | 53 53 | 57 57 | 21 21 | 25 25 | 27 27 |
| 0x0000030 | 31 31 | 77 77 | 03 03 | 29 29 | 33 33 | 01 01 | 01 01 | 35 35 |
| 0x0000050 | 39 39 | 03 03 | 07 07 | 37 37 | 41 41 | 05 05 | 09 09 | 43 43 |
| 0x0000070 | 47 47 | 11 11 | 15 15 | 45 45 | 07 07 | 47 47 | 49 49 | 09 09 |
| 0x0000090 | 11 11 | 51 51 | 53 53 | 13 13 | 15 15 | 55 55 | 57 57 | 59 59 |
| 0x00000b0 | 61 61 | 27 27 | 29 29 | 63 63 | 65 65 | 31 31 | 33 33 | 67 67 |
| 0x00000d0 | 69 69 | 35 35 | 37 37 | 71 71 | 73 73 | 39 39 | 41 41 | 75 75 |
| 0x00000f0 | 77 77 | 43 43 | 45 45 | 05 05 | 31 31 | 69 69 | 73 73 | 41 41 |
| 0x0000110 | 45 45 | 09 09 | 13 13 | 43 43 | 47 47 | 11 11 | 15 15 | 17 17 |
| 0x0000130 | 21 21 | 59 59 | 63 63 | 19 19 | 23 23 | 61 61 | 65 65 | 33 33 |
| 0x0000150 | 37 37 | 75 75 | 05 05 | 35 35 | 39 39 | 77 77 | 07 07 | 25 25 |
| 0x0000170 | 29 29 | 67 67 | 71 71 | 27 27 | 63 63 | 29 29 | 31 31 | 73 73 |
| 0x0000190 | 75 75 | 41 41 | 43 43 | 77 77 | 01 01 | 45 45 | 47 47 | 49 49 |
| 0x00001b0 | 51 51 | 17 17 | 19 19 | 53 53 | 55 55 | 21 21 | 23 23 | 65 65 |
| 0x00001d0 | 67 67 | 33 33 | 35 35 | 69 69 | 71 71 | 37 37 | 39 39 | 57 57 |
| 0x00001f0 | 59 59 | 25 25 | 27 27 | 61 61 | 19 19 | 67 67 | 71 71 | 07 07 |
| 0x0000210 | 11 11 | 59 59 | 63 63 | 23 23 | 27 27 | 75 75 | 01 01 | 03 03 |
| 0x0000230 | 01 01 | 49 49 | 53 53 | 13 13 | 17 17 | 65 65 | 69 69 | 05 05 |
| 0x0000250 | 09 09 | 57 57 | 61 61 | 21 21 | 25 25 | 73 73 | 77 77 | 05 05 |
| 0x0000270 | 03 03 | 51 51 | 55 55 | 15 15 | 51 51 | 17 17 | 19 19 | 41 41 |
| 0x0000290 | 43 43 | 09 09 | 11 11 | 57 57 | 59 59 | 25 25 | 27 27 | 29 29 |
| 0x00002b0 | 31 31 | 03 03 | 05 05 | 45 45 | 47 47 | 13 13 | 15 15 | 37 37 |
| 0x00002d0 | 39 39 | 05 05 | 07 07 | 53 53 | 55 55 | 21 21 | 23 23 | 33 33 |
| 0x00002f0 | 35 35 | 01 01 | 03 03 | 49 49 | 75 75 | 39 39 | 43 43 | 07 07 |
| 0x0000310 | 11 11 | 47 47 | 51 51 | 15 15 | 19 19 | 55 55 | 59 59 | 61 61 |
| 0x0000330 | 65 65 | 29 29 | 33 33 | 69 69 | 73 73 | 37 37 | 41 41 | 77 77 |
| 0x0000350 | 09 09 | 45 45 | 49 49 | 13 13 | 17 17 | 53 53 | 57 57 | 63 63 |
| 0x0000370 | 67 67 | 31 31 | 35 35 | 71 71 | 35 35 | 73 73 | 75 75 | 41 41 |
| 0x0000390 | 43 43 | 09 09 | 11 11 | 49 49 | 51 51 | 17 17 | 19 19 | 21 21 |
| 0x00003b0 | 23 23 | 61 61 | 63 63 | 29 29 | 31 31 | 69 69 | 71 71 | 37 37 |
| 0x00003d0 | 39 39 | 77 77 | 07 07 | 45 45 | 47 47 | 13 13 | 15 15 | 25 25 |
| 0x00003f0 | 27 27 | 65 65 | 67 67 | 33 33 | 51 51 | 39 39 | 43 43 | 77 77 |

Sample Data



2.3 THIRD SET

Hop sequence {k} for PAGE SCAN/INQUIRY SCAN SUBSTATE:

| | | | | | | | | |
|-------------|------------|------|------|------|------|------|------|------|
| CLKN start: | 0x0000000 | | | | | | | |
| ULAP: | 0x6587cba9 | | | | | | | |
| #ticks: | 0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
| ----- | | | | | | | | |
| 0x0000000: | 16 | 65 | 67 | 18 | 20 | 53 | 55 | 6 |
| 0x0008000: | 8 | 57 | 59 | 10 | 12 | 69 | 71 | 22 |
| 0x0010000: | 24 | 73 | 75 | 26 | 28 | 45 | 47 | 77 |
| 0x0018000: | 0 | 49 | 51 | 2 | 4 | 61 | 63 | 14 |
| 0x0020000: | 16 | 65 | 67 | 18 | 20 | 53 | 55 | 6 |
| 0x0028000: | 8 | 57 | 59 | 10 | 12 | 69 | 71 | 22 |
| 0x0030000: | 24 | 73 | 75 | 26 | 28 | 45 | 47 | 77 |
| 0x0038000: | 0 | 49 | 51 | 2 | 4 | 61 | 63 | 14 |

Hop sequence {k} for PAGE STATE/INQUIRY SUBSTATE:

| | | | | | | | | | | | | | | | | |
|-------------|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| CLKE start: | 0x0000000 | | | | | | | | | | | | | | | |
| ULAP: | 0x6587cba9 | | | | | | | | | | | | | | | |
| #ticks: | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 0a | 0b | 0c | 0d | 0e | 0f |
| ----- | | | | | | | | | | | | | | | | |
| 0x0000000: | 00 | 49 | 36 | 38 | 51 | 02 | 42 | 40 | 04 | 61 | 44 | 46 | 63 | 14 | 50 | 48 |
| 0x0000010: | 16 | 65 | 52 | 54 | 67 | 18 | 58 | 56 | 20 | 53 | 60 | 62 | 55 | 06 | 66 | 64 |
| 0x0000020: | 00 | 49 | 36 | 38 | 51 | 02 | 42 | 40 | 04 | 61 | 44 | 46 | 63 | 14 | 50 | 48 |
| 0x0000030: | 16 | 65 | 52 | 54 | 67 | 18 | 58 | 56 | 20 | 53 | 60 | 62 | 55 | 06 | 66 | 64 |
| ... | | | | | | | | | | | | | | | | |
| 0x0001000: | 00 | 57 | 36 | 70 | 59 | 10 | 74 | 72 | 12 | 69 | 76 | 78 | 71 | 22 | 03 | 01 |
| 0x0001010: | 24 | 73 | 05 | 07 | 75 | 26 | 11 | 09 | 28 | 45 | 13 | 30 | 47 | 77 | 34 | 32 |
| 0x0001020: | 00 | 57 | 36 | 70 | 59 | 10 | 74 | 72 | 12 | 69 | 76 | 78 | 71 | 22 | 03 | 01 |
| 0x0001030: | 24 | 73 | 05 | 07 | 75 | 26 | 11 | 09 | 28 | 45 | 13 | 30 | 47 | 77 | 34 | 32 |
| ... | | | | | | | | | | | | | | | | |
| 0x0002000: | 08 | 57 | 68 | 70 | 51 | 02 | 42 | 40 | 04 | 61 | 44 | 46 | 63 | 14 | 50 | 48 |
| 0x0002010: | 16 | 65 | 52 | 54 | 67 | 18 | 58 | 56 | 20 | 53 | 60 | 62 | 55 | 06 | 66 | 64 |
| 0x0002020: | 08 | 57 | 68 | 70 | 51 | 02 | 42 | 40 | 04 | 61 | 44 | 46 | 63 | 14 | 50 | 48 |
| 0x0002030: | 16 | 65 | 52 | 54 | 67 | 18 | 58 | 56 | 20 | 53 | 60 | 62 | 55 | 06 | 66 | 64 |
| ... | | | | | | | | | | | | | | | | |
| 0x0003000: | 00 | 49 | 36 | 38 | 51 | 10 | 42 | 72 | 12 | 69 | 76 | 78 | 71 | 22 | 03 | 01 |
| 0x0003010: | 24 | 73 | 05 | 07 | 75 | 26 | 11 | 09 | 28 | 45 | 13 | 30 | 47 | 77 | 34 | 32 |
| 0x0003020: | 00 | 49 | 36 | 38 | 51 | 10 | 42 | 72 | 12 | 69 | 76 | 78 | 71 | 22 | 03 | 01 |
| 0x0003030: | 24 | 73 | 05 | 07 | 75 | 26 | 11 | 09 | 28 | 45 | 13 | 30 | 47 | 77 | 34 | 32 |

Hop sequence {k} for SLAVE PAGE RESPONSE SUBSTATE:

| | | | | | | | | | | | | | | | | |
|------------|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| CLKN* = | 0x0000010 | | | | | | | | | | | | | | | |
| ULAP: | 0x6587cba9 | | | | | | | | | | | | | | | |
| #ticks: | 00 | 02 | 04 | 06 | 08 | 0a | 0c | 0e | 10 | 12 | 14 | 16 | 18 | 1a | 1c | 1e |
| ----- | | | | | | | | | | | | | | | | |
| 0x0000012: | 52 | 65 | 54 | 67 | 58 | 18 | 56 | 20 | 60 | 53 | 62 | 55 | 66 | 06 | 64 | 08 |
| 0x0000032: | 68 | 57 | 70 | 59 | 74 | 10 | 72 | 12 | 76 | 69 | 78 | 71 | 03 | 22 | 01 | 24 |
| 0x0000052: | 05 | 73 | 07 | 75 | 11 | 26 | 09 | 28 | 13 | 45 | 30 | 47 | 34 | 77 | 32 | 00 |
| 0x0000072: | 36 | 49 | 38 | 51 | 42 | 02 | 40 | 04 | 44 | 61 | 46 | 63 | 50 | 14 | 48 | 16 |

Hop sequence {k} for MASTER PAGE RESPONSE SUBSTATE:

| | | | | | | | | | | | | | | | | |
|---------------|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Offset value: | 24 | | | | | | | | | | | | | | | |
| CLKE* = | 0x0000012 | | | | | | | | | | | | | | | |
| ULAP: | 0x6587cba9 | | | | | | | | | | | | | | | |
| #ticks: | 00 | 02 | 04 | 06 | 08 | 0a | 0c | 0e | 10 | 12 | 14 | 16 | 18 | 1a | 1c | 1e |
| ----- | | | | | | | | | | | | | | | | |
| 0x0000014: | 65 | 54 | 67 | 58 | 18 | 56 | 20 | 60 | 53 | 62 | 55 | 66 | 06 | 64 | 08 | 68 |
| 0x0000034: | 57 | 70 | 59 | 74 | 10 | 72 | 12 | 76 | 69 | 78 | 71 | 03 | 22 | 01 | 24 | 05 |
| 0x0000054: | 73 | 07 | 75 | 11 | 26 | 09 | 28 | 13 | 45 | 30 | 47 | 34 | 77 | 32 | 00 | 36 |
| 0x0000074: | 49 | 38 | 51 | 42 | 02 | 40 | 04 | 44 | 61 | 46 | 63 | 50 | 14 | 48 | 16 | 52 |

Sample Data



Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence; ie, non-AFH):

CLK start: 0x0000010

ULAP: 0x6587cba9

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0x0000010: | 20 60 | 53 62 | 55 66 | 06 64 | 08 68 | 57 70 | 59 74 | 10 72 |
| 0x0000030: | 12 76 | 69 78 | 71 03 | 22 01 | 24 05 | 73 07 | 75 11 | 26 09 |
| 0x0000050: | 28 13 | 45 30 | 47 34 | 77 32 | 00 36 | 49 38 | 51 42 | 02 40 |
| 0x0000070: | 04 44 | 61 46 | 63 50 | 14 48 | 50 05 | 16 07 | 20 09 | 48 11 |
| 0x0000090: | 52 13 | 06 15 | 10 17 | 38 19 | 42 21 | 08 23 | 12 25 | 40 27 |
| 0x00000b0: | 44 29 | 22 31 | 26 33 | 54 35 | 58 37 | 24 39 | 28 41 | 56 43 |
| 0x00000d0: | 60 45 | 77 62 | 02 64 | 30 66 | 34 68 | 00 70 | 04 72 | 32 74 |
| 0x00000f0: | 36 76 | 14 78 | 18 01 | 46 03 | 72 29 | 42 39 | 44 43 | 74 41 |
| 0x0000110: | 76 45 | 46 47 | 48 51 | 78 49 | 01 53 | 50 63 | 52 67 | 03 65 |
| 0x0000130: | 05 69 | 54 55 | 56 59 | 07 57 | 09 61 | 58 71 | 60 75 | 11 73 |
| 0x0000150: | 13 77 | 30 15 | 32 19 | 62 17 | 64 21 | 34 31 | 36 35 | 66 33 |
| 0x0000170: | 68 37 | 38 23 | 40 27 | 70 25 | 27 61 | 72 71 | 76 73 | 25 75 |
| 0x0000190: | 29 77 | 78 00 | 03 02 | 31 04 | 35 06 | 01 16 | 05 18 | 33 20 |
| 0x00001b0: | 37 22 | 07 08 | 11 10 | 39 12 | 43 14 | 09 24 | 13 26 | 41 28 |
| 0x00001d0: | 45 30 | 62 47 | 66 49 | 15 51 | 19 53 | 64 63 | 68 65 | 17 67 |
| 0x00001f0: | 21 69 | 70 55 | 74 57 | 23 59 | 53 22 | 35 12 | 37 28 | 67 14 |
| 0x0000210: | 69 30 | 23 32 | 25 48 | 55 34 | 57 50 | 39 40 | 41 56 | 71 42 |
| 0x0000230: | 73 58 | 27 36 | 29 52 | 59 38 | 61 54 | 43 44 | 45 60 | 75 46 |
| 0x0000250: | 77 62 | 15 00 | 17 16 | 47 02 | 49 18 | 31 08 | 33 24 | 63 10 |
| 0x0000270: | 65 26 | 19 04 | 21 20 | 51 06 | 06 54 | 65 42 | 69 58 | 18 46 |
| 0x0000290: | 22 62 | 55 64 | 59 01 | 08 68 | 12 05 | 71 72 | 75 09 | 24 76 |
| 0x00002b0: | 28 13 | 57 66 | 61 03 | 10 70 | 14 07 | 73 74 | 77 11 | 26 78 |
| 0x00002d0: | 30 15 | 47 32 | 51 48 | 00 36 | 04 52 | 63 40 | 67 56 | 16 44 |
| 0x00002f0: | 20 60 | 49 34 | 53 50 | 02 38 | 38 78 | 12 05 | 14 13 | 44 07 |
| 0x0000310: | 46 15 | 16 17 | 18 25 | 48 19 | 50 27 | 24 33 | 26 41 | 56 35 |
| 0x0000330: | 58 43 | 20 21 | 22 29 | 52 23 | 54 31 | 28 37 | 30 45 | 60 39 |
| 0x0000350: | 62 47 | 00 64 | 02 72 | 32 66 | 34 74 | 08 01 | 10 09 | 40 03 |
| 0x0000370: | 42 11 | 04 68 | 06 76 | 36 70 | 70 31 | 42 35 | 46 43 | 74 39 |
| 0x0000390: | 78 47 | 48 49 | 52 57 | 01 53 | 05 61 | 56 65 | 60 73 | 09 69 |
| 0x00003b0: | 13 77 | 50 51 | 54 59 | 03 55 | 07 63 | 58 67 | 62 75 | 11 71 |
| 0x00003d0: | 15 00 | 32 17 | 36 25 | 64 21 | 68 29 | 40 33 | 44 41 | 72 37 |
| 0x00003f0: | 76 45 | 34 19 | 38 27 | 66 23 | 11 71 | 05 18 | 07 22 | 13 20 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with all channel used; ie, AFH(79)):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels: 0x7fffffffffffffffffff

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 20 20 | 53 53 | 55 55 | 06 06 | 08 08 | 57 57 | 59 59 | 10 10 |
| 0x0000030 | 12 12 | 69 69 | 71 71 | 22 22 | 24 24 | 73 73 | 75 75 | 26 26 |
| 0x0000050 | 28 28 | 45 45 | 47 47 | 77 77 | 00 00 | 49 49 | 51 51 | 02 02 |
| 0x0000070 | 04 04 | 61 61 | 63 63 | 14 14 | 50 50 | 16 16 | 20 20 | 48 48 |
| 0x0000090 | 52 52 | 06 06 | 10 10 | 38 38 | 42 42 | 08 08 | 12 12 | 40 40 |
| 0x00000b0 | 44 44 | 22 22 | 26 26 | 54 54 | 58 58 | 24 24 | 28 28 | 56 56 |
| 0x00000d0 | 60 60 | 77 77 | 02 02 | 30 30 | 34 34 | 00 00 | 04 04 | 32 32 |
| 0x00000f0 | 36 36 | 14 14 | 18 18 | 46 46 | 72 72 | 42 42 | 44 44 | 74 74 |
| 0x0000110 | 76 76 | 46 46 | 48 48 | 78 78 | 01 01 | 50 50 | 52 52 | 03 03 |
| 0x0000130 | 05 05 | 54 54 | 56 56 | 07 07 | 09 09 | 58 58 | 60 60 | 11 11 |
| 0x0000150 | 13 13 | 30 30 | 32 32 | 62 62 | 64 64 | 34 34 | 36 36 | 66 66 |
| 0x0000170 | 68 68 | 38 38 | 40 40 | 70 70 | 27 27 | 72 72 | 76 76 | 25 25 |
| 0x0000190 | 29 29 | 78 78 | 03 03 | 31 31 | 35 35 | 01 01 | 05 05 | 33 33 |
| 0x00001b0 | 37 37 | 07 07 | 11 11 | 39 39 | 43 43 | 09 09 | 13 13 | 41 41 |
| 0x00001d0 | 45 45 | 62 62 | 66 66 | 15 15 | 19 19 | 64 64 | 68 68 | 17 17 |
| 0x00001f0 | 21 21 | 70 70 | 74 74 | 23 23 | 53 53 | 35 35 | 37 37 | 67 67 |
| 0x0000210 | 69 69 | 23 23 | 25 25 | 55 55 | 57 57 | 39 39 | 41 41 | 71 71 |
| 0x0000230 | 73 73 | 27 27 | 29 29 | 59 59 | 61 61 | 43 43 | 45 45 | 75 75 |
| 0x0000250 | 77 77 | 15 15 | 17 17 | 47 47 | 49 49 | 31 31 | 33 33 | 63 63 |
| 0x0000270 | 65 65 | 19 19 | 21 21 | 51 51 | 06 06 | 65 65 | 69 69 | 18 18 |
| 0x0000290 | 22 22 | 55 55 | 59 59 | 08 08 | 12 12 | 71 71 | 75 75 | 24 24 |
| 0x00002b0 | 28 28 | 57 57 | 61 61 | 10 10 | 14 14 | 73 73 | 77 77 | 26 26 |
| 0x00002d0 | 30 30 | 47 47 | 51 51 | 00 00 | 04 04 | 63 63 | 67 67 | 16 16 |
| 0x00002f0 | 20 20 | 49 49 | 53 53 | 02 02 | 38 38 | 12 12 | 14 14 | 44 44 |
| 0x0000310 | 46 46 | 16 16 | 18 18 | 48 48 | 50 50 | 24 24 | 26 26 | 56 56 |
| 0x0000330 | 58 58 | 20 20 | 22 22 | 52 52 | 54 54 | 28 28 | 30 30 | 60 60 |
| 0x0000350 | 62 62 | 00 00 | 02 02 | 32 32 | 34 34 | 08 08 | 10 10 | 40 40 |
| 0x0000370 | 42 42 | 04 04 | 06 06 | 36 36 | 70 70 | 42 42 | 46 46 | 74 74 |
| 0x0000390 | 78 78 | 48 48 | 52 52 | 01 01 | 05 05 | 56 56 | 60 60 | 09 09 |
| 0x00003b0 | 13 13 | 50 50 | 54 54 | 03 03 | 07 07 | 58 58 | 62 62 | 11 11 |
| 0x00003d0 | 15 15 | 32 32 | 36 36 | 64 64 | 68 68 | 40 40 | 44 44 | 72 72 |
| 0x00003f0 | 76 76 | 34 34 | 38 38 | 66 66 | 11 11 | 05 05 | 07 07 | 13 13 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with channels 0 to 21 unused):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels: 0x7fffffffffffffc00000

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 29 29 | 53 53 | 55 55 | 72 72 | 74 74 | 57 57 | 59 59 | 76 76 |
| 0x0000030 | 78 78 | 69 69 | 71 71 | 22 22 | 24 24 | 73 73 | 75 75 | 26 26 |
| 0x0000050 | 28 28 | 45 45 | 47 47 | 77 77 | 66 66 | 49 49 | 51 51 | 68 68 |
| 0x0000070 | 70 70 | 61 61 | 63 63 | 23 23 | 50 50 | 25 25 | 29 29 | 48 48 |
| 0x0000090 | 52 52 | 72 72 | 76 76 | 38 38 | 42 42 | 74 74 | 78 78 | 40 40 |
| 0x00000b0 | 44 44 | 22 22 | 26 26 | 54 54 | 58 58 | 24 24 | 28 28 | 56 56 |
| 0x00000d0 | 60 60 | 77 77 | 68 68 | 30 30 | 34 34 | 66 66 | 70 70 | 32 32 |
| 0x00000f0 | 36 36 | 23 23 | 27 27 | 46 46 | 72 72 | 42 42 | 44 44 | 74 74 |
| 0x0000110 | 76 76 | 46 46 | 48 48 | 78 78 | 32 32 | 50 50 | 52 52 | 34 34 |
| 0x0000130 | 36 36 | 54 54 | 56 56 | 38 38 | 40 40 | 58 58 | 60 60 | 42 42 |
| 0x0000150 | 44 44 | 30 30 | 32 32 | 62 62 | 64 64 | 34 34 | 36 36 | 66 66 |
| 0x0000170 | 68 68 | 38 38 | 40 40 | 70 70 | 27 27 | 72 72 | 76 76 | 25 25 |
| 0x0000190 | 29 29 | 78 78 | 34 34 | 31 31 | 35 35 | 32 32 | 36 36 | 33 33 |
| 0x00001b0 | 37 37 | 38 38 | 42 42 | 39 39 | 43 43 | 40 40 | 44 44 | 41 41 |
| 0x00001d0 | 45 45 | 62 62 | 66 66 | 46 46 | 50 50 | 64 64 | 68 68 | 48 48 |
| 0x00001f0 | 52 52 | 70 70 | 74 74 | 23 23 | 53 53 | 35 35 | 37 37 | 67 67 |
| 0x0000210 | 69 69 | 23 23 | 25 25 | 55 55 | 57 57 | 39 39 | 41 41 | 71 71 |
| 0x0000230 | 73 73 | 27 27 | 29 29 | 59 59 | 61 61 | 43 43 | 45 45 | 75 75 |
| 0x0000250 | 77 77 | 46 46 | 48 48 | 47 47 | 49 49 | 31 31 | 33 33 | 63 63 |
| 0x0000270 | 65 65 | 50 50 | 52 52 | 51 51 | 59 59 | 65 65 | 69 69 | 71 71 |
| 0x0000290 | 22 22 | 55 55 | 59 59 | 61 61 | 65 65 | 71 71 | 75 75 | 24 24 |
| 0x00002b0 | 28 28 | 57 57 | 61 61 | 63 63 | 67 67 | 73 73 | 77 77 | 26 26 |
| 0x00002d0 | 30 30 | 47 47 | 51 51 | 53 53 | 57 57 | 63 63 | 67 67 | 69 69 |
| 0x00002f0 | 73 73 | 49 49 | 53 53 | 55 55 | 38 38 | 65 65 | 67 67 | 44 44 |
| 0x0000310 | 46 46 | 69 69 | 71 71 | 48 48 | 50 50 | 24 24 | 26 26 | 56 56 |
| 0x0000330 | 58 58 | 73 73 | 22 22 | 52 52 | 54 54 | 28 28 | 30 30 | 60 60 |
| 0x0000350 | 62 62 | 53 53 | 55 55 | 32 32 | 34 34 | 61 61 | 63 63 | 40 40 |
| 0x0000370 | 42 42 | 57 57 | 59 59 | 36 36 | 70 70 | 42 42 | 46 46 | 74 74 |
| 0x0000390 | 78 78 | 48 48 | 52 52 | 76 76 | 23 23 | 56 56 | 60 60 | 27 27 |
| 0x00003b0 | 31 31 | 50 50 | 54 54 | 78 78 | 25 25 | 58 58 | 62 62 | 29 29 |
| 0x00003d0 | 33 33 | 32 32 | 36 36 | 64 64 | 68 68 | 40 40 | 44 44 | 72 72 |
| 0x00003f0 | 76 76 | 34 34 | 38 38 | 66 66 | 29 29 | 23 23 | 25 25 | 31 31 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with even channels used):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels: 0x55555555555555555555

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 20 20 | 52 52 | 54 54 | 06 06 | 08 08 | 56 56 | 58 58 | 10 10 |
| 0x0000030 | 12 12 | 68 68 | 70 70 | 22 22 | 24 24 | 72 72 | 74 74 | 26 26 |
| 0x0000050 | 28 28 | 44 44 | 46 46 | 76 76 | 00 00 | 48 48 | 50 50 | 02 02 |
| 0x0000070 | 04 04 | 60 60 | 62 62 | 14 14 | 50 50 | 16 16 | 20 20 | 48 48 |
| 0x0000090 | 52 52 | 06 06 | 10 10 | 38 38 | 42 42 | 08 08 | 12 12 | 40 40 |
| 0x00000b0 | 44 44 | 22 22 | 26 26 | 54 54 | 58 58 | 24 24 | 28 28 | 56 56 |
| 0x00000d0 | 60 60 | 76 76 | 02 02 | 30 30 | 34 34 | 00 00 | 04 04 | 32 32 |
| 0x00000f0 | 36 36 | 14 14 | 18 18 | 46 46 | 72 72 | 42 42 | 44 44 | 74 74 |
| 0x0000110 | 76 76 | 46 46 | 48 48 | 78 78 | 78 78 | 50 50 | 52 52 | 00 00 |
| 0x0000130 | 02 02 | 54 54 | 56 56 | 04 04 | 06 06 | 58 58 | 60 60 | 08 08 |
| 0x0000150 | 10 10 | 30 30 | 32 32 | 62 62 | 64 64 | 34 34 | 36 36 | 66 66 |
| 0x0000170 | 68 68 | 38 38 | 40 40 | 70 70 | 24 24 | 72 72 | 76 76 | 22 22 |
| 0x0000190 | 26 26 | 78 78 | 00 00 | 28 28 | 32 32 | 78 78 | 02 02 | 30 30 |
| 0x00001b0 | 34 34 | 04 04 | 08 08 | 36 36 | 40 40 | 06 06 | 10 10 | 38 38 |
| 0x00001d0 | 42 42 | 62 62 | 66 66 | 12 12 | 16 16 | 64 64 | 68 68 | 14 14 |
| 0x00001f0 | 18 18 | 70 70 | 74 74 | 20 20 | 50 50 | 32 32 | 34 34 | 64 64 |
| 0x0000210 | 66 66 | 20 20 | 22 22 | 52 52 | 54 54 | 36 36 | 38 38 | 68 68 |
| 0x0000230 | 70 70 | 24 24 | 26 26 | 56 56 | 58 58 | 40 40 | 42 42 | 72 72 |
| 0x0000250 | 74 74 | 12 12 | 14 14 | 44 44 | 46 46 | 28 28 | 30 30 | 60 60 |
| 0x0000270 | 62 62 | 16 16 | 18 18 | 48 48 | 06 06 | 62 62 | 66 66 | 18 18 |
| 0x0000290 | 22 22 | 52 52 | 56 56 | 08 08 | 12 12 | 68 68 | 72 72 | 24 24 |
| 0x00002b0 | 28 28 | 54 54 | 58 58 | 10 10 | 14 14 | 70 70 | 74 74 | 26 26 |
| 0x00002d0 | 30 30 | 44 44 | 48 48 | 00 00 | 04 04 | 60 60 | 64 64 | 16 16 |
| 0x00002f0 | 20 20 | 46 46 | 50 50 | 02 02 | 38 38 | 12 12 | 14 14 | 44 44 |
| 0x0000310 | 46 46 | 16 16 | 18 18 | 48 48 | 50 50 | 24 24 | 26 26 | 56 56 |
| 0x0000330 | 58 58 | 20 20 | 22 22 | 52 52 | 54 54 | 28 28 | 30 30 | 60 60 |
| 0x0000350 | 62 62 | 00 00 | 02 02 | 32 32 | 34 34 | 08 08 | 10 10 | 40 40 |
| 0x0000370 | 42 42 | 04 04 | 06 06 | 36 36 | 70 70 | 42 42 | 46 46 | 74 74 |
| 0x0000390 | 78 78 | 48 48 | 52 52 | 76 76 | 00 00 | 56 56 | 60 60 | 04 04 |
| 0x00003b0 | 08 08 | 50 50 | 54 54 | 78 78 | 02 02 | 58 58 | 62 62 | 06 06 |
| 0x00003d0 | 10 10 | 32 32 | 36 36 | 64 64 | 68 68 | 40 40 | 44 44 | 72 72 |
| 0x00003f0 | 76 76 | 34 34 | 38 38 | 66 66 | 06 06 | 00 00 | 02 02 | 08 08 |

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with odd channels used):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels: 0x2aaaaaaaaaaaaaaaaaaaa

| #ticks: | 00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|
| | ----- | | | | | | | |
| 0x0000010 | 23 23 | 53 53 | 55 55 | 09 09 | 11 11 | 57 57 | 59 59 | 13 13 |
| 0x0000030 | 15 15 | 69 69 | 71 71 | 25 25 | 27 27 | 73 73 | 75 75 | 29 29 |
| 0x0000050 | 31 31 | 45 45 | 47 47 | 77 77 | 03 03 | 49 49 | 51 51 | 05 05 |
| 0x0000070 | 07 07 | 61 61 | 63 63 | 17 17 | 53 53 | 19 19 | 23 23 | 51 51 |
| 0x0000090 | 55 55 | 09 09 | 13 13 | 41 41 | 45 45 | 11 11 | 15 15 | 43 43 |
| 0x00000b0 | 47 47 | 25 25 | 29 29 | 57 57 | 61 61 | 27 27 | 31 31 | 59 59 |
| 0x00000d0 | 63 63 | 77 77 | 05 05 | 33 33 | 37 37 | 03 03 | 07 07 | 35 35 |
| 0x00000f0 | 39 39 | 17 17 | 21 21 | 49 49 | 75 75 | 45 45 | 47 47 | 77 77 |
| 0x0000110 | 01 01 | 49 49 | 51 51 | 03 03 | 01 01 | 53 53 | 55 55 | 03 03 |
| 0x0000130 | 05 05 | 57 57 | 59 59 | 07 07 | 09 09 | 61 61 | 63 63 | 11 11 |
| 0x0000150 | 13 13 | 33 33 | 35 35 | 65 65 | 67 67 | 37 37 | 39 39 | 69 69 |
| 0x0000170 | 71 71 | 41 41 | 43 43 | 73 73 | 27 27 | 75 75 | 01 01 | 25 25 |
| 0x0000190 | 29 29 | 03 03 | 03 03 | 31 31 | 35 35 | 01 01 | 05 05 | 33 33 |
| 0x00001b0 | 37 37 | 07 07 | 11 11 | 39 39 | 43 43 | 09 09 | 13 13 | 41 41 |
| 0x00001d0 | 45 45 | 65 65 | 69 69 | 15 15 | 19 19 | 67 67 | 71 71 | 17 17 |
| 0x00001f0 | 21 21 | 73 73 | 77 77 | 23 23 | 53 53 | 35 35 | 37 37 | 67 67 |
| 0x0000210 | 69 69 | 23 23 | 25 25 | 55 55 | 57 57 | 39 39 | 41 41 | 71 71 |
| 0x0000230 | 73 73 | 27 27 | 29 29 | 59 59 | 61 61 | 43 43 | 45 45 | 75 75 |
| 0x0000250 | 77 77 | 15 15 | 17 17 | 47 47 | 49 49 | 31 31 | 33 33 | 63 63 |
| 0x0000270 | 65 65 | 19 19 | 21 21 | 51 51 | 11 11 | 65 65 | 69 69 | 23 23 |
| 0x0000290 | 27 27 | 55 55 | 59 59 | 13 13 | 17 17 | 71 71 | 75 75 | 29 29 |
| 0x00002b0 | 33 33 | 57 57 | 61 61 | 15 15 | 19 19 | 73 73 | 77 77 | 31 31 |
| 0x00002d0 | 35 35 | 47 47 | 51 51 | 05 05 | 09 09 | 63 63 | 67 67 | 21 21 |
| 0x00002f0 | 25 25 | 49 49 | 53 53 | 07 07 | 43 43 | 17 17 | 19 19 | 49 49 |
| 0x0000310 | 51 51 | 21 21 | 23 23 | 53 53 | 55 55 | 29 29 | 31 31 | 61 61 |
| 0x0000330 | 63 63 | 25 25 | 27 27 | 57 57 | 59 59 | 33 33 | 35 35 | 65 65 |
| 0x0000350 | 67 67 | 05 05 | 07 07 | 37 37 | 39 39 | 13 13 | 15 15 | 45 45 |
| 0x0000370 | 47 47 | 09 09 | 11 11 | 41 41 | 75 75 | 47 47 | 51 51 | 01 01 |
| 0x0000390 | 05 05 | 53 53 | 57 57 | 01 01 | 05 05 | 61 61 | 65 65 | 09 09 |
| 0x00003b0 | 13 13 | 55 55 | 59 59 | 03 03 | 07 07 | 63 63 | 67 67 | 11 11 |
| 0x00003d0 | 15 15 | 37 37 | 41 41 | 69 69 | 73 73 | 45 45 | 49 49 | 77 77 |
| 0x00003f0 | 03 03 | 39 39 | 43 43 | 71 71 | 11 11 | 05 05 | 07 07 | 13 13 |





3 ACCESS CODE SAMPLE DATA

Different access codes (GIAC, DIACs, others...)

LAP with LSB as rightmost bit.

| Bit transmit order on air | | | | |
|---------------------------|-----------|--------------------|----------|--|
| -----> | | | | |
| LAP: | Preamble: | Sync word: | Trailer: | |
| ----- | | | | |
| 000000 | 5 | 7e7041e3 4000000d | 5 | |
| ffffff | a | e758b522 7fffffff2 | a | |
| 9e8b33 | 5 | 475c58cc 73345e72 | a | |
| 9e8b34 | 5 | 28ed3c34 cb345e72 | a | |
| 9e8b36 | 5 | 62337b64 1b345e72 | a | |
| 9e8b39 | a | c05747b9 e7345e72 | a | |
| 9e8b3d | 5 | 7084eab0 2f345e72 | a | |
| 9e8b42 | 5 | 64c86d2b 90b45e72 | a | |
| 9e8b48 | a | e3c3725e 04b45e72 | a | |
| 9e8b4f | a | 8c7216a6 bcb45e72 | a | |
| 9e8b57 | a | b2f16c30 fab45e72 | a | |
| 9e8b60 | 5 | 57bd3b22 c1b45e72 | a | |
| 9e8b6a | a | d0b62457 55b45e72 | a | |
| 9e8b75 | a | 81843a39 abb45e72 | a | |
| 9e8b81 | 5 | 0ca96681 e0745e72 | a | |
| 9e8b8e | a | aecd5a5c 1c745e72 | a | |
| 9e8b9c | 5 | 17453fbf ce745e72 | a | |
| 9e8bab | a | f20968ad f5745e72 | a | |
| 9e8bbb | 5 | 015f4a1e f7745e72 | a | |
| 9e8bcc | a | d8c695a0 0cf45e72 | a | |
| 9e8bde | 5 | 614ef043 def45e72 | a | |
| 9e8bf1 | a | ba81ddc7 a3f45e72 | a | |
| 9e8c05 | 5 | 64a7dc4f 680c5e72 | a | |
| 9e8c1a | 5 | 3595c221 960c5e72 | a | |
| 9e8c30 | a | cb35cc0d 830c5e72 | a | |
| 9e8c47 | 5 | 12ac13b3 788c5e72 | a | |
| 9e8c5f | 5 | 2c2f6925 3e8c5e72 | a | |
| 9e8c78 | 5 | 3a351c84 078c5e72 | a | |
| 9e8c92 | 5 | 7396d0f3 124c5e72 | a | |
| 9e8cad | 5 | 5b0fdffc4 6d4c5e72 | a | |
| 9e8cc9 | a | aea2eb38 e4cc5e72 | a | |
| 9e8ce6 | 5 | 756dc6bc 99cc5e72 | a | |
| 9e8d04 | 5 | 214cf934 882c5e72 | a | |
| 9e8d23 | 5 | 37568c95 b12c5e72 | a | |
| 9e8d43 | 5 | 72281560 f0ac5e72 | a | |
| 9e8d64 | 5 | 643260c1 c9ac5e72 | a | |
| 9e8d86 | a | e044f493 986c5e72 | a | |
| 9e8da9 | 5 | 3b8bd917 e56c5e72 | a | |
| 9e8dcd | a | ce26edeb 6cec5e72 | a | |
| 9e8df2 | a | e6bfe2dc 13ec5e72 | a | |
| 9e8e18 | a | 82dcde3d c61c5e72 | a | |
| 9e8e3f | a | 94c6ab9c ff1c5e72 | a | |

Sample Data

| | | | | | | | | |
|--------|--|---|--|----------|----------|--|---|--|
| 9e8e67 | | a | | 969059a6 | 799c5e72 | | a | |
| 9e8e90 | | a | | c4dfccef | 425c5e72 | | a | |
| 9e8eba | | 5 | | 3a7fc2c3 | 575c5e72 | | a | |
| 9e8ee5 | | 5 | | 57985401 | 69dc5e72 | | a | |
| 9e8f11 | | 5 | | 0ae2a363 | 623c5e72 | | a | |
| 9e8f3e | | a | | d12d8ee7 | 1f3c5e72 | | a | |
| 9e8f6c | | 5 | | 547063a8 | 0dbc5e72 | | a | |
| 9e8f9b | | 5 | | 063ff6e1 | 367c5e72 | | a | |
| 9e8fcb | | a | | c9bc5cfe | f4fc5e72 | | a | |
| 9e8ffc | | 5 | | 2cf00bec | cffc5e72 | | a | |
| 9e902e | | a | | 8ec5052f | 5d025e72 | | a | |
| 9e9061 | | 5 | | 1074b15e | 61825e72 | | a | |
| 9e9095 | | a | | 9d59ede6 | 2a425e72 | | a | |
| 9e90ca | | a | | f0be7b24 | 14c25e72 | | a | |
| 9e9100 | | 5 | | 10e10dd0 | c0225e72 | | a | |
| 9e9137 | | a | | f5ad5ac2 | fb225e72 | | a | |
| 9e916f | | a | | f7fba8f8 | 7da25e72 | | a | |
| 9e91a8 | | 5 | | 2f490e5b | c5625e72 | | a | |
| 9e91e2 | | a | | 94979982 | 91e25e72 | | a | |
| 9e921d | | 5 | | 26cda478 | 2e125e72 | | a | |
| 9e9259 | | a | | aacb81dd | 26925e72 | | a | |
| 9e9296 | | a | | bfac7f5b | da525e72 | | a | |
| 9e92d4 | | a | | c9a7b0a7 | cad25e72 | | a | |
| 9e9313 | | a | | c142bdde | 32325e72 | | a | |
| 616cec | | 5 | | 586a491f | 0dcda18d | | 5 | |
| 616ceb | | 5 | | 37db2de7 | b5cda18d | | 5 | |
| 616ce9 | | 5 | | 7d056ab7 | 65cda18d | | 5 | |
| 616ce6 | | a | | df61566a | 99cda18d | | 5 | |
| 616ce2 | | 5 | | 6fb2fb63 | 51cda18d | | 5 | |
| 616cdd | | 5 | | 472bf454 | 2ecda18d | | 5 | |
| 616cd7 | | a | | c020eb21 | bacda18d | | 5 | |
| 616cd0 | | a | | af918fd9 | 02cda18d | | 5 | |
| 616cc8 | | a | | 9112f54f | 44cda18d | | 5 | |
| 616cbf | | 5 | | 488b2af1 | bf4da18d | | 5 | |
| 616cb5 | | a | | cf803584 | 2b4da18d | | 5 | |
| 616caa | | a | | 9eb22bea | d54da18d | | 5 | |
| 616c9e | | a | | a49cb509 | 9e4da18d | | 5 | |
| 616c91 | | 5 | | 06f889d4 | 624da18d | | 5 | |
| 616c83 | | a | | bf70ec37 | b04da18d | | 5 | |
| 616c74 | | a | | ed3f797e | 8b8da18d | | 5 | |
| 616c64 | | 5 | | 1e695bcd | 898da18d | | 5 | |
| 616c53 | | a | | fb250cdf | b28da18d | | 5 | |
| 616c41 | | 5 | | 42ad693c | 608da18d | | 5 | |
| 616c2e | | a | | a5b7cc14 | dd0da18d | | 5 | |
| 616c1a | | a | | 9f9952f7 | 960da18d | | 5 | |
| 616c05 | | a | | ceab4c99 | 680da18d | | 5 | |
| 616bef | | a | | d403ddde | fdf5a18d | | 5 | |
| 616bd8 | | 5 | | 314f8acc | c6f5a18d | | 5 | |
| 616bc0 | | 5 | | 0fccf05a | 80f5a18d | | 5 | |
| 616ba7 | | 5 | | 25030d57 | 7975a18d | | 5 | |
| 616b8d | | a | | dba3037b | 6c75a18d | | 5 | |
| 616b72 | | 5 | | 4439ce17 | 13b5a18d | | 5 | |

Sample Data

| | | | | | | | |
|--------|--|---|--|-------------------|--|---|--|
| 616b56 | | a | | 8d417247 5ab5a18d | | 5 | |
| 616b39 | | 5 | | 6a5bd76f e735a18d | | 5 | |
| 616b1b | | 5 | | 592e8166 b635a18d | | 5 | |
| 616afc | | 5 | | 28609d46 cfd5a18d | | 5 | |
| 616adc | | 5 | | 51cb8c1f 4ed5a18d | | 5 | |
| 616abb | | 5 | | 7b047112 b755a18d | | 5 | |
| 616a99 | | 5 | | 4871271b e655a18d | | 5 | |
| 616a76 | | 5 | | 24bdc8c4 9b95a18d | | 5 | |
| 616a52 | | a | | edc57494 d295a18d | | 5 | |
| 616a2d | | a | | f989f30f 6d15a18d | | 5 | |
| 616a07 | | 5 | | 0729fd23 7815a18d | | 5 | |
| 6169e0 | | a | | 8bf0ba4f 81e5a18d | | 5 | |
| 6169b8 | | a | | 89a64875 0765a18d | | 5 | |
| 61698f | | 5 | | 6cealf67 3c65a18d | | 5 | |
| 616965 | | 5 | | 2549d310 29a5a18d | | 5 | |
| 61693a | | 5 | | 48ae45d2 1725a18d | | 5 | |
| 61690e | | 5 | | 7280db31 5c25a18d | | 5 | |
| 6168e1 | | a | | ce1b9f34 61c5a18d | | 5 | |
| 6168b3 | | 5 | | 4b46727b 7345a18d | | 5 | |
| 616884 | | a | | ae0a2569 4845a18d | | 5 | |
| 616854 | | a | | ea5fc581 4a85a18d | | 5 | |
| 616823 | | 5 | | 33c61a3f b105a18d | | 5 | |
| 6167f1 | | a | | c49fb8c5 63f9a18d | | 5 | |
| 6167be | | 5 | | 5a2e0cb4 5f79a18d | | 5 | |
| 61678a | | 5 | | 60009257 1479a18d | | 5 | |
| 616755 | | a | | 86314e62 eab9a18d | | 5 | |
| 61671f | | 5 | | 3defd9bb be39a18d | | 5 | |
| 6166e8 | | a | | bff7e728 c5d9a18d | | 5 | |
| 6166b0 | | a | | bda11512 4359a18d | | 5 | |
| 616677 | | 5 | | 6513b3b1 fb99a18d | | 5 | |
| 61663d | | a | | dec2468 af19a18d | | 5 | |
| 616602 | | a | | f6542b5f d019a18d | | 5 | |
| 6165c6 | | a | | dc44b49b d8e9a18d | | 5 | |
| 616589 | | 5 | | 42f500ea e469a18d | | 5 | |
| 61654b | | a | | bf2885e1 34a9a18d | | 5 | |
| 61650c | | a | | ec4c69b5 4c29a18d | | 5 | |



4 HEC AND PACKET HEADER SAMPLE DATA

This section contains examples of HECs computed for sample UAP and packet header contents (Data). The resulting 54 bit packet headers are shown in the rightmost column. Note that the UAP, Data and HEC values are in hexadecimal notation, while the header is in octal notation. The header is transmitted from left to right over the air.

| UAP | Data | HEC | Header (octal) |
|-------|------|-----|----------------------|
| ----- | | | |
| 00 | 123 | e1 | 770007 007070 000777 |
| 47 | 123 | 06 | 770007 007007 700000 |
| 00 | 124 | 32 | 007007 007007 007700 |
| 47 | 124 | d5 | 007007 007070 707077 |
| 00 | 125 | 5a | 707007 007007 077070 |
| 47 | 125 | bd | 707007 007070 777707 |
| 00 | 126 | e2 | 077007 007007 000777 |
| 47 | 126 | 05 | 077007 007070 700000 |
| 00 | 127 | 8a | 777007 007007 070007 |
| 47 | 127 | 6d | 777007 007070 770770 |
| 00 | 11b | 9e | 770770 007007 777007 |
| 47 | 11b | 79 | 770770 007070 077770 |
| 00 | 11c | 4d | 007770 007070 770070 |
| 47 | 11c | aa | 007770 007007 070707 |
| 00 | 11d | 25 | 707770 007070 700700 |
| 47 | 11d | c2 | 707770 007007 000077 |
| 00 | 11e | 9d | 077770 007070 777007 |
| 47 | 11e | 7a | 077770 007007 077770 |
| 00 | 11f | f5 | 777770 007070 707777 |
| 47 | 11f | 12 | 777770 007007 007000 |





5 CRC SAMPLE DATA

This section shows the CRC computed for a sample 10 byte payload and a UAP of 0x47.

Data:

```
data[0] = 0x4e
data[1] = 0x01
data[2] = 0x02
data[3] = 0x03
data[4] = 0x04
data[5] = 0x05
data[6] = 0x06
data[7] = 0x07
data[8] = 0x08
data[9] = 0x09
```

UAP = 0x47

==> CRC = 6d d2

Codeword (hexadecimal notation):

4e 01 02 03 04 05 06 07 08 09 6d d2

NB: Over the air each byte in the codeword
is sent with the LSB first.





6 COMPLETE SAMPLE PACKETS

6.1 EXAMPLE OF DH1 PACKET

Packet header: (MSB...LSB)

LT_ADDR = 011

TYPE = 0100 (DH1)

FLOW = 0

ARQN = 1

SEQN = 0

Payload: (MSB...LSB)

payload length: 5 bytes

logical channel = 10 (UA/I, Start L2CAP message)

flow = 1

data byte 1 = 00000001

data byte 2 = 00000010

data byte 3 = 00000011

data byte 4 = 00000100

data byte 5 = 00000101

HEC and CRC initialization: (MSB...LSB)

uap = 01000111

NO WHITENING USED

AIR DATA (LSB...MSB)

Packet header (incl HEC):

111111000

000000111000

000111000

00011111100000000000000000

Payload (incl payload header and CRC):

01110100

10000000

01000000

11000000

00100000

10100000

1110110000110110



6.2 EXAMPLE OF DM1 PACKET

Packet header: (MSB...LSB)

LT_ADDR = 011

TYPE = 0011 (DM1)

FLOW = 0

ARQN = 1

SEQN = 0

Payload: (MSB...LSB)

payload length: 5 bytes

logical channel = 10 (UA/I, Start L2CAP message)

flow = 1

data byte 1 = 00000001

data byte 2 = 00000010

data byte 3 = 00000011

data byte 4 = 00000100

data byte 5 = 00000101

HEC and CRC initialization: (MSB...LSB)

uap = 01000111

NO WHITENING USED

AIR DATA (LSB...MSB)

Packet header (incl HEC):

111111000

111111000000

000111000

11100000011111111111000

Payload (incl payload header, FEC23, CRC and 6 padded zeros):

0111010010 11001

0000000100 01011

0000110000 11110

0000100000 00111

1010000011 01100

1011000011 00010

0110000000 10001

7 WHITENING SEQUENCE SAMPLE DATA

This section shows the output of the whitening sequence generator.

| Whitening Sequence (=D7) | Whitening LFSR D7.....D0 |
|--------------------------------|--------------------------------|
| 1 | 11111111 |
| 1 | 11011111 |
| 1 | 10011111 |
| 0 | 00011111 |
| 0 | 00111110 |
| 0 | 01111100 |
| 1 | 11110000 |
| 1 | 11000001 |
| 1 | 10100111 |
| 0 | 01101111 |
| 1 | 11011110 |
| 1 | 10011101 |
| 0 | 00010111 |
| 0 | 00101110 |
| 0 | 01011100 |
| 1 | 10110000 |
| 0 | 01000001 |
| 1 | 10000101 |
| 0 | 00101011 |
| 0 | 01010110 |
| 1 | 10101010 |
| 0 | 01110011 |
| 1 | 11100110 |
| 1 | 11101011 |
| 1 | 11110111 |
| 1 | 11001111 |
| 1 | 10111111 |
| 0 | 01011111 |
| 1 | 10111110 |
| 0 | 01011101 |
| 1 | 10110110 |
| 0 | 01001011 |
| 1 | 10010110 |
| 0 | 00001011 |
| 0 | 00010110 |
| 0 | 00101100 |
| 0 | 01010000 |
| 1 | 10100000 |
| 0 | 01100001 |
| 1 | 11000101 |
| 1 | 10101011 |
| 0 | 01110111 |
| 1 | 11101110 |

Sample Data

| | |
|---|---------|
| 1 | 1111101 |
| 1 | 1101011 |
| 1 | 1000111 |
| 0 | 0011111 |
| 0 | 0111110 |
| 1 | 1111100 |
| 1 | 1101001 |
| 1 | 1000011 |
| 0 | 0010111 |
| 0 | 0101110 |
| 1 | 1011100 |
| 0 | 0101001 |
| 1 | 1010010 |
| 0 | 0110101 |
| 1 | 1101010 |
| 1 | 1000101 |
| 0 | 0011011 |
| 0 | 0110110 |
| 1 | 1101100 |
| 1 | 1001001 |
| 0 | 0000011 |
| 0 | 0000110 |
| 0 | 0001100 |
| 0 | 0011000 |
| 0 | 0110000 |
| 1 | 1100000 |
| 1 | 1010001 |
| 0 | 0110011 |
| 1 | 1100110 |
| 1 | 1011101 |
| 0 | 0101011 |
| 1 | 1010110 |
| 0 | 0111101 |
| 1 | 1111010 |
| 1 | 1100101 |
| 1 | 1011011 |
| 0 | 0100111 |
| 1 | 1001110 |
| 0 | 0001101 |
| 0 | 0011010 |
| 0 | 0110100 |
| 1 | 1101000 |
| 1 | 1000001 |
| 0 | 0010011 |
| 0 | 0100110 |
| 1 | 1001100 |
| 0 | 0001001 |
| 0 | 0010010 |
| 0 | 0100100 |
| 1 | 1001000 |
| 0 | 0000001 |
| 0 | 0000010 |

Sample Data

| | |
|---|---------|
| 0 | 0000100 |
| 0 | 0001000 |
| 0 | 0010000 |
| 0 | 0100000 |
| 1 | 1000000 |
| 0 | 0010001 |
| 0 | 0100010 |
| 1 | 1000100 |
| 0 | 0011001 |
| 0 | 0110010 |
| 1 | 1100100 |
| 1 | 1011001 |
| 0 | 0100011 |
| 1 | 1000110 |
| 0 | 0011101 |
| 0 | 0111010 |
| 1 | 1110100 |
| 1 | 1111001 |
| 1 | 1100011 |
| 1 | 1010111 |
| 0 | 0111111 |
| 1 | 1111110 |
| 1 | 1101101 |
| 1 | 1001011 |
| 0 | 0000111 |
| 0 | 0001110 |
| 0 | 0011100 |
| 0 | 0111000 |
| 1 | 1110000 |
| 1 | 1110001 |
| 1 | 1110011 |
| 1 | 1110111 |
| 1 | 1111111 |



8 FEC SAMPLE DATA

=====
Rate 2/3 FEC -- (15,10) Shortened Hamming Code
=====

Data is in hexadecimal notation, the codewords are in binary notation. The codeword bits are sent from left to right over the air interface. The space in the codeword indicates the start of parity bits.

| Data: | Codeword: |
|-------|------------------|
| 0x001 | 1000000000 11010 |
| 0x002 | 0100000000 01101 |
| 0x004 | 0010000000 11100 |
| 0x008 | 0001000000 01110 |
| 0x010 | 0000100000 00111 |
| 0x020 | 0000010000 11001 |
| 0x040 | 0000001000 10110 |
| 0x080 | 0000000100 01011 |
| 0x100 | 0000000010 11111 |
| 0x200 | 0000000001 10101 |





9 ENCRYPTION KEY SAMPLE DATA

Explanation:

For the sections 9.1 - 9.5, the hexadecimal sample data is written with the least significant byte at the leftmost position and the most significant byte at the rightmost position. Within each byte, the *least significant bit* (LSB) is at the rightmost position and the *most significant bit* (MSB) is at the leftmost position. Thus, a line reading:

aco: 48afcdd4bd40fef76693b113

means aco[0]=0x48, ac[1]=0xaf, ..., aco[11]=0x13. The LSB of aco[11] is '1' and the MSB of aco[11] is '0'.

Key [i]: denotes the ith sub-key in Ar or A'r;
 round r: denotes the input to the rth round;
 added ->: denotes the input to round 3 in
 A'r after adding original input (of round 1).

9.1 FOUR TESTS OF E1

```

rand      :00000000000000000000000000000000
address   :000000000000
key       :00000000000000000000000000000000
round  1:00000000000000000000000000000000
Key [ 1]:00000000000000000000000000000000
Key [ 2]:4697b1baa3b7100ac537b3c95a28ac64
round  2:78d19f9307d2476a523ec7a8a026042a
Key [ 3]:ecabaac66795580df89af66e66dc053d
Key [ 4]:8ac3d8896ae9364943bfebd4969b68a0
round  3:600265247668dda0e81c07bbb30ed503
Key [ 5]:5d57921fd5715cbb22c1be7bbc996394
Key [ 6]:2a61b8343219fdfb1740e6511d41448f
round  4:d7552ef7cc9dbde568d80c2215bc4277
Key [ 7]:dd0480dee731d67f01a2f739da6f23ca
Key [ 8]:3ad01cd1303e12a1cd0fe0a8af82592c
round  5:fb06bef32b52ab8f2a4f2b6ef7f6d0cd
Key [ 9]:7dadb2efc287ce75061302904f2e7233
Key [10]:c08dcfa981e2c4272f6c7a9f52e11538
round  6:b46b711ebb3cf69e847a75f0ab884bdd
Key [11]:fc2042c708e409555e8c147660ffdfd7
Key [12]:fa0b21001af9a6b9e89e624cd99150d2
round  7:c585f308ff19404294f06b292e978994
Key [13]:18b40784ea5ba4c80ecb48694b4e9c35
Key [14]:454d54e5253c0c4a8b3fcca7db6baef4
round  8:2665fadbf13acf952bf74b4ab12264b9f
Key [15]:2df37c6d9db52674f29353b0f011ed83
Key [16]:b60316733b1e8e70bd861b477e2456f1
Key [17]:884697b1baa3b7100ac537b3c95a28ac

```

Sample Data

```

round  1:158ffe43352085e8a5ec7a88e1ff2ba8
Key [ 1]:e9e5dfc1b3a79583e9e5dfc1b3a79583
Key [ 2]:7595bf57e0632c59f435c16697d4c864
round  2:0b5cc75febcdf7827ca29ec0901b6b5b
Key [ 3]:e31b96afcc75d286ef0ae257cbbc05b7
Key [ 4]:0d2a27b471bc0108c6263aff9d9b3b6b
round  3:e4278526c8429211f7f2f0016220aef4
added  ->:f1b68365fd6217f952de6a89831fd95c
Key [ 5]:98d1eb5773cf59d75d3b17b3bc37c191
Key [ 6]:fd2b79282408ddd4ea0aa7511133336f
round  4:d0304ad18337f86040145d27aa5c8153
Key [ 7]:331227756638a41d57b0f7e071ee2a98
Key [ 8]:aa0dd8cc68b406533d0f1d64aabacf20
round  5:84db909d213bb0172b8b6aaf71bf1472
Key [ 9]:669291b0752e63f806fce76f10e119c8
Key [10]:ef8bdd46be8ee0277e9b78adef1ec154
round  6:f835f52921e903dfa762f1df5abd7f95
Key [11]:f3902eb06dc409cfd78384624964bf51
Key [12]:7d72702b21f97984a721c99b0498239d
round  7:ae6c0b4bb09f25c6a5d9788a31b605d1
Key [13]:532e60bceaf902c52a06c2c283ecfa32
Key [14]:181715e5192efb2a64129668cf5d9dd4
round  8:744a6235b86cc0b853cc9f74f6b65311
Key [15]:83017c1434342d4290e961578790f451
Key [16]:2603532f365604646ff65803795ccce5
Key [17]:882f7c907b565ea58dae1c928a0dcf41
sres    :056c0fe6
aco     :48afcd4bd40fef76693b113
-----
rand    :bc3f30689647c8d7c5a03ca80a91eceb
address :7ca89b233c2d
key     :159dd9f43fc3d328efba0cd8a861fa57
round  1:bc3f30689647c8d7c5a03ca80a91eceb
Key [ 1]:159dd9f43fc3d328efba0cd8a861fa57
Key [ 2]:326558b3c15551899a97790e65ff669e
round  2:3e950edf197615638cc19c09f8fedc9b
Key [ 3]:62e879b65b9f53bbfbd020c624b1d682
Key [ 4]:73415f30bac8ab61f410adc9442992db
round  3:6a7640791cb536678936c5ecd4ae5a73
Key [ 5]:5093cfa1d31c1c48acd76df030ea3c31
Key [ 6]:0b4acc2b8f1f694fc7bd91f4a70f3009
round  4:fca2c022a577e2ffb2aa007589693ec7
Key [ 7]:2ca43fc817947804ecff148d50d6f6c6
Key [ 8]:3fcd73524b533e00b7f7825bea2040a4
round  5:e97f8ea4ed1a6f4a36ffc179dc6bb563
Key [ 9]:6c67bec76ae8c8cc4d289f69436d3506
Key [10]:95ed95ee8cb97e61d75848464bffb379
round  6:38b07261d7340d028749de1773a415c7
Key [11]:ff566c1fc6b9da9ac502514550f3e9d2
Key [12]:ab5ce3f5c887d0f49b87e0d380e12f47
round  7:58241f1aed7c1c3e047d724331a0b774
Key [13]:a2cab6f95eac7d655dbe84a6cd4c47f5

```


Sample Data

```

Key [14]:f5caff88af0af8c42a20b5bbd2c8b460
round 8:3d1aaeff53c0910de63b9788b13c490f
Key [15]:185099c1131cf97001e2f36fda415025
Key [16]:a0ebb82676bc75e8378b189eff3f6b1d
Key [17]:cf5b348aaee27ae332b4f1bfa10289a6
round 1:2e4b417b9a2a9cfd7d8417d9a6a556eb
Key [ 1]:fe78b835f26468ab069fd3991b086fda
Key [ 2]:095c5a51c6fa6d3ac1d57fa19aa382bd
round 2:b8bca81d6bb45af9d92beadd9300f5ed
Key [ 3]:1af866df817fd9f4ec00bc704192cfff
Key [ 4]:f4a8a059c1f575f076f5fbb24bf16590
round 3:351aa16dec2c3a4787080249ed323eae
added ->:1b65e2167656d6bafa8c19904bd79445
Key [ 5]:8c9d18d9356a9954d341b4286e88ea1f
Key [ 6]:5c958d370102c9881bf753e69c7da029
round 4:2ce8fef47dda6a5bee74372e33e478a2
Key [ 7]:7eb2985c3697429fbe0da334bb51f795
Key [ 8]:af900f4b63a1138e2874bfb7c628b7b8
round 5:572787f563e1643c1c862b7555637fb4
Key [ 9]:834c8588dd8f3d4f31117a488420d69b
Key [10]:bc2b9b81c15d9a80262f3f48e9045895
round 6:16b4968c5d02853c3a43aa4cdb5f26ac
Key [11]:f08608c9e39ad3147cba61327919c958
Key [12]:2d4131decf4fa3a959084714a9e85c11
round 7:10e4120c7cccef9dd4ba4e6da8571b01
Key [13]:c934fd319c4a2b5361fa8eef05ae9572
Key [14]:4904c17aa47868e40471007cde3a97c0
round 8:f9081772498fed41b6ffd72b71fcf6c6
Key [15]:ea5e28687e97fa3f833401c86e6053ef
Key [16]:1168f58252c4ecfccafbdb3af857b9f2
Key [17]:b3440f69ef951b78b5cbd6866275301b
sres      :8d5205c5
aco       :3ed75df4abd9af638d144e94
-----
rand      :0891caee063f5da1809577ff94ccdcfb
address   :c62f19f6ce98
key       :45298d06e46bac21421ddfbcd94c032b
round 1:0891caee063f5da1809577ff94ccdcfb
Key [ 1]:45298d06e46bac21421ddfbcd94c032b
Key [ 2]:8f03e1e1fe1c191cad35a897bc400597
round 2:1c6ca013480a685c1b28e0317f7167e1
Key [ 3]:4f2ce3a092dde854ef496c8126a69e8e
Key [ 4]:968caee2ac6d7008c07283daec67f2f2
round 3:06b4915f5fcc1fc551a52048f0af8a26
Key [ 5]:ab0d5c31f94259a6bf85ee2d22edf56c
Key [ 6]:dfb74855c0085ce73dc17b84bfd50a92
round 4:077a92b040acc86e6e0a877db197a167
Key [ 7]:8f888952662b3db00d4e904e7ea53b5d
Key [ 8]:5e18bfcc07799b0132db88cd6042f599
round 5:7204881fb300914825fdc863e8ceadf3
Key [ 9]:bfca91ad9bd3d1a06c582b1d5512dddf
Key [10]:a88bc477e3fa1d5a59b5e6cf793c7a41

```

Sample Data

```

round 6:27031131d86cea2d747deb4f756143aa
Key [11]:f3cfb8dac8aea2a6a8ef95af3a2a2767
Key [12]:77beb90670c5300b03aa2b2232d3d40c
round 7:fc8c13d49149b1ce8d86f96e44a00065
Key [13]:b578373650af36a06e19fe335d726d32
Key [14]:6bcee918c7d0d24dfdf42237fcf99d53
round 8:04ef5f5a7ddf846cda0a07782fc23866
Key [15]:399f158241eb3e079f45d7b96490e7ea
Key [16]:1bcfbe98ecde2add52aa63ea79fb917a
Key [17]:ee8bc03ec08722bc2b075492873374af
round 1:d989d7a40cde7032d17b52f8117b69d5
Key [ 1]:2ecc6cc797cc41a2ab02007f6af396ae
Key [ 2]:acfaef7609c12567d537aefcf9dc2198
round 2:8e76eb9a29b2ad5eea790db97aee37c1
Key [ 3]:079c8ff9b73d428df879906a0b87a6c8
Key [ 4]:19f2710baf403a494193d201f3a8c439
round 3:346bb7c35b2539676375aafe3af69089
added ->:edf48e675703a955b2f0fc062b71f95c
Key [ 5]:d623a6498f915cb2c8002765247b2f5a
Key [ 6]:900109093319bc30108b3d9434a77a72
round 4:fafb6c1f3ebbd2477be2da49dd923f69
Key [ 7]:e28e2ee6e72e7f4e5b5c11f10d204228
Key [ 8]:8e455cd11f8b9073a2dfa5413c7a4bc5
round 5:7c72230df588060a3cf920f9b0a08f06
Key [ 9]:28afb26e2c7a64238c41cefcd16c53e74
Key [10]:d08dcafc2096395ba0d2ddd0e471f4d
round 6:55991df991db26ff00073a12baa3031d
Key [11]:fcffdcc3ad8faae091a7055b934f87c1
Key [12]:f8df082d77060252c02d91e55bd6a7d6
round 7:70ec682ff864375f63701fa4f6be5377
Key [13]:bef3706e523d708e8a44147d7508bc35
Key [14]:3e98ab283ca2422d56a56cf8b06caeb3
round 8:172f12ec933da85504b4ea5c90f8f0ea
Key [15]:87ad9625d06645d22598dd5ef811ea2c
Key [16]:8bd3db0cc8168009e5da90877e13a36f
Key [17]:0e74631d813a8351ac7039b348c41b42
sres      :00507e5f
aco       :2a5f19fbf60907e69f39ca9f
-----
rand      :0ecd61782b4128480c05dc45542b1b8c
address   :f428f0e624b3
key       :35949a914225fabad91995d226de1d92
round 1:0ecd61782b4128480c05dc45542b1b8c
Key [ 1]:35949a914225fabad91995d226de1d92
Key [ 2]:ea6b3dcccc8ee5d88de349fa5010404f
round 2:8935e2e263fbc4b9302cabdfc06bce3e
Key [ 3]:920f3a0f2543ce535d4e7f25ad80648a
Key [ 4]:ad47227edf9c6874e80ba80ebb95d2c9
round 3:b4c8b878675f184a0c72f3dab51f8f05
Key [ 5]:81a941ca7202b5e884ae8fa493ecac3d
Key [ 6]:bcde1520bee3660e86ce2f0fb78b9157
round 4:77ced9f2fc42bdd5c6312b87fc2377c5

```

Sample Data

```

Key [ 7]:c8eee7423d7c6efa75ecec0d2cd969d3
Key [ 8]:910b3f838a02ed441fbe863a02b4a1d0
round 5:fe28e8056f3004d60bb207e628b39cf2
Key [ 9]:56c647c1e865eb078348962ae070972d
Key [10]:883965da77ca5812d8104e2b640aec0d
round 6:1f2ba92259d9e88101518f145a33840f
Key [11]:61d4cb7e4f8868a283327806a9bd8d4d
Key [12]:9f57de3a3ff310e21dc1e696ce060304
round 7:cc9b5d0218d29037e88475152ebebb2f
Key [13]:7aa1d8adc1aeed7127ef9a18f6eb2d8e
Key [14]:b4db9da3bf865912acd14904c7f7785d
round 8:b04d352bedc02682e4a7f59d7cda1dba
Key [15]:a13d7141ef1f6c7d867e3d175467381b
Key [16]:08b2bc058e50d6141cdd566a307e1acc
Key [17]:057b2b4b4be5dc0ac49e50489b8006c9
round 1:5cfacc773bae995cd7f1b81e7c9ec7df
Key [ 1]:1e717950f5828f3930fe4a9395858815
Key [ 2]:d1623369b733d98bbc894f75866c544c
round 2:d571ffa21d9daa797b1a0a3c962fc64c
Key [ 3]:4abf27664ae364cc8a7e5bcf88214cc4
Key [ 4]:2aaedda8dc4933dd6aeaf6e5c0d5a482
round 3:e17c8e498a00f125bf654c938c23f36d
added ->:bd765a3eb1ae8a796856048df0c1bab2
Key [ 5]:bc7f8ab2d86000f47b1946cc8d7a7a2b
Key [ 6]:6b28544cb13ec6c5d98470df2cf900b7
round 4:a9727c26f2f06bd9920e83c8605dcd76
Key [ 7]:1be840d9107f2c9523f66bb19f5464a1
Key [ 8]:61d6fb1aa2f0c2b26fb2a3d6de8c177c
round 5:aeff751f146eab7e4626b2e2c9e2fb39
Key [ 9]:adabfc82570c568a233173099f23f4c2
Key [10]:b7df6b55ad266c0f1ff7452101f59101
round 6:cf412b95f454d5185e67ca671892e5bd
Key [11]:8e04a7282a2950dcbaea28f300e22de3
Key [12]:21362c114433e29bda3e4d51f803b0cf
round 7:16165722fe4e07ef88f8056b17d89567
Key [13]:710c8fd5bb3cbb5f132a7061de518bd9
Key [14]:0791de7334f4c87285809343f3ead3bd
round 8:28854cd6ad4a3c572b15490d4b81bc3f
Key [15]:4f47f0e5629a674bfcd13770eb3a3bd9
Key [16]:58a6d9a16a284cc0aead2126c79608a1
Key [17]:a564082a0a98399f43f535fd5cefad34
sres      :80e5629c
aco       :a6fe4dcde3924611d3cc6ba1

```

=====

Sample Data**9.2 FOUR TESTS OF E21**

```

rand      :00000000000000000000000000000000
address   :000000000000
round    1:00000000000000000000000000000000
Key [ 1]:00000000000000000000000000000000
Key [ 2]:4697b1baa3b7100ac537b3c95a28dc94
round    2:98611307ab76bbde9a86af1ce8cad412
Key [ 3]:ecabaac66795580df89af66e665d863d
Key [ 4]:8ac3d8896ae9364943bfebd4a2a768a0
round    3:820999ad2e6618f4b578974beedf9e7
added ->:820999ad2e6618f4b578974beedf9e7
Key [ 5]:5d57921fd5715cbb22c1bedb1c996394
Key [ 6]:2a61b8343219fdfb1740e9541d41448f
round    4:acd6edec87581ac22dbdc64ea4ced3a2
Key [ 7]:dd0480dee731d67f01ba0f39da6f23ca
Key [ 8]:3ad01cd1303e12a18dcfe0a8af82592c
round    5:1c7798732f09fbfe25795a4a2fbc93c2
Key [ 9]:7dadb2efc287ce7b0c1302904f2e7233
Key [10]:c08dcfa981e2f4572f6c7a9f52e11538
round    6:c05b88b56aa70e9c40c79bb81cd911bd
Key [11]:fc2042c708658a555e8c147660ffdfdf7
Key [12]:fa0b21002605a6b9e89e624cd99150d2
round    7:abacc71b481c84c798d1bdf3d62f7e20
Key [13]:18b407e44a5ba4c80ecb48694b4e9c35
Key [14]:454d57e8253c0c4a8b3fcca7db6baef4
round    8:e8204e1183ae85cf19edb2c86215b700
Key [15]:2d0b946d9db52674f29353b0f011ed83
Key [16]:76c316733b1e8e70bd861b477e2456f1
Key [17]:8e4697b1baa3b7100ac537b3c95a28ac
Ka        :d14ca028545ec262cee700e39b5c39ee
-----
rand      :2dd9a550343191304013b2d7e1189d09
address   :cac4364303b6
round    1:cac4364303b6cac4364303b6cac43643
Key [ 1]:2dd9a550343191304013b2d7e1189d0f
Key [ 2]:14c4335b2c43910c5dcc71d81a14242b
round    2:e169f788aad45a9011f11db5270b1277
Key [ 3]:55bfb712cba168d1a48f6e74cd9f4388
Key [ 4]:2a2b3aacca695caef2821b0fb48cc253
round    3:540f9c76652e92c44987c617035037bf
added ->:9ed3d23566e45c007fcac9a1c9146dfc
Key [ 5]:a06aab22d9a287384042976b4b6b00ee
Key [ 6]:c229d054bb72e8eb230e6dcdb32d16b7
round    4:83659a41675f7171ea57909dc5a79ab4
Key [ 7]:23c4812ab1905ddf77dedaed4105649a
Key [ 8]:40d87e272a7a1554ae2e85e3638cdf52
round    5:0b9382d0ed4f2fccdbb69d0db7b130a4
Key [ 9]:bdc064c6a39f6b84fe40db359f62a3c4
Key [10]:58228db841ce3cee983aa721f36aa1b9
round    6:c6ebda0f8f489792f09c189568226c1f
Key [11]:a815bacd6fa747a0d4f52883ac63ebe7

```

Sample Data

```

Key [12]:a9ce513b38ea006c333ecaaefcf1d0f8
round 7:75a8aba07e69c9065bcd831c40115116
Key [13]:3635e074792d4122130e5b824e52cd60
Key [14]:511bdb61bb28de72a5d794bffb407df
round 8:57a6e279dcb764cf7dd6a749dd60c735
Key [15]:a32f5f21044b6744b6d913b13cdb4c0a
Key [16]:9722bbaeef281496ef8c23a9d41e92f4
Key [17]:807370560ad7e8a13a054a65a03b4049
Ka      :e62f8bac609139b3999aedbc9d228042
-----
rand    :dab3cffe9d5739d1b7bf4a667ae5ee24
address :02f8fd4cd661
round 1:02f8fd4cd66102f8fd4cd66102f8fd4c
Key [ 1]:dab3cffe9d5739d1b7bf4a667ae5ee22
Key [ 2]:e315a8a65d809ec7c289e69c899fbdcc
round 2:ef85ff081b8709405e19f3e275cec7dc
Key [ 3]:df6a119bb50945f8c8a3394e7216448f3
Key [ 4]:87fe86fb0d58b5dd0fb3b6b1dab51d07
round 3:aa25c21bf577d92dd97381e3e9edcc54
added ->:a81dbf5723d8dbd524bf5782ebe5c918
Key [ 5]:36cc253c506c0021c91fac9d8c469e90
Key [ 6]:d5fda00f113e303809b7f7d78a1a2b0e
round 4:9e69ce9b53caec3990894d2baed41e0d
Key [ 7]:c14b5edc10cabf16bc2a2ba4a8ae1e40
Key [ 8]:74c6131afc8dce7e11b03b1ea8610c16
round 5:a5460fa8cedca48a14fd02209e01f02e
Key [ 9]:346cfc553c6cbc9713edb55f4dcbc96c
Key [10]:bddf027cb059d58f0509f8963e9bdec6
round 6:92b33f11eadcacc5a43dd05f13d334dd
Key [11]:8eb9e040c36c4c0b4a7fd3dd354d53c4
Key [12]:c6ffecdd5e135b20879b9dfa4b34bf51
round 7:fb0541aa5e5df1a61c51aef606eb5a41
Key [13]:bf12f5a6ba08dfc4fda4bdfc68c997d9
Key [14]:37c4656b9215f3c959ea688fb64ad327
round 8:f0bbd2b94ae374346730581fc77a9c98
Key [15]:e87bb0d86bf421ea4f779a8eee3a866c
Key [16]:faa471e934fd415ae4c0113ec7f0a5ad
Key [17]:95204a80b8400e49db7cf6fd2fd40d9a
Ka      :b0376d0a9b338c2e133c32b69cb816b3
-----
rand    :13ecad08ad63c37f8a54dc56e82f4dc1
address :9846c5ead4d9
round 1:9846c5ead4d99846c5ead4d99846c5ea
Key [ 1]:13ecad08ad63c37f8a54dc56e82f4dc7
Key [ 2]:ad04f127bed50b5e671d6510d392eaed
round 2:97374e18cdd0a6f7a5aa49d1ac875c84
Key [ 3]:57ad159e5774fa222f2f3039b9cd5101
Key [ 4]:9a1e9e1068fede02ef90496e25fd8e79
round 3:9dd3260373edd9d5f4e774826b88fd2d
added ->:0519ebe9a7c6719331d1485bf3cec2c7
Key [ 5]:378dce167db62920b0b392f7cfca316e
Key [ 6]:db4277795c87286faee6c9e9a6b71a93

```

Sample Data

```

round  4:40ec6563450299ac4e120d88672504d6
Key [ 7]:ec01aa2f5a8a793b36c1bb858d254380
Key [ 8]:2921a66cfa5bf74ac535424564830e98
round  5:57287bbb041bd6a56c2bd931ed410cd4
Key [ 9]:07018e45aab61b3c3726ee3d57dbd5f6
Key [10]:627381f0fa4c02b0c7d3e7dfbffc3333
round  6:66affa66a8dcd36e36bf6c3f1c6a276e
Key [11]:33b57c925bd5551999f716e138efbe79
Key [12]:a6dc7f9aa95bcc9243aebd12608f657a
round  7:450e65184fd8c72c578d5cdec286743
Key [13]:a6a6db00fd8c72a28ea57ea542f6e102
Key [14]:dcf3377daeb2e24e61f0ad6620951c1f
round  8:e5eb180b519a4e673f21b7c4f4573f3d
Key [15]:621240b9506b462a7fa250da41844626
Key [16]:ae297810f01f43dc35756cd119ee73d6
Key [17]:b959835ec2501ad3894f8b8f1f4257f9
Ka      :5b61e83ad04d23e9d1c698851fa30447
=====

```

9.3 THREE TESTS OF E22

(for K_master and overlay generation)

```

rand      :001de169248850245a5f7cc7f0d6d633
PIN       :d5a51083a04a1971f18649ea8b79311a
round  1:001de169248850245a5f7cc7f0d6d623
Key [ 1]:d5a51083a04a1971f18649ea8b79311a
Key [ 2]:7317cdbff57f9b99f9810a2525b17cc7
round  2:5f05c143347b59acae3cb00db23830f
Key [ 3]:f08bd258adf1d4ae4a54d8ccb26220b2
Key [ 4]:91046cbb4ccc43db18d6dd36ca7313eb
round  3:c8f3e3300541a25b6ac5a80c3105f3c4
added ->:c810c45921c9f27f302424cbc1dbc9e7
Key [ 5]:67fb2336f4d9f069da58d11c82f6bd95
Key [ 6]:4fed702c75bd72c0d3d8f38707134c50
round  4:bd5e0c3a97fa55b91a3bbbf306ebb978
Key [ 7]:41c947f80cdc0464c50aa89070af314c
Key [ 8]:680eecfa8daf41c7109c9a5cb1f26d75
round  5:21c1a762c3cc33e75ce8976a73983087
Key [ 9]:6e33fbd94d00ff8f72e8a7a0d2cebc4c
Key [10]:f4d726054c6b948add99fabb5733ddc3
round  6:56d0df484345582f6b574a449ba155eb
Key [11]:4eda2425546a24cac790f49ef2453b53
Key [12]:cf2213624ed1510408a5a3e00b7333df
round  7:120cf9963fe9ff22993f7fdf9600d9b8
Key [13]:d04b1a25b0b8fec946d5ecfa626d04c9
Key [14]:01e5611b0f0e140bdb64585fd3ae5269
round  8:a6337400ad8cb47fefb91332f5cb2713
Key [15]:f15b2dc433f534f61bf718770a3698b1
Key [16]:f990d0273d8ea2b9e0b45917a781c720
Key [17]:f41b3cc13d4301297bb6bdfcb3e5a1dd
Ka      :539e4f2732e5ae2de1e0401f0813bd0d

```

Sample Data

```

-----
rand      :67ed56bfcf99825f0c6b349369da30ab
PIN       :7885b515e84b1f082cc499976f1725ce
round 1:67ed56bfcf99825f0c6b349369da30bb
Key [ 1]:7885b515e84b1f082cc499976f1725ce
Key [ 2]:72445901fdaf506beb036f4412512248
round 2:6b160b66a1f6c26c1f3432f463ef5aa1
Key [ 3]:59f0e4982e97633e5e7fd133af8f2c5b
Key [ 4]:b4946ec77a41bf7c729d191e33d458ab
round 3:3f22046c964c3e5ca2a26ec9a76a9f67
added ->:580f5ad359e5c003ae0da25ace44cfdc
Key [ 5]:eb0b839f97bdf534183210678520bbef
Key [ 6]:cff0bc4a94e5c8b2a2d24d9f59031e19
round 4:87aa61fc0ff88e744c195249b9a33632
Key [ 7]:592430f14d8f93db95dd691af045776d
Key [ 8]:3b55b404222bf445a6a2ef5865247695
round 5:83dcf592a854226c4dcd94e1ecf1bc75
Key [ 9]:a9714b86319ef343a28b87456416bd52
Key [10]:e6598b24390b3a0bf2982747993b0d78
round 6:dee0d13a52e96bcf7c72045a21609fc6
Key [11]:62051d8c51973073bff959b032c6e1e2
Key [12]:29e94f4ab73296c453c833e217a1a85b
round 7:08488005761e6c7c4dbb203ae453fe3a
Key [13]:0e255970b3e2fc235f59fc5acb10e8ce
Key [14]:d0dfbb3361fee6d4ffe45babf1cd7abf
round 8:0d81e89bddde7a7065316c47574feb8f
Key [15]:c12eee4eb38b7a171f0f736003774b40
Key [16]:8f962523f1c0abd9a087a0dfb11643d3
Key [17]:24be1c66cf8b022f12f1fb4c60c93fd1
Ka        :04435771e03a9daceb8bb1a493ee9bd8
-----

rand      :40a94509238664f244ff8e3d13b119d3
PIN       :1ce44839badde30396d03c4c36f23006
round 1:40a94509238664f244ff8e3d13b119c3
Key [ 1]:1ce44839badde30396d03c4c36f23006
Key [ 2]:6dd97a8f91d628be4b18157af1a9dcba
round 2:0eac5288057d9947a24eabc1744c4582
Key [ 3]:fef9583d5f55fd4107ad832a725db744
Key [ 4]:fc3893507016d7c1db2bd034a230a069
round 3:60b424f1082b0cc3bd61be7b4c0155f0
added ->:205d69f82bb17031f9604c465fb26e33
Key [ 5]:0834d04f3e7e1f7f85f0c1db685ab118
Key [ 6]:1852397f9a3723169058e9b62bb3682b
round 4:2c6b65a49d66af6566675afdd6fa7d7d
Key [ 7]:6c10da21d762ae4ac1ba22a96d9007b4
Key [ 8]:9aa23658b90470a78d686344b8a9b0e7
round 5:a2c537899665113a42f1ac24773bdc31
Key [ 9]:137dee3bf879fe7bd02fe6d888e84f16
Key [10]:466e315a1863f47d0f93bc6827cf3450
round 6:e26982980d79b21ed3e20f8c3e71ba96
Key [11]:0b33cf831465bb5c979e6224d7f79f7c
Key [12]:92770660268ede827810d707a0977d73

```

Sample Data

```

round 7:e7b063c4e2e3110b89b7e1631c762dd5
Key [13]:7be30ae4961cf24ca17625a77bb7a9f8
Key [14]:be65574a33ae30e6e82dbd2826d3cc1a
round 8:7a963e37b2c2e76b489cfe40a2cf00e5
Key [15]:ed0ba7dd30d60a5e69225f0a33011e5b
Key [16]:765c990f4445e52b39e6ed6105ad1c4f
Key [17]:52627bf9f35d94f30d5b07ef15901adc
Ka      :9cde4b60f9b5861ed9df80858bac6f7f

```

```
=====
```

9.4 TESTS OF E22 WITH PIN AUGMENTING

for PIN lengths 1,...,16 bytes

```

rand      :24b101fd56117d42c0545a4247357048
PIN length =16 octets
PIN       :fd397c7f5c1f937cdf82d8816cc377e2
round 1:24b101fd56117d42c0545a4247357058
Key [ 1]:fd397c7f5c1f937cdf82d8816cc377e2
Key [ 2]:0f7aac9c9b53f308d9fdbf2c78e3c30e
round 2:838edfe1226266953ccba8379d873107
Key [ 3]:0b8ac18d4bb44fad2efa115e43945abc
Key [ 4]:887b16b062a83bfa469772c25b456312
round 3:8cd0c9283120aba89a7f9d635dd4fe3f
added ->:a881cad5673128ea5ad3f7211a096e67
Key [ 5]:2248cbe6d299e9d3e8fd35a91178f65b
Key [ 6]:b92af6237385bd31f8fb57fb1bdd824e
round 4:2648d9c618a622b10ef80c4dbaf68b99
Key [ 7]:2bf5ffe84a37878ede2d4c30be60203b
Key [ 8]:c9cb6cec60cb8a8f29b99fcf3e71e40f
round 5:b5a7d9e96f68b14ccebf361de3914d0f
Key [ 9]:5c2f8a702e4a45575b103b0cce8a91c6
Key [10]:d453db0c9f9d9dbd11e355d9a34d9b11b
round 6:632a091e7eefe1336857ddafd1ff3265
Key [11]:32805db7e59c5ed4acabf38d27e3fece
Key [12]:fde3a8eedfa3a12be09c1a8a00890fd7
round 7:048531e9fd3efa95910540150f8b137b
Key [13]:def07eb23f3a378f059039a2124bc4c2
Key [14]:2608c58f23d84a09b9ce95e5caac1ab4
round 8:461814ec7439d412d0732f0a6f799a6a
Key [15]:0a7ed16481a623e56ee1442ffa74f334
Key [16]:12add59aca0d19532f1516979954e369
Key [17]:dd43d02d39ffd6a386a4b98b4ac6eb23
Ka      :a5f2adf328e4e6a2b42f19c8b74ba884
-----
rand      :321964061ac49a436f9fb9824ac63f8b
PIN length =15 octets
PIN       :ad955d58b6b8857820ac1262d617a6
address   :0314c0642543
round 1:321964061ac49a436f9fb9824ac63f9b

```


Sample Data

```

Key [ 1]:ad955d58b6b8857820ac1262d617a603
Key [ 2]:f281736f68e3d30b2ac7c67f125dc416
round  2:7c4a4ece1398681f4bafd309328b7770
Key [ 3]:43c157f4c8b360387c32ab330f9c9aa8
Key [ 4]:3a3049945a298f6d076c19219c47c3cb
round  3:9672b00738bdfaf9bd92a855bc6f3afb
added  ->:a48b1401228194bad23161d7f6357960
Key [ 5]:c8e2eaa6d73b7de18f3228ab2173bc69
Key [ 6]:8623f44488222e66a293677cf30bf2bb
round  4:9b30247aad3bf133712d034b46d21c68
Key [ 7]:f3e500902fba31db9bae50ef30e484a4
Key [ 8]:49d4b1137c18f4752dd9955a5a8d2f43
round  5:4492c25fda08083a768b4b5588966b23
Key [ 9]:9d59c451989e74785cc097eda7e42ab8
Key [10]:251de25f3917dcd99c18646107a641fb
round  6:21ae346635714d2623041f269978c0ee
Key [11]:80b8f78cb1a49ec0c3e32a238e60fddf
Key [12]:beb84f4d20a501e4a24ecfbde481902b
round  7:9b56a3d0f8932f20c6a77a229514fb00
Key [13]:852571b44f35fd9d9336d3c1d2506656
Key [14]:d0a0d510fb06ba76e69b8ee3ebc1b725
round  8:6cd8492b2fd31a86978bcd644eb08a8
Key [15]:c7ffd523f32a874ed4a93430a25976de
Key [16]:16cdcb25e62964876d951fdcc07030d3
Key [17]:def32c0e12596f9582e5e3c52b303f52
Ka      :c0ec1a5694e2b48d54297911e6c98b8f
-----
rand    :d4ae20c80094547d7051931b5cc2a8d6
PIN length =14 octets
PIN     :e1232e2c5f3b833b3309088a87b6
address :fabecc58e609
round  1:d4ae20c80094547d7051931b5cc2a8c6
Key [ 1]:e1232e2c5f3b833b3309088a87b6fabe
Key [ 2]:5f0812b47cd3e9a30d7707050ffa1f2
round  2:1f45f16be89794bef33e4547c9c0916a
Key [ 3]:77b681944763244ffa3cd71b248b79b5
Key [ 4]:e2814e90e04f485958ce58c9133e2be6
round  3:b10d2f4ac941035263cee3552d774d2f
added  ->:65bb4f82c9d5572f131f764e7139f5e9
Key [ 5]:520acad20801dc639a2c6d66d9b79576
Key [ 6]:c72255cdb61d42be72bd45390dd25ba5
round  4:ead4dc34207b6ea721c62166e155aaad
Key [ 7]:ebf04c02075bf459ec9c3ec06627d347
Key [ 8]:a1363dd2812ee800a4491c0c74074493
round  5:f507944f3018e20586d81d7f326aae9d
Key [ 9]:b0b6ba79493dc833d7f425be7b8dadb6
Key [10]:08cd23e536b9b9b53e85eb004cba3111
round  6:fff450f4302a2b3571e8405e148346da
Key [11]:fec22374c6937dcd26171f4d2edfada3
Key [12]:0f1a8ef5979c69ff44f620c2e007b6e4
round  7:de558779589897f3402a90ee78c3f921
Key [13]:901fb66f0779d6aad0c0fba1fe812cb5

```

Sample Data

```

Key [14]:a0cab3cd15cd23603adc8d4474efb239
round 8:b2df0aa0c9f07fbbaa02f510a29cf540
Key [15]:18edc3f4296dd6f1dea13f7c143117a1
Key [16]:8d3d52d700a379d72ded81687f7546c7
Key [17]:5927badfe602f29345f840bb53e1dea6
Ka      :d7b39be13e3692c65b4a9e17a9c55e17
-----
rand    :272b73a2e40db52a6a61c6520549794a
PIN length =13 octets
PIN     :549f2694f353f5145772d8ae1e
address :20487681eb9f
round 1:272b73a2e40db52a6a61c6520549795a
Key [ 1]:549f2694f353f5145772d8ae1e204876
Key [ 2]:42c855593d66b0c458fd28b95b6a5fbf
round 2:d7276dc8073f7677c31f855bde9501e2
Key [ 3]:75d0a69ae49a2da92e457d767879df52
Key [ 4]:b3aa7e7492971afaa0fb2b64827110df
round 3:71aae503831133d19bc452da4d0e409b
added ->:56d558a1671ee8fbf12518884857b9c1
Key [ 5]:9c8cf1604a98e9a503c342e272de5cf6
Key [ 6]:d35bc2df6b85540a27642106471057d9
round 4:f41a709c89ea80481aa3d2b9b2a9f8ca
Key [ 7]:b454dda74aeb4eff227ba48a58077599
Key [ 8]:bcba6aec050116aa9b7c6a9b7314d796
round 5:20fdda20f4a26b1bd38eb7f355a7be87
Key [ 9]:d41f8a9de0a716eb7167alb6e321c528
Key [10]:5353449982247782d168ab43f17bc4d8
round 6:a70e316997eed49a5a9ef9ba5e913b5
Key [11]:32cbc9cf1a81e36a45153972347ce4ac
Key [12]:5747619006cf4ef834c749f2c4b9feb6
round 7:e66f2317a825f589f76b47b6aa6e73fb
Key [13]:f9b68beba0a09d2a570a7dc88cc3c3c2
Key [14]:55718f9a4f0b1f9484e8c6b186a41a4b
round 8:5f68f940440a9798e074776019804ada
Key [15]:4ecc29be1b4d78433f6aa30db974a7fb
Key [16]:8470a066ffb00cda7b08059599f919f5
Key [17]:f39a36d74e960a051e1ca98b777848f4
Ka      :9ac64309a37c25c3b4a584fc002a1618
-----
rand    :7edb65f01a2f45a2bc9b24fb3390667e
PIN length =12 octets
PIN     :2e5a42797958557b23447ca8
address :04f0d2737f02
round 1:7edb65f01a2f45a2bc9b24fb3390666e
Key [ 1]:2e5a42797958557b23447ca804f0d273
Key [ 2]:18a97c856561eb23e71af8e9e1be4799
round 2:3436e12db8ffdc1265cb5a86da2fed0b
Key [ 3]:7c0908dcbc73201e17c4f7aa1ab8aec8
Key [ 4]:7cb58833602fbe4194c7cc797ce8c454
round 3:caed6af4226f67e4ad1914620803ef2a
added ->:b4c8cf04389eac4611b438993b935544
Key [ 5]:f4dce7d607b5234562d0ebb2267b08b8

```

Sample Data

```

Key [ 6 ] : 560b75c5545751fd8fa99fa4346e654b
round 4 : ee67c87d6f74bb75db98f68bff0192c1
Key [ 7 ] : 32f10cefd8d3e6424c6f91f1437808af
Key [ 8 ] : a934a46045be30fb3be3a5f3f7b18837
round 5 : 792398dcbbeb8d10bdb07ae3c819e943c
Key [ 9 ] : a0f12e97c677a0e8ac415cd2c8a7ca88
Key [10] : e27014c908785f5ca03e8c6a1da3bf13
round 6 : e778b6e0c3e8e7edf90861c7916d97a8
Key [11] : 1b4a4303bcc0b2e0f41c72d47654bd9f
Key [12] : 4b1302a50046026d6c9054fc8387965a
round 7 : 1fafddc7efa5f04c1dec1869d3f2d9bb
Key [13] : 58c334bb543d49eca562cdbe0280e0fc
Key [14] : bdb60d383c692d06476b76646c8dec48
round 8 : 3d7c326d074bd6aa222ea050f04a3c7f
Key [15] : 78c0162506be0b5953e8403c01028f93
Key [16] : 24d7dbbe834dbd7b67f57fcf0d39d60f
Key [17] : 2e74f1f3331c0f6585e87b2f715e187e
Ka      : d3af4c81e3f482f062999dee7882a73b
-----
rand    : 26a92358294dce97b1d79ec32a67e81a
PIN length = 11 octets
PIN     : 05fbad03f52fa9324f7732
address : b9ac071f9d70
round 1 : 26a92358294dce97b1d79ec32a67e80a
Key [ 1 ] : 05fbad03f52fa9324f7732b9ac071f9d
Key [ 2 ] : 2504c9691c04a18480c8802e922098c0
round 2 : 0be20e3d76888e57b6bf77f97a8714fb
Key [ 3 ] : 576b2791d1212bea8408212f2d43e77e
Key [ 4 ] : 90ae36dcce8724adb618f912d1b27297
round 3 : 1969667060764453257d906b7e58bd5b
added -> : 3f12892849c312c494542ea854bfa551
Key [ 5 ] : bc492c42c9e87f56ec31af5474e9226e
Key [ 6 ] : c135d1dbed32d9519acfb4169f3e1a10
round 4 : ac404205118fe771e54aa6f392da1153
Key [ 7 ] : 83ccbdbbaf17889b7d18254dc9252fa1
Key [ 8 ] : 80b90a1767d3f2848080802764e21711
round 5 : 41795e89ae9a0cf776ffece76f47fd7a
Key [ 9 ] : cc24e4a86e8eed129118fd3d5223a1dc
Key [10] : 7b1e9c0eb9dab083574be7b7015a62c9
round 6 : 29ca9e2f87ca00370ef1633505bfba4b
Key [11] : 888e6d88cf4beb965cf7d4f32b696baa
Key [12] : 6d642f3e5510b0b043a44daa2cf5eec0
round 7 : 81fc891c3c6fd99acc00028a387e2366
Key [13] : e224f85da2ab63a23e2a3a036e421358
Key [14] : c8dc22aaa739e2cb85d6a0c08226c7d0
round 8 : e30b537e7a000e3d2424a9c0f04c4042
Key [15] : a969aa818c6b324bae391bedcdd9d335
Key [16] : 6974b6f2f07e4c55f2cc0435c45bebd1
Key [17] : 134b925ebd98e6b93c14aee582062fcb
Ka      : be87b44d079d45a08a71d15208c5cb50
-----
rand    : 0edef05327eab5262430f21fc91ce682

```

Sample Data

```

PIN length =10 octets
PIN      :8210e47390f3f48c32b3
address  :7a3cdfe377d1
round   1:0edef05327eab5262430f21fc91ce692
Key [ 1]:8210e47390f3f48c32b37a3cdfe377d1
Key [ 2]:c6be4c3e425e749b620a94c779e33a7e
round   2:07ca3c7a7a6bcb31d79a856d9cfff0e
Key [ 3]:2587cec2a4b8e4f996a9ed664350d5dd
Key [ 4]:70e4bf72834d9d3dbb7eb2c239216dc0
round   3:792ad2ac4e4559d1463714d2f161b6f4
added ->:7708c2ff692f0ef7626706cd387d9c66
Key [ 5]:6696e1e7f8ac037e1fff3598f0c164e2
Key [ 6]:23dbfe4d0b561bea08fbcef25e49b648
round   4:7d8c71a9d7fbdcbd851bdf074550b100
Key [ 7]:b03648acd021550edee904431a02f00c
Key [ 8]:cb169220b7398e8f077730aa4bf06baa
round   5:b6fcaa45064ffd557e4b7b30cfbb83e0
Key [ 9]:af602c2ba16a454649951274c2be6527
Key [10]:5d60b0a7a09d524143eca13ad680bc9c
round   6:b3416d391a0c26c558843debd0601e9e
Key [11]:9a2f39bfe558d9f562c5f09a5c3c0263
Key [12]:72cae8eebd7fabd9b1848333c2aab439
round   7:abe4b498d9c36ea97b8fd27d7f813913
Key [13]:15f27ea11e83a51645d487b81371d7dc
Key [14]:36083c8666447e03d33846edf444eb12
round   8:8032104338a945ba044d102eabda3b22
Key [15]:0a3a8977dd48f3b6c1668578befadd02
Key [16]:f06b6675d78ca0ee5b1761bdcdab516d
Key [17]:cbc8a7952d33aa0496f7ea2d05390b23
Ka      :bf0706d76ec3b11cce724b311bf71ff5
-----
rand     :86290e2892f278ff6c3fb917b020576a
PIN length = 9 octets
PIN      :3dcdffcfcd086802107
address  :791a6a2c5cc3
round   1:86290e2892f278ff6c3fb917b0205765
Key [ 1]:3dcdffcfcd086802107791a6a2c5cc33d
Key [ 2]:b4962f40d7bb19429007062a3c469521
round   2:1ec59ffd3065f19991872a7863b0ef02
Key [ 3]:eb9ede6787dd196b7e340185562bf28c
Key [ 4]:2964e58aacf7287d1717a35b100ae23b
round   3:f817406f1423fc2fe33e25152679eaaaf
added ->:7e404e47861574d08f7dde02969941ca
Key [ 5]:6abf9a314508fd61e486fa4e376c3f93
Key [ 6]:6da148b7ee2632114521842cbb274376
round   4:e9c2a8fac22b8c7cf0c619e2b3f890ed
Key [ 7]:df889cc34fda86f01096d52d116e620d
Key [ 8]:5eb04b147dc39d1974058761ae7b73fc
round   5:444a8aac0efee1c02f8d38f8274b7b28
Key [ 9]:8426cc59eee391b2bd50cf8f1efef8b3
Key [10]:8b5d220a6300ade418da791dd8151941
round   6:9185f983db150b1bccab1e5c12eb63a1

```

Sample Data

```

Key [11]:82ba4ddef833f6a4d18b07aa011f2798
Key [12]:ce63d98794682054e73d0359dad35ec4
round 7:5eded2668f5916dfd036c09e87902886
Key [13]:da794357652e80c70ad8b0715dbe33d6
Key [14]:732ef2c0c3220b31f3820c375e27bb29
round 8:88a5291b4acbba009a85b7dd6a834b3b
Key [15]:3ce75a61d4b465b70c95d7ccd5799633
Key [16]:5df9bd2c3a17a840cdaafb76c171db7c
Key [17]:3f8364b089733d902bccb0cd3386846f
Ka      :cdb0cc68f6f6fbd70b46652de3ef3ffb
-----
rand    :3ab52a65bb3b24a08eb6cd284b4b9d4b
PIN length = 8 octets
PIN     :d0fb9b6838d464d8
address :25a868db91ab
round 1:3ab52a65bb3b24a08eb6cd284b4b9d45
Key [ 1]:d0fb9b6838d464d825a868db91abd0fb
Key [ 2]:2573f47b49dad6330a7a9155b7ae8ba1
round 2:ad2ffdfdf408fcfab44941016a9199251
Key [ 3]:d2c5b8fb80cba13712905a589adaee71
Key [ 4]:5a3381511b338719fae242758dea0997
round 3:2ddc17e570d7931a2b1d13f6ace928a5
added ->:17914180cb12b7baa5d3e0dee734c5e0
Key [ 5]:e0a4d8ac27fbe2783b7bcb3a36a6224d
Key [ 6]:949324c6864deac3eca8e324853e11c3
round 4:62c1db5cf31590d331ec40ad692e8df5
Key [ 7]:6e67148088a01c2d4491957cc9ddc4aa
Key [ 8]:557431deab7087bb4c03fa27228f60c6
round 5:9c8933bc361f4bde4d1bda2b5f8bb235
Key [ 9]:a2551aca53329e70ade3fd2bb7664697
Key [10]:05d0ad35de68a364b54b56e2138738fe
round 6:9156db34136aa06655bf28a05be0596a
Key [11]:1616a6b13ce2f2895c722e8495181520
Key [12]:b12e78a1114847b01f6ed2f5a1429a23
round 7:84dcc292ed836c1c2d523f2a899a2ad5
Key [13]:316e144364686381944e95afd8a026bb
Key [14]:1ab551b88d39d97ea7a9fe136dbfe2e1
round 8:87bdcac878d777877f4eccf042cfee5e
Key [15]:70e21ab08c23c7544524b64492b25cc9
Key [16]:35f730f2ae2b950a49a1bf5c8b9f8866
Key [17]:2f16924c22db8b74e2eadf1ba4ebd37c
Ka      :983218718ca9aa97892e312d86dd9516
-----
rand    :a6dc447ff08d4b366ff96e6cf207e179
PIN length = 7 octets
PIN     :9c57e10b4766cc
address :54ebd9328cb6
round 1:a6dc447ff08d4b366ff96e6cf207e174
Key [ 1]:9c57e10b4766cc54ebd9328cb69c57e1
Key [ 2]:00a609f4d61db26993c8177e3ee2bba8
round 2:1ed26b96a306d7014f4e5c9ee523b73d
Key [ 3]:646d7b5f9aaa528384bda3953b542764

```

Sample Data

```

Key [ 4 ] : a051a42212c0e9ad5c2c248259aca14e
round 3 : a53f526db18e3d7d53edbf9711041ed
added -> : 031b9612411b884b3ce62da583172299
Key [ 5 ] : d1bd5e64930e7f838d8a33994462d8b2
Key [ 6 ] : 5dc7e2291e32435665ebd6956bec3414
round 4 : 9438be308ec83f35c560e2796f4e0559
Key [ 7 ] : 10552f45af63b0f15e2919ab37f64fe7
Key [ 8 ] : c44d5717c114a58b09207392ebe341f8
round 5 : b79a7b14386066d339f799c40479cb3d
Key [ 9 ] : 6886e47b782325568eaf59715a75d8ff
Key [10] : 8e1e335e659cd36b132689f78c147bda
round 6 : ef232462228aa166438d10c34e17424b
Key [11] : 8843efeedd5c2b7c3304d647f932f4d1
Key [12] : 13785aaedd0adf67abb4f01872392785
round 7 : 02d133fe40d15f1073673b36bba35abd
Key [13] : 837d7ca2722419e6be3fae35900c3958
Key [14] : 93f8442973e7fccf2e7232d1d057c73a
round 8 : 275506a3d08c84e94cc58ed60054505e
Key [15] : 8a7a9edffa3c52918bc6a45f57d91f5d
Key [16] : f214a95d777f763c56109882c4b52c84
Key [17] : 10e2ee92c5ea1ddc5eb010e55510c403
Ka      : 9cd6650ead86323e87cafb1ff516d1e0
-----
rand    : 3348470a7ea6cc6eb81b40472133262c
PIN length = 6 octets
PIN     : fcaad169d7295
address : 430d572f8842
round 1 : 3348470a7ea6cc6eb81b404721332620
Key [ 1 ] : fcaad169d7295430d572f8842fcaad169d
Key [ 2 ] : b3479d4d4fd178c43e7bc5b0c7d8983c
round 2 : af976da9225066d563e10ab955e6fc32
Key [ 3 ] : 7112462b37d82dd81a2a35d9eb43cb7c
Key [ 4 ] : c5a7030f8497945ac7b84600d1d161fb
round 3 : d08f826ebd55a0bd7591c19a89ed9bde
added -> : e3d7c964c3fb6cd3cdac01dda820c1fe
Key [ 5 ] : 84b0c6ef4a63e4dff19b1f546d683df5
Key [ 6 ] : f4023edfc95d1e79ed4bb4de9b174f5d
round 4 : 6cd952785630dfc7cf81eea625e42c5c
Key [ 7 ] : ea38dd9a093ac9355918632c90c79993
Key [ 8 ] : dbba01e278ddc76380727f5d7135a7de
round 5 : 93573b2971515495978264b88f330f7f
Key [ 9 ] : d4dc3a31be34e412210fafa6eca00776
Key [10] : 39d1e190ee92b0ff16d92a8be58d2fa0
round 6 : b3f01d5e7felce6da7b46d8c389baf47
Key [11] : 1eb081328d4bcf94c9117b12c5cf22ac
Key [12] : 7e047c2c552f9f1414d946775fabfe30
round 7 : 0b833bfff6106d5bae033b4ce5af5a924
Key [13] : e78e685d9b2a7e29e7f2a19d1bc38ebd
Key [14] : 1b582272a3121718c4096d2d8602f215
round 8 : 23de0bbdc70850a7803f4f10c63b2c0f
Key [15] : 8569e860530d9c3d48a0870dac33f676
Key [16] : 6966b528fdd1dc222527052c8f6cf5a6

```

Sample Data

```

Key [17]:a34244c757154c53171c663b0b56d5c2
Ka      :98f1543ab4d87bd5ef5296fb5e3d3a21
-----
rand    :0f5bb150b4371ae4e5785293d22b7b0c
PIN length = 5 octets
PIN     :b10d068bca
address :b44775199f29
round   1:0f5bb150b4371ae4e5785293d22b7b07
Key [ 1]:b10d068bcab44775199f29b10d068bca
Key [ 2]:aec70d1048f1bbd2c18040318a8402ad
round   2:342d2b79d7fb7cd110379742b9842c79
Key [ 3]:6d8d5cf338f29ef4420639ef488e4fa9
Key [ 4]:a1584117541b759ba6d9f7eb2bedcbbba
round   3:9407e8e3e810603921bf81cfda62770a
added ->:9b6299b35c477addc437d35c088df20d
Key [ 5]:09a20676666aedd6f22176274eb433f4
Key [ 6]:840472c001add5811a054be5f5c74754
round   4:9a3ba953225a7862c0a842ed3d0b2679
Key [ 7]:fad9e45c8bf70a972fcd9bfff0e8751f5
Key [ 8]:e8f30ff666dfd212263416496ff3b2c2
round   5:2c573b6480852e875df34b28a5c44509
Key [ 9]:964cdba0cf8d593f2fc40f96daf8267a
Key [10]:bcd65c11b13e1a70bcd4aafba8864fe3
round   6:21b0cc49e880c5811d24dee0194e6e9e
Key [11]:468c8548ea9653c1a10df6288dd03c1d
Key [12]:5d252d17af4b09d3f4b5f7b5677b8211
round   7:e6d6bdcd63e1d37d9883543ba86392fd
Key [13]:e814bf307c767428c67793dda2df95c7
Key [14]:4812b979fdc20f0ff0996f61673a42cc
round   8:e3dde7ce6bd7d8a34599aa04d6a760ab
Key [15]:5b1e2033d1cd549fc4b028146eb5b3b7
Key [16]:0f284c14fb8fe706a5343e3aa35af7b1
Key [17]:b1f7a4b7456d6b577fded6dc7a672e37
Ka      :c55070b72bc982adb972ed05d1a74ddb
-----
rand    :148662a4baa73cfadb55489159e476e1
PIN length = 4 octets
PIN     :fb20f177
address :a683bd0b1896
round   1:148662a4baa73cfadb55489159e476eb
Key [ 1]:fb20f177a683bd0b1896fb20f177a683
Key [ 2]:47266cefbf4a68ca7916b458155dc825
round   2:3a942eb6271c3f4e433838a5d3fcbd27
Key [ 3]:688853a6d6575eb2f6a2724b0fbc133b
Key [ 4]:7810df048019634083a2d9219d0b5fe0
round   3:9c835b98a063701c0887943596780769
added ->:8809bd3c1a0aace6d3dcdca4cf5c7d82
Key [ 5]:c78f6dcf56da1bbd413828b33f5865b3
Key [ 6]:eb3f3d407d160df3d293a76d1a513c4a
round   4:7e68c4bafa020a4a59b5a1968105bab5
Key [ 7]:d330e038d6b19d5c9bb0d7285a360064
Key [ 8]:9bd3ee50347c00753d165faced702d9c

```

Sample Data

```

round 5:227bad0cf0838bdb15b3b3872c24f592
Key [ 9]:9543ad0fb3fe74f83e0e2281c6d4f5f0
Key [10]:746cd0383c17e0e80e6d095a87fd0290
round 6:e026e98c71121a0cb739ef6f59e14d26
Key [11]:fa28bea4b1c417536608f11f406ea1dd
Key [12]:3aee0f4d21699df9cb8caf5354a780ff
round 7:cd6a6d8137d55140046f8991da1fa40a
Key [13]:372b71bc6d1aa6e785358044fbcf05f4
Key [14]:00a01501224c0405de00aa2ce7b6ab04
round 8:52cd7257fe8d0c782c259bcb6c9f5942
Key [15]:c7015c5c1d7c030e00897f104a006d4a
Key [16]:260a9577790c62e074e71e19fd2894df
Key [17]:c041b7a231493acd15ddcdae94b9f52
Ka      :7ec864df2f1637c7e81f2319ae8f4671
-----
rand    :193a1b84376c88882c8d3b4ee93ba8d5
PIN length = 3 octets
PIN     :a123b9
address :4459a44610f6
round 1:193a1b84376c88882c8d3b4ee93ba8dc
Key [ 1]:a123b94459a44610f6a123b94459a446
Key [ 2]:5f64d384c8e990c1d25080eb244dde9b
round 2:3badbd58f100831d781ddd3ccedefd3f
Key [ 3]:5abc00eff8991575c00807c48f6d5ea5
Key [ 4]:127521158ad6798fb6479d1d2268abe6
round 3:0b53075a49c6bf2df2421c655fdedf68
added ->:128d22de7e3247a5decf572bb61987b4
Key [ 5]:f2a1f620448b8e56665608df2ab3952f
Key [ 6]:7c84c0af02aad91dc39209c4edd220b1
round 4:793f4484fb592e7a78756fd4662f990d
Key [ 7]:f6445b647317e7e493bb92bf6655342f
Key [ 8]:3cae503567c63d3595eb140ce60a84c0
round 5:9e46a8df925916a342f299a8306220a0
Key [ 9]:734ed5a806e072bbebcb4254993871679
Key [10]:cda69ccb4b07f65e3c8547c11c0647b8
round 6:6bf9cd82c9e1be13fc58eae0b936c75a
Key [11]:c48e531d3175c2bd26fa25cc8990e394
Key [12]:6d93d349a6c6e9ff5b26149565b13d15
round 7:e96a9871471240f198811d4b8311e9a6
Key [13]:5c4951e85875d663526092cd4cbdb667
Key [14]:f19f7758f5cde86c3791efaf563b3fd0
round 8:e94ca67d3721d5fb08ec069191801a46
Key [15]:bf0c17f3299b37d984ac938b769dd394
Key [16]:7edf4ad772a6b9048588f97be25bde1c
Key [17]:6ee7ba6afefc5b561abbd8d6829e8150
Ka      :ac0daabf17732f632e34ef193658bf5d
-----
rand    :1453db4d057654e8eb62d7d62ec3608c
PIN length = 2 octets
PIN     :3eaf
address :411fbbb51d1e
round 1:1453db4d057654e8eb62d7d62ec36084

```


Sample Data

```

Key [ 1]:3eaf411fbbb51d1e3eaf411fbbb51d1e
Key [ 2]:c3a1a997509f00fb4241aba607109c64
round 2:0b78276c1ebc65707d38c9c5fa1372bd
Key [ 3]:3c729833ae1ce7f84861e4dbad6305cc
Key [ 4]:c83a43c3a66595cb8136560ed29be4ff
round 3:23f3f0f6441563d4c202cee0e5cb2335
added ->:3746cbbb418bb73c2964a536cb8e83b1
Key [ 5]:18b26300b86b70acdd1c8f5cbc7c5da8
Key [ 6]:04efc75309b98cd8f1cef5513c18e41e
round 4:c61afa90d3c14bdf588320e857afdc00
Key [ 7]:517c789cecad4c55751af73198749fb8
Key [ 8]:fd9711f913b5c844900fa79dd765d0e2
round 5:a8a0e02ceb556af8bfa321789801183a
Key [ 9]:bb5cf30e7d3ceb930651b1d16ee92750
Key [10]:3d97c7862ecab42720e984972f8efd28
round 6:0b58e922438d224db34b68fca9a5ea12
Key [11]:4ce730344f6b09e449dcdb64cd466666
Key [12]:38828c3a56f922186adcd9b713cdcc31
round 7:b90664c4ac29a8b4bb26debec9ffcf5f2
Key [13]:d30fd865ea3e9edcfff86a33a2c319649
Key [14]:1fdb63e54413acd968195ab6fa424e83
round 8:6934de3067817cefd811abc5736c163b
Key [15]:a16b7c655bbaa262c807cba8ae166971
Key [16]:7903dd68630105266049e23ca607cda7
Key [17]:888446f2d95e6c2d2803e6f4e815ddc9
Ka      :1674f9dc2063cc2b83d3ef8ba692ebef
-----
rand    :1313f7115a9db842fcedc4b10088b48d
PIN length = 1 octets
PIN     :6d
address :008aa9be62d5
round 1:1313f7115a9db842fcedc4b10088b48a
Key [ 1]:6d008aa9be62d56d008aa9be62d56d00
Key [ 2]:46ebfeafb6657b0a1984a8dc0893accf
round 2:839b23b83b5701ab095bafd162ec0ac7
Key [ 3]:8e15595edcf058af62498ee3c1dc6098
Key [ 4]:dd409c3444e94b9cc08396ae967542a0
round 3:c0a2010cc44f2139427f093f4f97ae68
added ->:d3b5f81d9eecd97bbe6ccd8e4f1f62e2
Key [ 5]:487deff5d519f6a6481e947b926f633c
Key [ 6]:5b4b6e3477ed5c2c01f6e607d3418963
round 4:1a5517a0efad3575931d8ea3bee8bd07
Key [ 7]:34b980088d2b5fd6b6a2aceeda99c9c4
Key [ 8]:e7d06d06078acc4ecdbc8da800b73078
round 5:d3ce1fdfe716d72c1075ff37a8a2093f
Key [ 9]:7d375bad245c3b757380021af8ecd408
Key [10]:14dac4bc2f4dc4929a6cceec47f4c3a3
round 6:47e90cb55be6e8dd0f583623c2f2257b
Key [11]:66cfda3c63e464b05e2e7e25f8743ad7
Key [12]:77cfccdalad380b9fdf1df10846b50e7
round 7:f866ae6624f7abd4a4f5bd24b04b6d43
Key [13]:3e11dd84c031a470a8b66ec6214e44cf

```

Sample Data

```

Key [14]: 2f03549bdb3c511eea70b65ddbb08253
round 8: 02e8e17cf8be4837c9c40706b613dfa8
Key [15]: e2f331229ddfcc6e7bea08b01ab7e70c
Key [16]: b6b0c3738c5365bc77331b98b3fba2ab
Key [17]: f5b3973b636119e577c5c15c87bcfd19
Ka      : 38ec0258134ec3f08461ae5c328968a1

```

```

=====

```

9.5 FOUR TESTS OF E3

```

rand      : 00000000000000000000000000000000
aco       : 48afcdd4bd40fef76693b113
key       : 00000000000000000000000000000000
round 1: 00000000000000000000000000000000
Key [ 1]: 00000000000000000000000000000000
Key [ 2]: 4697b1baa3b7100ac537b3c95a28ac64
round 2: 78d19f9307d2476a523ec7a8a026042a
Key [ 3]: ecabaac66795580df89af66e66dc053d
Key [ 4]: 8ac3d8896ae9364943bfebd4969b68a0
round 3: 600265247668dda0e81c07bbb30ed503
Key [ 5]: 5d57921fd5715cbb22c1be7bbc996394
Key [ 6]: 2a61b8343219fdfb1740e6511d41448f
round 4: d7552ef7cc9dbde568d80c2215bc4277
Key [ 7]: dd0480dee731d67f01a2f739da6f23ca
Key [ 8]: 3ad01cd1303e12a1cd0fe0a8af82592c
round 5: fb06bef32b52ab8f2a4f2b6ef7f6d0cd
Key [ 9]: 7dadb2efc287ce75061302904f2e7233
Key [10]: c08dcfa981e2c4272f6c7a9f52e11538
round 6: b46b711ebb3cf69e847a75f0ab884bdd
Key [11]: fc2042c708e409555e8c147660ffdfdf7
Key [12]: fa0b21001af9a6b9e89e624cd99150d2
round 7: c585f308ff19404294f06b292e978994
Key [13]: 18b40784ea5ba4c80ecb48694b4e9c35
Key [14]: 454d54e5253c0c4a8b3fcc7db6baef4
round 8: 2665fadb13acf952bf74b4ab12264b9f
Key [15]: 2df37c6d9db52674f29353b0f011ed83
Key [16]: b60316733b1e8e70bd861b477e2456f1
Key [17]: 884697b1baa3b7100ac537b3c95a28ac
round 1: 5d3ecb17f26083df0b7f2b9b29aef87c
Key [ 1]: e9e5dfc1b3a79583e9e5dfc1b3a79583
Key [ 2]: 7595bf57e0632c59f435c16697d4c864
round 2: de6fe85c5827233fe22514a16f321bd8
Key [ 3]: e31b96afcc75d286ef0ae257cbbc05b7
Key [ 4]: 0d2a27b471bc0108c6263aff9d9b3b6b
round 3: 7cd335b50d09d139ea6702623af85edb
added ->: 211100a2ff6954e6e1e62df913a656a7
Key [ 5]: 98d1eb5773cf59d75d3b17b3bc37c191
Key [ 6]: fd2b79282408ddd4ea0aa7511133336f
round 4: 991dcc3201b5b1c4ceff65a3711e1e9
Key [ 7]: 331227756638a41d57b0f7e071ee2a98

```

Sample Data

```

Key [ 8 ] :aa0dd8cc68b406533d0f1d64aabacf20
round 5:18768c7964818805fe4c6ecae8a38599
Key [ 9 ] :669291b0752e63f806fce76f10e119c8
Key [10] :ef8bdd46be8ee0277e9b78adef1ec154
round 6:82f9aa127a72632af43d1a17e7bd3a09
Key [11] :f3902eb06dc409cfd78384624964bf51
Key [12] :7d72702b21f97984a721c99b0498239d
round 7:1543d7870bf2d6d6efab3cbf62dca97d
Key [13] :532e60bceaf902c52a06c2c283ecfa32
Key [14] :181715e5192efb2a64129668cf5d9dd4
round 8:eee3e8744a5f8896de95831ed837ffd5
Key [15] :83017c1434342d4290e961578790f451
Key [16] :2603532f365604646ff65803795ccce5
Key [17] :882f7c907b565ea58dae1c928a0dcf41
kc      :cc802aecc7312285912e90af6a1e1154
-----
rand    :950e604e655ea3800fe3eb4a28918087
aco     :68f4f472b5586ac5850f5f74
key     :34e86915d20c485090a6977931f96df5
round 1:950e604e655ea3800fe3eb4a28918087
Key [ 1 ] :34e86915d20c485090a6977931f96df5
Key [ 2 ] :8de2595003f9928efaf37e5229935bdb
round 2:d46f5a04c967f55840f83d1cdb5f9afc
Key [ 3 ] :46f05ec979a97cb6ddf842ecc159c04a
Key [ 4 ] :b468f0190a0a83783521daae8178d071
round 3:e16edede9cb6297f32e1203e442ac73a
Key [ 5 ] :8a171624dedbd552356094daaadcf12a
Key [ 6 ] :3085e07c85e4b99313f6e0c837b5f819
round 4:805144e55e1ece96683d23366fc7d24b
Key [ 7 ] :fe45c27845169a66b679b2097d147715
Key [ 8 ] :44e2f0c35f64514e8bec66c5dc24b3ad
round 5:edba77af070bd22e9304398471042f1
Key [ 9 ] :0d534968f3803b6af447eaf964007e7b
Key [10] :f5499a32504d739ed0b3c547e84157ba
round 6:0dab1a4c846aef0b65b1498812a73b50
Key [11] :e17e8e456361c46298e6592a6311f3fb
Key [12] :ec6d14da05d60e8abac807646931711f
round 7:1e7793cac7f55a8ab48bd33bc9c649e0
Key [13] :2b53dde3d89e325eff808ed505706ae
Key [14] :41034e5c3fb0c0d4f445f0cf23be79b0
round 8:3723768baa78b6a23ade095d995404da
Key [15] :e2ca373d405a7abf22b494f28a6fd247
Key [16] :74e09c9068c0e8f1c6902d1b70537c30
Key [17] :767a7f1acf75c3585a55dd4a428b2119
round 1:39809afb773efd1b7510cd4cb7c49f34
Key [ 1 ] :1d0d48d485abddd3798b483a82a0f878
Key [ 2 ] :aed957e600a5aed5217984dd5fef6fd8
round 2:6436ddbabe92655c87a7d0c12ae5e5f6
Key [ 3 ] :fee00bb0de89b6ef0a289696a4faa884
Key [ 4 ] :33ce2f4411db4dd9b7c42cc586b8a2ba
round 3:cec690f7e0aa5f063062301e049a5cc5
added ->:f7462a0c97e85c1d4572fd52b35efbf1

```

Sample Data

```

Key [ 5]:b5116f5c6c29e05e4acb4d02a46a3318
Key [ 6]:ff4fa1f0f73d1a3c67bc2298abc768f9
round 4:dcdfe942e9f0163fc24a4718844b417d
Key [ 7]:5453650c0819e001e48331ad0e9076e0
Key [ 8]:b4ff8dda778e26c0dce08349b81c09a1
round 5:265a16b2f766afae396e7a98c189fda9
Key [ 9]:f638fa294427c6ed94300fd823b31d10
Key [10]:1ccfa0bd86a9879b17d4bc457e3e03d6
round 6:628576b5291d53d1eb8611c8624e863e
Key [11]:0eaae2ef4602ac9ca19e49d74a76d335
Key [12]:6e1062f10a16e0d378476da3943842e9
round 7:d7b9c2e9b2d5ea5c27019324cae882b3
Key [13]:40be960bd22c744c5b23024688e554b9
Key [14]:95c9902cb3c230b44d14ba909730d211
round 8:97fb6065498385e47eb3df6e2ca439dd
Key [15]:10d4b6e1d1d6798aa00aa2951e32d58d
Key [16]:c5d4b91444b83ee578004ab8876ba605
Key [17]:1663a4f98e2862eddd3ec2fb03dcc8a4
kc      :c1beafea6e747e304cf0bd7734b0a9e2
-----
rand    :6a8ebcf5e6e471505be68d5eb8a3200c
aco     :658d791a9554b77c0b2f7b9f
key     :35cf77b333c294671d426fa79993a133
round 1:6a8ebcf5e6e471505be68d5eb8a3200c
Key [ 1]:35cf77b333c294671d426fa79993a133
Key [ 2]:c4524e53b95b4bf2d7b2f095f63545fd
round 2:ade94ec585db0d27e17474b58192c87a
Key [ 3]:c99776768c6e9f9dd3835c52cea8d18a
Key [ 4]:f1295db23823ba2792f21217fc01d23f
round 3:da8dc1a10241ef9e6e069267cd2c6825
Key [ 5]:9083db95a6955235bbfad8aeefec5f0b
Key [ 6]:8bab6bc253d0d0c7e0107feab728ff68
round 4:e6665ca0772ceecbc21222ff7be074f8
Key [ 7]:2fa1f4e7a4cf3ccd876ec30d194cf196
Key [ 8]:267364be247184d5337586a19df8bf84
round 5:a857a9326c9ae908f53fee511c5f4242
Key [ 9]:9aef21965b1a6fa83948d107026134c7
Key [10]:d2080c751def5dc0d8ea353cebf7b973
round 6:6678748a1b5f21ac05cf1b117a7c342f
Key [11]:d709a8ab70b0d5a2516900421024b81e
Key [12]:493e4843805f1058d605c8d1025f8a56
round 7:766c66fe9c460bb2ae39ec01e435f725
Key [13]:b1ed21b71daea03f49fe74b2c11fc02b
Key [14]:0e1ded7ebf23c72324a0165a698c65c7
round 8:396e0ff7b2b9b7a3b35c9810882c7596
Key [15]:b3bf4841dc92f440fde5f024f9ce8be9
Key [16]:1c69bc6c2994f4c84f72be8f6b188963
Key [17]:bb7b66286dd679a471e2792270f3bb4d
round 1:45654f2f26549675287200f07cb10ec9
Key [ 1]:1e2a5672e66529e4f427b0682a3a34b6
Key [ 2]:974944f1ce0037b1febcf61a2bc961a2
round 2:990cd869c534e76ed4f4af7b3bfbcb6c8

```

Sample Data

```

Key [ 3]:8147631fb1ce95d624b480fc7389f6c4
Key [ 4]:6e90a2db33d284aa13135f3c032aa4f4
round 3:ceb662f875aa6b94e8192b5989abf975
added ->:8b1bb1d753fe01e1c08b2ba9f55c07bc
Key [ 5]:cbad246d24e36741c46401e6387a05f9
Key [ 6]:dcf52aaec5713110345a41342c566fc8
round 4:d4e000be5de78c0f56ff218f3c1df61b
Key [ 7]:8197537aa9d27e67d17c16b182c8ec65
Key [ 8]:d66e00e73d835927a307a3ed79d035d8
round 5:9a4603bdef954cfaade2052604bed4e4
Key [ 9]:71d46257ecc1022bcd312ce6c114d75c
Key [10]:f91212fa528379651fbd2c32890c5e5f
round 6:09a0fd197ab81eb933eece2fe0132dbb
Key [11]:283acc551591fadce821b02fb9491814
Key [12]:ca5f95688788e20d94822f162b5a3920
round 7:494f455a2e7a5db861ece816d4e363e4
Key [13]:ba574aef663c462d35399efb999d0e40
Key [14]:6267afc834513783fef1601955fe0628
round 8:37a819f91c8380fb7880e640e99ca947
Key [15]:fdcd9be5450eef0f8737e6838cd38e2b
Key [16]:8cfbd9b8056c6a1ce222b92b94319b38
Key [17]:4f64c1072c891c39eeb95e63318462e0
kc      :a3032b4df1cceba8adc1a04427224299
-----
rand    :5ecd6d75db322c75b6afbd799cb18668
aco     :63f701c7013238bbf88714ee
key     :b9f90c53206792b1826838b435b87d4d
round 1:5ecd6d75db322c75b6afbd799cb18668
Key [ 1]:b9f90c53206792b1826838b435b87d4d
Key [ 2]:15f74bbbde4b9d1e08f858721f131669
round 2:72abb85fc80c15ec2b00d72873ef9ad4
Key [ 3]:ef7fb29f0b01f82706c7439cc52f2dab
Key [ 4]:3003a6aecdee06b9ac295cce30dcdb93
round 3:2f10bab93a0f73742183c68f712dfa24
Key [ 5]:5fcdabb3afdf7df06754c954fc6340254
Key [ 6]:ddaa90756635579573fe8ca1f93d4a38
round 4:183b145312fd99d5ad08e7ca4a52f04e
Key [ 7]:27ca8a7fc703aa61f6d7791fc19f704a
Key [ 8]:702029d8c6e42950762317e730ec5d18
round 5:cbad52d3a026b2e38b9ae6fefffec32
Key [ 9]:ff15eaa3f73f4bc2a6ccfb9ca24ed9c5
Key [10]:034e745246cd2e2cfc3bda39531ca9c5
round 6:ce5f159d0a1acaacd9fb4643272033a7
Key [11]:0a4d8ff5673731c3dc8fe87e39a34b77
Key [12]:637592fab43a19ac0044a21afef455a2
round 7:8a49424a10c0bea5aba52dbbffcbbce8
Key [13]:6b3fde58f4f6438843cdbe92667622b8
Key [14]:a10bfa35013812f39bf2157f1c9fca4e
round 8:f5e12da0e93e26a5850251697ec0b917
Key [15]:2228fe5384e573f48fdd19ba91f1bf57
Key [16]:5f174db2bc88925c0fbc6b5485bafc08
Key [17]:28ff90bd0dc31ea2bb479feb7d8fe029


```

Sample Data

```
round 1:0c75eed2b54c1cfb9ff522daef94ed4d
Key [ 1]:a21ceb92d3c027326b4de775865fe8d0
Key [ 2]:26f64558a9f0a1652f765efd546f3208
round 2:48d537ac209a6aa07b70000016c602e8
Key [ 3]:e64f9ef630213260f1f79745a0102ae5
Key [ 4]:af6a59d7cebfd0182dcca9a537c4add8
round 3:8b6d517ac893743a401b3fb7911b64e1
added ->:87e23fa87ddf90c1df10616d7eaf51ac
Key [ 5]:9a6304428b45da128ab64c8805c32452
Key [ 6]:8af4d1e9d80cb73ec6b44e9b6e4f39d8
round 4:9f0512260a2f7a5067efc35bf1706831
Key [ 7]:79cc2d138606f0fca4e549c34a1e6d19
Key [ 8]:803dc5cdde0efdbee7a1342b2cd4d344
round 5:0cfd7856edfafac51f29e86365de6f57
Key [ 9]:e8fa996448e6b6459ab51e7be101325a
Key [10]:2acc7add7b294acb444cd933f0e74ec9
round 6:2f1fa34bf352dc77c0983a01e8b7d622
Key [11]:f57de39e42182efd6586b86a90c86bb1
Key [12]:e418dfd1bb22ebf1bf309cd27f5266c
round 7:ee4f7a53849bf73a747065d35f3752b1
Key [13]:80a9959133856586370854db6e0470b3
Key [14]:f4c1bc2f764a0193749f5fc09011a1ae
round 8:8fec6f7249760ebf69e370e9a4b80a92
Key [15]:d036cef70d6470c3f52f1b5d25b0c29d
Key [16]:d0956af6b8700888a1cc88f07ad226dc
Key [17]:1ce8b39c4c7677373c30849a3ee08794
kc      :ea520cfc546b00eb7c3a6cea3ecb39ed
```

=====

SECURITY SPECIFICATION



This document describes the specification of the security system which may be used at the link layer. The Encryption, Authentication and Key Generation schemes are specified. The requirements for the supporting process of random number generation are also specified.



CONTENTS

| | | |
|----------|--|------------|
| 1 | Security Overview | 773 |
| 2 | Random Number Generation | 775 |
| 3 | Key Management..... | 777 |
| 3.1 | Key Types | 777 |
| 3.2 | Key Generation and Initialization | 779 |
| 3.2.1 | Generation of initialization key, | 780 |
| 3.2.2 | Authentication..... | 780 |
| 3.2.3 | Generation of a unit key | 780 |
| 3.2.4 | Generation of a combination key..... | 781 |
| 3.2.5 | Generating the encryption key | 782 |
| 3.2.6 | Point-to-multipoint configuration..... | 783 |
| 3.2.7 | Modifying the link keys | 784 |
| 3.2.8 | Generating a master key | 784 |
| 4 | Encryption..... | 787 |
| 4.1 | Encryption Key Size Negotiation..... | 788 |
| 4.2 | Encryption of Broadcast Messages..... | 788 |
| 4.3 | Encryption Concept..... | 789 |
| 4.4 | Encryption Algorithm | 790 |
| 4.4.1 | The operation of the cipher | 792 |
| 4.5 | LFSR Initialization | 793 |
| 4.6 | Key Stream Sequence | 796 |
| 5 | Authentication | 797 |
| 5.1 | Repeated Attempts | 799 |
| 6 | The Authentication And Key-Generating Functions | 801 |
| 6.1 | The Authentication Function E1 | 801 |
| 6.2 | The Functions Ar and A'r..... | 803 |
| 6.2.1 | The round computations..... | 803 |
| 6.2.2 | The substitution boxes “e” and “l” | 803 |
| 6.2.3 | Key scheduling | 804 |
| 6.3 | E2-Key Generation Function for Authentication..... | 805 |
| 6.4 | E3-Key Generation Function for Encryption..... | 807 |
| 7 | List of Figures..... | 809 |
| 8 | List of Tables | 811 |



1 SECURITY OVERVIEW

Bluetooth wireless technology provides peer-to-peer communications over short distances. In order to provide usage protection and information confidentiality, the system provides security measures both at the application layer and the link layer. These measures are designed to be appropriate for a peer environment. This means that in each device, the authentication and encryption routines are implemented in the same way. Four different entities are used for maintaining security at the link layer: a Bluetooth device address, two secret keys, and a pseudo-random number that shall be regenerated for each new transaction. The four entities and their sizes are summarized in [Table 1.1](#).

| Entity | Size |
|---|------------|
| BD_ADDR | 48 bits |
| Private user key, authentication | 128 bits |
| Private user key, encryption configurable length (byte-wise) | 8-128 bits |
| RAND | 128 bits |

Table 1.1: Entities used in authentication and encryption procedures.

The Bluetooth device address (BD_ADDR) is the 48-bit address. The BD_ADDR can be obtained via user interactions, or, automatically, via an inquiry routine by a device.

The secret keys are derived during initialization and are never disclosed. The encryption key is derived from the authentication key during the authentication process. For the authentication algorithm, the size of the key used is always 128 bits. For the encryption algorithm, the key size may vary between 1 and 16 octets (8 - 128 bits). The size of the encryption key is configurable for two reasons. The first has to do with the many different requirements imposed on cryptographic algorithms in different countries – both with respect to export regulations and official attitudes towards privacy in general. The second reason is to facilitate a future upgrade path for the security without the need of a costly redesign of the algorithms and encryption hardware; increasing the effective key size is the simplest way to combat increased computing power at the opponent side.

The encryption key is entirely different from the authentication key (even though the latter is used when creating the former, as is described in [Section 6.4 on page 807](#)). Each time encryption is activated, a new encryption key shall be generated. Thus, the lifetime of the encryption key does not necessarily correspond to the lifetime of the authentication key.

It is anticipated that the authentication key will be more static in its nature than the encryption key – once established, the particular application running on the device decides when, or if, to change it. To underline the fundamental impor-



tance of the authentication key to a specific link, it is often be referred to as the link key.

The RAND is a pseudo-random number which can be derived from a random or pseudo-random process in the device. This is not a static parameter, it will change frequently.

In the remainder of this chapter, the terms user and application will be used interchangeably to designate the entity that is at either side.

2 RANDOM NUMBER GENERATION

Each device has a pseudo-random number generator. Pseudo-random numbers are used for many purposes within the security functions – for instance, for the challenge-response scheme, for generating authentication and encryption keys, etc. Ideally, a true random generator based on some physical process with inherent randomness should be used as a seed. Examples of such processes are thermal noise from a semiconductor or resistor and the frequency instability of a free running oscillator. For practical reasons, a software based solution with a pseudo-random generator is probably preferable. In general, it is quite difficult to classify the randomness of a pseudo-random sequence. Within this specification, the requirements placed on the random numbers used are non-repeating and randomly generated.

The expression ‘non-repeating’ means that it shall be highly unlikely that the value will repeat itself within the lifetime of the authentication key. For example, a non-repeating value could be the output of a counter that is unlikely to repeat during the lifetime of the authentication key, or a date/time stamp.

The expression ‘randomly generated’ means that it shall not be possible to predict its value with a chance that is significantly larger than 0 (e.g., greater than $1/2^L$ for a key length of L bits).

The LM may use such a generator for various purposes; i.e. whenever a random number is needed (such as the RANDs, the unit keys, K_{init} , K_{master} , and random back-off or waiting intervals).



3 KEY MANAGEMENT

It is important that the encryption key size within a specific device cannot be set by the user – this should be a factory preset entity. In order to prevent the user from over-riding the permitted key size, the Bluetooth baseband processing shall not accept an encryption key given from higher software layers. Whenever a new encryption key is required, it shall be created as defined in [Section 6.4 on page 807](#).

Changing a link key shall also be done through the defined baseband procedures. Depending on what kind of link key it is, different approaches are required. The details are found in [Section 3.2.7 on page 784](#).

3.1 KEY TYPES

The link key is a 128-bit random number which is shared between two or more parties and is the base for all security transactions between these parties. The link key itself is used in the authentication routine. Moreover, the link key is used as one of the parameters when the encryption key is derived.

In the following, a session is defined as the time interval for which the device is a member of a particular piconet. Thus, the session terminates when the device disconnects from the piconet.

The link keys are either semi-permanent or temporary. A semi-permanent link key may be stored in non-volatile memory and may be used after the current session is terminated. Consequently, once a semi-permanent link key is defined, it may be used in the authentication of several subsequent connections between the devices sharing it. The designation semi-permanent is justified by the possibility of changing it. How to do this is described in [Section 3.2.7 on page 784](#).

The lifetime of a temporary link key is limited by the lifetime of the current session – it shall not be reused in a later session. Typically, in a point-to-multipoint configuration where the same information is to be distributed securely to several recipients, a common encryption key is useful. To achieve this, a special link key (denoted master key) may temporarily replace the current link keys. The details of this procedure are found in [Section 3.2.6 on page 783](#).

In the following, the current link key is the link key in use at the current moment. It can be semi-permanent or temporary. Thus, the current link key is used for all authentications and all generation of encryption keys in the on-going connection (session).



In order to accommodate different types of applications, four types of link keys have been defined:

- the combination key K_{AB}
- the unit key K_A
- the temporary key K_{master}
- the initialization key K_{init}

Note: the use of unit keys is deprecated since it is implicitly insecure.

In addition to these keys there is an encryption key, denoted K_C . This key is derived from the current link key. Whenever encryption is activated by an LM command, the encryption key shall be changed automatically. The purpose of separating the authentication key and encryption key is to facilitate the use of a shorter encryption key without weakening the strength of the authentication procedure. There are no governmental restrictions on the strength of authentication algorithms. However, in some countries, such restrictions exist on the strength of encryption algorithms.

The combination key K_{AB} and the unit key K_A are functionally indistinguishable; the difference is in the way they are generated. The unit key K_A is generated in, and therefore dependent on, a single device A. The unit key shall be generated once at installation of the device; thereafter, it is very rarely changed. The combination key is derived from information in both devices A and B, and is therefore always dependent on two devices. The combination key is derived for each new combination of two devices.

It depends on the application or the device whether a unit key or a combination key is used. Devices which have little memory to store keys, or are installed in equipment that will be accessible to a large group of users, should use their own unit key. In that case, they only have to store a single key. Applications that require a higher security level should use the combination keys. These applications will require more memory since a combination key for each link to a different device has to be stored.

The master key, K_{master} , shall only be used during the current session. It shall only replace the original link key temporarily. For example, this may be utilized when a master wants to reach more than two devices simultaneously using the same encryption key, see [Section 3.2.6 on page 783](#).

The initialization key, K_{init} , shall be used as the link key during the initialization process when no combination or unit keys have been defined and exchanged yet or when a link key has been lost. The initialization key protects the transfer of initialization parameters. The key is derived from a random number, an L-octet PIN code, and a BD_ADDR. This key shall only be used during initialization.



The PIN may be a fixed number provided with the device (for example when there is no user interface as in a PSTN plug). Alternatively, the PIN can be selected by the user, and then entered in both devices that are to be matched. The latter procedure should be used when both devices have a user interface, for example a phone and a laptop. Entering a PIN in both devices is more secure than using a fixed PIN in one of the devices, and should be used whenever possible. Even if a fixed PIN is used, it shall be possible to change the PIN; this is in order to prevent re-initialization by users who once got hold of the PIN. If no PIN is available, a default value of zero may be used. The length of this default PIN is one byte, PIN(default) = 0x00. This default PIN may be provided by the host.

For many applications the PIN code will be a relatively short string of numbers. Typically, it may consist of only four decimal digits. Even though this gives sufficient security in many cases, there exist countless other, more sensitive, situations where this is not reliable enough. Therefore, the PIN code may be chosen to be any length from 1 to 16 octets. For the longer lengths, the devices exchanging PIN codes may not use mechanical (i.e. human) interaction, but rather may use software at the application layer. For example, this can be a Diffie-Hellman key agreement, where the exchanged key is passed on to the K_{init} generation process in both devices, just as in the case of a shorter PIN code.

3.2 KEY GENERATION AND INITIALIZATION

The link keys must be generated and distributed among the devices in order to be used in the authentication procedure. Since the link keys shall be secret, they shall not be obtainable through an inquiry routine in the same way as the Bluetooth device addresses. The exchange of the keys takes place during an initialization phase which shall be carried out separately for each two devices that are using authentication and encryption. The initialization procedures consist of the following five parts:

- generation of an initialization key
- generation of link key
- link key exchange
- authentication
- generation of encryption key in each device (optional)

After the initialization procedure, the devices can proceed to communicate, or the link can be disconnected. If encryption is implemented, the E_0 algorithm shall be used with the proper encryption key derived from the current link key. For any new connection established between devices A and B, they should use the common link key for authentication, instead of once more deriving K_{init} from the PIN. A new encryption key derived from that particular link key shall be created next time encryption is activated.

If no link key is available, the LM shall automatically start an initialization procedure.

3.2.1 Generation of initialization key, K_{init}

A link key is used temporarily during initialization, the initialization key K_{init} . This key shall be derived by the E_{22} algorithm from a BD_ADDR, a PIN code, the length of the PIN (in octets), and a random number IN_RAND. The principle is depicted in [Figure 6.4 on page 807](#). The 128-bit output from E_{22} shall be used for key exchange during the generation of a link key. When the devices have performed the link key exchange, the initialization key shall be discarded.

When the initialization key is generated, the PIN is augmented with the BD_ADDR. If one device has a fixed PIN the BD_ADDR of the other device shall be used. If both devices have a variable PIN the BD_ADDR of the device that received IN_RAND shall be used. If both devices have a fixed PIN they cannot be paired. Since the maximum length of the PIN used in the algorithm cannot exceed 16 octets, it is possible that not all octets of BD_ADDR will be used. This procedure ensures that K_{init} depends on the identity of the device with a variable PIN. A fraudulent device may try to test a large number of PINs by claiming another BD_ADDR each time. It is the application's responsibility to take countermeasures against this threat. If the device address is kept fixed, the waiting interval before the next try may be increased exponentially (see [Section 5.1 on page 799](#)).

The details of the E_{22} algorithm can be found in [Section 6.3 on page 805](#).

3.2.2 Authentication

The authentication procedure shall be carried out as described in [Section 5 on page 797](#). During each authentication, a new AU_RAND_A shall be issued.

Mutual authentication is achieved by first performing the authentication procedure in one direction and then immediately performing the authentication procedure in the opposite direction.

As a side effect of a successful authentication procedure an auxiliary parameter, the Authenticated Ciphering Offset (ACO), will be computed. The ACO shall be used for ciphering key generation as described in [Section 3.2.5 on page 782](#).

The claimant/verifier status is determined by the LM.

3.2.3 Generation of a unit key

A unit key K_A shall be generated when the device is in operation for the first time; i.e. not during each initialization. The unit key shall be generated by the E_{21} algorithm as described in [Section 6.3 on page 805](#). Once created, the unit key should be stored in non-volatile memory and very rarely changed. If after initialization

the unit key is changed, any previously initialized devices will possess a wrong link key. At initialization, the application must determine which of the two parties will provide the unit key as the link key. Typically, this will be the device with restricted memory capabilities, since this device only has to remember its own unit key. The unit key shall be transferred to the other party and then stored as the link key for that particular party. So, for example in [Figure 3.1 on page 781](#), the unit key of device A, K_A , is being used as the link key for the connection A-B; device A sends the unit key K_A to device B; device B will store K_A as the link key K_{BA} . For another initialization, for example with device C, device A will reuse its unit key K_A , whereas device C stores it as K_{CA} .

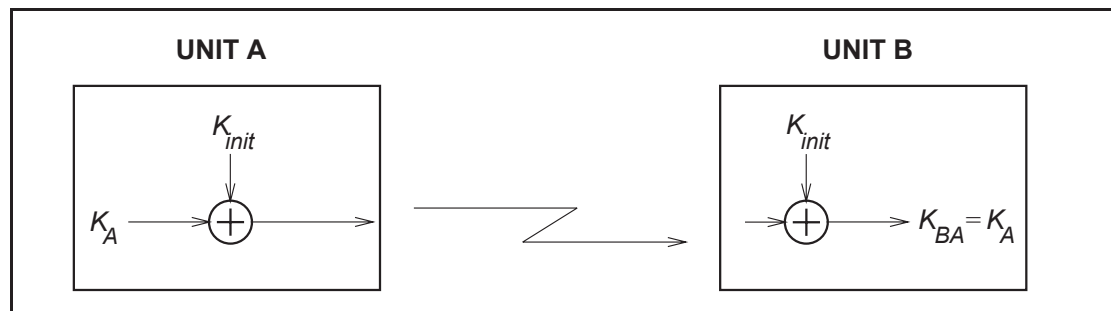


Figure 3.1: Generation of unit key. When the unit key has been exchanged, the initialization key is discarded in both devices.

3.2.4 Generation of a combination key

To use a combination key, it is first generated during the initialization procedure. The combination key is the combination of two numbers generated in device A and B, respectively. First, each device shall generate a random number, LK_RAND_A and LK_RAND_B . Then, utilizing E_{21} with the random number and their own BD_ADDRs , the two random numbers

$$LK_K_A = E_{21}(LK_RAND_A, BD_ADDR_A), \quad (EQ\ 1)$$

and

$$LK_K_B = E_{21}(LK_RAND_B, BD_ADDR_B), \quad (EQ\ 2)$$

shall be created in device A and device B, respectively. These numbers constitute the devices' contribution to the combination key that is to be created. Then, the two random numbers LK_RAND_A and LK_RAND_B shall be exchanged securely by XORing with the current link key, K . Thus, device A shall send $K \oplus LK_RAND_A$ to device B, while device B shall send $K \oplus LK_RAND_B$ to device A. If this is done during the initialization phase the link key $K = K_{init}$.

When the random numbers LK_RAND_A and LK_RAND_B have been mutually exchanged, each device shall recalculate the other device's contribution to the combination key. This is possible since each device knows the Bluetooth device address of the other device. Thus, device A shall calculate (EQ 2) on page 781 and device B shall calculate (EQ 1) on page 781. After this, both devices shall combine the two numbers to generate the 128-bit link key. The combining operation is a simple bitwise modulo-2 addition (i.e. XOR). The result shall be stored in device A as the link key K_{AB} and in device B as the link key K_{BA} . When both devices have derived the new combination key, a mutual authentication procedure shall be initiated to confirm the success of the transaction. The old link key shall be discarded after a successful exchange of a new combination key. The message flow between master and slave and the principle for creating the combination key is depicted in Figure 3.2 on page 782.

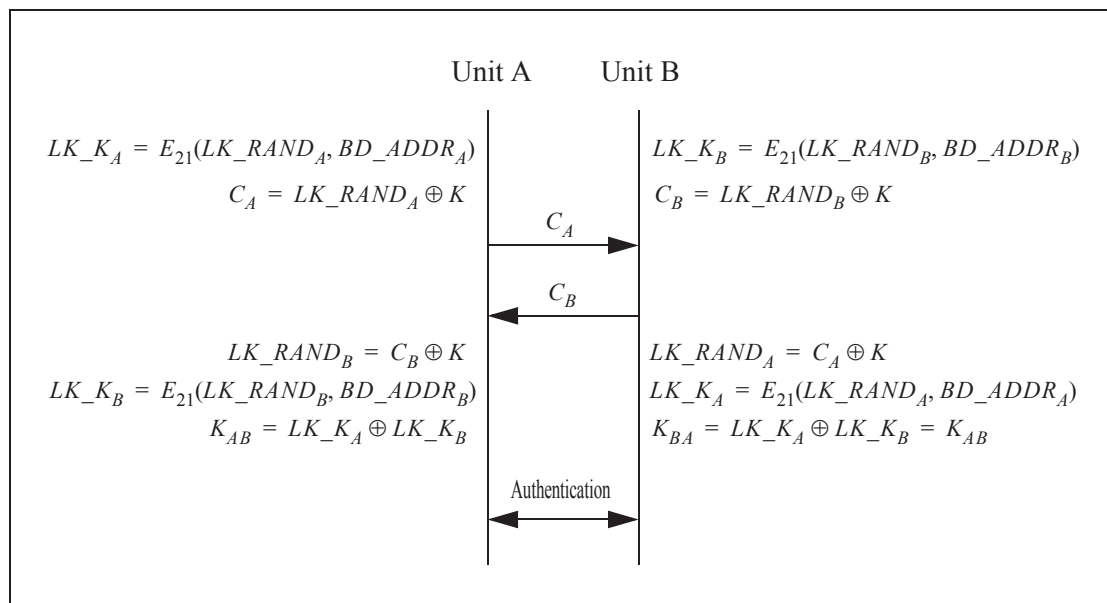


Figure 3.2: Generating a combination key. The old link key (K) is discarded after the exchange of a new combination key has succeeded

3.2.5 Generating the encryption key

The encryption key, K_C , is derived by algorithm E_3 from the current link key, a 96-bit Ciphering Offset number (COF), and a 128-bit random number. The COF is determined in one of two ways. If the current link key is a master key, then COF shall be derived from the master BD_ADDR. Otherwise the value of COF shall be set to the value of ACO as computed during the authentication procedure. Therefore:¹

1. $x \cup y$ denotes the concatenation of x and y .

$$\text{COF} = \begin{cases} \text{BD_ADDR} \cup \text{BD_ADDR}, & \text{if link key is a master key} \\ \text{ACO}, & \text{otherwise.} \end{cases} \quad (\text{EQ 3})$$

There is an explicit call of E_3 when the LM activates encryption. Consequently, the encryption key is automatically changed each time the device enters encryption mode. The details of the key generating function E_3 can be found in [Section 6.4 on page 807](#).

3.2.6 Point-to-multipoint configuration

It is possible for the master to use separate encryption keys for each slave in a point-to-multipoint configuration with ciphering activated. Then, if the application requires more than one slave to listen to the same payload, each slave must be addressed individually. This can cause unwanted capacity loss for the piconet. Moreover, a slave might not be capable of switching between two or more encryption keys in real time (e.g., after looking at the LT_ADDR in the header). Thus, the master cannot use different encryption keys for broadcast messages and individually addressed traffic. Therefore, the master may tell several slave devices to use a common link key (and, hence, indirectly also to use a common encryption key) and may then broadcast the information encrypted. For many applications, this key is only of temporary interest. In the following discussion, this key is denoted by K_{master} .

The transfer of necessary parameters shall be protected by the routine described in [Section 3.2.8 on page 784](#). After the confirmation of successful reception in each slave, the master shall issue a command to the slaves to replace their respective current link key by the new (temporary) master key. Before encryption can be activated, the master shall also generate and distribute a common EN_RAND to all participating slaves. Using this random number and the newly derived master key, each slave shall generate a new encryption key.

Note that the master must negotiate the encryption key length to use individually with each slave that will use the master key. If the master has already negotiated with some of these slaves, it has knowledge of the sizes that can be accepted. There may be situations where the permitted key lengths of some devices are incompatible. In that case, the master must exclude the limiting device from the group.

When all slaves have received the necessary data, the master can communicate information on the piconet securely using the encryption key derived from the new temporary link key. Each slave in possession of the master key can eavesdrop on all encrypted traffic, not only the traffic intended for itself. The master may tell all participants to fall back to their old link keys simultaneously.

3.2.7 Modifying the link keys

A link key based on a unit key can be changed. The unit key is created once during first use. Typically, the link key should be changed rather than the unit key, as several devices may share the same unit key as link key (e.g. a printer whose unit key is distributed to all users using the printer's unit key as link key). Changing the unit key will require re-initialization of all devices connecting. Changing the unit key can be justified in some circumstances, e.g. to deny access to all previously allowed devices.

If the key change concerns combination keys, then the procedure is straightforward. The change procedure is identical to the procedure described in [Figure 3.2 on page 782](#), using the current value of the combination key as link key. This procedure can be carried out at any time after the authentication and encryption start. Since the combination key corresponds to a single link, it can be modified each time this link is established. This will improve the security of the system since then old keys lose their validity after each session.

Starting up an entirely new initialization procedure is also possible. In that case, user interaction is necessary since a PIN will be required in the authentication and encryption procedures.

3.2.8 Generating a master key

The key-change routines described so far are semi-permanent. To create the master link key, which can replace the current link key during a session (see [Section 3.2.6 on page 783](#)), other means are needed. First, the master shall create a new link key from two 128-bit random numbers, RAND1 and RAND2. This shall be done by

$$K_{master} = E_{22}(\text{RAND1}, \text{RAND2}, 16). \quad (\text{EQ } 4)$$

This key is a 128-bit random number. The reason for using the output of E_{22} and not directly choosing a random number as the key, is to avoid possible problems with degraded randomness due to a poor implementation of the random number generator within the device.

Then, a third random number, RAND, shall be transmitted to the slave. Using E_{22} with the current link key and RAND as inputs, both the master and the slave shall compute a 128-bit overlay. The master shall send the bitwise XOR of the overlay and the new link key to the slave. The slave, who knows the overlay, shall recalculate K_{master} . To confirm the success of this transaction, the devices shall perform a mutual authentication procedure using the new link key. This procedure shall then be repeated for each slave that receives the new link key. The ACO values from the authentications shall not replace the current ACO, as this ACO is needed to (re)compute a ciphering key when the master falls back to the previous (non-temporary) link key.

The master activates encryption by an LM command. Before activating encryption, the master shall ensure that all slaves receive the same random number, EN RAND, since the encryption key is derived through the means of E_3 individually in all participating devices. Each slave shall compute a new encryption key as follows:

$$K_C = E_3(K_{master}, EN_RAND, COF)$$

(EQ 5)

where the value of COF shall be derived from the master’s BD_ADDR as specified by equation (EQ 3) on page 783. The details of the encryption key generating function are described in Section 6.4 on page 807. The message flow between the master and the slave when generating the master key is depicted in Figure 3.3. Note that in this case the ACO produced during the authentication is not used when computing the ciphering key.

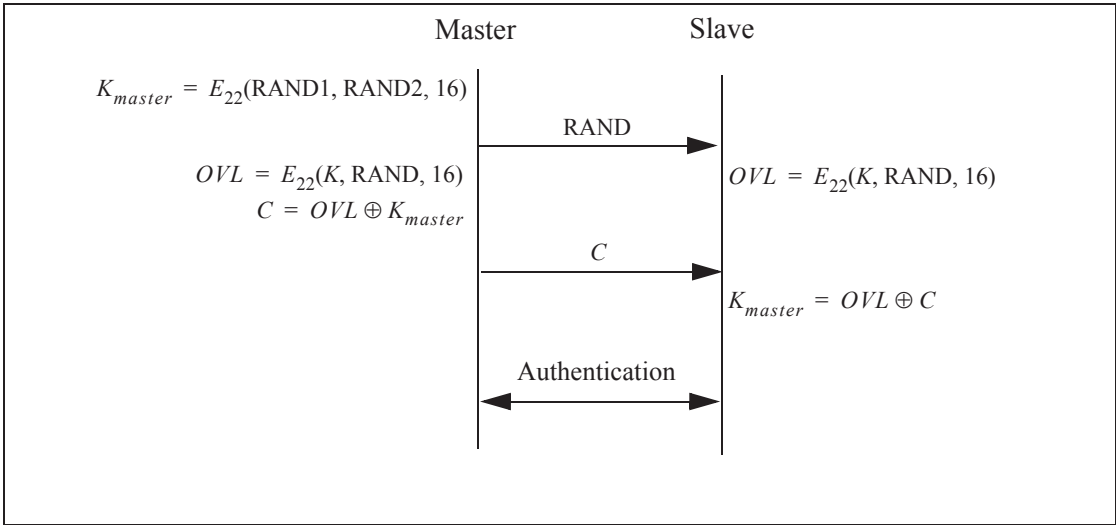


Figure 3.3: Master link key distribution and computation of the corresponding encryption key.



4 ENCRYPTION

User information can be protected by encryption of the packet payload; the access code and the packet header shall never be encrypted. The encryption of the payload shall be carried out with a stream cipher called E_0 that shall be re-synchronized for every payload. The overall principle is shown in [Figure 4.1 on page 787](#).

The stream cipher system E_0 shall consist of three parts:

- the first part performs initialization (generation of the payload key). The payload key generator shall combine the input bits in an appropriate order and shall shift them into the four LFSRs used in the key stream generator.
- the second part generates the key stream bits and shall use a method derived from the summation stream cipher generator attributable to Massey and Rueppel. The second part is the main part of the cipher system, as it will also be used for initialization.
- the third part performs encryption and decryption.

The Massey and Rueppel method has been thoroughly investigated, and there exist good estimates of its strength with respect to presently known methods for cryptanalysis. Although the summation generator has weaknesses that can be used in correlation attacks, the high re-synchronization frequency will disrupt such attacks.

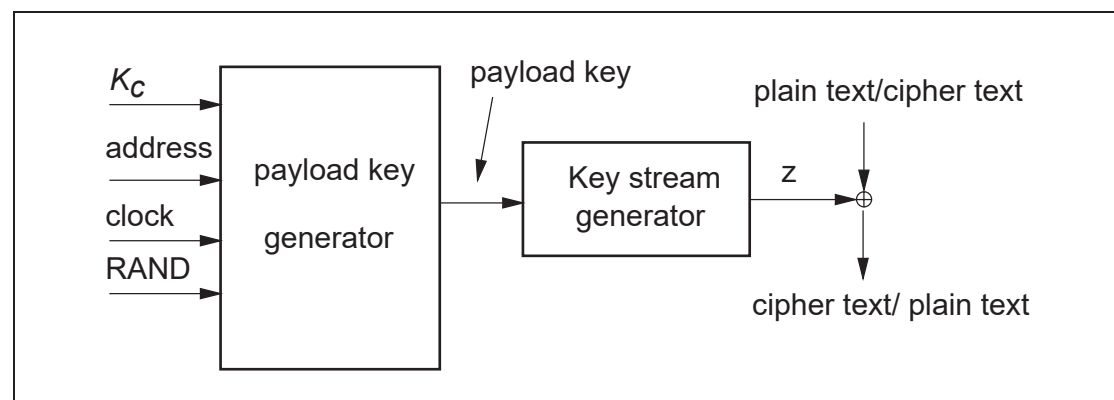


Figure 4.1: Stream ciphering for Bluetooth with E_0 .

4.1 ENCRYPTION KEY SIZE NEGOTIATION

Each device implementing the baseband specification shall have a parameter defining the maximal allowed key length, L_{max} , $1 \leq L_{max} \leq 16$ (number of octets in the key). For each application using encryption, a number L_{min} shall be defined indicating the smallest acceptable key size for that particular application. Before generating the encryption key, the devices involved shall negotiate to decide the key size to use.

The master shall send a suggested value, $L_{sug}^{(M)}$, to the slave. Initially, the suggested value shall be set to $L_{max}^{(M)}$. If $L_{min}^{(S)} \leq L_{sug}^{(M)}$, and, the slave supports the suggested length, the slave shall acknowledge and this value shall be the length of the encryption key for this link. However, if both conditions are not fulfilled, the slave shall send a new proposal, $L_{sug}^{(S)} < L_{sug}^{(M)}$, to the master. This value shall be the largest among all supported lengths less than the previous master suggestion. Then, the master shall perform the corresponding test on the slave suggestion. This procedure shall be repeated until a key length agreement is reached, or, one device aborts the negotiation. An abort may be caused by lack of support for L_{sug} and all smaller key lengths, or if $L_{sug} < L_{min}$ in one of the devices. In case of an abort link encryption can not be employed.

The possibility of a failure in setting up a secure link is an unavoidable consequence of letting the application decide whether to accept or reject a suggested key size. However, this is a necessary precaution. Otherwise a fraudulent device could enforce a weak protection on a link by claiming a small maximum key size.

4.2 ENCRYPTION OF BROADCAST MESSAGES

There may be three settings for the baseband regarding encryption:

1. No encryption.
This is the default setting. No messages are encrypted
2. Point-to-point only encryption.
Broadcast messages are not encrypted. This may be enabled either during the connection establishment procedure or after the connection has been established.
3. Point-to-point and broadcast encryption.
All messages are encrypted. This may be enabled after the connection has been established only. This setting should not be enabled unless all affected links share the same master link key as well as the same EN_RANDOM value, both used in generating the encryption key.

4.3 ENCRYPTION CONCEPT

| Broadcast traffic | Individually addressed traffic |
|--------------------------|--------------------------------|
| No encryption | No encryption |
| No encryption | Encryption, K_{master} |
| Encryption, K_{master} | Encryption, K_{master} |

Table 4.1: Possible encryption modes for a slave in possession of a master key.

For the encryption routine, a stream cipher algorithm is used in which ciphering bits are bit-wise modulo-2 added to the data stream to be sent over the air interface. The payload is ciphered after the CRC bits are appended, but, prior to the FEC encoding.

Each packet payload shall be ciphered separately. The cipher algorithm E_0 uses the master Bluetooth device address (BD_ADDR), 26 bits of the master real-time clock (CLK₂₆₋₁) and the encryption key K_C as input, see [Figure 4.2 on page 790](#) (where it is assumed that device A is the master).

The encryption key K_C is derived from the current link key, COF, and a random number, EN_RANDOM_A (see [Section 6.4 on page 807](#)). The random number shall be issued by the master before entering encryption mode. Note that EN_RANDOM_A is publicly known since it is transmitted as plain text over the air.

Within the E_0 algorithm, the encryption key K_C is modified into another key denoted K'_C . The maximum effective size of this key shall be factory preset and may be set to any multiple of eight between one and sixteen (8-128 bits). The procedure for deriving the key is described in [Section 4.5 on page 793](#).

The real-time clock is incremented for each slot. The E_0 algorithm shall be re-initialized at the start of each new packet (i.e. for Master-to-Slave as well as for Slave-to-Master transmission). By using CLK₂₆₋₁ at least one bit is changed between two transmissions. Thus, a new keystream is generated after each re-initialization. For packets covering more than a single slot, the Bluetooth clock as found in the first slot shall be used for the entire packet.

The encryption algorithm E_0 generates a binary keystream, K_{cipher} , which shall be modulo-2 added to the data to be encrypted. The cipher is symmetric; decryption shall be performed in exactly the same way using the same key as used for encryption.

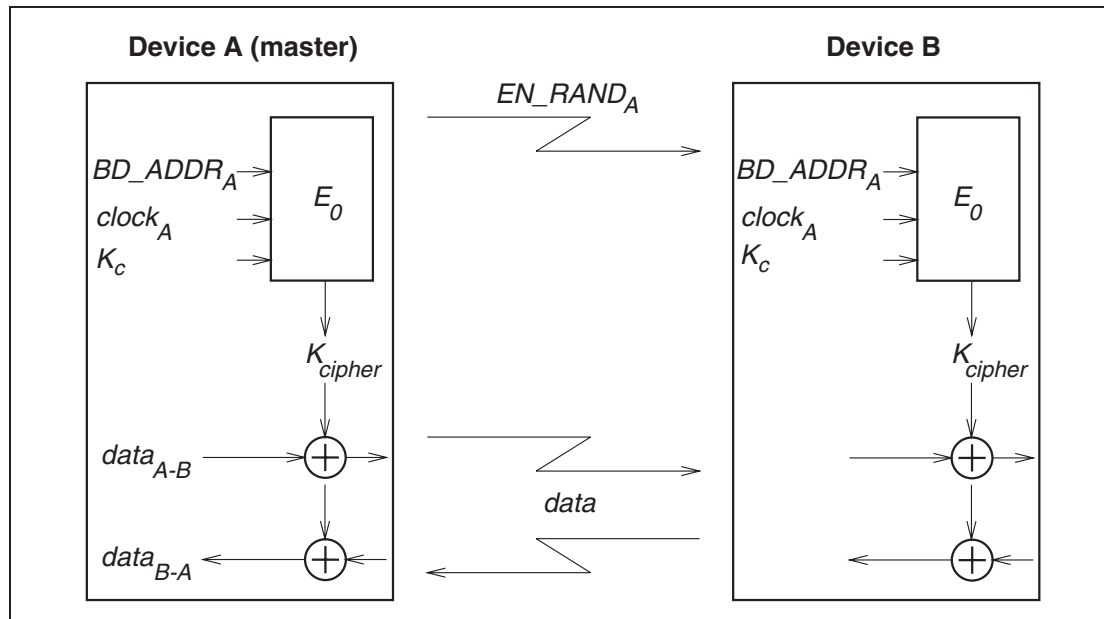


Figure 4.2: Functional description of the encryption procedure

4.4 ENCRYPTION ALGORITHM

The system uses linear feedback shift registers (LFSRs) whose output is combined by a simple finite state machine (called the summation combiner) with 16 states. The output of this state machine is the key stream sequence, or, during initialization phase, the randomized initial start value. The algorithm uses an encryption key K_C , a 48-bit Bluetooth address, the master clock bits CLK_{26-1} , and a 128-bit RAND value. [Figure 4.3 on page 791](#) shows the setup.

There are four LFSRs ($\text{LFSR}_1, \dots, \text{LFSR}_4$) of lengths $L_1 = 25$, $L_2 = 31$, $L_3 = 33$, and, $L_4 = 39$, with feedback polynomials as specified in [Table 4.2 on page 791](#). The total length of the registers is 128. These polynomials are all primitive. The Hamming weight of all the feedback polynomials is chosen to be five – a reasonable trade-off between reducing the number of required XOR gates in the hardware implementation and obtaining good statistical properties of the generated sequences.

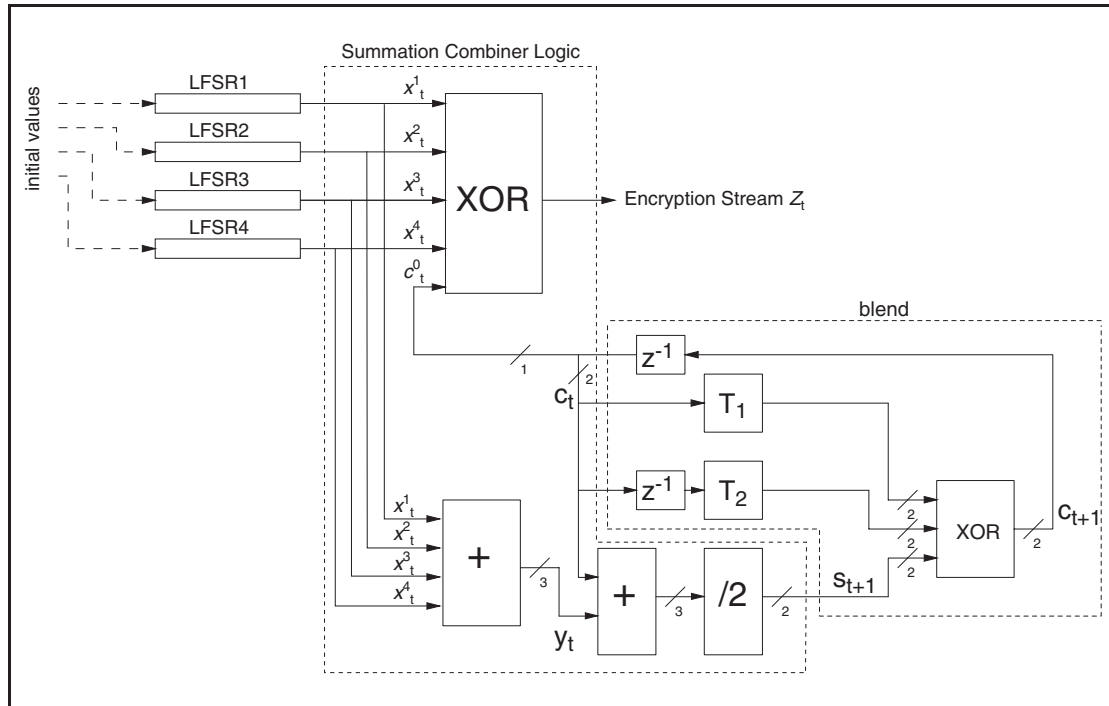


Figure 4.3: Concept of the encryption engine.

| i | L_i | feedback $f_i(t)$ | weight |
|-----|-------|---|--------|
| 1 | 25 | $t^{25} + t^{20} + t^{12} + t^8 + 1$ | 5 |
| 2 | 31 | $t^{31} + t^{24} + t^{16} + t^{12} + 1$ | 5 |
| 3 | 33 | $t^{33} + t^{28} + t^{24} + t^4 + 1$ | 5 |
| 4 | 39 | $t^{39} + t^{36} + t^{28} + t^4 + 1$ | 5 |

Table 4.2: The four primitive feedback polynomials.

Let x_t^i denote the t^{th} symbol of LFSR $_i$. The value y_t is derived from the four-tuple x_t^1, \dots, x_t^4 using the following equation:

$$y_t = \sum_{i=1}^4 x_t^i, \quad (\text{EQ } 6)$$

where the sum is over the integers. Thus y_t can take the values 0,1,2,3, or 4. The output of the summation generator is obtained by the following equations:

$$z_t = x_t^1 \oplus x_t^2 \oplus x_t^3 \oplus x_t^4 \oplus c_t^0 \in \{0, 1\}, \quad (\text{EQ } 7)$$

$$s_{t+1} = (s_{t+1}^1, s_{t+1}^0) = \left\lfloor \frac{y_t + c_t}{2} \right\rfloor \in \{0, 1, 2, 3\}, \quad (\text{EQ } 8)$$

$$c_{t+1} = (c_{t+1}^1, c_{t+1}^0) = s_{t+1} \oplus T_1[c_t] \oplus T_2[c_{t-1}], \quad (\text{EQ } 9)$$

where $T_1[\cdot]$ and $T_2[\cdot]$ are two different linear bijections over GF(4). Suppose GF(4) is generated by the irreducible polynomial $x^2 + x + 1$, and let α be a zero of this polynomial in GF(4). The mappings T_1 and T_2 are now defined as:

$$T_1: \text{GF}(4) \rightarrow \text{GF}(4)$$

$$x \mapsto x$$

$$T_2: \text{GF}(4) \rightarrow \text{GF}(4)$$

$$x \mapsto (\alpha + 1)x.$$

The elements of GF(4) can be written as binary vectors. This is summarized in [Table 4.3](#).

| x | $T_1[x]$ | $T_2[x]$ |
|-----|----------|----------|
| 00 | 00 | 00 |
| 01 | 01 | 11 |
| 10 | 10 | 01 |
| 11 | 11 | 10 |

Table 4.3: The mappings T_1 and T_2 .

Since the mappings are linear, they can be implemented using XOR gates; i.e.

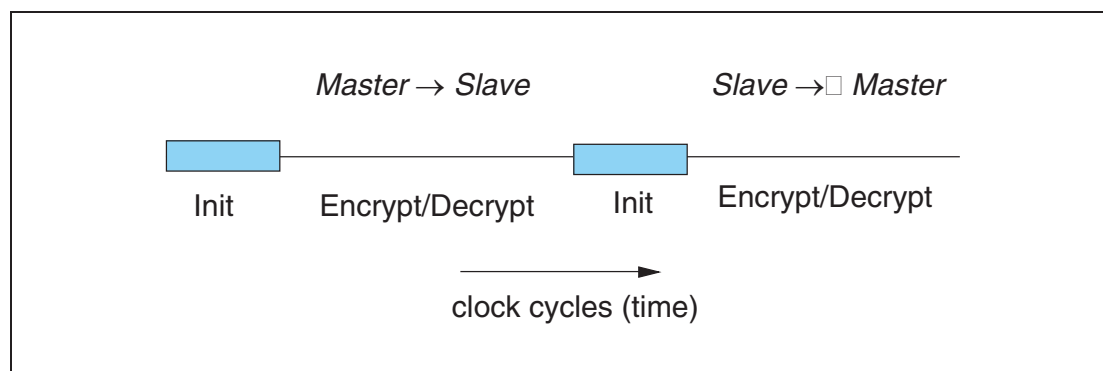
$$T_1: (x_1, x_0) \mapsto (x_1, x_0),$$

$$T_2: (x_1, x_0) \mapsto (x_0, x_1 \oplus x_0).$$

4.4.1 The operation of the cipher

[Figure 4.4 on page 792](#) gives an overview of the operation in time. The encryption algorithm shall run through the initialization phase before the start of transmission or reception of a new packet. Thus, for multislots packets the cipher is initialized using the clock value of the first slot in the multislots sequence.

Figure 4.4: Overview of the operation of the encryption engine. Between each start of a packet (TX or RX), the LFSRs are re-initialized.



4.5 LFSR INITIALIZATION

The key stream generator is loaded with an initial value for the four LFSRs (in total 128 bits) and the 4 bits that specify the values of c_0 and c_{-1} . The 132 bit initial value is derived from four inputs by using the key stream generator. The input parameters are the key K_C , a 128-bit random number RAND, a 48-bit Bluetooth device address, and the 26 master clock bits CLK_{26-1} .

The effective length of the encryption key may vary between 8 and 128 bits. Note that the actual key length as obtained from E_3 is 128 bits. Then, within E_0 , the key length may be reduced by a modulo operation between K_C and a polynomial of desired degree. After reduction, the result is encoded with a block code in order to distribute the starting states more uniformly. The operation shall be as defined in (EQ 10) on page 794.

When the encryption key has been created the LFSRs are loaded with their initial values. Then, 200 stream cipher bits are created by operating the generator. Of these bits, the last 128 are fed back into the key stream generator as an initial value of the four LFSRs. The values of c_t and c_{t-1} are kept. From this point on, when clocked the generator produces the encryption (decryption) sequence which is bitwise XORed to the transmitted (received) payload data.

In the following, octet i of a binary sequence X is $X[i]$. Bit 0 of X is the LSB. Then, the LSB of $X[i]$ corresponds to bit $8i$ of the sequence X , the MSB of $X[i]$ is bit $8i + 7$ of X . For instance, bit 24 of the Bluetooth device address is the LSB of $BD_ADDR[3]$.

The details of the initialization shall be as follows:

1. Create the encryption key to use from the 128-bit secret key K_C and the 128-bit publicly known EN_RANDOM. Let L , $1 \leq L \leq 16$, be the

effective key length in number of octets. The resulting encryption key is K'_C :

$$K'_C(x) = g_2^{(L)}(x)(K_C(x) \bmod g_1^{(L)}(x)), \quad (\text{EQ 10})$$

where $\deg(g_1^{(L)}(x)) = 8L$ and $\deg(g_2^{(L)}(x)) \leq 128 - 8L$. The polynomials are defined in [Table 4.4](#).

2. Shift the 3 inputs K'_C , the Bluetooth device address, the clock, and the six-bit constant 111001 into the LFSRs. In total, 208 bits are shifted in:
 - a) Open all switches shown in [Figure 4.5 on page 795](#);
 - b) Arrange inputs bits as shown in [Figure 4.5](#); Set the content of all shift register elements to zero. Set $t = 0$.
 - c) Start shifting bits into the LFSRs. The rightmost bit at each level of [Figure 4.5](#) is the first bit to enter the corresponding LFSR.
 - d) When the first input bit at level i reaches the rightmost position of LFSR_i , close the switch of this LFSR.
 - e) At $t = 39$ (when the switch of LFSR_4 is closed), reset both blend registers $c_{39} = c_{39-1} = 0$; Up to this point, the content of c_t and c_{t-1} has been of no concern. However, their content will now be used in computing the output sequence.
 - f) From now on output symbols are generated. The remaining input bits are continuously shifted into their corresponding shift registers. When the last bit has been shifted in, the shift register is clocked with input = 0;

Note: When finished, LFSR_1 has effectively clocked 30 times with feedback closed, LFSR_2 has clocked 24 times, LFSR_3 has clocked 22 times, and LFSR_4 has effectively clocked 16 times with feedback closed.
3. To mix initial data, continue to clock until 200 symbols have been produced with all switches closed ($t = 239$);
4. Keep blend registers c_t and c_{t-1} , make a parallel load of the last 128 generated bits into the LFSRs according to [Figure 4.6](#) at $t = 240$;

After the parallel load in item 4, the blend register contents shall be updated for each subsequent clock.

| L | deg | $g_1^{(L)}$ | deg | $g_2^{(L)}$ |
|-----|------|-------------------------------------|-------|-------------------------------------|
| 1 | [8] | 00000000 00000000 00000000 0000011d | [119] | 00e275a0 abd218d4 cf928b9b bf6cb08f |
| 2 | [16] | 00000000 00000000 00000000 0001003f | [112] | 0001e3f6 3d7659b3 7f18c258 cff6efef |
| 3 | [24] | 00000000 00000000 00000000 010000db | [104] | 000001be f66c6c3a b1030a5a 1919808b |
| 4 | [32] | 00000000 00000000 00000001 000000af | [96] | 00000001 6ab89969 de17467f d3736ad9 |

Table 4.4: Polynomials used when creating K'_C . ¹

| L | deg | $g_1^{(L)}$ | deg | $g_2^{(L)}$ |
|-----|-------|---------------------------------------|------|-------------------------------------|
| 5 | [40] | 00000000 00000000 00000100 00000039 | [88] | 00000000 01630632 91da50ec 55715247 |
| 6 | [48] | 00000000 00000000 00010000 00000291 | [77] | 00000000 00002c93 52aa6cc0 54468311 |
| 7 | [56] | 00000000 00000000 01000000 00000095 | [71] | 00000000 000000b3 f7ffce2 79f3a073 |
| 8 | [64] | 00000000 00000001 00000000 0000001b | [63] | 00000000 00000000 a1ab815b c7ec8025 |
| 9 | [72] | 00000000 00000100 00000000 00000609 | [49] | 00000000 00000000 0002c980 11d8b04d |
| 10 | [80] | 00000000 00010000 00000000 00000215 | [42] | 00000000 00000000 0000058e 24f9a4bb |
| 11 | [88] | 00000000 01000000 00000000 0000013b | [35] | 00000000 00000000 0000000c a76024d7 |
| 12 | [96] | 00000001 00000000 00000000 000000dd | [28] | 00000000 00000000 00000000 1c9c26b9 |
| 13 | [104] | 00000100 00000000 00000000 0000049d | [21] | 00000000 00000000 00000000 0026d9e3 |
| 14 | [112] | 00010000 00000000 00000000 0000014f | [14] | 00000000 00000000 00000000 00004377 |
| 15 | [120] | 01000000 00000000 00000000 000000e7 | [7] | 00000000 00000000 00000000 00000089 |
| 16 | [128] | 1 00000000 00000000 00000000 00000000 | [0] | 00000000 00000000 00000000 00000001 |

Table 4.4: Polynomials used when creating K'_c .¹

1. All polynomials are in hexadecimal notation. The LSB is in the rightmost position.

In Figure 4.5, all bits are shifted into the LFSRs, starting with the least significant bit (LSB). For instance, from the third octet of the address, BD_ADDR[2], first BD_ADDR₁₆ is entered, followed by BD_ADDR₁₇, etc. Furthermore, CL₀ corresponds to CLK₁, ..., CL₂₅ corresponds to CLK₂₆.

Note that the output symbols x_t^i , $i = 1, \dots, 4$ are taken from the positions 24, 24, 32, and 32 for LFSR₁, LFSR₂, LFSR₃, and LFSR₄, respectively (counting the leftmost position as number 1).

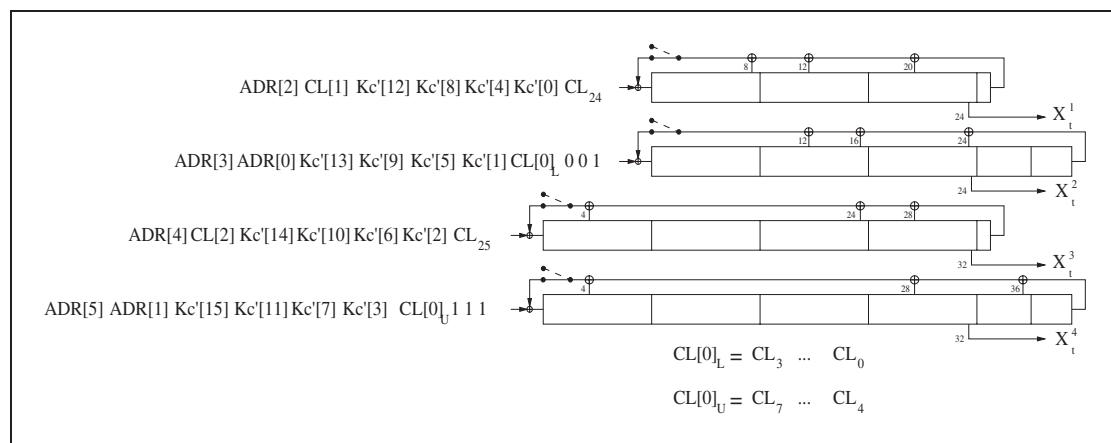


Figure 4.5: Arranging the input to the LFSRs.

In [Figure 4.6](#), the 128 binary output symbols Z_0, \dots, Z_{127} are arranged in octets denoted $Z[0], \dots, Z[15]$. The LSB of $Z[0]$ corresponds to the first of these symbols, the MSB of $Z[15]$ is the last output from the generator. These bits shall be loaded into the LFSRs according to the figure. It is a parallel load and no update of the blend registers is done. The first output symbol is generated at the same time. The octets shall be written into the registers with the LSB in the leftmost position (i.e. the opposite of before). For example, Z_{24} is loaded into position 1 of LFSR₄.

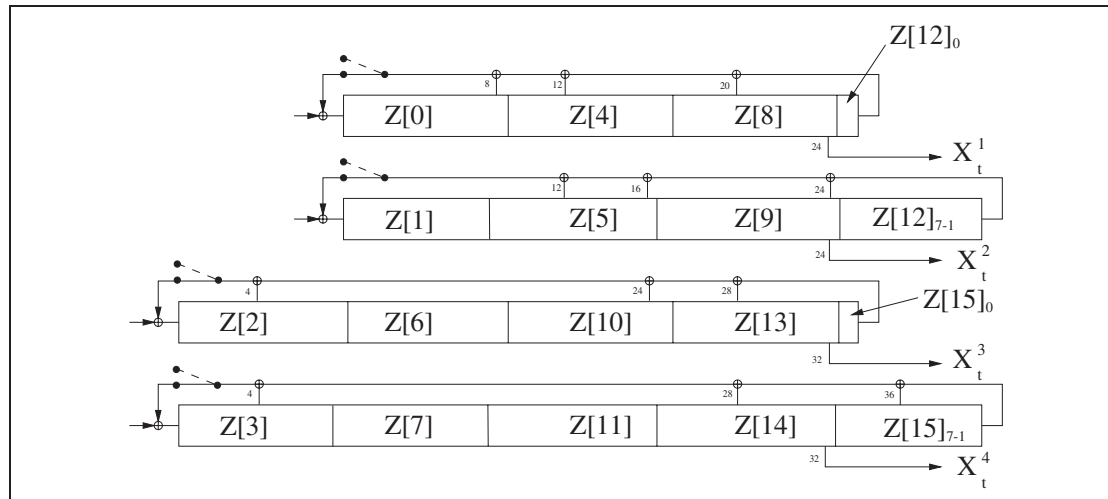


Figure 4.6: Distribution of the 128 last generated output symbols within the LFSRs.

4.6 KEY STREAM SEQUENCE

When the initialization is finished, the output from the summation combiner is used for encryption/decryption. The first bit to use shall be the one produced at the parallel load, i.e. at $t = 240$. The circuit shall be run for the entire length of the current payload. Then, before the reverse direction is started, the entire initialization process shall be repeated with updated values on the input parameters.

Sample data of the encryption output sequence can be found in [\[Part G\] Section 1 on page 673](#). A necessary, but not sufficient, condition for all Bluetooth compliant implementations of encryption is to produce these encryption streams for identical initialization values.

5 AUTHENTICATION

Authentication uses a challenge-response scheme in which a claimant's knowledge of a secret key is checked through a 2-move protocol using symmetric secret keys. The latter implies that a correct claimant/verifier pair share the same secret key, for example K . In the challenge-response scheme the verifier challenges the claimant to authenticate a random input (the challenge), denoted by AU_RAND_A , with an authentication code, denoted by E_1 , and return the result $SRES$ to the verifier, see [Figure 5.1 on page 797](#). This figure also shows that the input to E_1 consists of the tuple AU_RAND_A and the Bluetooth device address (BD_ADDR) of the claimant. The use of this address prevents a simple reflection attack¹. The secret K shared by devices A and B is the current link key.

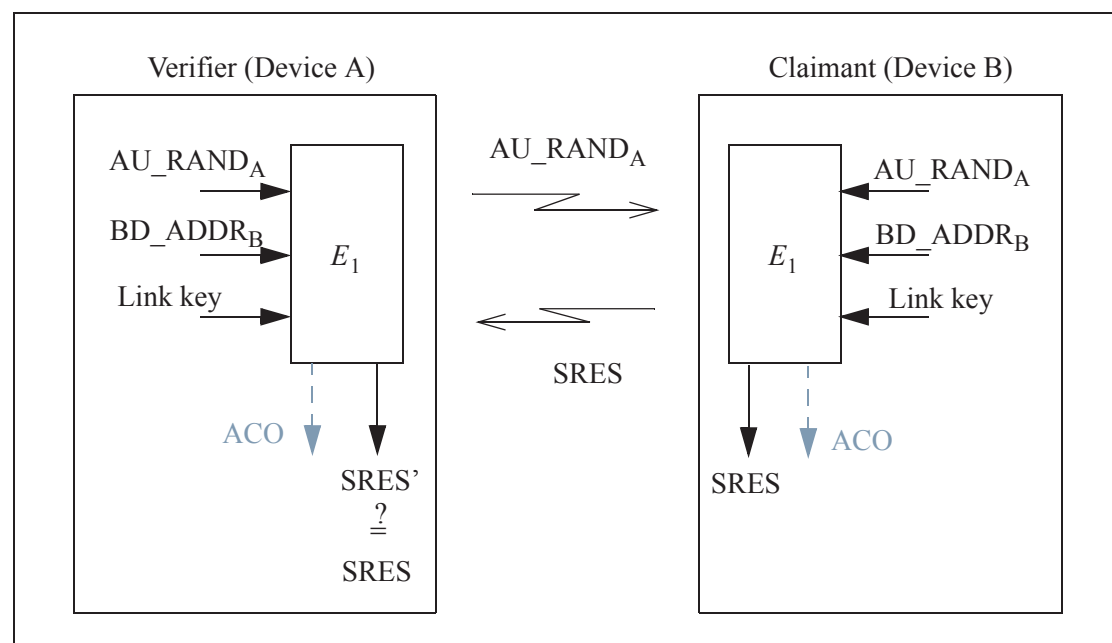


Figure 5.1: Challenge-response for the Bluetooth.

The challenge-response scheme for symmetric keys is depicted in [Figure 5.2 on page 798](#).

1. The reflection attack actually forms no threat because all service requests are dealt with on a FIFO bases. When preemption is introduced, this attack is potentially dangerous.

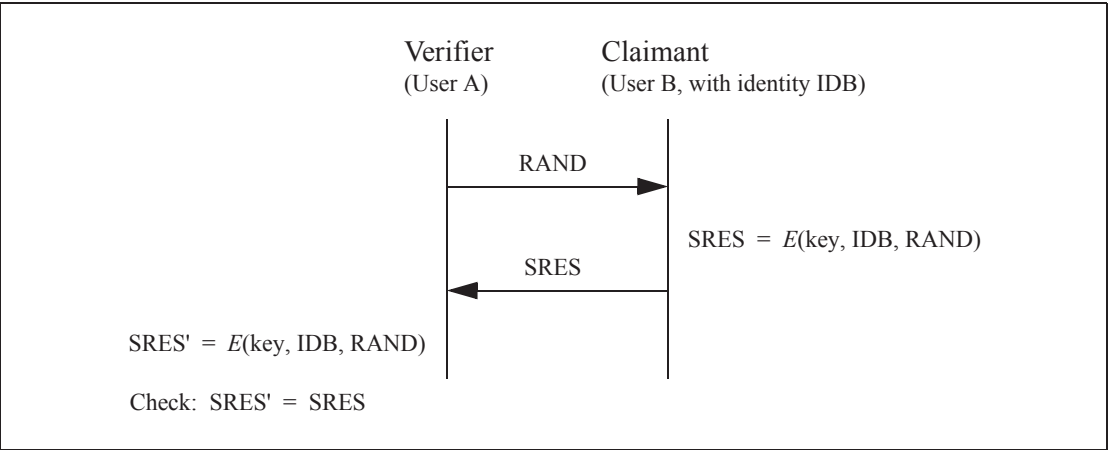


Figure 5.2: Challenge-response for symmetric key systems.

The verifier is not required to be the master. The application indicates which device has to be authenticated. Some applications only require a one-way authentication. However, some peer-to-peer communications, should use a mutual authentication in which each device is subsequently the challenger (verifier) in two authentication procedures. The LM shall process authentication preferences from the application to determine in which direction(s) the authentication(s) takes place. For mutual authentication with the devices of [Figure 5.1 on page 797](#), after device A has successfully authenticated device B, device B could authenticate device A by sending an AU_RAND_B (different from the AU_RAND_A that device A issued) to device A, and deriving the SRES and SRES' from the new AU_RAND_B , the address of device A, and the link key K_{AB} .

If an authentication is successful the value of ACO as produced by E_1 shall be retained.

5.1 REPEATED ATTEMPTS

When the authentication attempt fails, a waiting interval shall pass before the verifier will initiate a new authentication attempt to the same claimant, or before it will respond to an authentication attempt initiated by a device claiming the same identity as the failed device. For each subsequent authentication failure with the same Bluetooth device address, the waiting interval shall be increased exponentially. That is, after each failure, the waiting interval before a new attempt can be made, could be for example, twice as long as the waiting interval prior to the previous attempt¹. The waiting interval shall be limited to a maximum. The maximum waiting interval depends on the implementation. The waiting time shall exponentially decrease to a minimum when no new failed attempts are made during a certain time period. This procedure prevents an intruder from repeating the authentication procedure with a large number of different keys.

To make the system less vulnerable to denial-of-service attacks, the devices should keep a list of individual waiting intervals for each device it has established contact with. The size of this list may be restricted to only contain the N devices with which the most recent contacts have been made. The number N may vary for different devices depending on available memory size and user environment.

1. Another appropriate value larger than 1 may be used.



6 THE AUTHENTICATION AND KEY-GENERATING FUNCTIONS

This section describes the algorithms used for authentication and key generation.

6.1 THE AUTHENTICATION FUNCTION E_1

The authentication function E_1 is a computationally secure authentication code. E_1 uses the encryption function SAFER+. The algorithm is an enhanced version of an existing 64-bit block cipher SAFER-SK128, and it is freely available. In the following discussion, the block cipher will be denoted as the function A_r , which maps using a 128-bit key, a 128-bit input to a 128-bit output, i.e.

$$A_r: \{0, 1\}^{128} \times \{0, 1\}^{128} \rightarrow \{0, 1\}^{128} \quad (EQ 11)$$

$$(k \times x) \mapsto t.$$

The details of A_r are given in the next section. The function E_1 is constructed using A_r as follows

$$E_1: \{0, 1\}^{128} \times \{0, 1\}^{128} \times \{0, 1\}^{48} \rightarrow \{0, 1\}^{32} \times \{0, 1\}^{96} \quad (EQ 12)$$

$$(K, \text{RAND}, \text{address}) \mapsto (\text{SRES}, \text{ACO}),$$

where $\text{SRES} = \text{Hash}(K, \text{RAND}, \text{address}, 6)[0, \dots, 3]$, where Hash is a keyed hash function defined as¹,

$$\text{Hash}: \{0, 1\}^{128} \times \{0, 1\}^{128} \times \{0, 1\}^{8 \times L} \times \{6, 12\} \rightarrow \{0, 1\}^{128} \quad (EQ 13)$$

$$(K, I_1, I_2, L) \mapsto A'_r([\tilde{K}], [E(I_2, L) +_{16} (A_r(K, I_1) \oplus_{16} I_1)]),$$

and where

$$E: \{0, 1\}^{8 \times L} \times \{6, 12\} \rightarrow \{0, 1\}^{8 \times 16} \quad (EQ 14)$$

$$(X[0, \dots, L-1], L) \mapsto (X[i \bmod L]) \text{ for } i = 0 \dots 15),$$

is an expansion of the L octet word X into a 128-bit word. The function A_r is evaluated twice for each evaluation of E_1 . The key \tilde{K} for the second use of A_r (actually A'_r) is offset from K as follows²

1. The operator $+_{16}$ denotes bitwise addition mod 256 of the 16 octets, and the operator \oplus_{16} denotes bitwise XORing of the 16 octets.
2. The constants are the largest primes below 257 for which 10 is a primitive root.

$$\begin{aligned}
 \tilde{K}[0] &= (K[0] + 233) \bmod 256, & \tilde{K}[1] &= K[1] \oplus 229, \\
 \tilde{K}[2] &= (K[2] + 223) \bmod 256, & \tilde{K}[3] &= K[3] \oplus 193, \\
 \tilde{K}[4] &= (K[4] + 179) \bmod 256, & \tilde{K}[5] &= K[5] \oplus 167, \\
 \tilde{K}[6] &= (K[6] + 149) \bmod 256, & \tilde{K}[7] &= K[7] \oplus 131, \\
 \tilde{K}\{8\} &= K[8] \oplus 233, & \tilde{K}[9] &= (K[9] + 229) \bmod 256, \\
 \tilde{K}[10] &= K[10] \oplus 223, & \tilde{K}[11] &= (K[11] + 193) \bmod 256, \\
 \tilde{K}[12] &= K[12] \oplus 179, & \tilde{K}[13] &= (K[13] + 167) \bmod 256, \\
 \tilde{K}[14] &= K[14] \oplus 149, & \tilde{K}[15] &= (K[15] + 131) \bmod 256.
 \end{aligned}
 \tag{EQ 15}$$

A data flowchart of the computation of E_1 is shown in [Figure 6.1 on page 802](#). E_1 is also used to deliver the parameter ACO (Authenticated Ciphering Offset) that is used in the generation of the ciphering key by E_3 , see equations [\(EQ 3\) on page 783](#) and [\(EQ 23\) on page 807](#). The value of ACO is formed by the octets 4 through 15 of the output of the hash function defined in [\(EQ 13\) on page 801](#), i.e.

$$ACO = Hash(K, RAND, address, 6)[4, \dots, 15]. \tag{EQ 16}$$

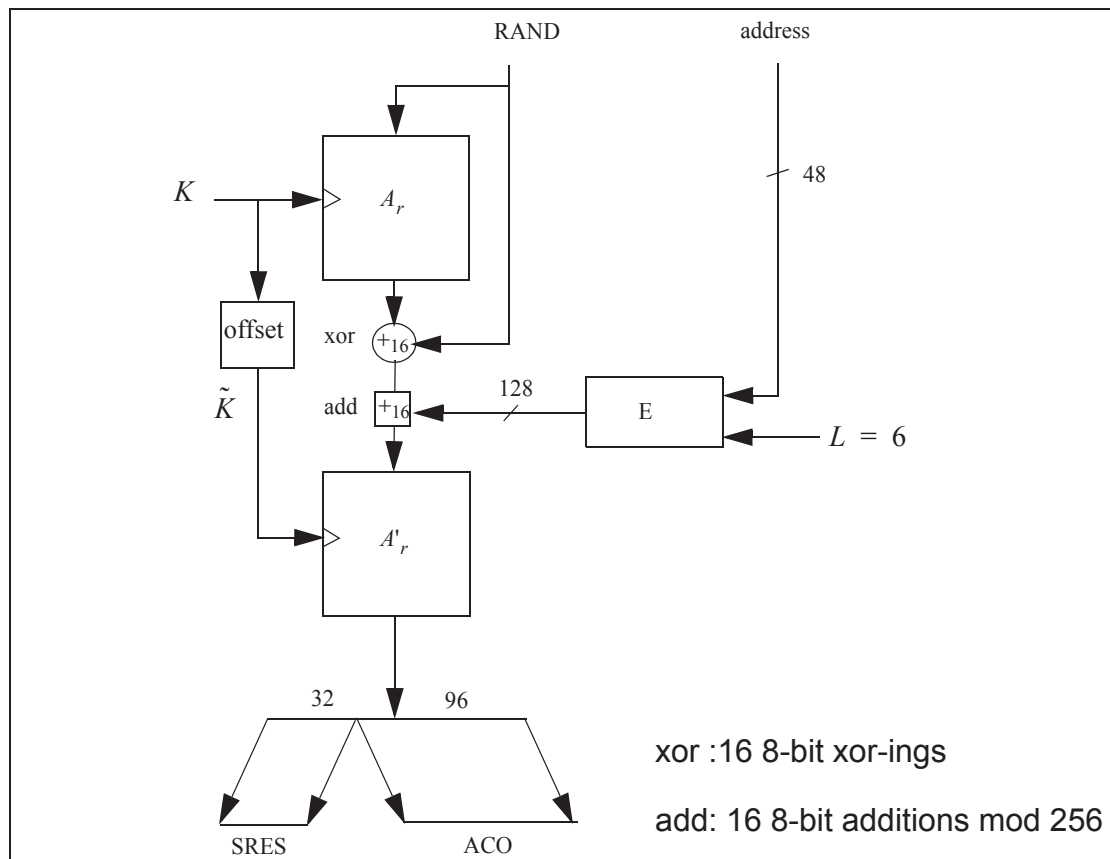


Figure 6.1: Flow of data for the computation of E_1 .

6.2 THE FUNCTIONS A_r AND A'_r

The function A_r is identical to SAFER+. It consists of a set of 8 layers, (each layer is called a round) and a parallel mechanism for generating the sub keys $K_p[j]$, $p = 1, 2, \dots, 17$, which are the round keys to be used in each round. The function will produce a 128-bit result from a 128-bit random input string and a 128-bit key. Besides the function A_r , a slightly modified version referred to as A'_r is used in which the input of round 1 is added to the input of round 3. This is done to make the modified version non-invertible and prevents the use of A'_r (especially in E_{2x}) as an encryption function. See [Figure 6.2 on page 804](#) for details.

6.2.1 The round computations

The computations in each round are a composition of encryption with a round key, substitution, encryption with the next round key, and, finally, a Pseudo Hadamard Transform (PHT). The computations in a round shall be as shown in [Figure 6.2 on page 804](#). The sub keys for round r , $r = 1, 2, \dots, 8$ are denoted $K_{2r-1}[j]$, $K_{2r}[j]$, $j = 0, 1, \dots, 15$. After the last round $K_{17}[j]$ is applied identically to all previous odd numbered keys.

6.2.2 The substitution boxes “e” and “l”

In [Figure 6.2 on page 804](#) two boxes are shown, marked “e” and “l”. These boxes implement the same substitutions as are used in SAFER+; i.e. they implement

$$\begin{aligned}
 e, l &: \{0, \dots, 255\} \rightarrow \{0, \dots, 255\}, \\
 e &: i \mapsto (45^i \pmod{257}) \pmod{256}, \\
 l &: i \mapsto j \text{ s.t. } i = e(j).
 \end{aligned}$$

Their role, as in the SAFER+ algorithm, is to introduce non-linearity.

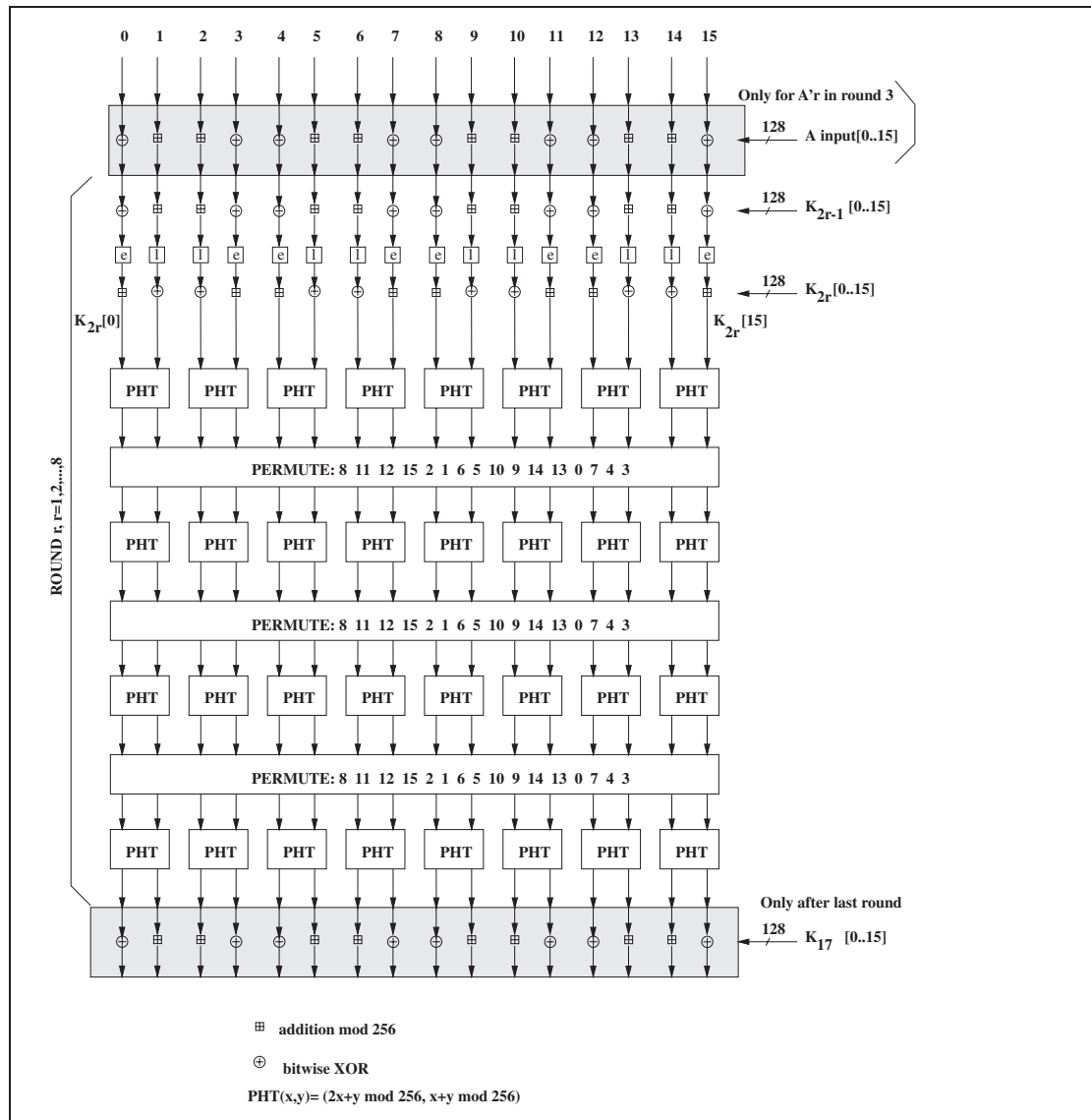


Figure 6.2: One round in A_r and A'_r . The permutation boxes show how input byte indices are mapped onto output byte indices. Thus, position 8 is mapped on position 0 (leftmost), position 11 is mapped on position 1, etc.

6.2.3 Key scheduling

In each round, 2 batches of 16 octet-wide keys are needed. These round keys are derived as specified by the key scheduling in SAFER+. Figure 6.3 on page 805 gives an overview of how the round keys $K_p[j]$ are determined. The bias vectors B_2, B_3, \dots, B_{17} shall be computed according to following equation:

$$B_p[i] = ((45^{(45^{17p+i+1} \bmod 257)} \bmod 257) \bmod 256), \text{ for } i = 0, \dots, 15. \quad (\text{EQ 17})$$

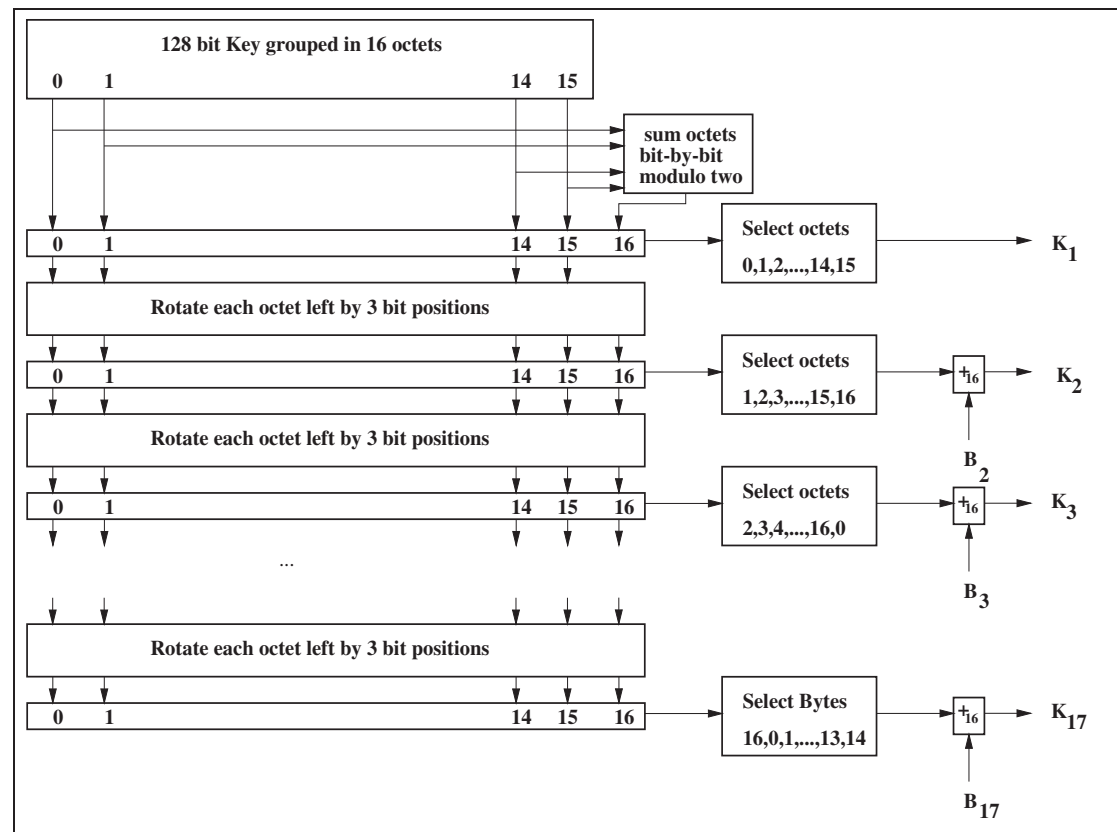


Figure 6.3: Key scheduling in A_r .

6.3 E_2 -KEY GENERATION FUNCTION FOR AUTHENTICATION

The key used for authentication shall be derived through the procedure that is shown in [Figure 6.4 on page 807](#). The figure shows two modes of operation for the algorithm. In the first mode, E_{21} produces a 128-bit link key, K , using a 128-bit RAND value and a 48-bit address. This mode shall be utilized when creating unit keys and combination keys. In the second mode, E_{22} produces a 128-bit link key, K , using a 128-bit RAND value and an L octet user PIN. The second mode shall be used to create the initialization key, and also when a master key is to be generated.

When the initialization key is generated, the PIN is augmented with the BD_ADDR, see [Section 3.2.1 on page 780](#) for which address to use. The augmentation shall always start with the least significant octet of the address immediately following the most significant octet of the PIN. Since the maximum length of the PIN used in the algorithm cannot exceed 16 octets, it is possible that not all octets of BD_ADDR will be used.



This key generating algorithm again exploits the cryptographic function. E_2 for mode 1 (denoted E_{21}) is computed according to following equations:

$$E_{21}: \{0, 1\}^{128} \times \{0, 1\}^{48} \rightarrow \{0, 1\}^{128} \quad (\text{EQ 18})$$

$$(\text{RAND}, \text{address}) \mapsto A'_r(X, Y)$$

where (for mode 1)

$$\begin{cases} X = \text{RAND}[0 \dots 14] \cup (\text{RAND}[15] \oplus 6) \\ Y = \bigcup_{i=0}^{15} \text{address}[i \pmod{6}] \end{cases} \quad (\text{EQ 19})$$

Let L be the number of octets in the user PIN. The augmenting is defined by

$$\text{PIN}' = \begin{cases} \text{PIN}[0 \dots L-1] \cup \text{BD_ADDR}[0 \dots \min\{5, 15-L\}], & L < 16, \\ \text{PIN}[0 \dots L-1], & L = 16, \end{cases} \quad (\text{EQ 20})$$

Then, in mode 2, E_2 (denoted E_{22}) is

$$E_{22}: \{0, 1\}^{8L'} \times \{0, 1\}^{128} \times \{1, 2, \dots, 16\} \rightarrow \{0, 1\}^{128} \quad (\text{EQ 21})$$

$$(\text{PIN}', \text{RAND}, L') \mapsto A'_r(X, Y)$$

where

$$\begin{cases} X = \bigcup_{i=0}^{15} \text{PIN}'[i \pmod{L'}], \\ Y = \text{RAND}[0 \dots 14] \cup (\text{RAND}[15] \oplus L'), \end{cases} \quad (\text{EQ 22})$$

and $L' = \min\{16, L + 6\}$ is the number of octets in PIN' .

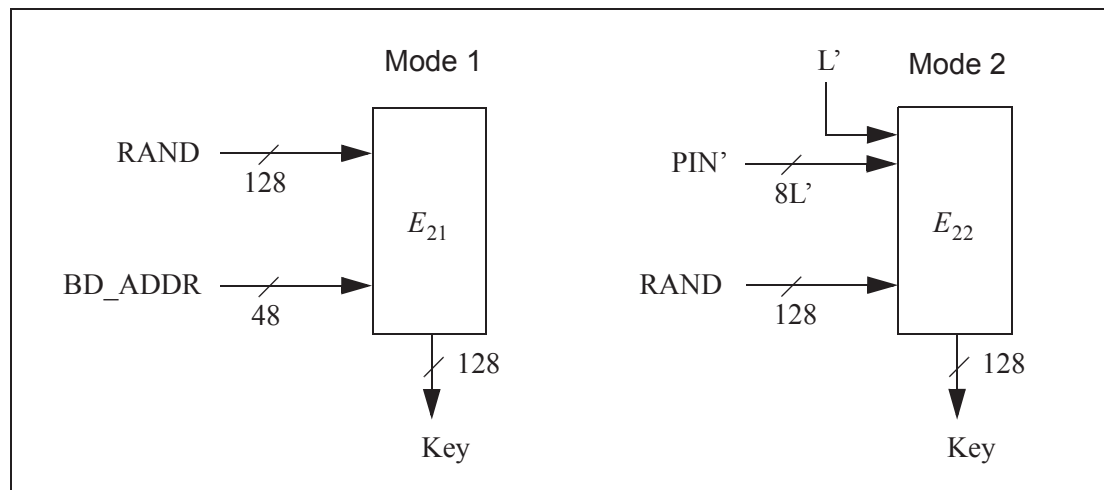


Figure 6.4: Key generating algorithm E_2 and its two modes. Mode 1 is used for unit and combination keys, while mode 2 is used for K_{init} and K_{master} .

6.4 E_3 -KEY GENERATION FUNCTION FOR ENCRYPTION

The ciphering key K_C used by E_0 shall be generated by E_3 . The function E_3 is constructed using A'_r as follows

$$E_3: \{0, 1\}^{128} \times \{0, 1\}^{128} \times \{0, 1\}^{96} \rightarrow \{0, 1\}^{128} \quad (\text{EQ 23})$$

$$(K, RAND, COF) \mapsto Hash(K, RAND, COF, 12)$$

where $Hash$ is the hash function as defined by (EQ 13) on page 801. The key length produced is 128 bits. However, before use within E_0 , the encryption key K_C is shortened to the correct encryption key length, as described in Section 4.5 on page 793. A block scheme of E_3 is depicted in Figure 6.5.

The value of COF is determined as specified by equation (EQ 3) on page 783.

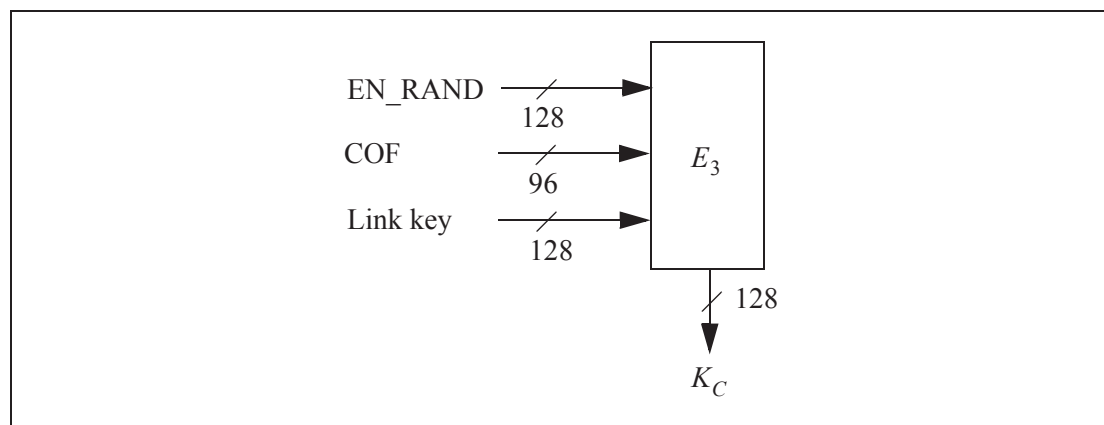


Figure 6.5: Generation of the encryption key.



7 LIST OF FIGURES

| | | |
|-------------|---|-----|
| Figure 3.1: | Generation of unit key. When the unit key has been exchanged, the initialization key is discarded in both devices. | 777 |
| Figure 3.2: | Generating a combination key. The old link key (K) is discarded after the exchange of a new combination key has succeeded | 778 |
| Figure 3.3: | Master link key distribution and computation of the corresponding encryption key. | 781 |
| Figure 4.1: | Stream ciphering for Bluetooth with E0. | 783 |
| Figure 4.2: | Functional description of the encryption procedure | 786 |
| Figure 4.3: | Concept of the encryption engine. | 787 |
| Figure 4.4: | Overview of the operation of the encryption engine. Between each start of a packet (TX or RX), the LFSRs are re-initialized. | 788 |
| Figure 4.5: | Arranging the input to the LFSRs. | 791 |
| Figure 4.6: | Distribution of the 128 last generated output symbols within the LFSRs. | 792 |
| Figure 5.1: | Challenge-response for the Bluetooth. | 793 |
| Figure 5.2: | Challenge-response for symmetric key systems. | 794 |
| Figure 6.1: | Flow of data for the computation of E_1 | 798 |
| Figure 6.2: | One round in A_r and A_f . The permutation boxes show how input byte indices are mapped onto output byte indices. Thus, position 8 is mapped on position 0 (leftmost), position 11 is mapped on position 1, etc. | 800 |
| Figure 6.3: | Key scheduling in A_r | 801 |
| Figure 6.4: | Key generating algorithm E_2 and its two modes. Mode 1 is used for unit and combination keys, while mode 2 is used for K_{init} and K_{master} | 803 |
| Figure 6.5: | Generation of the encryption key. | 803 |





8 LIST OF TABLES

| | | |
|------------|--|-----|
| Table 1.1: | Entities used in authentication and encryption procedures..... | 769 |
| Table 4.1: | Possible encryption modes for a slave in possession of a master key. | 785 |
| Table 4.2: | The four primitive feedback polynomials..... | 787 |
| Table 4.3: | The mappings $T1$ and $T2$ | 788 |
| Table 4.4: | Polynomials used when creating $K'c$ | 790 |



