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CONFIRMATION NO. 1089

FILING RECEIPT

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92629
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Date Mailed: 02/16/2012

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Applicant(s)

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Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

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**** SMALL ENTITY ****

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Carrier Groups in Multicarrier Networks

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Document Description: Provisional Cover Sheet (SB16)

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Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

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All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Title of Invention	Carrier Groups in Multicarrier Networks
Attorney Docket Number (if applicable)	DD-12-1001P

Correspondence Address

Direct all correspondence to (select one):

◉ The address corresponding to Customer Number	◯ Firm or Individual Name
Customer Number	92629

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

◉ No.

◯ Yes, the name of the U.S. Government agency and the Government contract number are:

Doc Code: **TR.PROV**
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Applicant claims small entity status under 37 CFR 1.27

(●) Yes, applicant qualifies for small entity status under 37 CFR 1.27

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Signature	/Esmael Dinan, Reg. No 64,478/			Date (YYYY-MM-DD)	2012-01-25
First Name	Esmael	Last Name	Dinan	Registration Number (If appropriate)	64478

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Carrier Groups in Multicarrier Networks

BACKGROUND

The technology disclosed herein is in the technical field of multicarrier communication systems. More particularly, the technology disclosed herein is related to a method and system for carrier groups in multicarrier Networks.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

An exemplary embodiment of the present invention is described herein with reference to the drawings, in which:

FIG. 1 is a diagram depicting example sets of OFDM subcarriers according to an exemplary embodiment;

FIG. 2 is a diagram depicting an example transmission and reception time for two carriers, according to an exemplary embodiment;

FIG. 3 is a diagram depicting OFDM radio resources according to an exemplary embodiment;

FIG. 4 is a block diagram of a base station and a wireless device, according to an exemplary embodiment; and

FIG. 5 is a simplified block diagram depicting a system for transmitting data traffic over a multicarrier OFDM radio, according to an exemplary embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

Embodiments of the present invention provide methods and systems for carrier groups in multicarrier Networks.

Embodiments of the invention could be implemented using various physical layer modulation and transmission mechanisms. Example transmission mechanisms include but is not limited to CDMA, OFDM, TDMA, or Wavelet technologies. Hybrid transmission mechanisms such as TDMA/CDMA, and OFDM/CDMA could also be considered. Various modulation schemes could be applied for signal transmission in the physical layer. Examples modulation schemes include but is not limited to phase, amplitude, code, and/or a combination of these. An example radio transmission method may implement QAM modulation using BPSK, QPSK, 16-QAM, 64-QAM, and/or 256-QAM. Physical radio transmission could be optimized by dynamically or semi-dynamically changing the modulation and coding scheme depending on transmission requirements and radio conditions.

FIG. 1 is a diagram depicting example sets of OFDM subcarriers according to one aspect of the illustrative embodiments. Each arrow in the diagram depicts a subcarrier in a multicarrier

OFDM system. The OFDM system could use OFDM technology or SC-OFDM technology. For example, arrow 101 shows a subcarrier transmitting information symbols. FIG. 1 is only for illustration purposes, and a typical multicarrier OFDM system includes a lot more subcarriers in a carrier, ranging from 10 to 10,000 subcarriers in a carrier. FIG. 1 shows two guard bands 106 and 107 in the transmission band. As illustrated in FIG. 1, guard band 106 is between the subcarriers 103 and subcarriers 104. The example set of subcarriers A 102 includes subcarriers 103 and subcarriers 104. FIG. 1 also illustrates an example set of subcarriers B 105. There is no guard band between any two subcarriers in the example set of subcarriers B 105. Carriers in a multicarrier OFDM communication system could be contiguous carriers, non-contiguous carriers, or a combination of both contiguous and non-contiguous carriers.

FIG. 2 is a diagram depicting an example transmission and reception time for two carriers according to one aspect of the illustrative embodiments. A multicarrier OFDM communication system may include two or more carriers, practically ranging from 2 to 10 carriers. Carrier one 204 and carrier two 205 could have the same or different timing structures. Carrier one 204 and carrier two 205 may or may not be synchronized with each other. Different radio frame structures could be supported for FDD and TDD duplex mechanisms. FIG. 2 shows an example FDD frame timing. Downlink and uplink transmissions could be organized into radio frames 201. In this example, radio frame duration is 10 msec. Other frame duration in the range of 1 to 100 msec may also be supported. In this example, each 10 ms radio frame 201 is divided into ten equally sized sub-frames 202. Other subframe durations including 0.5, 1, 2, and 5 msec may also be supported. Each sub-frame may consist of two or more equally sized slots 206. For FDD, 10 subframes may be available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. Each slot includes a plurality of OFDM symbols 203. The number of OFDM symbols 203 in a slot 206 depends on the cyclic prefix length and subcarrier spacing.

In the case of TDD, uplink and downlink transmissions are separated in the time domain. In an example embodiment, each 10 ms radio frame may include two half-frames of 5 ms each. Each half-frame may include eight slots of length 0.5 ms and three special fields: DwPTS, GP and UpPTS. The length of DwPTS and UpPTS could be configurable subject to the total length of DwPTS, GP and UpPTS being equal to 1ms. Both 5ms and 10ms switch-point periodicity could be supported. Subframe 1 in all configurations and subframe 6 in configuration with 5ms switch-point periodicity may include DwPTS, GP and UpPTS. Subframe 6 in configuration with 10ms switch-point periodicity may include DwPTS only. All other subframes may include two equally sized slots. For TDD, GP may be used for downlink to uplink transition. Other subframes/fields may be assigned for either downlink or uplink transmission. Other frame structures in addition to the above two frame structures may also be supported, for example in one example embodiment the frame duration may be selected dynamically based on the packet sizes.

FIG. 3 is a diagram depicting OFDM radio resources according to one aspect of the illustrative embodiments. The resource grid structure in time 304 and frequency 305 is illustrated in FIG. 3. The quantity of downlink subcarriers or resource blocks (in this example 6 to100 RBs) depends on the downlink transmission bandwidth 306 configured in the cell. The smallest radio resource unit is called a resource element 301. Resource elements may be grouped into resource blocks 302. And resource blocks may be grouped into larger radio resources called Resource Block Groups (RBG) 303. The transmitted signal in each slot 206 could be described by one or several resource grids of a plurality of subcarriers and a plurality of OFDM symbols. Resource blocks may be used to describe the mapping of certain physical channels to resource elements. Other pre-defined groupings of physical resource elements could be implemented in the system depending on the radio technology. For example, 24 subcarriers could be grouped as a radio block for a duration of 5 msec.

Physical and virtual resource blocks may be defined. A physical resource block could be defined as N consecutive OFDM symbols in the time domain and M consecutive subcarriers in the frequency domain, wherein M and N are integers. A physical resource block thus may include MxN resource elements. In one example, a resource block corresponds to one slot in the time domain and 180 kHz in the frequency domain (for 15 KHz subcarrier bandwidth and 12 subcarriers). A virtual resource block could be of the same size as a physical resource block. Two types of virtual resource blocks may be defined: virtual resource blocks of localized type and virtual resource blocks of distributed type. For each type of virtual resource blocks, a pair of virtual resource blocks over two slots in a subframe may be assigned together by a single virtual resource block number. Virtual resource blocks of localized type may be mapped directly to physical resource blocks such that virtual resource block k corresponds to physical resource block k. Virtual resource blocks of distributed type may be mapped to physical resource blocks according to a predefined table or a predefined formula. Various configurations for radio resources may be supported under an OFDM framework, for example a resource block could be defined as including the subcarriers in the entire band for an allocated time duration.

In an example embodiment, an antenna port may be defined such that the channel over which a symbol on the antenna port is conveyed could be inferred from the channel over which another symbol on the same antenna port is conveyed. There could be one resource grid per antenna port. The set of antenna ports supported may depend on the reference signal configuration in the cell. Cell-specific reference signals may support a configuration of one, two, or four antenna ports and are transmitted on antenna ports {0}, {0, 1}, and {0, 1, 2, 3}, respectively. Multicast-broadcast reference signals could be transmitted on antenna port 4.

Wireless device-specific reference signals could be transmitted on antenna port(s) 5, 7, 8, or one or several of ports {7, 8, 9, 10, 11, 12, 13, 14}. Positioning reference signals could be transmitted on antenna port 6. Channel state information (CSI) reference signals could support a configuration of one, two, four or eight antenna ports and could be transmitted on antenna ports 15, {15, 16}, {15,…,18} and {15,…,22}, respectively. Various configurations for antenna configuration could be supported depending on the number of antennas and the capability of the wireless devices and wireless base stations.

In the above example embodiments, radio resource framework using OFDM technology is presented. The method and system implemented in the example embodiments of this invention could be implemented using other radio technologies. Example transmission mechanisms include but not limited to CDMA, OFDM, TDMA, or Wavelet technologies. Hybrid transmission mechanisms such as TDMA/CDMA, and OFDM/CDMA could also be considered.

FIG. 4 is a block diagram of a base station 401 and a wireless device 406, according to an exemplary embodiment. A communication network includes at least one base station 401 and at least one wireless device 406. The base station 401 includes at least one communication interface 402, a processor 403, and program code instructions 405 that is stored in memory 404 and executable by processor 403. The wireless device 406 includes at least one communication interface 407, a processor 408, and program code instructions 410 that is stored in memory 409 and executable by processor 408. Communication interface 402 in base station 401 may be configured to engage in a communication with communication interface 407 in wireless device 406 via a communication path that includes at least one wireless link 411. The wireless link 411 is a bi-directional link. Communication interface 407 in wireless device 406 may also be configured to engage in a communication with communication interface 402 in the base station 401. The base station 401 and wireless device 406 could be configured to send and receive data over the wireless link 411 using multiple frequency carriers. Example embodiments for radio technology implemented in communication interface 402, 407 and the wireless link 411 are presented in the specification.

FIG. 5 is a simplified block diagram depicting a system for transmitting data traffic generated by a wireless device 502 to a server 508 over a multicarrier OFDM radio according to one aspect of the illustrative embodiments. As shown, the system includes at its core a Wireless Cellular Network/Internet Network 507, which may function to provide connectivity between one or more wireless devices 502 (e.g., a cell phone, PDA, or other wirelessly-equipped device), and one or more servers 508, such as multimedia server, application servers, email servers, or database servers.

It should be understood, however, that this and other arrangements described herein are set forth for purposes of example only. As such, those skilled in the art will appreciate that other arrangements and other elements (e.g., machines, interfaces, functions, orders of functions, etc.) can be used instead, some elements may be added, and some elements may be omitted altogether. Further, as in most telecommunications applications, those skilled in the art will appreciate that many of the elements described herein are functional entities that may be implemented as discrete or distributed components or in conjunction with other components, and in any suitable combination and location. Still further, various functions described herein as being performed by one or more entities may be carried out by hardware, firmware and/or software logic. For instance, various functions may be carried out by a processor executing a set of machine language instructions stored in memory.

As shown, the access network may include a plurality of base stations 503-504. Each base station 503-504 of the access network may function to transmit and receive RF radiation 505-506 at one or more carrier frequencies, and the RF radiation may then provide one or more air interfaces over which the wireless device 502 may communicate with the base stations 503-504. The user 501 may use the wireless device to receive data traffic, such as one or more multimedia files, data files, pictures, video files, or voice mails, etc. The wireless device 502 may include applications such as web email, email applications, upload and ftp applications, MMS applications, or file sharing applications. In another example embodiment, the wireless device 502 may automatically send traffic to a server 508 without direct involvement of a user. For example, consider a wireless camera with automatic upload feature, or a video camera uploading videos to the remote server 508, or a personal computer equipped with an application transmitting traffic to a remote server.

Each of the one or more base stations 503-504 may define a corresponding wireless coverage area. The RF radiation 505-506 of the base stations 503-504 may carry communications between the Wireless Cellular Network/Internet Network 507 and access device 502 according to any of a variety of protocols. For example, RF radiation 505-506 may carry communications according to WiMAX (e.g., IEEE 802.16), LTE, microwave, satellite, MMDS, Wi-Fi (e.g., IEEE 802.11), Bluetooth, infrared, and other protocols now known or later developed. The communication between the wireless device 502 and the server 508 may be enabled by any networking and transport technology for example TCP/IP, RTP, RTCP, HTTP or any other networking protocol.

An LTE network includes many base stations, providing a user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the wireless device. The base stations could be interconnected with each other by means of the X2 interface. The base stations can also be connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME interface and to the Serving Gateway (S-GW) by means of the S1-U interface. The S1 interface may support a many-to-many relation between MMEs / Serving Gateways and base stations. A base station may include many sectors for example 2, 3, 4, or 6 sectors. A base station may include many cells. A cell could be categorized as a primary cell or secondary cell. When carrier aggregation is configured, a wireless device may have one RRC connection with the network. At RRC connection establishment/re-establishment/handover, one serving cell provides the NAS (non-access stratum) mobility information (e.g. TAI), and at RRC connection re-establishment/handover, one serving cell provides the security input. This cell is referred to as the Primary Cell (PCell). In the downlink, the carrier corresponding to the PCell is the Downlink Primary Component Carrier (DL PCC) while in the uplink it is the Uplink Primary Component Carrier (UL PCC). Depending on wireless device capabilities, Secondary Cells (SCells) could be configured to form together with the PCell a set of serving cells. In the downlink, the carrier corresponding to an SCell is a Downlink Secondary Component Carrier (DL SCC) while in the uplink it is an Uplink Secondary Component Carrier (UL SCC). An SCell may or may not have an uplink carrier.

An example embodiment of the invention provides a method and system for carrier groups in multicarrier transmission. Another example embodiment provides a tangible computer readable media containing a series of instructions that when executed by one or more processors perform a method for carrier groups in multicarrier transmission. Furthermore, another example embodiment of the present invention provides an article of manufacture, comprising a machine-accessible medium having instructions encoded thereon for enabling a processor in a wireless device to perform a method for carrier groups in multicarrier transmission.

The signals carrying packets in the downlink are transmitted via downlink physical channels. The signals carrying packets in the uplink are transmitted via uplink physical channels. The baseband signal representing a downlink physical channel may be defined in terms of at least one of the following steps: scrambling of coded bits in each of the codewords to be transmitted on a physical channel; modulation of scrambled bits to generate complex-valued modulation symbols; mapping of the complex-valued modulation symbols onto one or several transmission layers; precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports; mapping of complex-valued modulation symbols for each antenna port to resource elements; and generation of complex-valued time-domain OFDM signal for each antenna port.

Each codeword, transmitted on the physical channel in one subframe, may be scrambled prior to modulation, resulting in a block of scrambled bits. The scrambling sequence generator may be initialized at the start of each subframe. Each codeword may be modulated using QPSK, 16QAM or 64 QAM, resulting in a block of complex-valued modulation symbols. The complex-valued modulation symbols for each of the codewords to be transmitted could be mapped onto one or several layers. For transmission on a single antenna port, a single layer is used. For spatial multiplexing, the number of layers is preferably less than or equal to the number of antenna ports used for transmission of the physical channel. The case of a single codeword mapped to multiple layers may be applicable when the number of cell-specific reference signals is four or when the number of UE-specific reference signals is two or larger. For transmit diversity, there could be one codeword and the number of layers may be equal to the number of antenna ports used for transmission of the physical channel.

The precoder may take as input a block of vectors from the layer mapping and generates a block of vectors to be mapped onto resources on each of the antenna ports. Precoding for spatial multiplexing using antenna ports with cell-specific reference signals may be used in combination with layer mapping for spatial multiplexing. Spatial multiplexing may support two or four antenna ports and the set of antenna ports used is {0,1}or {0, 1, 2, 3}. Precoding for transmit diversity may be used in combination with layer mapping for transmit diversity. The precoding operation for transmit diversity may be defined for two and four antenna ports. Precoding for spatial multiplexing using antenna ports with UE-specific reference signals may also be used in combination with layer mapping for spatial multiplexing. Spatial multiplexing using antenna ports with UE-specific reference signals could support up to eight antenna ports. Reference signals are pre-defined signals that are used by the receiver for decoding the received physical signal.

For each of the antenna ports used for transmission of the physical channel, the block of complex-valued symbols may be mapped in sequence to resource elements. In resource blocks in which UE-specific reference signals are not transmitted, the PDSCH may be transmitted on the same set of antenna ports as the physical broadcast channel in the downlink (PBCH). In resource blocks in which UE-specific reference signals are transmitted, the PDSCH may be transmitted on antenna port(s) {5, {7}, {8}, or {7, 8, ..., v+6}, where v is the number of layers used for transmission of the PDSCH.

Common reference signal may be transmitted in each physical antenna port. Common reference signal may be a cell-specific reference signal used for both demodulation and measurement purposes. Channel estimation accuracy using common reference signal may be reasonable for demodulation (high RS density). Common reference signal is defined for LTE and LTE-advanced technologies. Demodulation reference signal may be transmitted in each virtual antenna port (i.e., layer or stream). Channel estimation accuracy using demodulation reference signal may be reasonable within allocated time/frequency resources. Demodulation reference signal is defined for LTE-advanced technology and is not applicable to LTE technology. Measurement Reference signal, also called CSI reference signal, may be transmitted in each physical antenna port or virtualized antenna port. Measurement reference signal may be Cell-specific RS used for measurement purpose. Channel estimation accuracy may be relatively lower than demodulation RS. CSI reference signal is defined for LTE-advanced technology and is not applicable to LTE technology.

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers. The following uplink physical channels may be defined for uplink: a) Physical Uplink Shared Channel, PUSCH, b) Physical Uplink Control Channel, PUCCH, and c) Physical Random Access Channel, PRACH. An uplink physical signal could be used by the physical layer but may not carry information originating from higher layers. For example, reference signal could be considered as an uplink physical signals. The transmitted signal in each slot is described by one or several resource grids including subcarriers and SC-FDMA or OFDMA symbols. An antenna port may be defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal depends on the number of antenna ports configured for the physical channel or signal.

Each element in the resource grid is called a resource element. A physical resource block is defined as N consecutive SC-FDMA symbols in the time domain and M consecutive subcarriers in the frequency domain, wherein M and N are pre-defined integer values. A physical resource block in the uplink thus consists of MxN resource elements. For example, a physical resource block could corresponding to one slot in the time domain and 180 kHz in the frequency domain. The baseband signal representing the physical uplink shared channel could be defined in terms of the following steps: a) scrambling, b) modulation of scrambled bits to generate complex-valued symbols, c) mapping of the complex-valued modulation symbols onto one or several transmission layers, d) transform precoding to generate complex-valued symbols, e) precoding of the complex-valued symbols, f) mapping of precoded complex-valued symbols to resource elements, g) generation of complex-valued time-domain SC-FDMA signal for each antenna port.

For each codeword, the block of bits may be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits. The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or two layers. For spatial multiplexing, the layer mapping could be performed according to a pre-defined formula. The number of layers could be less than or equal to the number of antenna ports used for transmission of the physical uplink shared channel. The case of a single codeword mapped to multiple layers may be applicable when the number of antenna ports used for PUSCH is four. For each layer, the block of complex-valued symbols may be divided into multiple sets, each corresponding to one SC-FDMA symbol. Transform precoding may be applied. For each antenna port used for transmission of the PUSCH in a subframe, the block of complex-valued symbols could be multiplied with the amplitude scaling factor in order to conform to the required transmit power, and mapped in sequence to physical resource blocks on each antenna port and assigned for transmission of PUSCH.

Data could arrive to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per UL cell. The following coding steps could be identified for each transport block of an uplink carrier: a) Add CRC to the transport block, b) Code block segmentation and code block CRC attachment, c) Channel coding of data and control information, d) Rate matching, e) Code block concatenation. f) Multiplexing of data and control information, g) Channel interleaver, h) Error detection is provided on each UL-SCH transport block through a Cyclic Redundancy Check (CRC). The entire transport block is used to calculate the CRC parity bits. Code blocks may be delivered to the channel coding block. Each code block could be individually turbo encoded. Turbo coded blocks may be delivered to the rate matching block.

The physical uplink control channel, PUCCH, carries uplink control information. Simultaneous transmission of PUCCH and PUSCH from the same UE could be supported if enabled by higher layers. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field. PUCCH could use one resource block in each of the two slots in a subframe. The resources allocated to each UE and PUCCH configuration is transmitted via control messages. PUCCH may comprise: a) positive and negative acknowledgements for data packets transmitted at least one downlink carrier, b) channel state information for at least one downlink carrier, c) scheduling request.

Cell search is the procedure by which a wireless device could acquire time and frequency synchronization with a cell and could detect the physical layer Cell ID of that cell (transmitter). An example embodiment for synchronization signal and cell search is presented below. Cell search may support a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards. The primary and secondary synchronization signals are transmitted in the downlink and could facilitate cell search. 504 unique physical-layer cell identities may be defined using synchronization signals. The physical-layer cell identities may be grouped into 168 unique physical-layer cell-identity groups, each group containing three unique identities. The grouping could be such that each physical-layer cell identity is part of one and only one physical-layer cell-identity group. A physical-layer cell identity is thus defined by a number in the range of 0 to 167, representing the physical-layer cell-identity group, and a number in the range of 0 to 2, representing the physical-layer identity within the physical-layer cell-identity group. The synchronization signal may include primary synchronization signal and secondary synchronization signal.

The sequence used for the primary synchronization signal may be generated from a frequency-domain Zadoff-Chu sequence according to a pre-defined formula. Zadoff-Chu root sequence index may also be predefined in the standard. The mapping of the sequence to resource elements may depend on the frame structure. The wireless device may not assume that the primary synchronization signal is transmitted on the same antenna port as any of the downlink reference signals. The wireless device may not assume that any transmission instance of the primary synchronization signal is transmitted on the same antenna port, or ports, used for any other transmission instance of the primary synchronization signal. The sequence could be mapped to the resource elements according to a predefined formula.

For FDD frame structure, the primary synchronization signal may be mapped to the last OFDM symbol in slots 0 and 10. For TDD frame structure, the primary synchronization signal may be mapped to the third OFDM symbol in subframes 1 and 6. Some of the resource elements allocated to primary or secondary synchronization signals may be reserved and not used for transmission of the primary synchronization signal.

The sequence used for the secondary synchronization signal may be an interleaved concatenation of two length-31 binary sequences. The concatenated sequence may be scrambled with a scrambling sequence given by the primary synchronization signal. The combination of two length-31 sequences defining the secondary synchronization signal differs between subframe 0 and subframe 5 according to a predefined formula. The mapping of the sequence to resource elements may depend on the frame structure. In a subframe for FDD frame structure and in a half-frame for TDD frame structure, the same antenna port as for the primary synchronization signal may be used for the secondary synchronization signal. The sequence may be mapped to resource elements according to a predefined formula.

The physical broadcast channel may be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits. PBCH may be modulated using QPSK. The block of complex-valued symbols for each antenna port may be transmitted during four consecutive radio frames. PBCH data may arrive to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI) of 40ms. The following coding steps could be identified: Add CRC to the transport block, channel coding, and rate matching. Error detection may be provided on PBCH transport blocks through a Cyclic Redundancy Check (CRC). The entire transport block may be used to calculate the CRC parity bits. The parity bits may be computed and attached to the BCH transport block. After the attachment, the CRC bits may be scrambled according to the transmitter transmit antenna configuration. Information bits may be delivered to the channel coding block and they could be tail biting convolutionally encoded. A tail biting convolutionally coded block may be delivered to the rate matching block. This coded block may be rate matched before transmission.

A master information block is transmitted in PBCH and could include the system information transmitted on broadcast channel. It could include downlink bandwidth, system frame number, and PHICH configuration. Downlink bandwidth is the transmission bandwidth configuration, in terms of resource blocks in downlink, for example 6 corresponds to 6 resource blocks, 15 corresponds to 15 resource blocks and so on. System frame number defines the N (for example N=8) most significant bits of the system frame number. The M (for example M=2) least significant bits of the SFN are acquired implicitly in the PBCH decoding. For example timing of a 40ms PBCH TTI indicates 2 least significant bits (within 40ms PBCH TTI, the first radio frame: 00, the second radio frame: 01, the third radio frame: 10, the last radio frame: 11). One value applies for all the carriers in the same sector of a base station (the associated functionality is common i.e. not performed independently for each cell). PHICH configuration may be used to specify the PHICH configuration. PHICH configuration may include PHICH duration, which could be normal (one symbol duration) or extended (3 symbol duration). PHICH resource defines the resources used for PHICH transmission.

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe may depend on many parameters including downlink carrier bandwidth, in terms of downlink resource blocks. PCFICH transmitted in one subframe may be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits. The scrambling sequence generator may be initialized at the start of each subframe. The block of scrambled bits may be modulated using QPSK. The block of modulation symbols may be mapped to at least one layer and precoded resulting in a block of vectors representing the signal for at least one antenna port. Each instance of said PCFICH control channel indicates one of three possible values after being decoded. The range of possible values of each instance of said first control channel depends on the first carrier bandwidth.

The physical downlink control channel may carry scheduling assignments and other control information. The number of resource-elements not assigned to PCFICH or PHICH may be assigned to PDCCH. The PDCCH supports multiple formats. Multiple PDCCH packets may be transmitted in a subframe. PDCCH may be coded by tail biting convolutionally encoder before transmission. PDCCH bits may be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits. The scrambling sequence generator may be initialized at the start of each subframe. The block of scrambled bits may be modulated using QPSK. The block of modulation symbols may be mapped to at least one layer and precoded resulting in a block of vectors representing the signal for at least one antenna port. The PDCCH may be transmitted on the same set of antenna ports as the PBCH, wherein PBCH is the physical broadcast channel broadcasting at least one basic system information field.

A scheduling control packet is transmitted before each packet is transmitted in the downlink shared channel. The scheduling control packet may include information about the subcarriers used for packet transmission. PDCCH could also providing power control commands for uplink channels. OFDM subcarriers that are allocated for transmission of the PDCCH may occupy the entire bandwidth of a downlink carrier. PDCCH channel could carry a plurality of downlink control packets in each subframe. PDCCH is transmitted on a downlink carrier starting from the first OFDM symbol of each subframe, and may occupy up to 3 or 4 symbol duration.

The PHICH carries the hybrid-ARQ ACK/NACK. Multiple PHICHs mapped to the same set of resource elements constitute a PHICH group, where PHICHs within the same PHICH group are separated through different orthogonal sequences. A PHICH resource could identified by the index pair (group, sequence), where group is the PHICH group number and sequence is the orthogonal sequence index within the group. For frame structure type 1, the number of PHICH groups could be constant in all subframes and may depend on parameters from higher layers (RRC). For frame structure type 2, the number of PHICH groups may vary between downlink subframes according to a pre-defined arrangement. The block of bits transmitted on one PHICH in one subframe could be modulated using BPSK or QPSK, resulting in a block of complex-valued modulation symbols. The block of modulation symbols may be symbol-wise multiplied with an orthogonal sequence and scrambled, resulting in a sequence of modulation symbols

The physical layer random access preamble comprises a cyclic prefix of length Tcp and a sequence part of length Tseq. The parameter values could be pre-defined and depend on the frame structure and the random access configuration. In an example implementation, Tcp could be 0.1 msec, and Tseq could be 0.9 msec. Higher layers could control the preamble format. The transmission of a random access preamble, if triggered by the MAC layer, may be preferably restricted to certain time and frequency resources. The start of the random access preamble may be aligned with the start of the correspondin uplink subframe at the wireless device.

The random access preambles could be generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. In another example embodiment, the preambles could also be generated using other random sequences such as Gold sequences. The network could configure the set of preamble sequences the wireless is allowed to use. In an example embodiment, there are 64 preambles available in each cell. From the physical layer perspective, the physical layer random access procedure may include the transmission of random access preamble and random access response. The remaining messages could be scheduled for transmission by the higher layer on the shared data channel and may not be considered part of the physical layer random access procedure. For example, a random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions.

The following steps could be preferably followed for the physical random access procedure: 1) layer 1 procedure is triggered upon request of a preamble transmission by higher layers, 2) a preamble index, a target preamble received power, a corresponding RA-RNTI and a PRACH resource are indicated by higher layers as part of the request, 3) a preamble transmission power PPRACH is determined, 4) a preamble sequence is selected from the preamble sequence set using the preamble index, 5) a single preamble is transmitted using the selected preamble sequence with transmission power PPRACH on the indicated PRACH resource, 6) detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers. If detected, the corresponding downlink shared channel transport block is passed to higher layers. The higher layers parse the transport block and indicate the uplink grant to the physical layer.

In an example embodiment, the random access procedure could be initiated by a physical downlink control channel (PDCCH) order or by the MAC sublayer in the wireless device. If a wireless device receives a PDCCH transmission consistent with a PDCCH order masked with its radio identifier, it may initiate a random access procedure. Preamble transmission on physical random access channel (PRACH) could be supported on the first uplink carrier and reception of a PDCCH order could be supported on the first downlink carrier.

Before the wireless device initiates transmission of a random access preamble, it may access one or many of the following information: a) the available set of PRACH resources for the transmission of the random access preamble, b) the groups of random access preambles and the set of available random access preambles in each group, c) the random access response window size, d) the power-ramping factor, e) the maximum number of preamble transmissions, f) the initial preamble power, g) the preamble format based offset, and h) the contention resolution timer. These parameters may be updated from upper layers or may be received from the base station before each random access procedure is initiated.

The wireless device may select a random access preamble using the available information. The preamble may be signaled by the base station or it may be randomly selected by the wireless device. The wireless device may determine the next available subframe containing PRACH permitted by the restrictions given by the base station and physical layer timing requirements for TDD or FDD. Subframe timing and the timing of transmitting the random access preamble is determined based on the synchronization signals received from the base station and the information received from the base station. The wireless device may proceed to the transmission of the random access preamble when it has determined the timing. The random access preamble is transmitted on a second plurality of subcarriers on the first uplink carrier.

Once the random access preamble is transmitted, the wireless device may monitor the PDCCH of the first downlink carrier for random access response(s) identified by the RA-RNTI, in the random access response window. RA-RNTI is the identifier in PDCCH that indentifies a random access response. The wireless device may stop monitoring for random access response(s) after successful reception of a random access response containing random access preamble identifiers that matches the transmitted random access preamble. Base station random access response may include a time alignment command. The wireless device may process the received time alignment command and adjust its uplink transmission timing according the time alignment value in the command. For example, in a random access response, time alignment command could be coded using 11 bits, where an amount of the time alignment is based on the value in command. When an uplink transmission is required, the base station may provide the wireless device a grant for uplink transmission.

If no random access response is received within the random access response window, or if none of all received random access responses contains a random access preamble identifier corresponding to the transmitted random access preamble, the random access response reception is considered not successful and the wireless device may, based on the backoff parameter in the wireless device, select a random backoff time and delay the subsequent random access transmission by the backoff time, and may retransmit another random access preamble.

The wireless device could transmit packets on an uplink carrier. Uplink packet transmission timing could be calculated in the wireless device using the timing of the synchronization signals received in the downlink. Upon reception of a timing alignment command by the wireless device, the wireless device may adjust its uplink transmission timing. The timing alignment command indicates the change of the uplink timing relative to the current uplink timing. The uplink transmission timing for an uplink carrier could be determined using time alignment commands.

A time alignment command could indicate timing adjustment for transmission of signals on uplink carriers. For example, a time alignment command could use 6 bits. Adjustment of the uplink timing by a positive or a negative amount indicates advancing or delaying the uplink transmission timing by a given amount respectively.

For a timing alignment command received on subframe n, the corresponding adjustment of the timing may be applied with some delay, for example it can be applied from the beginning of subframe n+6. When the wireless device’s uplink transmissions in subframe n and subframe n+1 are overlapped due to the timing adjustment, the wireless device could transmit complete subframe n and not transmit the overlapped part of subframe n+1.

The wireless device may include a configurable timer (timeAlignmentTimer) which is used to control how long the wireless device is considered uplink time aligned. When a timing alignment command MAC control element is received, the wireless device may apply the timing alignment command and start or restart timeAlignmentTimer. The wireless device may not perform any uplink transmission except the random access preamble transmission when timeAlignmentTimer is not running or when it exceeds its limit. The time alignment command substantially aligns frame and subframe reception timing of the first uplink carrier and the at least one additional uplink carrier. In an example embodiment, the time alignment command value range that is used during the random access process is substantially larger than the time alignment command value range during active data transmission.

In the example embodiments of this invention, control messages or control packets may be scheduled for transmission in the physical downlink shared channel (PDSCH) or uplink physical shared channel PUSCH. PDSCH and PUSCH may carry control and data messages/packets. Control messages or packets may be processed before transmission, for example they may be fragmented or multiplexed before transmission. A control message in the upper layer may be processed as a data packet in the MAC or physical layer. For example, system information blocks as well as data traffic are scheduled for transmission in PDSCH. The data packets may be encrypted packets.

Data packets may be encrypted before transmission to secure the packets from unwanted receivers. The desired recipient may be able to decrypt the packets. The first plurality of data packets and the second plurality of data packets could be encrypted using an encryption key and at least one parameter that changes substantially rapidly over time. This encryption mechanism provides a transmission that could not be easily eavesdropped by unwanted receivers. Including additional parameters in encryption module that changes substantially rapidly in time enhances the security mechanism. An example varying parameter could be any types of system counter. The encryption may be provided by the PDCP layer between the transmitter and receiver. Additional overhead added to the packets by the lower layers such as RLC, MAC, and Physical layer may not be encrypted before transmission. In the receiver, the plurality of encrypted data packets may be decrypted using a first decryption key and at least one first parameter. The plurality of data packets may be decrypted using an additional parameter that changes substantially rapidly over time.

The wireless device may be preconfigured with one or more carriers. When the transmitter could be a base station configured with more than one carrier, the base station may activate and deactivate the configured carriers. One of the carriers (the primary carrier) may always be activated, but other carriers may be deactivated by default and could be activated by base station when needed. The base station may activate and deactivate carriers by sending the activation/deactivation MAC control element. Furthermore, the UE may maintain a carrier deactivation timer per configured carrier and deactivate the associated carrier upon its expiry. The same initial timer value applies to each instance of the carrier deactivation timer and the initial value of the timer is configured by the network. The configured carriers (unless the primary carrier) may be initially deactivated upon addition and after a handover.

In an example embodiment, if a wireless device receives an activation/deactivation MAC control element activating the carrier, the wireless device may activate the carrier, and may apply normal carrier operation including: sounding reference signal transmissions on the carrier, CQI/PMI/RI reporting for the carrier, PDCCH monitoring on the carrier, PDCCH monitoring for the carrier, start or restart the carrier deactivation timer associated with the carrier. If the device receives an activation/deactivation MAC control element deactivating the carrier, or if the carrier deactivation timer associated with the activated carrier expires, the base station or device may deactivate the carrier, and may stop the carrier deactivation timer associated with the carrier, and may flush all HARQ buffers associated with the carrier.

If PDCCH on a carrier scheduling the activated carrier indicates an uplink grant or a downlink assignment for the activated carrier, then the device may restart the carrier deactivation timer associated with the carrier. When a carrier is deactivated, the wireless device may not transmit SRS for the carrier, may not report CQI/PMI/RI for the carrier, may not transmit on UL-SCH for the carrier, may not monitor the PDCCH on the carrier, and may not monitor the PDCCH for the carrier.

The method to assign subcarriers to data packets may be executed by the MAC layer scheduler. The decision on assigning subcarriers to a packet may be made based on data packet size, resources required for transmission of data packets (number of radio resource blocks), modulation and coding assigned to each data packet, QoS required by the data packets (i.e. QoS parameters assigned to data packet bearer), the service class of the subscriber receiving the data packet, or subscriber device capability, or the combination of the above.

Packets may be referred to service data units or protocols data units at Layer 1, Layer 2 or Layer 3 of the communications network. Layer 2 in an LTE network includes three sub-layers: PDCP sub-layer, RLC sub-layer, and MAC sub-layer. A layer 2 packet may be a PDCP packet, an RLC packet or a MAC layer packet. Layer 3 in an LTE network may be Internet Protocol (IP) layer, and therefore a layer 3 packet may be an IP data packet. Packets are transmitted and received via the air interface physical layer. A packet at the physical layer may be called a transport block. The methods and systems disclosed in this specification could be implemented at one or many different communication network layers. For example, some of the steps may be executed by the PDCP layer and some others by the MAC layer.

In an example embodiment, subcarriers or resource blocks may be a plurality of physical subcarriers or resource blocks. In another example embodiment, subcarriers may be a plurality of virtual or logical subcarriers or resource blocks.

The radio bearer may be a GBR bearer or a non-GBR bearer. A GBR or guaranteed bit rate bearer may be used for transfer of real-time packets, and a non-GBR bearer may be used for transfer of non-real-time packets. The non-GBR bearer may be assigned a plurality of attributes including: a scheduling priority, an allocation and retention priority, and a portable device aggregate maximum bit rate. These parameters are used by the scheduler in scheduling non-GBR packets. GBR bearers may be assigned attributes such as delay, jitter, and packet loss parameters.

The subcarriers may include data subcarrier symbols and pilot subcarrier symbols. Pilot symbols do not carry user data, and may be included in the transmission to help the receiver to perform synchronization, channel estimation and signal quality detection. Base stations and wireless devices (wireless receiver) may use different methods to generate and transmit pilot symbols along with information symbols.

The transmitter in the disclosed embodiments of the present invention may be a wireless device (also called user equipment), a base station (also called eNodeB), or a relay node transmitter. The receiver in the disclosed embodiments of the present invention may be a wireless device (also called user equipment-UE), a base station (also called eNodeB), or a relay node receiver. In an example embodiment of the present invention, layer 1 (physical layer) may be based on OFDMA or SC-FDMA. Time could be divided into frames with fixed duration. Each frame may be divided into equally sized subframes, and each subframe may be divided into equally sized slots. A plurality of OFDM or SC-FDMA symbols are transmitted in each slot duration. OFDMA or SC-FDMA symbols may be grouped into resource blocks. A scheduler may assign resources in resource block units, or a group of resource block units. Physical resource blocks may be resources in the physical layer, and logical resource blocks may be resource blocks used by the MAC layer. Similar to virtual and physical subcarriers, resource blocks may be mapped from logical to physical resource blocks. Logical resource blocks may be contiguous, but corresponding physical resource block may be non-contiguous. The proposed methods and systems of this invention may be implemented at the physical or logical resource block levels.

In an example embodiment, layer 2 transmission may include PDCP (packet data convergence protocol), RLC (radio link control), and MAC (media access control) sub-layers. MAC may be responsible for the multiplexing and mapping of logical channels to transport channels and vice versa. MAC layer may perform channel mapping, scheduling, random access channel procedures, or uplink timing maintenance.

The MAC layer may map logical channels carrying RLC PDUs to transport channels. For transmission, multiple SDUs from logical channels may be mapped to the Transport Block (TB) to be sent over transport channels. For reception, TBs from transport channels may be demultiplexed and assigned to the corresponding logical channels. The MAC layer may perform all the scheduling related functions in both the uplink and downlink and thus may be responsible for transport format selection associated with all transport channels. This includes all HARQ functionality. Since all scheduling is done at the base station, the MAC layer may be responsible for reporting scheduling related information such as UE (user equipment or wireless device) buffer occupancy and power headroom. It may also handle prioritization from both an inter-UE and intra-UE logical channel perspective. MAC may also be responsible for random access procedures for the uplink that may be performed following either a contention and non-contention based process. UE needs to maintain timing synchronization with the cell at all times. The MAC layer may perform required procedures for periodic synchronization.

MAC layer may be responsible for the mapping of multiple logical channels to transport channels during transmissions, and demultiplexing and mapping of transport channel data to logical channels during reception. A MAC PDU includes of a header that describes the format of the PDU itself, which may include of control elements, SDUs, and Padding. The header may be composed of multiple sub-headers, one for each constituent part of the MAC PDU. MAC may also operate in transparent mode, where no header is pre-pended to the PDU. The activation command in the embodiments of this invention may be inserted in a packet using a MAC control element.

MAC layer in the wireless device may report buffer size of either a single Logical Channel Group (LCG) or a group of LCGs to the base station. An LCG is a group of logical channels identified by an LCG ID. The mapping of logical channels to LCG is set up during radio configuration. The buffer status reports may be used by the MAC scheduler to assign radio resources for packet transmission from wireless devices. HARQ and ARQ processes may be used for packet retransmission to enhance the reliability of radio transmission and reduce the overall probability of packet loss.

RLC sub-layer may control the applicability and functionality of error correction, concatenation, segmentation, re-segmentation, duplicate detection, and in-sequence delivery. Other functions of RLC may include protocol error detection and recovery and SDU discard. RLC sub-layer receives data from upper layer radio bearers (signaling and data) called service data units (SDU). The transmission entities in the RLC layer convert them to RLC PDU after performing functions such as segmentation, concatenation, and adding RLC headers. In the other direction, the receiving entities receive RLC PDUs from the MAC layer. After performing reordering, the PDUs are assembled back into RLC SDUs and delivered to the upper layer. RLC interaction with MAC layer may include: a) data transfer for uplink and downlink through logical channels, b) MAC notifies RLC when a transmission opportunity becomes available, including the size of total number of RLC PDUs that can be transmitted in the current transmission opportunity, c) the MAC entity at the transmitter can inform RLC at the transmitter of HARQ transmission failure.

PDCP (packet data convergence protocol) is a layer 2 sub-layer on top of RLC sub-layer. The PDCP may be responsible for the following functions: a) PDCP layer transfers user plane and control plane data to and from upper layers. It receives SDUs from upper layers and sends PDUs to the lower layers. In other direction, it receives PDUs from the lower layers and sends SDUs to upper layers. b) PDCP may be responsible for security functions. It may apply ciphering (encryption) for user and control plane bearers, if configured. It may also perform integrity protection for control plane bearers, if configured. c) PDCP may perform header compression services to improve the efficiency of over the air transmission. The header compression is based on robust header compression (ROHC). ROHC may be performed on VOIP packets. d) PDCP is responsible for in-order delivery of packets and duplicate detection services to upper layers after handovers. After handover, the source base station may transfer unacknowledged packets to target base station when operating in RLC acknowledged mode (AM). The target forwards packets received from the source base station to the UE (user equipment).

In this specification, “a” and “an” and similar phrases are to be interpreted as “at least one” and “one or more.”

Many of the elements described in the disclosed embodiments may be implemented as modules. A module is defined here as an isolatable element that performs a defined function and has a defined interface to other elements. The modules described in this disclosure may be implemented in hardware, software, firmware, wetware (i.e hardware with a biological element) or a combination thereof, all of which are behaviorally equivalent. For example, modules may be implemented as a software routine written in a computer language (such as C, C++, Fortran, Java, Basic, Matlab or the like) or a modeling/simulation program such as Simulink, Stateflow, GNU Octave, or LabVIEW MathScript. Additionally, it may be possible to implement modules using physical hardware that incorporates discrete or programmable analog, digital and/or quantum hardware. Examples of programmable hardware include: computers, microcontrollers, microprocessors, application-specific integrated circuits (ASICs); field programmable gate arrays (FPGAs); and complex programmable logic devices (CPLDs). Computers, microcontrollers and microprocessors are programmed using languages such as assembly, C, C++ or the like. FPGAs, ASICs and CPLDs are often programmed using hardware description languages (HDL) such as VHSIC hardware description language (VHDL) or Verilog that configure connections between internal hardware modules with lesser functionality on a programmable device. Finally, it needs to be emphasized that the above mentioned technologies are often used in combination to achieve the result of a functional module.

While various embodiments have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be apparent to persons skilled in the relevant art(s) that various changes in form and detail can be made therein without departing from the spirit and scope. In fact, after reading the above description, it will be apparent to one skilled in the relevant art(s) how to implement alternative embodiments. Thus, the present embodiments should not be limited by any of the above described exemplary embodiments. In particular, it should be noted that, for example purposes, the above explanation has focused on the example(s) using FDD communication systems. However, one skilled in the art will recognize that embodiments of the invention could also be implemented in TDD communication systems.

In addition, it should be understood that any figures which highlight the functionality and advantages, are presented for example purposes only. The disclosed architecture is sufficiently flexible and configurable, such that it may be utilized in ways other than that shown. For example, the steps listed in any flowchart may be re-ordered or only optionally used in some embodiments.

Further, the purpose of the Abstract of the Disclosure is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers and practitioners in the art who are not familiar with patent or legal terms or phraseology, to determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The Abstract of the Disclosure is not intended to be limiting as to the scope in any way.

Finally, it is the applicant's intent that only claims that include the express language "means for" or "step for" be interpreted under 35 U.S.C. 112, paragraph 6. Claims that do not expressly include the phrase "means for" or "step for" are not to be interpreted under 35 U.S.C. 112, paragraph 6.

Introduction

Serving cells having uplink to which the same time alignment (TA) applies and using the same timing reference could be grouped in a TA group (TAG). For a given TAG, a UE may use one downlink carrier as the timing reference at a given time. For a given TAG, a UE may synchronize uplink subframe and frame transmission timing of the uplink carriers belonging to the same

TAG. In an example embodiment, serving cells having uplink to which the same TA applies may correspond to the serving cells hosted by the same receiver. Each TA group comprises at least one serving cell with configured uplink. A UE supporting multiple TAs may support two or more TA groups. One TA group contains the PCell and may be called primary TAG (pTAG). At least one TA group may not contain the PCell and may be called secondary TAG (sTAG). Carriers within the same TA group may use the same TA value and the same timing reference.

TA maintenance, pathloss reference handling and the timing reference for pTAG may follow LTE release Rel-10 principles. The UE may successfully complete a CFRA (contention free random access) procedure from the reception of a RAR (random access response) message within the RA (random access) response window using RA-RNTI. The UE may decode scheduling information for uplink transmission in the PDCCH CSS (common search space) with RA-RNTI. In an example embodiment, in addition to the TAC (time alignment command) field, RAR for the PCell may contain Random Access Preamble Identifier (RAPID), UL grant, Temporary C-RNTI, and Backoff Indicator (BI). RAPID may be used to confirm the association between RAR and the transmitted preamble. The UL grant is for uplink transmission. Temporary C-RNTI may be used for contention resolution in case of CBRA (contention based random access). Backoff Indicator (BI) may be used in case of collisions and/or high load on PRACH.

To obtain initial UL (uplink) time alignment for a sTAG, eNB may initiate RA (random access) procedure. The timing reference for all SCells in an sTAG may be the SIB2 linked downlink of the SCell on which the preamble for the latest RA procedure was sent. There may be one timing reference and one time alignment timer (TAT) per TA group and each TAT may be configured with a different value. When the TAT associated with the pTAG expires, all TATs may be considered as expired and the UE may flush all HARQ buffers of all serving cells, may clear any configured downlink assignment/uplink grants, and RRC may release PUCCH/SRS for all configured serving cells. When the TAT associated with sTAG expires: a) SRS transmissions may be stopped on the corresponding SCells, b) the type-0 SRS configuration may be released, but the type-1 SRS configuration may be maintained, c) CSI reporting configuration for the corresponding SCells may be maintained, d) MAC may flush the uplink HARQ buffers of the corresponding SCells.

Upon deactivation of the last SCell in an sTAG, UE may not stop TAT of the sTAG. Upon removal of the last SCell in an sTAG, TAT of the TA group may not be running. RA procedures in parallel may not be supported for a UE. If a new RA procedure is requested (either by UE or network) while another RA procedure is already ongoing, it could be up to the UE implementation whether to continue with the ongoing procedure or start with the new procedure. The eNB may initiate the RA procedure via a PDCCH order for an activated SCell. This PDCCH order may be sent on the scheduling cell of this SCell. At least non-contention based RA procedure may be supported. Upon new UL data arrival the UE may not trigger an RA procedure on an SCell.

PDCCH order for preamble transmission could be sent on a different serving cell than the SCell in which the preamble is sent. For each uplink in an sTAG, the SIB2 linked downlink of the reference SCell is used as a pathloss reference. TA grouping could be performed without requiring any additional UE assisted information.

The eNB may trigger a PDCCH order for the RA procedure on SCells due to UL data arrival in case of carrier aggregation, i.e. a PDCCH order could be triggered by the BSR reception due to the UL data arrival in the eNB. Preamble transmission could be triggered in the case of UL data arrival, meaning that preamble transmission could be triggered by the BSR reception in the eNB. Upon new UL data arrival the UE may not trigger an RA procedure on an SCell. The eNB may trigger the RA procedure based on the BSR reception due to the UL data arrival.

Initial timing alignment may be achieved through random access procedure. This involves the UE transmitting a random access preamble and the eNB responding an initial TA command NTA (amount of time alignment) within the random access response. The start of the random access preamble may be aligned with the start of the corresponding uplink subframe at the UE assuming NTA=0. The eNB may estimate the uplink timing from the random access preamble transmitted by the UE. Then the TA command could be derived by the eNB based on the estimation of the difference between the desired UL timing and the actual UL timing. The UE may determine the initial uplink transmission timing relative to the corresponding downlink of the SCell on which the preamble is transmitted

PDCCH order may be used to trigger RACH for an activated SCell. For a newly configured SCell or a configured but deactivated SCell, eNB may need to firstly activate the corresponding SCell and then trigger RACH on it. In an example implementation, with no retransmission of activation/deactivation command, activation of an SCell may need at least 8ms, which may be an extra delay for UE to acquire the valid TA value on SCell compared to the procedure on an already activated SCell. For a newly configured SCell or a deactivated SCell, 8ms is required for SCell activation, and at least 6ms is required for preamble transmission, and at least 4ms is required to receive the random access response. At least 18ms may be required for a UE to get a valid TA. The possible delay caused by retransmission or other configured parameters may need to be considered, e.g. the possible retransmission of activation/deactivation command, the time gap between when a RACH is triggered and when a preamble is transmitted (equal or larger than 6ms). The RAR may be transmitted within the RAR window (range from 2ms to 10ms), and possible retransmission of preamble may be considered. The delay for such a case may be more than 20ms or even 30ms if retransmissions are considered.

Each base station may communicate with a mix of wireless devices. A base station may be able to communicate with wireless devices, wherein each one of them supporting multiple technologies, or multiple releases of the same technology. Also base stations may comprise multiple sectors. In the specification, when it refers to a base station communicating with a plurality of wireless devices, it may refer to a subset of the total wireless devices in the coverage area. It may refer to for example a plurality of wireless devices of certain LTE release in a given sector of the base station. Therefore, the plurality of wireless devices in the specification may refer to a selected plurality of wireless devices, or a subset of total wireless devices in the coverage area, which perform according to the disclosed methods. There may be many more subscribers in the coverage area that do not comply with the disclosed methods, for example because they perform based on older releases of LTE technology.

Time alignment command MAC control element, which is unicast MAC command transmitted to a wireless base station. Each wireless device receives its own time alignment commands.

Step 1: eNB sends the activation command to activate an SCell.

Step 2: UE receives the MAC CE for SCell activation in subframe *n*. The SCell is in the status of activation in subframe *n*+8.

Step 3: UE begins to monitor PDCCH order for the SCell if it is not UL time aligned.

Step 4: eNB sends a PDCCH order to the UE to initiate RACH for the activated SCell.

Step 5: UE performs RACH for the activated SCell.

Step 6: After the RACH on Scell is successfully completed, UL transmission is performed on the SCell.

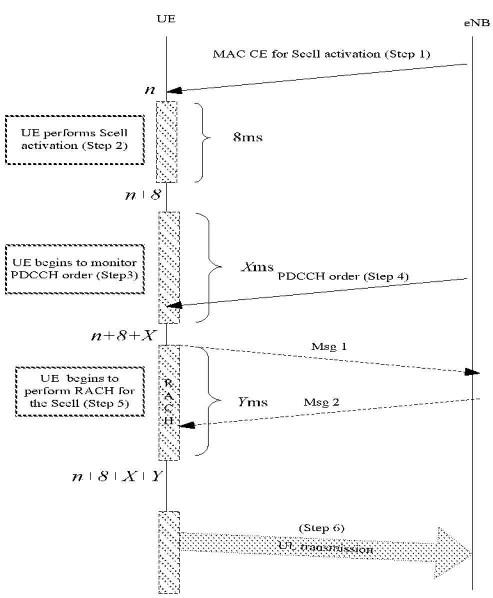


Figure 1 RACH initiation by PDCCH after SCell activation

RRC Configuration Message Format for sTAG, and pTAG configuration

The mapping of each serving cell to a TA group may be configured by the serving eNB with RRC signaling. The mechanism for TAG configuration and reconfiguration could be based on RRC signalling. When needed, the mapping between an SCell and a TA group may be reconfigured with RRC signaling. For example if there is a need to move an SCell from an sTAG to a pTAG, an

RRC signaling, for example an RRC reconfiguration message, may be send to the UE to reconfigure TAG configurations. PCell may not change TA group and may always be a member of the pTAG.

In an example embodiment, when an eNB performs SCell addition configuration, the related TAG configuration may be configured. eNB may modify TAG configuration by reconfiguring SCell parameters. An eNB may perform initial configuration based on an initial configuration parameters received from a network node, for example a management platform, or an initial eNB configuration, or based on UE location, or UE type. Initial configuration may also be based on UE channel state measurement. For example depending on the signal strength received from a UE on various SCells downlink carrier or by determination of UE being in repeater coverage area, or a combination of both, an eNB may determine the initial configuration of sTAGs and membership of SCells to sTAGs.

In an example implementation, the TA value of a serving cell may change, for example due to UE's mobility from a macro to a repeater or an RRH (remote radio head) coverage area. The signal delay for that SCell may become different from the original value and different from other serving cells in the same TAG. In this scenario, eNB may relocate this TA-changed serving cell to other existing TAGs. Or alternatively, the eNB may create a new TAG for the SCell, based on the updated TA value. TA value could be derived for example through eNB measurement of signal reception timing, RACH mechanism, or other standard or proprietary algorithms. An eNB may realize that the TA value of a serving cell is no longer consistent with its current TAG. There could be many other scenarios which require eNB to reconfigure TAGs. During reconfiguration, the eNB may need to move the reference SCell belong to an sTAG to another TAG. In this scenario, the sTAG would require a new reference SCell. In an example implementation, the new reference (timing or pathloss) SCell for the sTAG could be configured using RRC connection reconfiguration message. In another example, the new reference SCell for the sTAG could be configured by initiating a random access mechanism using a new PDCCH order. The downlink carrier corresponding (SIB2 linked) to the uplink carrier transmitting the preamble may be considered as the new reference SCell.

The purpose of RRC connection reconfiguration procedure is to modify an RRC connection, e.g. to establish, modify and/or release RBs, to perform handover, to setup, modify, and/or release measurements, to add, modify, and/or release SCells. As part of the procedure, NAS dedicated information may be transferred from E-UTRAN to the UE. If the received RRC Connection Reconfiguration message includes the sCellToReleaseList, UE performs SCell release. If the received RRC Connection Reconfiguration message includes the sCellToAddModList, UE performs SCell additions or modification. In an example embodiment, TAG configuration may be included in sCellToAddModList and a TAG ID may be included in the TAG configuration. The

TA group could be configured when an SCell is added. Thus the configuration of TA group could be seen as part of the SCell addition or modification. In an example embodiment, TAT configuration may be included in common configuration parameters transmitted to a UE. To configure a new TA group, at least eNB may configure TA group index, and TAT length.

There could be two options for an eNB to configure pathloss reference and/or timing reference. eNB may configure pathloss reference and timing reference for each UE in TAG configuration (for example in RRC connection reconfiguration message) or eNB may configure pathloss reference and/or timing reference explicitly or implicitly for each UE later and after carrier activation. Depending on UE conditions the pathloss reference and/or reference timing may vary on a per UE basis.

When a UE receives sCellToAddModList in an RRC reconfiguration message, the UE processes the content of the message. The UE may, for each sCellIndex value included in the sCellToAddModList that is not part of the current UE configuration (SCell addition), add the SCell, corresponding to the cellIdentification, in accordance with the received radioResourceConfigCommonSCell and radioResourceConfigDedicatedSCell. The UE may configure lower layers to consider the SCell to be in deactivated state. The UE may, for each sCellIndex value included in the sCellToAddModList that is part of the current UE configuration (SCell modification), modify the SCell configuration in accordance with the received radioResourceConfigDedicatedSCell.

SCellToAddModList transmitted to a UE may comprise sCellIndex, physCellId, dl-CarrierFreq, radioResourceConfigCommonSCell, and radioResourceConfigDedicatedSCell. SCellToAddModList transmitted to a UE may further comprise the TAG ID that the SCell belongs to and/or time alignment timer value. In an example embodiment, this parameter may also include the pathloss reference SCell (downlink carrier) and/or reference timing SCell (downlink carrier). In an example embodiment, the pathloss reference SCell (downlink carrier) and/or reference timing SCell (downlink carrier) may be implicitly signaled or selected, for example during PRACH process for sTAG, or using other proprietary or standardized algorithms. In both scenarios, the UE and eNB may both know which SCell is selected for timing reference. The UE and eNB may know which SCell is selected for pathloss reference. TAG change may be supported by SCell modification in order to avoid deactivation. The identity or index of a TA group which an SCell belongs to, a TA group identity (TAG ID), may be assigned to an SCell. When an SCell is released, the TA configuration may also be implicitly released so it may not be needed to include TAG ID in sCellToReleaseList.

The parameters related to time alignment may be dedicated to a UE or may be common to all UEs. For example PRACH configuration for the SCell may be common to all UEs. In an example embodiment, TAT for each sTAG may be common to all UEs. SCell reference timing and reference path loss may be UE specific or common to all UEs. Assignment of an SCell to an sTAG may be UE specific, and may be different for different UEs connected to the same eNB. For example, a UE in the coverage of a repeater connected to the eNB may have a different sTAG configuration than a UE which is directly connected to the same eNB. For example, sTAG configuration could be transmitted as a part of radioResourceConfigDedicatedSCell.

In an example embodiment common parameters may comprise downlink common parameters and uplink common parameters. Examples of downlink common parameters are: downlink bandwidth, antennaInfoCommon, mbsfn-SubframeConfigList, phich-Config, pdsch-ConfigCommon, tdd-Config. Examples of uplink common parameters are ul-CarrierFreq, ul-Bandwidth, p-Max, uplinkPowerControlCommonSCell, soundingRS-UL-ConfigCommon, ul-CyclicPrefixLength, prach-ConfigSCell (TDD), pusch-ConfigCommon. Dedicated parameters may comprise downlink dedicated parameters and uplink dedicated parameters. Examples of downlink dedicated parameters are AntennaInfoDedicated, CrossCarrierSchedulingConfig, csi-RS-Config, pdsch-ConfigDedicated. Examples of uplink dedicated parameters are antennaInfoUL, pusch-ConfigDedicatedSCell, uplinkPowerControlDedicatedSCell, cqi-ReportConfigSCell, soundingRS-UL-ConfigDedicated, soundingRS-UL-ConfigDedicated, soundingRS-UL-ConfigDedicatedAperiodic, and pathlossReferenceLinking. The names of these variables are self-explanatory and an example definition and format for these variables may be found in the latest release of LTE RRC standard documentations.

The TA maintenance for PCell could follow Rel-10 principles. If an SCell applying the TA of PCell is added, the Rel-10 procedures may be reused. In one example embodiment, there is no need to assign a TAG ID for pTAG. SCells configured with the PCell may be grouped implicitly and a TAG ID for pTAG may not be needed or a TAG ID may be assigned implicitly by default. SCells grouped with PCell may be grouped implicitly and a TAG ID for pTAG may not be required. If an SCell is not configured with RACH parameters nor TAG information, it may apply that the SCell belongs to pTAG.

In one example embodiment, the eNB may explicitly indicate which SCell provides the DL timing reference in an RRC reconfiguration message and the timing reference information for sTAG may be transmitted with TAG configuration message. In another example embodiment, the SCell timing reference may be explicitly determined using the SIB2 linked DL used for transmitting uplink random access preamble. In another example embodiment, SCell reference may be determined according to a predefined rule known by both UE and eNB.

The UE may need to measure downlink pathloss to calculate the uplink transmit power. In one example embodiment, the eNB may explicitly indicate which SCell provides the DL path loss reference in an RRC reconfiguration message and the path loss reference information for sTAG may be transmitted with TAG configuration message. In another example embodiment, the

SCell path loss reference may be explicitly determined using the SIB2 linked DL used for transmitting uplink random access preamble. In another example embodiment, SCell reference may be determined according to a predefined rule known by both UE and eNB. In one embodiment, the timing reference downlink carrier SCell could be the same as the downlink pathloss SCell. Such a configuration could be implementation specific, for example they could be configured separately, or one configuration could apply to both of them. It may be the baseline to take the SIB-2 linked SCell as pathloss reference for the sTAG. Initially downlink SCell in which RA is transmitted may be used as a timing reference and then the UE could use another downlink reference as the reference SCell.

TAT of an sTAG may not be running when the last SCell of the group is removed from the TA group. In an example embodiment, sTAG TAT configuration may be released when no SCell is maintained in the sTAG. When sTAG is released, then TAT is also released/de-configured. E.g. this may be achieved by de-configuring the timer. Upon sTAG depletion, the TAT may be de-configured by the eNB, which may implicitly stop the TAT of this group at the same time. If an sTAG is empty, the same RRC message may remove the sTAG and TAT and a removed sTAG may be released/de-configured.

In an example embodiment, maximum number of supported TAGs in an eNB and/or the time alignment timer value for each TAG may be broadcasted using system information. For example, SIB2 may include time alignment values for each time alignment groups. This may indicate the maximum number of time alignment groups that could be configured in the eNB. In another example embodiment, time alignment values may be included in the common or dedicated parameters in an RRC connection reconfiguration message.

PRACH Configuration for sTAG and pTAG

For pTAG, there may not be a need to have more than one PRACH resource for a UE configured with multiple serving cells in pTAG because the PCell is always activated as long as the UE is in connected mode. There may not be a need for RACH on the SCells in the TA group comprising the PCell. The TA maintenance of the TA group containing the PCell is based, at least in part, on preamble transmitted on PCell PRACH resource. In an example implementation in TDD LTE, PRACH resource may be configured on SCells in the group containing PCell, if PRACH resource on a TDD SCell is needed.

For sTAG, PRACH may be configured for more than one SCell. This may introduce flexibility for the network to balance the load on PRACH between cells. sTAG could have multiple SCells with PRACH because the SCell could be deactivated. A UE may change the timing/pathloss reference for example, when the timing/pathloss reference SCell is deactivated or moved to another sTAG. For each UE, the timing reference may be the SCell sending the PRACH preamble and the initial timing acquisition may be made by the PRACH transmission. A UE may perform RACH procedure on the cell designated as the reference cell. The network may choose to configure RACH for the cell used as the reference cell. If needed, RACH may also be configured for multiple SCells in the sTAG and the RACH procedure for the sTAG may be carried out on any of those SCell within the sTAG.

For the SCell TA group, RACH may be performed on an SCell in the SCell TA group based on the PDCCH order. For the network initiated RACH, the choice of SCell to perform RACH may be left to eNB implementation based on for example, the radio quality of SCells. There may be no need to fix a specific SCell in an SCell group for RACH. It could be left to the eNB to decide which SCell to pick for RACH. eNB could select the SCell for RACH. SCells in pTAG may not include PRACH resource, but one or more SCells in sTAG may have PRACH resource.

If the multiple SCells in the same TA group are configured with the RACH parameters, the preamble usage efficiency may increase. eNB may select the SCell where the UE is asked to perform the RA procedure and then allocate the dedicated preamble of the selected SCell to the UE. An eNB may configure RACH parameters to more than one SCell in sTAG. SCell RACH is triggered by the eNB and the SCell RACH may be contention-free. In such a configuration, eNB selects SCell and PRACH resource and preamble ID for a UE. Then UE starts the PRACH process by sending the preamble on the PRACH resource of the SCell selected by eNB. In this process each UE may also have a different SCell timing reference and a different SCell pathloss reference. For example, a first group of UEs use a first SCell in the sTAG as the reference SCell, and a second group of UEs use a second SCell in the sTAG as the reference SCell. In an example embodiment, SCell timing reference and/or SCell pathloss reference could be SIB2 linked downlink carrier of the uplink carrier used for preamble transmission determined by PDCCH order. In pTAG operation, all UEs use the same uplink carrier PRACH resource in PCell and use the same PCell timing reference and/or PCell pathloss reference. In sTAG operation, a UE may change its SCell timing reference and/or SCell pathloss reference during operation, and may use one or more SCell PRACH resources during its operation. A UE uses one SCell reference and SCell PRACH at a given time, and multiple parallel and simultaneous PRACH operations by a UE may not be allowed.

Cell Deactivation in Multi-Carrier Networks (deactivation timer)

In an example embodiment, the eNB may select one SCell DL as the DL timing reference cell for the secondary TAG in a given UE. This may reduce signalling overhead or complexity of implementation or increase efficiency. For a UE, each sTAG has one timing reference cell. For example, the SCell UL on which RACH was performed may be linked with the SCell DL which is used as the DL timing reference cell for the sTAG. Since the SCell where RACH is performed is chosen by eNB, and RACH timing is referred to its SCell DL, the SCell DL may be the DL timing reference. In other words, eNB may implicitly inform a UE which SCell DL is the UE's DL timing reference cell, by requesting that UE to perform RACH on the corresponding SCell UL. In the sTAG, the DL timing reference cell is the SCell DL SIB2-linked with the SCell UL where RACH was performed. eNB may configure the SCell as the timing reference cell by ordering RACH to be performed on this SCell in the sTAG and/or by transmitting RRC connection reconfiguration message. For preamble transmission, the SIB2 linked DL of the cell which the preamble is sent may be used as DL timing reference. When TA command is received in RAR or MAC CE, it applies to current UL timing and uses the SIB2 linked DL of the cell where RA was performed as DL timing reference. For the subframes without TA command, the SIB2 linked DL of the cell where RA was performed may be used as DL timing reference. Timing reference for preamble transmission and other UL channels of the cells within the sTAG may be the SIB2 linked DL of the cell where RACH is performed.

In another example embodiment, eNB may configure the reference timing SCell in the RRC configuration message. In this example embodiment, RRC configuration message explicitly or implicitly determines, which SCell may be used as the SCell timing reference.

One timing reference may be configured in an sTAG, the timing alignment offset in RAR (random access response) or TAC (time alignment command) could be applied to all SCell(s) in the same sTAG. Thus, the eNB could select the most suitable SCell for timing reference and RACH depending on different circumstances. For example, the SCell which has a larger coverage range may be selected as timing reference cell, since larger coverage could provide a more reliable mobility performance and thus reduce the need of re-configuring the timing reference cell. Channel quality of an SCell in an sTAG may be considered for initial SCell timing reference and for reselecting timing reference cell when the TAT associated with the same sTAG expires.

Since the SCell served as the timing reference cell in sTAG may be deactivated in some cases, the timing reference cell may be changed to another SCell in the sTAG for maintaining UL timing alignment for all SCells in the same sTAG. Change of timing reference cell in an sTAG may be supported. The reference cell may also be changed for other reasons such as coverage quality, PRACH failure, or subscriber mobility. These scenarios may apply to cases where time alignment is running. If the time alignment is not running and the sTAG is not time aligned, then there is no uplink synchronization and UE may not use any reference SCell for uplink synchronization.

BS knows and therefore it initiates a new selection via RRC or RACH

In an example embodiment, if the SCell serving as the time reference of the sTAG is deactivated or moved to another TAG, the eNB knows when such event occurs and a new timing reference cell may be selected implicitly or explicitly by the eNB for the sTAG. For example, eNB may initiate RACH process and select a new SCell timing reference, or eNB may send an RRC message to reconfigure the sTAG and assign a new SCell timing reference to the sTAG. When the SCell timing reference needs to be deactivated or released, the timing reference SCell may be changed. If the reference cell is moved to another TAG, the timing reference could be reselected.

eNB transmits downlink and uplink packets to the Scell that is the reference first to ensure that it is not deactivated. Schedules packets on the downlink carrier in a way that the reference secondary carrier stays active as long as other carriers stay active.

The PCell may not be deactivated and may serve as a timing reference for pTAG as long as the UE is in connected mode. In an example embodiment, the eNB may keep the SCell DL used as reference active at least as long as other SCells in the sTAG are active. Such restrictions may be handled by the eNB implementation to keep the downlink reference SCell activated as long as other SCells are activated or as long as UE is scheduled with any uplink transmissions for the sTAG. eNB may schedule downlink and uplink packets to the SCell that is the reference SCell to ensure that it is not deactivated before other SCells. eNB may schedule packets on the downlink reference carrier in a way that the reference SCell stays active at least as long as other SCells are active. A well-defined reference cell known to both the eNodeB and the UE may also allow the eNodeB to take it into account when deciding which SCell to be deactivated. The eNodeB may keep the SCell chosen as the reference cell activated for as long as it is needed.

Deactivation rules change and that the reference SCell is deactivated after all other SCells are deactivated: The secondary carrier in the secondary TAG which is used for timing reference stays active, at least as long as any other secondary carrier in this group stays active, for example no matter which SCell the packet is transmitted, the reference SCell timer gets restarted

In another example embodiment, a new rule may be defined for reference SCell deactivation. The reference SCell may be deactivated after all other SCells are deactivated. The secondary carrier in the sTAG which is used for timing reference may stay active, at least as long as any other secondary carrier in this group stays active. For example, no matter which SCell is used for packet transmission, the reference SCell activation timer may get restarted. With this implementation, the reference SCell stays as the reference SCell and eNB or UE does not need to look for a new SCell. This may simplify the synchronization operation in UE and/or eNB.

Reference SCell gets a different deactivation timer. Different secondary carriers have different de-activation timers, and the reference secondary carrier has the longest deactivation timer.

In another example embodiment, the reference SCell may be assigned a different deactivation timer. Different secondary carriers may have different de-activation timers. The reference SCell may be assigned the largest deactivation timer compared with other SCells belonging to the same sTAG.

Send cell activate MAC command to keep the SCell active, even though there is no traffic

In another example embodiment, eNB may keep the SCell active by transmitting MAC activation command for that SCell even though there is no traffic for uplink or downlink transmission on the reference SCell. By keeping the reference SCell active as long as it is needed, the UE and eNB may not need to change the reference SCell so frequently. eNB may send an activation command when the activation timer for the reference SCell is near expiration. eNB may use this method for the reference SCell to reduce the possibility of changing the reference SCell in an sTAG.

UE autonomously selects another Scell.

In another example embodiment, UE may autonomously select another reference SCell when the reference SCell becomes deactivated. Since the timing reference is used to derive the UL transmission timing at the UE, there is a need for the UE to select a downlink SCell as the timing reference. The UE may autonomously reselect another activated SCell in the sTAG as the reference when needed. Timing reference for uplink transmission on SCell may be reselected to the DL timing of any activated SCell of the same sTAG when needed. Any activated SCell in the sTAG may be chosen by UE autonomously as the timing reference for this sTAG. For example, initially downlink SCell in which RA is transmitted may be used as a timing reference and then the UE may use another SCell as the timing reference, when the reference SCell needs to be changed.

a simple definition known by both the network and the UE is used, e.g. the reference cell can simply be the activated SCell with the smallest SCellIndex in the sTAG.

In another example embodiment, a pre-defined rule may be defined for eNB and the UE for SCell selection. For example, the reference cell may be the activated SCell with the smallest SCellIndex in the sTAG, or the largest SCellIndex in the sTAG, or the SCell with the lowest frequency may be selected. In case the reference SCell is deactivated, or its signal quality gets unacceptable, or if there is a change in the sTAG configuration such that a new reference SCell is needed, the UE may reselect a new cell as the reference cell using the pre-defined rule. In this embodiment, the reference SCell is known to the UE and eNB, when a change in reference SCell occurs.

SCell Deactivation Timer and TimeAlignment Timer and PRACH Process

If the UE is configured with one or more SCells, the network may activate and deactivate the configured SCells. The PCell is always activated. The network may activate and deactivate the SCell(s) by sending the Activation/Deactivation MAC control element. Furthermore, the UE may maintain an SCellDeactivationTimer timer per configured SCell and may deactivate the associated SCell upon its expiry. sCellDeactivationTimer may be configured by RRC. The same initial timer value may apply to each instance of the sCellDeactivationTimer. The configured SCells may be initially deactivated upon addition and/or after a handover. With the current sCellDeactivationTimer, SCell may be deactivated during the PRACH process, this issue may be addressed by introducing a change in sCellDeactivationTimer management.

The UE may for each TTI and for each configured SCell, if the UE receives an Activation/Deactivation MAC control element in this TTI activating the SCell, the UE may in the TTI according to a predefined timing activate the SCell and start or restart the sCellDeactivationTimer associated with the SCell. Activating an SCell may imply applying normal SCell operation including: SRS transmissions on the SCell, CQI/PMI/RI/PTI reporting for the SCell, PDCCH monitoring on the SCell, PDCCH monitoring for the SCell. The UE may also. If the UE receives an Activation/Deactivation MAC control element in this TTI deactivating the SCell, or if the sCellDeactivationTimer associated with the activated SCell expires in this TTI, in the TTI according to a predefined timing: deactivate the SCell, stop the sCellDeactivationTimer associated with the SCell, flush all HARQ buffers associated with the SCell.

If PDCCH on the activated SCell indicates an uplink grant or downlink assignment, or if PDCCH on the Serving Cell scheduling the activated SCell indicates an uplink grant or a downlink assignment for the activated SCell, the UE may restart the sCellDeactivationTimer associated with the SCell. If the SCell is deactivated, the UE may: not transmit SRS on the SCell, not report CQI/PMI/RI/PTI for the SCell, not transmit on UL-SCH on the SCell, not monitor the PDCCH on the SCell, and/or not monitor the PDCCH for the SCell.

In one example embodiment, the sCellDeactivationTimer associated with an SCell, which is activated for uplink transmission, may not start before the SCell is uplink time aligned. When UE receives an Activation/Deactivation MAC control element to activate an SCell belonging to sTAG, the UE may start the sCellDeactivationTimer associated with the SCell only if the timeAlignmentTimer associated with the SCell is running. If the SCell is added to an existing sTAG, which is time aligned, then the activation timer would start after the SCell activation according to a predefined timing. Or when a deactivated SCell belonging to a time aligned sTAG is activated, its time alignment timer starts according to a predefined timing. In this embodiment, a deactivation timer for a secondary cell belonging to a secondary cell group is started after the secondary cell is activated and the time alignment timer for said secondary cell group is running. This process may prevent or reduce the UE deactivation for an SCell with an ongoing Random Access procedure.

In another example embodiment, sCellDeactivationTimer of an activated SCell may be restarted when or before the eNB initiates the RA procedure via a PDCCH order for the activated SCell. This may also apply to cross carrier scheduling scenario, when PDCCH order is sent on the scheduling cell of the activated SCell. In an example implementation, the sCellDeactivationTimer of the activated carrier that carries the PDCCH order may also be restarted (if it is an sCell). If PDCCH on the activated SCell indicates a PDDCH order to start a random access process for the activated SCell, or if PDCCH on a Serving Cell indicates a PDDCH order to start a random access process for the activated SCell, the UE may restart the sCellDeactivationTimer associated with the SCell. This process may prevent or reduce the UE deactivation for an SCell with an ongoing Random Access procedure. In another example embodiment, an eNB may send an SCell activation MAC CE to restart the activation timer of the SCell that carries the RACH process. This may be done if the deactivation timer is above certain threshold, meaning that the time to deactivation is below a threshold. The threshold could be a range or any predefined rule defined in an eNB.

In another example embodiment, sCellDeactivationTimer of an activated SCell may be stopped when the eNB initiates the RA procedure via a PDCCH order for the activated SCell. This may also apply to cross carrier scheduling scenario, when PDCCH order is sent on the scheduling cell of the activated SCell. In an example implementation, the sCellDeactivationTimer of the activated carrier that carries the PDCCH order may also be stopped (if it is an SCell). If PDCCH on the activated SCell indicates a PDDCH order to start a random access process for the activated SCell, or if PDCCH on a Serving Cell indicates a PDDCH order to start a random access process for the activated SCell, the UE may stop the sCellDeactivationTimer associated with the SCell. In this scenario, the sCellDeactivationTimer may be started (from the point it was stopped) or may be restarted after a predetermined event is triggered for said random access process, for example when the PRACH process is ended. For example, this could be marked by transmitting RAR by eNB for the UE or by assigning the first downlink or uplink resources to the UE or by first UE uplink transmission. This process may prevent or reduce the UE deactivation for an SCell with an ongoing Random Access procedure.

Radio Link Failure for PRACH failure on pTAG and no action or some other action for sTAG PRACH failure

For pTAG, in the case of RACH failure MAC and RRC layers perform certain functions. When the number of RA preamble transmissions reaches preambleTransMax, MAC layer in the UE may indicate Random Access problem to upper layers. UE may or may not continue RACH procedure, i.e. transmit the preamble. When RRC is informed of RACH failure from MAC, if neither T300,T301,T304 nor T311 is running, the RRC layer may trigger reestablishment if AS (access stratum) security has been activated. Otherwise the UE may directly move to RRC_IDLE. The RACH procedure may be stopped and other processes, for example, connection reestablishment, may start. For pTAG, when the number of RA preamble transmissions reaches preambleTransMax, the RACH procedure may be stopped by further RRC procedures. For pTAG, if random access fails, MAC may indicate a random access problem to upper layers and RRC may declare radio link failure and initiate RRC connection re-establishment procedure.

The purpose of RRC connection re-establishment procedure could be to re-establish the RRC connection, which involves the resumption of SRB1 operation, the re-activation of security and/or the configuration of the PCell. The UE may initiate the procedure when AS security has been activated. The UE may initiate the procedure upon detecting radio link failure. A UE in RRC_CONNECTED, for which security has been activated, may initiate the procedure in order to continue the RRC connection. The connection re-establishment could succeed if the concerned cell is prepared i.e. has a valid UE context. In case E-UTRAN accepts the re-establishment, SRB1 (signalling radio bearer one) operation resumes while the operation of other radio bearers remains suspended. If AS security has not been activated, the UE may not initiate the procedure but instead may directly move to RRC_IDLE. E-UTRAN may apply RRC connection re-establishment procedure to reconfigure SRB1 and to resume data transfer for this RB (radio bearer) and/or to re-activate AS security without changing algorithms.

If either T300,T301,T304 or T311 is running, when RACH problem is indicated from MAC to RRC, the RRC layer may do different handling if corresponding Timer expired. In an example embodiment, timer T300 starts by transmission of RRCConnectionRequest and stops by reception of RRCConnectionSetup or RRCConnectionReject message, cell re-selection and upon abortion of connection establishment by upper layers. If timer T300 expires, UE may reset MAC, release the MAC configuration and re-establish RLC for all RBs that are established. UE may also inform upper layers about the failure to establish the RRC connection, upon which the procedure may end. Timer T301 starts by transmission of RRCConnectionReestabilshmentRequest and stops by reception of RRCConnectionReestablishment or RRCConnectionReestablishmentReject message as well as when the selected cell becomes unsuitable. After expiry UE may go to Go to RRC_IDLE. Timer T304 starts by reception of RRCConnectionReconfiguration message including the MobilityControl Info or reception of MobilityFromEUTRACommand message including CellChangeOrder and stops by criterion for successful completion of handover to EUTRA or cell change order is met (the criterion is specified in the target RAT in case of inter-RAT). At expiry, in case of cell change order from E-UTRA or intra E-UTRA handover, UE may initiate the RRC connection re-establishment procedure; In case of handover to E-UTRA, UE may perform the actions applicable for the source RAT. Timer T311 starts by initiating the RRC connection re-establishment procedure and stops by selection of a suitable E-UTRA cell or a cell using another RAT. After expiry UE may enter RRC_IDLE.

UE may not perform radio link monitoring (RLM) on SCells. eNB may prevent any UL transmission (PUSCH, SRS and ordered RA) if a UE SCell is in insufficient radio conditions. RLM on SCells may not be required. RACH on an SCell in an sTAG may be triggered when sTAG is out-of-sync. The RACH on SCell may be used to synchronize sTAG for UL data transmission. In this case, normally PCell is in sync and there may be no need to trigger reestablishment for SCell RACH failure. The eNB may configure other suitable SCells if available and RRC connection reestablishment may not be needed.

RACH triggered on SCell may be unrelated to initial setup, HO, or reestablishment procedure. No further RRC procedure may be used to stop it. UE may autonomously stop SCell RACH process if SCell RACH process fails. The UE may stop preamble transmission on SCell and may not report Random Access problem to upper layers when the number of RA preamble transmissions on SCell reaches preambleTransMax. UE may let eNB detect SCell RA failure. eNB may detect RA failure by its own timer. eNB may set the timer value according to configured RA parameters (e.g. the maximum number of preamble transmissions, etc). eNB may start a timer when triggering RA on SCell, and upon the timer expiry eNB may consider a RA failure. When SCell RA fails, eNB may detect the failure without UE reporting it to the eNB.

In one example embodiment, eNB may initiate sTAG random access when the sTAG is out-of-sync, when the UE sTAG is in out-of synch state and SCell RA fails, uplink timing is still out-of-sync, and the sTAG may stay in out-of-sync state. eNB may also initiate sTAG RA procedure when the sTAG is in-sync. eNB may trigger SCell RA on in-sync SCell, for example when it detects that the uplink timing is deteriorating or time-alignment timer is expiring, and sTAG needs initial uplink synchronization. In this case, if SCell RA fails, eNB and UE may consider the SCell out-of-sync. When SCell RA failure, the related sTAG could be in out-of-sync state. When sTAG is in out-of-sync state the following may occur: SRS transmissions may be stopped on the corresponding SCells in the sTAG; the type-0 SRS configuration may be released; the type-1 SRS configuration may be maintained; CSI reporting configuration for the corresponding SCells may be maintained; and/or MAC may flush the uplink HARQ buffers of the corresponding SCells.

In an example embodiment, MAC may indicate a random access problem to higher layers when random access on PCell fails, and MAC may not indicate a random access problem when random access on SCell fails. No special UE behavior for SCell UL random access problem may be defined and network-based detection and control may be assumed sufficient. Random access failure on SCell could be mainly handled by L1/L2. The eNB may detect random access problem, and there may be less RRC impact compared with PCell RACH failure.

Power Headroom Message

In an example embodiment, power headroom report (PHR) may not be reported for deactivated SCells. The deactivated SCell is not scheduled for uplink or downlink transmission before being activated and there may not be a critical need for PHR for the deactivated SCells and PHR reporting for deactivated SCells may increase the overhead. There may not be a critical need to report the PHR for an activated but UL non-synchronized SCell. eNB may not schedule uplink transmission on an SCell which is not uplink synchronized before obtaining uplink synchronization for that SCell. PHR report may report PHR for activated and synchronized SCells. The PHR triggering and reporting for the activated but UL out-of-sync SCell may not be considered. The PHR may not be reported for the activated but uplink out-f-sync SCells.

For an sTAG, PHR may not be triggered and may not be transmitted for SCells in sTAG when the associated sTAG TAT (time alignment timer) is not running (sTAG is out-of-sync). There is no UL transmission for sTAG after TAT expiry. PHR reporting may be stopped while sTAG TAT expires. The PHR report for the sTAG may be started after RACH procedure on the sTAG is initiated, and the associated TAT is started or re-started. The PHR and the PH inclusion may be limited to the activated SCells that their uplink timing is aligned. When checking the PHR trigger conditions and when generating the PH, the activated serving cells may be considered if their uplink timing is synchronized. The PHR may not be triggered when the path loss of the activated but uplink out-of-sync SCell which is used as a path loss reference has changed more than a pre-defined threshold.

Since the UE power situation changes at the SCell activation, the UE may report the PHR for the SCell at the SCell activation so that the PHR is timely provided to the eNB. eNB may use UE power situation for example for packet scheduling, transmission format and power control. This may improve the allocation of the uplink resources to the UE. In an example embodiment, when the SCell UL in an sTAG become uplink synchronized, UE may timely provide the PHR to the eNB. The UE may trigger the PHR when the activated SCell where the uplink timing was not aligned becomes time-aligned. When uplink timing status changes from out-of-sync to in-sync for an active SCell, the PHR may be triggered. For example, after UE successfully finishes PRACH process on an SCell, UE may trigger and transmit PHR report. When checking the trigger conditions for PHR, the activated SCell that are UL time aligned may be considered. When a PHR is triggered, the PHR for the activated Serving Cell that are UL time aligned is reported. If the activated SCell is not time-aligned, then PHR for that SCell may not be triggered. For the SCell belonging to the sTAG, a PHR may be triggered when the SCell obtains the UL time alignment for the first time after it was activated.

PH (power headroom) reporting for pTAG, may be performed for an activated SCell. In a pTAG, uplink synchronization is based on PCell signal, which may not be de-activated. In pTAG, an SCell may be activated after pTAG synchronization is achieved. If pTAG goes out-of-synch, the UE may indicate a radio link failure.

The Power Headroom reporting procedure could be used to provide the serving eNB with information about the difference between the nominal UE maximum transmit power and the estimated power for UL-SCH transmission per activated and time aligned serving cell and also with information about the difference between the nominal UE maximum power and the estimated power for UL-SCH and PUCCH transmission on PCell.

In an example embodiment, RRC may control power headroom reporting by configuring the two timers periodicPHR-Timer and prohibitPHR-Timer, and by signalling dl-PathlossChange which sets the change in measured downlink pathloss to trigger a PHR. A power headroom report may be triggered if any of or at least one of the following events occur: a) prohibitPHR-Timer expires or has expired and the path loss has changed more than dl-PathlossChange dB for at least one activated (and time aligned) Serving Cell which is used as a pathloss reference since the last transmission of a PHR when the UE has UL resources for new transmission; b) periodicPHR-Timer expires; c) upon configuration or reconfiguration of the power headroom reporting functionality by upper layers, which is not used to disable the function; d) activation of an SCell with configured uplink, if its uplink is time aligned, e) uplink time alignment of a secondary SCell, f) prohibitPHR-Timer expires or has expired, when the UE has UL resources for new transmission, and the following is true in this TTI for any of the actived Serving Cells with configured uplink: there are UL resources allocated for transmission or there is a PUCCH transmission on this cell, and the required power backoff due to power management (as allowed by P-MPRc) for this cell has changed more than dl-PathlossChange dB since the last transmission of a PHR when the UE had UL resources allocated for transmission or PUCCH transmission on this cell. The UE may not trigger a PHR when the required power backoff due to power management decreases temporarily (e.g. for up to a few tens of milliseconds) and it may avoid reflecting such temporary decrease in the values of Pcmax,c/PH when a PHR is triggered by other triggering conditions.

In an example embodiment, if the UE has UL resources allocated for new transmission for this TTI UE may perform the function in this paragraph. If it is the first UL resource allocated for a new transmission since the last MAC reset, UE may start periodicPHR-Timer. If the Power Headroom reporting procedure determines that at least one PHR has been triggered since the last transmission of a PHR or this is the first time that a PHR is triggered, and if the allocated UL resources can accommodate a PHR MAC control element plus its subheader if extendedPHR is not configured, or the Extended PHR MAC control element plus its subheader if extendedPHR is configured, as a result of logical channel prioritization, the UE may: I) start or restart periodicPHR-Timer. II) start or restart prohibitPHR-Timer; III) cancel all triggered PHR(s), IV) If extendedPHR is configured: a) for each activated Serving Cell with configured and time-aligned uplink obtain the value of the Type 1 power headroom; if the UE has UL resources allocated for transmission on this Serving Cell for this TTI, the obtain the value for the corresponding PCMAX,c field from the physical layer; b) if simultaneousPUCCH-PUSCH is configured, obtain the value of the Type 2 power headroom for the PCell; if the UE has a PUCCH transmission in this TTI, then obtain the value for the corresponding PCMAX,c field from the physical layer; c) instruct the Multiplexing and Assembly procedure to generate and transmit an Extended PHR MAC control element based on the values reported by the physical layer. V) If extendedPHR is not configured: UE may obtain the value of the Type 1 power headroom from the physical layer; and may instruct the Multiplexing and Assembly procedure to generate and transmit a PHR MAC control element based on the value reported by the physical layer.

Impact of time alignment timer on uplink HARQ

When the TAT associated with the pTAG expires, all TATs are considered as expired and the UE flushes all HARQ buffers of all serving cells, clears any configured downlink assignment/uplink grants, and RRC releases PUCCH/SRS for all configured serving cells as in Rel-10. The UE may not perform any uplink transmission except the random access preamble transmission when TAT for pTAG is not running.

For primary TAG if timeAlignmentTimer is stopped or expired UE and eNB may not indicate the generated positive or negative acknowledgement to the physical layer. If primary TAG timeAlignmentTimer is running, UE and eNB may indicate the generated positive or negative acknowledgement for this TB to the physical layer. The UE may follow Rel-10 behavior for DL HARQ feedback handling when the PCell-TAT is stopped or expired.

When the TAT associated with sTAG expires, SRS transmissions may be stopped on the corresponding SCells. The type-0 SRS configuration may be released, but the type-1 SRS configuration may be maintained. CSI reporting configuration for the corresponding SCells is maintained. MAC flushes the uplink HARQ buffers of the corresponding SCells. MAC may stop transmission of HARQ feedback in the downlink to the UE. Whether the SCell-TAT is running or not may not impact the HARQ feedback transmission in the uplink.

Uplink HARQ feedback may be transmitted on PUCCH on PCell, and downlink HARQ feedback may be transmitted on the same or different serving cell as uplink transmission depending on cross carrier scheduling.

Different Carrier groups are time aligned

Frames and subframe transmission timing for all downlink carriers in the primary cell group and the secondary cell group of the base station may be substantially time aligned with each other. Frames and subframe for all downlink carriers in the primary cell group and the secondary cell group are transmitted and their timing are controlled by the same base station, and therefore achieving an accurate time alignment by the base station would be feasible by the base station.

In an example embodiment, frames and subframe transmission timing for all downlink carriers in the primary cell group and the secondary cell group of the base station may be substantially time aligned with frames and subframe transmission timing of all downlink carriers in the plurality of base stations. This may be an optional synchronization requirement and some network may not use this requirement. Such a time alignment requires, for example, coordination and signalling among the plurality of base stations. In another example, it requires that the plurality of base stations use the same synchronization source such as GPS signalling, some other sort of centralized algorithm, or some packet based synchronization system to achieve synchronization. Time alignment process between frames and subframes of the plurality of base stations thus involves many external factors, and therefore the accuracy of time alignment may not be precise, but it may be within certain pre-defined accuracy limits. Time alignment between carriers of the same base stations may be a simpler task compared with time alignment between carriers of multiple base stations. The accuracy of the former task may be higher then the accuracy of the later task. Therefore, the term substantially aligned here may imply that the carriers are time aligned within a certain time alignment accuracy range. For example, in an implementation the accuracy may be half a subframe.

Frames and subframe transmission timing for all uplink carriers in the primary cell group of the wireless device may be substantially time aligned with each other. Frames and subframe transmission timing for all uplink carriers in the secondary cell group of the wireless device may be substantially time aligned with each other. Frames and subframe transmission timing for uplink carriers in the primary cell group of the wireless device may not necessarily be time aligned with frames and subframe transmission timing for uplink carriers in the secondary cell group of the wireless device. Substantial time alignment here may be considered in the context. In a wireless device, uplink signal transmission are not time aligned if they are not precisely time aligned. Because the same device is generating the signal. The substantial alignment here imply that the wireless device makes every effort to align transmission timing. However, it is indicated here that uplink transmission timing of uplink carriers in the primary cell group and the secondary cell group are not exactly time aligned. Each cell group uses a different downlink synchronization signal as the reference timing, and time alignment commands for the uplink are different for the primary cell group and secondary cell group uplink transmission. In an example, in a wireless signal uplink transmission even a few micro-second mis-alignment between uplink transmissions in two different carrier groups may be considered as not being substantially time aligned.

In an example embodiment, the plurality of time alignment commands could substantially align frame and subframe reception timing of signals transmitted by the plurality of wireless devices to the base station in the primary cell group. The plurality of time alignment commands could substantially align frame and subframe reception timing of signals transmitted by the plurality of wireless devices to the base station in the secondary cell group. In this context, the substantial time alignment criteria is determined by base station performance criteria, and in normal condition the base station may transmit the time alignment commands with the goal of achieving a substantial time alignment in the uplink.

In another example embodiment, the plurality of time alignment commands could substantially align frame and subframe reception timing of signals transmitted by the plurality of wireless devices to the base station in the primary cell group and the secondary cell group. In this embodiment, time alignment commands are transmitted in order to maintain the same reception timing at the base station among all carriers of the cell, including all carriers in the primary cell group and secondary cell group. This process may require a more complex time alignment procedure in the base station, but may provide advantages because frames and subframes of all uplink transmissions by all wireless devices on all uplink carriers are substantially the same. The substantial time alignment implies that the base station may transmit time alignment commands to achieve such a time alignment in the received signal of all uplink carriers from all wireless devices in the coverage area of for example a base station sector.

Simultaneous Transmission and Transmission Power Scaling

SCells belonging to an sTAG may need to perform random access process in order to achieve UL synchronization. For example, this may happen when an SCell belonging to an un unsynchronized sTAG is activated. In these cases, the UE may be uplink out-of-synch for that SCell, but is uplink synchronized for pTAG. eNB may trigger RACH on SCell to let UE acquire uplink synchronization. There is the possibility of transmission of PUSCH/SRS/PUCCH on PCell or PUSCH/SRS on other serving cells belonging to pTAG while RACH (random access channel) transmission is carried out on SCell belonging to sTAG. Possible simultaneous transmission of PRACH (physical random access channel) on SCell and other UL channel on other serving cells in pTAG may be considered. UE may support parallel PRACH and PUSCH/PUCCH transmissions.

Parallel transmission of other UL packets at the time as the random access preamble is sent on the SCell may require special solution. There could be more than one TA group and hence one TA group may already be in sync while another TA (time alignment) group may not be in-sync. This means that UL transmission may be on-going on other cells while the UE receives a PDCCH order to transmit a preamble on a cell that is not yet in sync. Parallel transmission of a preamble on an SCell in one sTAG, and other UL transmissions on cells in other TAGs may happen.

Parallel transmission of a preamble on an SCell and of other UL data or control packets transmission on cells in other TA groups could have many advantages. The network may not need to coordinate the time when an RA is ordered on an SCell and with other UL transmissions. This may slightly increase UE complexity and it may make the power handling of the UE a bit more complex, but radio resources may be used more efficiently if parallel transmission is allowed. Supporting parallel transmission of a preamble on an SCell and of other UL data or control messages may reduce the complexity in an eNB. Allowing parallel PRACH and PUSCH/PUCCH transmissions avoids the scheduling restrictions.

When UE supports simultaneous PUSCH and PUCCH, power scaling may be applied when the UE is in power limited scenario, for example when UE is in poor coverage areas. Whenever UL SRS coincides with PUCCH in the same subframe, type-0 triggered SRS may not be transmitted by the UE. Whenever PUSCH coincides with the UL SRS (sounding reference signal) symbol, the type-0 triggered SRS may also not be transmitted. Priority is given to PUCCH and PUSCH over UL SRS.

With the introduction of multiple TA, RACH preamble may be transmitted on an SCell. Hence there will be TTI where RACH preamble transmission or retransmissions on SCell may coincide with either PUCCH or PUSCH on PCell/SCell or both. The following simultaneous PRACH on SCell with other UL transmissions may occur in a UE:

- PUSCHs on PCell and/or SCells and PRACH on an SCell
- PUCCH on PCell and PRACH on an SCell
- PUCCH on PCell and PUSCH on SCells and PRACH on an SCell
- PUCCH and PUSCH on PCell (if UE support simultaneous PUSCH and PUCCH), PUSCH on other SCells and PRACH on the SCell
- UL SRS transmission on serving cells along with PRACH on an SCell
- Overlapping transmission of SRS and PUSCH with PRACH on an SCell (if SCell is in synch is sending preamble)

UE behaviour could be defined when total power is not sufficient. There could be multiple solutions to address this issue. The priorities for power scaling between different channels may be determined. According to the priorities the powers may be scaled to ensure transmit power is less than or equal to $\hat{P}_{CMAX}(i)$.

In one example embodiment, he order of priorities may be PUCCH, PUSCH with UCI (uplink control information), PRACH, and then PUSCH (PUCCH has the highest priority). For the case when there is no simultaneous PUSCH with UCI transmission, if the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, then:

$$\hat{P}_{\mathrm{PRACH}}(i) = \min\left(\hat{P}_{PRACH}(i), \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i)\right)\right)$$

The UE may scale $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cell c in subframe *i* such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i) - \hat{P}_{\mathrm{PRACH}}(i)\right)$$

is satisfied where $\hat{P}_{\mathrm{PUCCH}}(i)$ may be the linear value of $P_{\mathrm{PUCCH}}(i)$, $\hat{P}_{\mathrm{PUSCH},c}(i)$ may be the linear value of $P_{\mathrm{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ may be the linear value of the UE total configured maximum output power P_{CMAX} in subframe *i* and $w(i)$ may be a scaling factor of $\hat{P}_{\mathrm{PUSCH},c}(i)$ for serving cell c where $0 \le w(i) \le 1$. In case there is no PUCCH transmission in subframe *i* $\hat{P}_{\mathrm{PUCCH}}(i) = 0$. $\hat{P}_{\mathrm{PRACH}}(i)$ may be the linear value of $P_{\mathrm{PRACH}}(i)$ or could be another function of the preamble transmission power on an uplink SCell. If there is no uplink preamble transmission, then $\hat{P}_{\mathrm{PRACH}}(i) = 0$. In an example, $w(i)$ values may be the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero. In this and other example embodiments, the linear value of a power, P, could be replaced with some other functions that represent the power, P, of a signal.

If the UE has PUSCH transmission with UCI on serving cell *j* and PUSCH without UCI in any of the remaining serving cells (and no simultaneous PUCCH message is transmitted), and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, then:

$$\hat{P}_{\mathrm{PRACH}}(i) = \min\left(\hat{P}_{PRACH}(i), \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUSCH,j}}(i)\right)\right)$$

The UE may scale $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cells without UCI in subframe *i* such that the condition

$$\sum_{c \ne j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \le \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUSCH},j}(i) - \hat{P}_{\mathrm{PRACH}}(i)\right)$$

is satisfied where $\hat{P}_{\mathrm{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\mathrm{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\mathrm{PUSCH},j}(i)$ unless $\sum_{c\neq j} w(i)\cdot \hat{P}_{\mathrm{PUSCH},c}(i)=0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE obtains $\hat{P}_{\mathrm{PUSCH},c}(i)$ according to

$$\hat{P}_{\mathrm{PUSCH},j}(i)=\min\left(\hat{P}_{\mathrm{PUSCH},j}(i),\left(\hat{P}_{\mathrm{CMAX}}(i)-\hat{P}_{\mathrm{PUCCH}}(i)\right)\right) \text{ and then}$$

$$\hat{P}_{PRACH}(i)=\min\left(\hat{P}_{\mathrm{PRACH}}(i),\left(\hat{P}_{\mathrm{CMAX}}(i)-\hat{P}_{\mathrm{PUCCH}}(i)-\hat{P}_{\mathrm{PUSCH},j}(i)\right)\right)$$

And then

$$\sum_{c\neq j} w(i)\cdot \hat{P}_{\mathrm{PUSCH},c}(i)\le\left(\hat{P}_{\mathrm{CMAX}}(i)-\hat{P}_{\mathrm{PUCCH}}(i)-\hat{P}_{\mathrm{PUSCH},j}(i)-\hat{P}_{\mathrm{PRACH}}(i)\right)$$

In another example embodiment, the order of priorities may be PRACH, PUCCH, PUSCH with UCI, and then PUSCH (PRACH has the highest priority). For the case when there is no simultaneous PUSCH with UCI transmission, if the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, then:

$$\hat{P}_{\mathrm{PUCCH}}(i)=\min\left(\hat{P}_{PUCCH}(i),\left(\hat{P}_{\mathrm{CMAX}}(i)-\hat{P}_{\mathrm{PRACH}}(i)\right)\right)$$

The UE may scale $\hat{P}_{\mathrm{PUSCH},c}(i)$ for the serving cell c in subframe *i* such that the condition

$$\sum_{c} w(i)\cdot \hat{P}_{\mathrm{PUSCH},c}(i)\le\left(\hat{P}_{\mathrm{CMAX}}(i)-\hat{P}_{\mathrm{PUCCH}}(i)-\hat{P}_{\mathrm{PRACH}}(i)\right)$$

is satisfied where $\hat{P}_{\mathrm{PUCCH}}(i)$ may be the linear value of $P_{\mathrm{PUCCH}}(i)$, $\hat{P}_{\mathrm{PUSCH},c}(i)$ may be the linear value of $P_{\mathrm{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ may be the linear value of the UE total configured maximum output power P_{CMAX} in subframe *i* and $w(i)$ may be a scaling factor of $\hat{P}_{\mathrm{PUSCH},c}(i)$ for serving cell c where $0\le w(i)\le 1$. In case there is no PUCCH transmission in subframe *i* $\hat{P}_{\mathrm{PUCCH}}(i)=0$. $\hat{P}_{\mathrm{PRACH}}(i)$ may be the linear value of $P_{\mathrm{PRACH}}(i)$ or could be another function of the preamble transmission power on an uplink SCell. If there is no uplink preamble transmission, then

$\hat{P}_{\text{PRACH}}(i) = 0$. In an example, $w(i)$ values may be the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero.

If the UE has PUSCH transmission with UCI on serving cell *j* and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$ (and no simultaneous PUCCH message is transmitted), then:

$$\hat{P}_{\text{PUSCH,j}}(i) = \min\left(\hat{P}_{\text{PUSCH,j}}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PRACH}}(i)\right)\right)$$

The UE may scale $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe *i* such that the condition

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUSCH},j}(i) - \hat{P}_{\text{PRACH}}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$ unless $\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to

$$\hat{P}_{\text{PUCCH}}(i) = \min\left(\hat{P}_{PUCCH}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PRACH}}(i)\right)\right) \text{ and then}$$

$$\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \hat{P}_{PRACH}(i)\right)\right)$$

And then

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \hat{P}_{\text{PUSCH},j}(i) - \hat{P}_{\text{PRACH}}(i)\right)$$

In another example embodiment, the order of priorities may be PUCCH, PUSCH with UCI, PUSCH, and then PRACH (PUCCH has the highest priority).

For the case when there is no simultaneous PUSCH with UCI transmission, if the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE may scale down the power of PRACH according to the following:

$$\hat{P}_{PRACH}(i) = \min\left(\hat{P}_{PRACH}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \sum_{c} \hat{P}_{\text{PUSCH},c}(i)\right)\right)$$

If power of PRACH is zero or below a certain threshold, then UE may not transmit a preamble on PRACH. If $\hat{P}_{\text{CMAX}}(i) \leq \hat{P}_{\text{PUCCH}}(i) + \sum_{c} \hat{P}_{\text{PUSCH},c}(i)$, then power scaling is required even that PRACH is not transmitted. The UE may scale $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cell c in subframe *i* such that the condition

$$\sum_{c} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUCCH}}(i)$ may be the linear value of $P_{\text{PUCCH}}(i)$, $\hat{P}_{\text{PUSCH},c}(i)$ may be the linear value of $P_{\text{PUSCH},c}(i)$, $\hat{P}_{CMAX}(i)$ may be the linear value of the UE total configured maximum output power P_{CMAX} in subframe *i* and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \leq w(i) \leq 1$. In case there is no PUCCH transmission in subframe *i* $\hat{P}_{\text{PUCCH}}(i) = 0$.

If the UE has PUSCH transmission with UCI on serving cell *j* and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$ (and no simultaneous PUCCH message is transmitted), the UE may scale $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe *i* such that the condition

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$ unless $\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{CMAX}(i)$. Note that $w(i)$ values are the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero. The power PRACH in this case could be the same as the above PRACH power formula.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{CMAX}(i)$, the UE may obtain $\hat{P}_{\mathrm{PUSCH},c}(i)$ according to

$$\hat{P}_{\mathrm{PUSCH},j}(i) = \min\left(\hat{P}_{\mathrm{PUSCH},j}(i), \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\mathrm{PUSCH},c}(i) \leq \left(\hat{P}_{\mathrm{CMAX}}(i) - \hat{P}_{\mathrm{PUCCH}}(i) - \hat{P}_{\mathrm{PUSCH},j}(i)\right)$$

The power PRACH in this case could be the same as the above PRACH power formula.

Whenever UL SRS coincides with PRACH in the same subframe, type-0 triggered SRS may not be transmitted by the UE, at least when there is power constraint in the UE. Whenever PRACH on an SCell is transmitted simultaneously with an scheduled PUSCH on the same SCell, UE would not transmit PUSCH packets.

In an example embodiment, some other power constraints may be applied to limit transmission power for each carrier below a maximum carrier transmission power. For example, when a simultaneous PUCCH and PUSCH on the same carrier is transmitted, the UE may perform a power scaling inside a carrier before applying the above power limitations on the overall transmit power.

MAC Random Access procedures

Random Access Procedure initialization

The Random Access procedure may be initiated by a PDCCH order or by the MAC sublayer itself. If a UE receives a PDCCH transmission consistent with a PDCCH order masked with its C-RNTI, it may initiate a Random Access procedure. The PDCCH order or RRC may indicate ra-PreambleIndex and ra-PRACH-MaskIndex. Preamble transmission on PRACH and reception of a PDCCH order may be supported for PCells and SCells. In an example embodiment, the procedure may use some of the following information:

a) the available set of PRACH resources for the transmission of the Random Access Preamble, for example using prach-ConfigIndex.

b) the groups of Random Access Preambles and the set of available Random Access Preambles in each group (if multiple groups are supported). The preambles that may be contained in Random Access Preambles group A and Random Access Preambles group B could be calculated from the parameters numberOfRA-Preambles and sizeOfRA-PreamblesGroupA. If sizeOfRA-

PreamblesGroupA is equal to numberOfRA-Preambles then there may be no Random Access Preambles group B. The preambles in Random Access Preamble group A could be the preambles 0 to sizeOfRA-PreamblesGroupA – 1 and, if it exists, the preambles in Random Access Preamble group B could be the preambles sizeOfRA-PreamblesGroupA to numberOfRA-Preambles – 1 from the set of 64 preambles.

c) If Random Access Preambles group B exists, the thresholds, *messagePowerOffsetGroupB* and *messageSizeGroupA*, the configured UE transmitted power of the Serving Cell performing the Random Access Procedure, $P_{CMAX,c}$, and the offset between the preamble and Msg3, *deltaPreambleMsg3*, that are required for selecting one of the two groups of Random Access Preambles.

d) the RA response window size *ra-ResponseWindowSize*.

e) the power-ramping factor *powerRampingStep*.

f) the maximum number of preamble transmission *preambleTransMax*.

g) the initial preamble power *preambleInitialReceivedTargetPower*.

h) the preamble format based offset DELTA_PREAMBLE.

i) the maximum number of Msg3 HARQ transmissions *maxHARQ-Msg3Tx*.

j) the Contention Resolution Timer *mac-ContentionResolutionTimer*.

The above parameters may be updated from upper layers before each Random Access procedure is initiated.

In an example embodiment, the Random Access procedure may be performed as follows: Flush the Msg3 buffer; set the PREAMBLE_TRANSMISSION_COUNTER to 1; set the backoff parameter value in the UE to 0 ms; for the RN, suspend any RN subframe configuration; proceed to the selection of the Random Access Resource. There could be one Random Access procedure ongoing at any point in time. If the UE receives a request for a new Random Access procedure while another is already ongoing, it may be up to UE implementation whether to continue with the ongoing procedure or start with the new procedure.

Random Access Resource selection

In an example embodiment, the Random Access Resource selection procedure may be performed as follows. If ra-PreambleIndex (Random Access Preamble) and ra-PRACH-MaskIndex (PRACH Mask Index) have been explicitly signalled and ra-PreambleIndex is not 0, then the Random Access Preamble and the PRACH Mask Index could be those explicitly signalled. Otherwise, the Random Access Preamble may be selected by the UE.

The UE may determine the next available subframe containing PRACH permitted by the restrictions given by the *prach-ConfigIndex,* the PRACH Mask Index and physical layer timing requirements (a UE may take into account the possible occurrence of measurement gaps when determining the next available PRACH subframe). If the transmission mode is TDD and the PRACH Mask Index is equal to zero, then if *ra-PreambleIndex* was explicitly signalled and it was not 0 (i.e., not selected by MAC), then randomly select, with equal probability, one PRACH from the PRACHs available in the determined subframe. Else, the UE may randomly select, with equal probability, one PRACH from the PRACHs available in the determined subframe and the next two consecutive subframes. If the transmission mode is not TDD or the PRACH Mask Index is not equal to zero, a UE may determine a PRACH within the determined subframe in accordance with the requirements of the PRACH Mask Index. Then the UE may proceed to the transmission of the Random Access Preamble.

PRACH mask index values may range for example from 0 to 16. PRACH mask index value may determine the allowed PRACH resource index that could be used for transmission. For example, PRACH mask index 0 may mean that all PRACH resource indeces are allowed; or PRACH mask index 1 may mean that PRACH resource index 0 may be used. PRACH mask index may have different meaning in TDD and FDD systems.

The random-access procedure may be performed by UE setting PREAMBLE_RECEIVED_TARGET_POWER to *preambleInitialReceivedTargetPower* + DELTA_PREAMBLE + (PREAMBLE_TRANSMISSION_COUNTER – 1) * *powerRampingStep*. The UE may instruct the physical layer to transmit a preamble using the selected PRACH, corresponding RA-RNTI, preamble index and PREAMBLE_RECEIVED_TARGET_POWER.

Random Access Response reception

In an example embodiment, once the Random Access Preamble is transmitted and regardless of the possible occurrence of a measurement gap, the UE may monitor the PDCCH of the PCell or one of SCells (the monitored serving cell is known to the UE) for Random Access Response(s) identified by a specific RA-RNTI. In the RA Response window which may start at the subframe that contains the end of the preamble transmission plus three subframes and has length *ra-ResponseWindowSize* subframes. The RA-RNTI associated with the PRACH in which the Random Access Preamble is transmitted, could be computed as: RA-RNTI= 1 + t_id+10*f_id. Where t_id may be the index of the first subframe of the specified PRACH (0≤ t_id <10), and f_id may be the index of the specified PRACH within that subframe, in ascending order of frequency domain (0≤ f_id< 6). In some other example, different formulas could be used for RA-RNTI for random access respones for preambles transmitted on SCells. The UE may stop monitoring for Random Access Response(s) after successful reception of a Random Access Response containing Random Access Preamble identifiers that matches the transmitted Random Access Preamble.

If a downlink assignment for this TTI has been received on the PDCCH for the RA-RNTI and the received TB is successfully decoded, the UE may, if the Random Access Response contains a Backoff Indicator subheader, then set the backoff parameter value in the UE as indicated by the BI field of the Backoff Indicator subheader, and else set the backoff parameter value in the UE to 0 ms. If the Random Access Response contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble, the UE may: consider this Random Access Response reception successful; process the received Timing Advance Command; indicate the *preambleInitialReceivedTargetPower* and the amount of power ramping applied to the latest preamble transmission to lower layers (i.e., (PREAMBLE_TRANSMISSION_COUNTER – 1) * *powerRampingStep*); and process the received UL grant value and indicate it to the lower layers. If *ra-PreambleIndex* was explicitly signalled and it was not 0 (i.e., not selected by MAC), the UE may consider the Random Access procedure successfully completed. Otherwise, if the Random Access Preamble was selected by UE MAC, the UE may set the Temporary C-RNTI to the value received in the Random Access Response message no later than at the time of the first transmission corresponding to the UL grant provided in the Random Access Response message. If this is the first successfully received Random Access Response within this Random Access procedure, and the UE may obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity and store it in the Msg3 buffer. If the transmission is not being made for the CCCH logical channel, the UE may indicate to the Multiplexing and assembly entity to include a C-RNTI MAC control element in the subsequent uplink transmission.

In an example implementation, when an uplink transmission is required, e.g., for contention resolution, the eNB may not provide a grant smaller than 56 bits in the Random Access Response. If within a Random Access procedure, an uplink grant provided in the Random Access Response for the same group of Random Access Preambles has a different size than the first uplink grant allocated during that Random Access procedure, the UE behavior may not be pre-defined. The UL grant value received in the Random Access Response may be valid for the PCell or SCell.

If no Random Access Response is received within the RA Response window, or if none of all received Random Access Responses contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble, the Random Access Response reception may be considered not successful. Then the UE may increment PREAMBLE_TRANSMISSION_COUNTER by 1. If PREAMBLE_TRANSMISSION_COUNTER = *preambleTransMax* + 1, then UE may indicate a Random Access problem to upper layers. If in this Random Access procedure, the Random Access Preamble was selected by MAC, based on the backoff parameter in the UE, the UE may select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value, and the UE may delay the subsequent Random Access transmission by the backoff time. The UE may proceed to the selection of a Random Access Resource.

Contention Resolution may be based on either C-RNTI on PDCCH or UE Contention Resolution Identity on DL-SCH. A contention resolution may be defined for contention based random access process, to resolve the contention, wherein two or more UEs transmit the same preamble at the same time on PRACH.

At successful completion of the Random Access procedure, the UE may discard explicitly signalled *ra-PreambleIndex* and *ra-PRACH-MaskIndex*, if any. The UE may flush the HARQ buffer used for transmission of the MAC PDU in the Msg3 buffer. In addition, the RN (relay node) may resume the suspended RN subframe configuration, if any.

Physical random access channel

Time and frequency structure

In an example embodiment, The physical layer random access preamble may comprise of a cyclic prefix of length T_{CP} and a sequence part of length T_{SEQ}. Example parameter values are listed in the following table and may depend on the frame structure and the random access configuration. Higher layers may control the preamble format. Preamble format 4 may be for frame structure type 2 and special subframe configurations with UpPTS lengths $4384 \cdot T_{\mathrm{s}}$ and $5120 \cdot T_{\mathrm{s}}$.

Table 1: Example random access preamble parameters.

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_{\mathrm{s}}$	$24576 \cdot T_{\mathrm{s}}$
1	$21024 \cdot T_{\mathrm{s}}$	$24576 \cdot T_{\mathrm{s}}$
2	$6240 \cdot T_{\mathrm{s}}$	$2 \cdot 24576 \cdot T_{\mathrm{s}}$
3	$21024 \cdot T_{\mathrm{s}}$	$2 \cdot 24576 \cdot T_{\mathrm{s}}$
4	$448 \cdot T_{\mathrm{s}}$	$4096 \cdot T_{\mathrm{s}}$

The transmission of a random access preamble, if triggered by the MAC layer, may be restricted to certain time and frequency resources. These resources may be enumerated in increasing order of the subframe number within the radio frame and the physical resource blocks in the frequency domain such that index 0 correspond to the lowest numbered physical resource block and subframe within the radio frame. PRACH resources within the radio frame may be indicated by a PRACH Resource Index, where the indexing could be in the order of appearance in a pre-defined table, for example a look up table.

Frame structure type 1 random access configuration for preamble formats 0-3 could be presented in a table format (for example a look up table), the first column could be PRACH configuration index, the second column could be preamble format, the third column could include system frame number limitation (for example even, odd, any), and the fourth column could be subframe number in a frame. In an example embodiment, PRACH configuration index 0 could refer to preamble format 0, even system frame numbers, and subframe number 1. Or PRACH configuration index 40 could refer to preamble format 2, any system frame number and subframe number 3 and 8. PRACH configuration could range from 0 to 63.

For frame structure type 1 with preamble format 0-3, there could be at most one random access resource per subframe. A look up table may include the preamble formats and the subframes in which random access preamble transmission may be allowed for a given configuration in frame structure type 1. The parameter *prach-ConfigurationIndex* may be given by higher layers. The start of the random access preamble may be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}}=0$, where N_{TA} may be the amount of time alignment. The first physical resource block $n_{\mathrm{PRB}}^{\mathrm{RA}}$ allocated to the PRACH opportunity considered for preamble formats 0, 1, 2 and 3 may be defined as $n_{\mathrm{PRB}}^{\mathrm{RA}}=n_{\mathrm{PRB\,offset}}^{\mathrm{RA}}$, where the parameter *prach-FrequencyOffset,* $n_{\mathrm{PRBoffset}}^{\mathrm{RA}}$ may be expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{\mathrm{PRBoffset}}^{\mathrm{RA}} \le N_{\mathrm{RB}}^{\mathrm{UL}}-6$.

For frame structure type 2 with preamble formats 0-4, there might be multiple random access resources in an UL subframe (or UpPTS for preamble format 4) depending on the UL/DL configuration. A table may be defined that lists PRACH configurations allowed for frame structure type 2 where the configuration index corresponds to a certain combination of preamble format, PRACH density value, D_{RA} and version index, r_{RA}. The parameter *prach-ConfigurationIndex* is given by higher layers.

Frame structure type 2 random access preamble mapping in time and frequency may be defined in a table format. A table may list the mapping to physical resources for the different random access opportunities needed for a certain PRACH density value, D_{RA}. Each quadruple of the format $(f_{\mathrm{RA}},t_{\mathrm{RA}}^{(0)},t_{\mathrm{RA}}^{(1)},t_{\mathrm{RA}}^{(2)})$ may indicates the location of a specific random access resource, where f_{RA} is a frequency resource index within the considered time instance, $t_{\mathrm{RA}}^{(0)}=0,1,2$ may indicate whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{\mathrm{RA}}^{(1)}=0,1$ may indicate whether the random access resource is located in first half frame or in second half frame, respectively, and where $t_{\mathrm{RA}}^{(2)}$ is the uplink subframe number where the preamble starts, counting from 0 at the first uplink subframe between 2 consecutive downlink-to-uplink switch points. The start of the random access preamble formats 0-3 may be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}} = 0$ and the random access preamble format 4 may start $4832 \cdot T_{\mathrm{s}}$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE's uplink frame timing assuming $N_{\mathrm{TA}} = 0$.

The random access opportunities for each PRACH configuration may be allocated in time first and then in frequency if and if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing may be done according to

$$n_{\mathrm{PRB}}^{\mathrm{RA}} = \begin{cases} n_{\mathrm{PRB\ offset}}^{\mathrm{RA}} + 6\left\lfloor \frac{f_{\mathrm{RA}}}{2} \right\rfloor, & \text{if } f_{\mathrm{RA}} \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 6 - n_{\mathrm{PRB\ offset}}^{\mathrm{RA}} - 6\left\lfloor \frac{f_{\mathrm{RA}}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$

where $N_{\mathrm{RB}}^{\mathrm{UL}}$ may be the number of uplink resource blocks, $n_{\mathrm{PRB}}^{\mathrm{RA}}$ may be the first physical resource block allocated to the PRACH opportunity considered and where the parameter *prach-FrequencyOffset*, $n_{\mathrm{PRB\ offset}}^{\mathrm{RA}}$ may be the first physical resource block available for PRACH expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{\mathrm{PRBoffset}}^{\mathrm{RA}} \le N_{\mathrm{RB}}^{\mathrm{UL}} - 6$.

For preamble format 4, the frequency multiplexing may be done according to

$$n_{\mathrm{PRB}}^{\mathrm{RA}} = \begin{cases} 6 f_{\mathrm{RA}}, & \text{if } \left((n_{\mathrm{f}} \bmod 2) \times (2 - N_{\mathrm{SP}}) + t_{\mathrm{RA}}^{(1)}\right) \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 6(f_{\mathrm{RA}} + 1), & \text{otherwise} \end{cases}$$

where n_{f} may be the system frame number and where N_{SP} may be the number of DL to UL switch points within the radio frame.

Each random access preamble may occupy a bandwidth corresponding to 6 consecutive resource blocks for both frame structures.

Preamble sequence generation

In an example embodiment, the random access preambles could be generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network may configure the set of preamble sequences the UE is allowed to use. There could be 64 preambles available in each cell. The set of 64 preamble sequences in a cell could be found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE may be broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles could not be generated from a single root Zadoff-

Chu sequence, may be obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order may be cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u could be defined in a pre-defined table for preamble formats 0 – 3 and 4, respectively. The first column of the table may include logical root sequence number, and the second column may include Physical root sequence number u (in increasing order of the corresponding logical sequence number). For example, Logical root sequence number of 0-23 could correspond to Physical root sequence number u of 129, 710, 140, 699, 120, 719, 210, 629, 168, 671, 84, 755, 105, 734, 93, 746, 70, 769, 60, 779, 2, 837, 1, 838.

The u^{th} root Zadoff-Chu sequence may be defined by

$$x_u(n) = e^{-j\frac{\pi u n(n+1)}{N_{\text{ZC}}}}, \quad 0 \le n \le N_{\text{ZC}} - 1$$

where the length N_{ZC} of the Zadoff-Chu sequence is given by a predefined table (for example a look up table). Random access preamble sequence length, Nzc, may be 839 for preamble format 0-3 and 139 for preamble format 4.

From the u^{th} root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{\text{CS}} - 1$ may be defined by cyclic shifts according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod N_{\text{ZC}})$$

where the cyclic shift may be given by

$$C_v = \begin{cases} vN_{\text{CS}} & v = 0,1,\ldots,\lfloor N_{\text{ZC}}/N_{\text{CS}} \rfloor - 1, N_{\text{CS}} \neq 0 \quad \text{for unrestricted sets} \\ 0 & N_{\text{CS}} = 0 \quad \text{for unrestricted sets} \\ d_{\text{start}} \lfloor v/n_{\text{shift}}^{\text{RA}} \rfloor + (v \bmod n_{\text{shift}}^{\text{RA}}) N_{\text{CS}} & v = 0,1,\ldots,n_{\text{shift}}^{\text{RA}} n_{\text{group}}^{\text{RA}} + \bar{n}_{\text{shift}}^{\text{RA}} - 1 \quad \text{for restricted sets} \end{cases}$$

and N_{CS} may be given by predefined tables (look-up tables) for preamble formats 0-3 and 4, respectively. The parameter zeroCorrelationZoneConfig may provided by higher layers. The parameter High-speed-flag may be provided by higher layers determines if unrestricted set or restricted set may be used.

In an example embodiment, for preamble format 0-3, two look up tables may be used for determining Ncs for each zeroCorrelationZoneConfig values. A first look up table may determine Ncs values for each zeroCorrelationZoneConfig when unrestricted set is used. A second look up table may determine Ncs values for each zeroCorrelationZoneConfig when restricted set is used. For example, for zeroCorrelationZoneConfig equal to 1, Ncs may be 13 for unrestricted set and 18 for restricted set. Or for zeroCorrelationZoneConfig equal to 14, Ncs may be 279 for unrestricted set and 237 for restricted set. For preamble format 4, Ncs may be independent of high-speed-flag. A single table (for example, look up table) may determine Ncs for each zeroCorrelationZoneConfig. For example, Ncs may equal to 4 for zeroCorrelationZoneConfig = 2, and Ncs may be equal to 15 for zeroCorrelationZoneConfig = 7. For preamble format 4, the maximum value of zeroCorrelationZoneConfig may be 6.

The variable d_u may be the cyclic shift corresponding to a Doppler shift of magnitude $1/T_{\mathrm{SEQ}}$ and may be given by

$$d_u = \begin{cases} p & 0 \le p < N_{\mathrm{ZC}}/2 \\ N_{\mathrm{ZC}} - p & \text{otherwise} \end{cases}$$

where p may be the smallest non-negative integer that fulfils $(pu) \bmod N_{\mathrm{ZC}} = 1$. The parameters for restricted sets of cyclic shifts may depend on d_u. For $N_{\mathrm{CS}} \le d_u < N_{\mathrm{ZC}}/3$, the parameters may be given by

$$\begin{aligned} n_{\mathrm{shift}}^{\mathrm{RA}} &= \lfloor (N_{\mathrm{ZC}} - 2d_u)/N_{\mathrm{CS}} \rfloor \\ d_{\mathrm{start}} &= N_{\mathrm{ZC}} - 2d_u + n_{\mathrm{shift}}^{\mathrm{RA}} N_{\mathrm{CS}} \\ n_{\mathrm{group}}^{\mathrm{RA}} &= \lfloor d_u / d_{\mathrm{start}} \rfloor \\ \bar{n}_{\mathrm{shift}}^{\mathrm{RA}} &= \min\left(\max\left(\lfloor (d_u - n_{\mathrm{group}}^{\mathrm{RA}} d_{\mathrm{start}})/N_{\mathrm{CS}} \rfloor, 0\right), n_{\mathrm{shift}}^{\mathrm{RA}}\right) \end{aligned}$$

For all other values of d_u, there are no cyclic shifts in the restricted set.

Baseband signal generation

The time-continuous random access signal $s(t)$ may be defined by

$$s(t) = \beta_{\mathrm{PRACH}} \sum_{k=0}^{N_{\mathrm{ZC}}-1} \sum_{n=0}^{N_{\mathrm{ZC}}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{\mathrm{ZC}}}} \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{\mathrm{RA}}(t-T_{\mathrm{CP}})}$$

where $0 \le t < T_{\mathrm{SEQ}} + T_{\mathrm{CP}}$, β_{PRACH} may be an amplitude scaling factor in order to conform to the transmit power P_{PRACH}, and $k_0 = n_{\mathrm{PRB}}^{\mathrm{RA}} N_{\mathrm{sc}}^{\mathrm{RB}} - N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2$. The location in the frequency domain may be controlled by the parameter $n_{\mathrm{PRB}}^{\mathrm{RA}}$. The factor $K = \Delta f / \Delta f_{\mathrm{RA}}$ may account for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, may be pre-defined for each preamble format. For example, for preamble format 1-3, Δf_{RA} may be 1250 Hz, and φ may be 7. For preamble format 4, Δf_{RA} may be 7500 Hz, and φ may be 2.

Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure may encompass the transmission of random access preamble and random access response. The remaining messages may be scheduled for transmission by the higher layer on the shared data channel and may not considered part of the L1 random access procedure. A random access channel may occupy 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB may not be prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

For example, the following steps may be required for the L1 random access procedure:

1. Layer 1 procedure may be triggered upon request of a preamble transmission by higher layers.
2. A preamble index, a target preamble received power (PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a PRACH resource may be indicated by higher layers as part of the request.
3. A preamble transmission power P_{PRACH} is determined as P_{PRACH} = min{ $P_{\mathrm{CMAX,c}}(i)$, PREAMBLE_RECEIVED_TARGET_POWER + PL_c }_[dBm], where $P_{\mathrm{CMAX,c}}(i)$ is the configured UE transmit power for subframe *i* of a cell and PL_c is the downlink pathloss estimate calculated in the UE.
4. A preamble sequence may be selected from the preamble sequence set using the preamble index.
5. A single preamble may be transmitted using the selected preamble sequence with transmission power P_{PRACH} on the indicated PRACH resource.
6. Detection of a PDCCH with the indicated RA-RNTI may be attempted during a window controlled by higher layers. If detected, the corresponding DL-SCH transport block may be passed to higher layers. The higher layers parse the transport block and indicate the 20-bit uplink grant to the physical layer.

In an example embodiment, for the L1 random access procedure, UE's uplink transmission timing after a random access preamble transmission may be as follows.

1. If a PDCCH with associated RA-RNTI is detected in subframe n, and the corresponding DL-SCH transport block contains a response to the transmitted preamble sequence, the UE may, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n+k_1$, $k_1 \geq 6$, if the UL delay field is set to zero where $n+k_1$ is the first available UL subframe for PUSCH transmission. The UE may postpone the PUSCH transmission to the next available UL subframe after $n+k_1$ if the field is set to 1.

2. If a random access response is received in subframe *n*, and the corresponding DL-SCH transport block does not contain a response to the transmitted preamble sequence, the UE may, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+5$.

3. If no random access response is received in subframe *n*, where subframe *n* is the last subframe of the random access response window, the UE may, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n+4$.

In case a random access procedure is initiated by a PDCCH order in subframe *n*, the UE may, if requested by higher layers, transmit random access preamble in the first subframe $n+k_2$, $k_2 \geq 6$, where a PRACH resource is available.

The higher layers may indicate the 20-bit UL Grant to the physical layer. This may be referred to the Random Access Response Grant in the physical layer. In an example, the content of these 20 bits may start with the MSB and ending with the LSB are as follows: Hopping flag – 1 bit; Fixed size resource block assignment – 10 bits; Truncated modulation and coding scheme – 4 bits; TPC command for scheduled PUSCH – 3 bits; UL delay – 1 bit; CSI request – 1 bit.

The UE may perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping may be performed. When the hopping flag is set, the UE may perform PUSCH hopping as indicated via the fixed size resource block assignment.

The truncated modulation and coding scheme field may interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15. The TPC command δ_{msg2} may be used for setting the power of the PUSCH.

In non-contention based random access procedure, the CSI request field may be interpreted to determine whether an aperiodic CQI, PMI, and RI report is included in the corresponding PUSCH transmission. The UL delay may apply for both TDD and FDD and this field may be set to 0 or 1 to indicate whether the delay of PUSCH is introduced.

PRACH Parameters in RRC Layer

The IE PRACH-Configuration may comprise rootSequenceIndex and/or prach-ConfigInfo, wherein Prach-ConfigInfo may comprise prach-ConfigIndex, highSpeedFlag, zeroCorrelationZoneConfig, and/or prach-FreqOffset.

Common RACH configuration commons in RRC layer may be called RACH-ConfigCommon, and may be included in system information block (for example SIB2) and may comprise preambleInfo, powerRampingParameters, ra-SupervisionInfo, and/or maxHARQ-Msg3Tx. preambleInfo may comprise numberOfRA-Preambles, and/or preamblesGroupAConfig (comprising sizeOfRA-PreamblesGroupA, messageSizeGroupA, and/or messagePowerOffsetGroupB). powerRampingParameters may comprise powerRampingStep and/or preambleInitialReceivedTargetPower. ra-SupervisionInfo may comprise preambleTransMax, ra-ResponseWindowSize, and/or mac-ContentionResolutionTimer.

mac-ContentionResolutionTimer may be a Timer for contention resolution. maxHARQ-Msg3Tx may be Maximum number of Msg3 HARQ transmissions, used for contention based random access (is an integer). messagePowerOffsetGroupB may be threshold for preamble selection. messageSizeGroupA may be Threshold for preamble selection. numberOfRA-Preambles may be number of non-dedicated random access preambles. powerRampingStep may be Power ramping factor. preambleInitialReceivedTargetPower may be Initial preamble power. preamblesGroupAConfig may be the configuration for preamble grouping. preambleTransMax may be maximum number of preamble transmission. ra-ResponseWindowSize may be duration of the RA response window. sizeOfRA-PreamblesGroupA may be the size of the random access preambles group A.

Common RACH configuration dedicated to each UE may be used for contention free random access process and may include ra-PreambleIndex and/or ra-PRACH-MaskIndex. ra-PRACH-MaskIndex may

explicitly signal PRACH Mask Index for RA Resource selection. ra-PreambleIndex may explicitly signal Random Access Preamble for RA Resource selection.

Timing Advance

In an example embodiment, the timing advance may be initiated from E-UTRAN with MAC message that implies and adjustment of the timing advance. UE may adjust the timing of its uplink transmission timing at sub-frame *n*+6 for a timing advancement command received in sub-frame *n*. The UE may adjust the timing of its transmissions with a relative accuracy better than or equal to ±4* T_S seconds to the signaled timing advance value compared to the timing of preceding uplink transmission. The timing advance command may be expressed in multiples of 16* T_S and may be relative to the current uplink timing. The reporting range of T_{ADV} could be defined from 0 to 49232T_s with 2T_s resolution for timing advance less or equal to 4096T_s and 8T_s for timing advance greater than 4096T_s. The mapping of measured quantity for each timing advance command may be pre-defined in a table.

The UE may have capability to follow the frame timing change of the connected eNode B. The uplink frame transmission may take place $(N_{\text{TA}} + N_{\text{TA offset}}) \times T_{\text{s}}$ before the reception of the first detected path (in time) of the corresponding downlink frame from the reference cell. When the UE is configured with SCell(s), it may use PCell as the reference cell for deriving the UE transmit timing for PCell. UE initial transmit timing accuracy, maximum amount of timing change in one adjustment, minimum and maximum adjustment rate may be defined.

The UE initial transmission timing error may be less than or equal to $\pm T_e$ where the timing error limit value T_e could be specified. T_e Timing Error Limit for Downlink Bandwidth (MHz) of 1.4 may be 24^*T_S, and for Downlink Bandwidth (MHz) ≥3 is may be 12^*T_S. This requirement may apply when it is the first transmission in a DRX cycle for PUCCH, PUSCH and SRS or it is the PRACH transmission. The reference point for the UE initial transmit timing control requirement may be the downlink timing minus $(N_{\text{TA\_Ref}} + N_{\text{TA offset}}) \times T_{\text{s}}$. The downlink timing could be defined as the time when [the first detected path (in time)] of the corresponding downlink frame is received from the reference cell. $N_{\text{TA\_Ref}}$ for PRACH may be defined as 0. $(N_{\text{TA\_Ref}} + N_{\text{TA offset}})$ (in T_s units) for other channels is the difference between UE transmission timing and the Downlink timing immediately after when the last timing advance was applied. $N_{\text{TA\_Ref}}$ for other channels may not be changed until next timing advance is received.

When it is not the first transmission in a DRX cycle or there is no DRX cycle, and when it is the transmission for PUCCH, PUSCH and SRS transmission, the UE may be capable of changing the transmission timing according to the received downlink frame except when the timing advance in applied. When the transmission timing error between the UE and the reference timing exceeds ±Te the UE may be required to adjust its timing to within ±Te. The reference timing may be $(N_{\text{TA\_Ref}} + N_{\text{TA offset}}) \times T_{\text{s}}$ before the downlink timing. All adjustments made to the UE uplink timing may follow these rules:

1) The maximum amount of the magnitude of the timing change in one adjustment may be Tq seconds.

2) The minimum aggregate adjustment rate may be 7*TS per second.

3) The maximum aggregate adjustment rate may be Tq per 200ms.

where the maximum autonomous time adjustment step T_q is specified in Table 7.1.2-2.

UE timers are used in different protocol entities to control the UE behavior. For UE timers, UE may comply with the timer accuracy requirements. The requirements may be related to the actual timing measurements internally in the UE. They may not include the following: Inaccuracy in the start and stop conditions of a timer (e.g. UE reaction time to detect that start and stop conditions of a timer is fulfilled), or Inaccuracies due to restrictions in observability of start and stop conditions of a UE timer (e.g. TTI alignment when UE sends messages at timer expiry).

Upon reception of a timing advance command, the UE may adjust its uplink transmission timing for PUCCH/PUSCH/SRS. The timing advance command may indicate the change of the uplink timing relative to the current uplink timing as multiples of $16T_s$. The start timing of the random access preamble may be specified. In case of random access response, 11-bit timing advance command, T_A, may indicate N_{TA} values by index values of T_A = 0, 1, 2, ..., 1282, where an amount of the time alignment is given by $N_{TA} = T_A \times 16$. In other cases, 6-bit timing advance command, T_A, may indicate adjustment of the current N_{TA} value, $N_{TA,old}$, to the new N_{TA} value, $N_{TA,new}$, by index values of T_A = 0, 1, 2,..., 63, where $N_{TA,new} = N_{TA,old} + (T_A - 31) \times 16$. Here, adjustment of N_{TA} value by a positive or a negative amount may indicate advancing or delaying the uplink transmission timing by a given amount respectively. The timing advance in RAR is longer than and cover a larger range compared with timing advances transmitted by MAC control element commands.

For a timing advance command received on subframe *n*, the corresponding adjustment of the timing may apply from the beginning of subframe *n+6.* When the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe *n* and subframe *n*+1 are overlapped due to the timing adjustment, the UE may transmit complete subframe *n* and not transmit the overlapped part of subframe *n*+1. If the received downlink timing changes and is not compensated or is partly compensated by the uplink timing adjustment without timing advance command, the UE may change N_{TA} accordingly.

When a UE receives an activation command for a secondary cell in subframe *n*, the corresponding actions in may be applied in subframe *n+8*. When a UE receives a deactivation command for a secondary cell or a secondary cell's deactivation timer expires in subframe *n*, the corresponding actions may apply no later than subframe *n+8*. For the actions related to CSI reporting which may be applied in subframe *n+8.*

Some example embodiments are presented in the following claims. Some of the steps may omitted and the steps may be re-ordered if the main functions are performed. Steps may be broadened and some of the limitations may be removed in claims. The following claims are compatible with some of the disclosed example embodiments in the specifications and are for example only. Other dependent or independent claims may be written based on this specifications.

1. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
   a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and at least one secondary cell;
   b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;
   c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :
      i) a plurality of cell groups; said plurality of cell groups comprising:
         (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
         (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; and
      ii) said at least one secondary cell; configuration for each cell in said at least one secondary cell comprising a plurality of common parameters and a plurality of dedicated parameters; wherein said plurality of common parameters are the same for all wireless devices in said plurality of wireless devices and said plurality of dedicated parameters are wireless device specific; wherein for a first secondary cell in said secondary cell group:
         (1) said plurality of common parameters comprise:
            (a) a plurality of random access resource parameters; and
            (b) a time alignment timer value; said time alignment timer value is the same for all cells belonging to said secondary cell group (this could be a part of SIB2); and
         (2) said plurality of dedicated parameters comprise:
            (a) a secondary cell group index;
            (b) an indication identifying if said first secondary cell is a timing reference for said secondary cell group (optional); and
            (c) an indication identifying if said first secondary cell is a pathloss reference for said secondary cell group (optional);
   d) transmitting an activation command to activate said first secondary cell in said secondary cell group;
   e) transmitting a PDCCH order for transmission of a random access preamble on a first secondary uplink carrier of said first secondary cell; said PDCCH order comprising:
      i) a mask index;

ii) a preamble identifier; and
iii) said first secondary cell index (optional);

f) receiving said random access preamble on said random access resource from said wireless device on said first secondary uplink carrier; the timing of said random access preamble is determined based on a second synchronization signal transmitted on a first secondary downlink carrier of said first secondary cell; and

g) transmitting at least one time alignment command to said plurality of wireless devices, said time alignment command comprising:
i) an amount of time adjustment for signal transmission on all the uplink carriers in said secondary cell group; and
ii) said secondary cell group index;

wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices and wherein all uplink transmissions in said secondary cell group use said second synchronization signal transmitted on said first secondary downlink carrier as the timing reference.

2. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to a wireless device in said plurality of wireless devices, said at least one control message configuring :
i) a plurality of cell groups; said plurality of cell groups comprising:
(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on a primary downlink carrier of said primary cell as the timing reference; and
(2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; and
ii) said at least one secondary cell; configuration for each cell in said at least one secondary cell comprising a plurality of common parameters and a plurality of dedicated parameters; wherein said plurality of common parameters are the same for all wireless devices in said plurality of wireless devices and said plurality of dedicated parameters are wireless device specific; wherein for a first secondary cell in said secondary cell group:
(1) said plurality of common parameters comprise:
(a) a plurality of random access resource parameters; and
(b) a time alignment timer value; said time alignment timer value is the same for all cells belonging to said secondary cell group; and
(2) said plurality of dedicated parameters comprise a secondary cell group index;

b) receiving a random access preamble on said random access resource from said wireless device on a first secondary uplink carrier of said first secondary cell; the timing of said random access preamble is determined based on a second synchronization signal transmitted on a first secondary downlink carrier of said first secondary cell; and

c) transmitting at least one time alignment command to said plurality of wireless devices, wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices and wherein all uplink transmissions in said secondary cell group use said second synchronization signal transmitted on said first secondary downlink carrier as the timing reference.

3. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a control message to a wireless device in said plurality of wireless devices, said control message reconfiguring a plurality of cell groups; said plurality of cell groups comprising:

i) a primary cell group comprising at least one cell comprising said primary cell with a primary downlink carrier and a primary uplink carrier; wherein all uplink transmissions in said primary cell group use a first synchronization signal transmitted on said primary downlink carrier as the timing reference; and

ii) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference;

wherein said reconfiguration re-assigns said first secondary cell from said secondary cell group to said primary cell group; and said control message comprising an indication identifying a new secondary downlink carrier in said reconfigured secondary cell group for timing reference; wherein all uplink transmissions in said reconfigured secondary cell group use a third synchronization signal transmitted on said new secondary downlink carrier as the timing reference; and

b) transmitting at least one time alignment command to said plurality of wireless devices, said time alignment command comprising:

i) an amount of time adjustment for signal transmission on all uplink carriers in said reconfigured secondary cell group; and

ii) a secondary cell group index;

wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said reconfigured secondary cell group by said plurality of wireless devices.

4. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
    a) transmitting a control message to a wireless device in said plurality of wireless devices, said control message reconfiguring a plurality of cell groups; said plurality of cell groups comprising:
        i) a primary cell group comprising a first secondary cell in said plurality of secondary cells and said primary cell with a primary downlink carrier and a primary uplink carrier; wherein all uplink transmissions in said primary cell group use a first synchronization signal transmitted on said primary downlink carrier as the timing reference; and
        ii) a secondary cell group comprising at least one secondary cell in said plurality of secondary cells; said secondary cell group comprising a second secondary cell with a second secondary downlink carrier and a second secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said second secondary downlink carrier as the timing reference;

    wherein said reconfiguration re-assigns said first secondary cell from said primary cell group to said secondary cell group; and said control message comprising an indication identifying a first secondary downlink carrier of said first secondary cell in said reconfigured secondary cell group for timing reference; wherein all uplink transmissions in said reconfigured secondary cell group use a third synchronization signal transmitted on said first secondary downlink carrier as the timing reference; and
    b) transmitting at least one time alignment command to said plurality of wireless devices, said time alignment command comprising:
        i) an amount of time adjustment for signal transmission on all uplink carriers in said reconfigured secondary cell group; and
        ii) a secondary cell group index;

    wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said reconfigured secondary cell group by said plurality of wireless devices.

5. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a control message to a wireless device in said plurality of wireless devices, said control message reconfiguring a plurality of cell groups; said plurality of cell groups comprising:
   i) a primary cell group comprising at least one cell comprising said primary cell with a primary downlink carrier and a primary uplink carrier; wherein all uplink transmissions in said primary cell group use a first synchronization signal transmitted on said primary downlink carrier as the timing reference; and
   ii) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference;

   wherein said reconfiguration moves said first secondary cell from said secondary cell group to said primary cell group;

b) transmitting a PDCCH order for transmission of a random access preamble on a new secondary uplink carrier of a new secondary cell in said reconfigured secondary cell group; said PDCCH order comprising:
   i) a mask index;
   ii) a sequence identifier; and
   iii) said new secondary cell index, if said PDCCH order is not transmitted on said new secondary cell;

c) receiving said random access preamble on a random access resource from said wireless device on said new secondary uplink carrier; the timing of said random access preamble is determined based on a third synchronization signal transmitted on a new secondary downlink carrier of said new secondary cell; and

d) transmitting at least one time alignment command to said plurality of wireless devices, said time alignment command comprising:
   i) an amount of time adjustment for signal transmission on all the uplink carriers in said reconfigured secondary cell group; and
   ii) a secondary cell group index;

   wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said reconfigured secondary cell group by said plurality of wireless devices and wherein all uplink transmissions in said reconfigured secondary cell group use said third synchronization signal on said new secondary downlink carrier as the timing reference.

6. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a control message to a wireless device in said plurality of wireless devices, said control message reconfiguring a plurality of cell groups; said plurality of cell groups comprising:
   i) a primary cell group comprising a first secondary cell in said plurality of secondary cells and said primary cell with a primary downlink carrier and a primary uplink carrier; wherein all uplink transmissions in said primary cell group use a first synchronization signal transmitted on said primary downlink carrier as the timing reference; and
   ii) a secondary cell group comprising at least one secondary cell in said plurality of secondary cells; said secondary cell group comprising a second secondary cell with a second secondary downlink carrier and a second secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said second secondary downlink carrier as the timing reference;

   wherein said reconfiguration re-assigns said first secondary cell from said primary cell group to said secondary cell group;

b) transmitting a PDCCH order for transmission of a random access preamble on a first secondary uplink carrier of said first secondary cell in said reconfigured secondary cell group; said PDCCH order comprising:
   i) a mask index;
   ii) a sequence identifier; and
   iii) said first secondary cell index, if said PDCCH order is not transmitted on said first secondary cell;

c) receiving said random access preamble on a random access resource from said wireless device on said first secondary uplink carrier; the timing of said random access preamble is determined based on a third synchronization signal transmitted on a first secondary downlink carrier of said first secondary cell; and

d) transmitting at least one time alignment command to said plurality of wireless devices, said time alignment command comprising:
   i) an amount of time adjustment for signal transmission on all the uplink carriers in said reconfigured secondary cell group; and
   ii) a secondary cell group index;

   wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said reconfigured secondary cell group by said plurality of wireless devices and wherein all uplink transmissions in said reconfigured secondary cell group use said third synchronization signal on said first secondary downlink carrier as the timing reference.

7. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a control message to a wireless device in said plurality of wireless devices, said control message reconfiguring a plurality of cell groups; said plurality of cell groups comprising:
   i) a primary cell group comprising at least one cell comprising said primary cell with a primary downlink carrier and a primary uplink carrier; wherein all uplink transmissions in said primary cell group use a first synchronization signal transmitted on said primary downlink carrier as the timing reference; and
   ii) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference;

   wherein said reconfiguration moves said first secondary cell from said secondary cell group to said primary cell group;
   wherein said wireless device selects a new secondary cell in said reconfigured secondary cell group; and
   wherein said selection is according to a pre-defined rule known to said wireless device and said base station; and
b) transmitting at least one time alignment command to said plurality of wireless devices, wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said reconfigured secondary cell group by said plurality of wireless devices and wherein all uplink transmissions in said reconfigured secondary cell group use a third synchronization signal on a new secondary downlink carrier in said new secondary cell as the timing reference.

8. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
   a) transmitting a control message to said wireless device, said control message reconfiguring a plurality of cell groups; said plurality of cell groups comprising:
      i) a primary cell group comprising at least one cell comprising said primary cell with a primary downlink carrier and a primary uplink carrier; wherein all uplink transmissions in said primary cell group use a first synchronization signal transmitted on said primary downlink carrier as the timing reference; and
      ii) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second

synchronization signal on said first secondary downlink carrier as the timing reference;

wherein with said reconfiguration every cell in said secondary cell group is re-assigned to said primary cell group or is released; and

b) de-configuring or releasing said secondary cell group and a time alignment timer associated with said secondary cell group.

9. The method of claim 1, wherein said plurality of random access resource parameters comprise an index, a frequency offset, a plurality of sequence parameters and a flag (flag is not applicable to TDD frame structure).

10. The method of claim 9, wherein said base station receives said random access preamble from said wireless device, wherein said wireless device:

    a) generates a sequence using said sequence identifier, said plurality of sequence parameters, and a first look-up table selected according to said flag; said sequence length is determined using a second look-up table and said index; and

    b) selects a transmission format for said sequence including a chip rate (or transmission duration) and transmitting said sequence on an uplink carrier in said second carrier group in at least one subframe and at a frequency determined using said frequency offset; said transmission format and said at least one subframe are determined using said second pre-defined look-up table and said index;

    wherein said at least one subframe is determined using said second pre-defined look-up table and said index and further using a mask filter further identifying a subset of subframes determined by said second pre-defined look-up table and said index.

11. The method of claim 10, wherein said index determines a transmission period for said sequence, the transmission period of a cyclic prefix according to said second look-up table.

12. The method of claim 11, wherein said cyclic prefix is transmitted before said sequence.

13. The method of claim 11, wherein said index identifies a subset of subframes in said plurality of subframes, in which said cyclic prefix and said sequence are transmitted; said identification is based on said index and said first lookup table.

14. The method of claim 11, wherein said first look-up table and said second look-up tables are predefined.

15. The method of claim 11, wherein said sequence is transmitted using seventy-two SC-OFDM subcarriers.

16. The method of claim 11, wherein said plurality of sequence parameters include a root sequence index and a zero correlation zone.

17. The method of claim 11, wherein said sequence is generated from at least one Zadoff-Chu sequence with zero correlation zone.

18. The method of claim 11, wherein plurality of sequence parameters further includes a sequence index.

19. The method of claim 11, wherein said sequence determines an amount of cyclic shift of a root Zadoff-Chu sequence with a logical index of said root sequence index, or an amount of cyclic shift of a root Zadoff-Chu sequence with a following logical index with respect to said root sequence index according to a pre-defined index order.

20. The method of claim 11, wherein said wireless device analyzes sCellToAddModList in RRC connection reconfiguration message to identify if sTAG configuration of a secondary cell is modified or a new secondary cell is configured (if cell ID exist-modify, if a new Cell ID-create).
21. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
    a) transmitting, to each wireless device in said plurality of wireless devices, at least one control message, said at least one control message configuring :
        i) a plurality of cell groups; said plurality of cell groups comprising:
            (1) a primary cell group comprising at least one cell comprising said primary cell and zero or more secondary cells; wherein all uplink transmissions by said plurality of wireless devices in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
            (2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; and
        ii) said plurality of secondary cells; wherein for each of a second plurality of secondary cells in said secondary cell group, said configuration comprising a plurality of random access resource parameters; and wherein no secondary cell in said primary cell group is configured with random access resource parameters;
    b) transmitting, to each wireless device in said plurality of wireless devices, a PDCCH order for transmission of a random access preamble on a secondary uplink carrier of a secondary cell in said second plurality of secondary cells; wherein a wireless device receiving said PDCCH order transmits said random access preamble on said configured random access resource of said secondary uplink carrier;
    c) receiving a random access preamble from each wireless device in said plurality of wireless devices; wherein the timing of said random access preamble transmission and a plurality of subsequent uplink packet transmissions by said wireless device is determined based on a second synchronization signal transmitted on a secondary downlink carrier of said secondary cell used for preamble transmission by said wireless device; and
    d) transmit at least one time alignment command to each wireless device in said plurality of wireless devices; wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices.
22. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and a

plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to a wireless device, said at least one control message configuring :
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell and zero or more secondary cells; wherein all uplink transmissions in said primary cell group use a first synchronization signal on a primary downlink carrier of said primary cell as the timing reference; and
      (2) a secondary cell group comprising a plurality of secondary cells in said plurality of secondary cells; and
   ii) said plurality of secondary cells; wherein:
      (1) for each of a second plurality of secondary cells in said secondary cell group, configuring a random access resource; and
      (2) no secondary cell in said primary cell group is configured with a random access resource;
b) transmitting PDCCH order for transmission of a random access preamble on a secondary uplink carrier of a secondary cell in said second plurality of secondary cells; wherein said secondary cell is selected among said second plurality of secondary cells by said base station according to a pre-defined criteria;
c) receiving said random access preamble from said wireless device; wherein the timing of said random access preamble transmission and a plurality of subsequent uplink packet transmissions by said wireless device is determined based on a second synchronization signal transmitted on a secondary downlink carrier of said secondary cell used for preamble transmission by said wireless device; and
d) transmitting at least one time alignment command to said wireless device; wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell.

23. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
   a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;
   b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
      (2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and
   ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

d) deactivating said first secondary cell (could be because the deactivation timer for said first secondary cell expires; this step could be after step e as well); and

e) transmitting a control message to said wireless device, said control message explicitly or implicitly identifying that all uplink transmissions in said secondary cell group use a third synchronization signal on a new secondary downlink carrier in a new secondary cell of said secondary cell group as the timing reference.

24. The method of claim 23, wherein said control message is a PDCCH order for transmission of random access preamble on a new secondary uplink carrier of said new secondary cell; said PDCCH order comprising:
   i) a mask index;
   ii) a sequence identifier; and
   iii) said secondary cell index, if said PDCCH is not transmitted on said new secondary cell.

25. The method of claim 23, wherein said control message is an RRC connection reconfiguration message comprising an indication identifying said new secondary downlink carrier as the reference timing.

26. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring a plurality of cell groups; said plurality of cell groups comprising:

i) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

ii) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

b) deactivating said first secondary cell; and

c) transmitting a control message to said wireless device, said control message explicitly or implicitly identifying that all uplink transmissions in said secondary cell group use a third synchronization signal on a new secondary downlink carrier in a new secondary cell of said secondary cell group as the timing reference.

27. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

d) transmitting scheduling PDCCH packets to schedule uplink and downlink transmission on said first plurality of secondary cells in a way that said first secondary cell is deactivated after all other secondary cells belonging to said secondary cell group are deactivated.

28. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

b) transmitting scheduling PDCCH packets to schedule uplink and downlink transmission on said first plurality of secondary cells in a way that said first secondary cell is deactivated after all other secondary cells belonging to said secondary cell group are deactivated.

29. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :

   i) a plurality of cell groups; said plurality of cell groups comprising:

      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

      (2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

   ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

d) managing deactivation timer for said first secondary cell, in a way that said first secondary cell is deactivated after all other secondary cells in said first plurality of secondary cells are deactivated.

30. The method of claim 29, further comprising transmitting scheduling PDCCH packets to schedule uplink and downlink transmission on said first plurality of secondary cells in a way that said first secondary cell is deactivated after all other secondary cells belonging to secondary cell group are deactivated.

31. The method of claim 29, further comprising restarting the deactivation timer of said first secondary cell, when a packet is transmitted on said secondary cell group. (uplink or downlink or both)

32. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :

   i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

b) managing deactivation timer for said first secondary cell, in a way that said first secondary cell is deactivated after all other secondary cells in said first plurality of secondary cells are deactivated.

33. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and wherein said first secondary cell is configured with the largest deactivation timer value compared with other secondary cell in said secondary cell group.

34. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and wherein said first secondary cell is configured with the largest deactivation timer value compared with other secondary cell in said secondary cell group; and

b) transmitting at least one time alignment command to said plurality of wireless devices, wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices.

35. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

d) transmitting MAC activation command for keeping said first secondary cell active as long as at least one other secondary cell in said secondary cell group is active.

36. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first

secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

b) transmitting a MAC activation command for keeping said first secondary cell active, before a deactivation timer of said first secondary cell expires.

37. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising a first plurality of secondary cells in said plurality of secondary cells; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

wherein when said first secondary cell is deactivated, said wireless device selects a new secondary cell in said secondary cell group and all uplink transmissions in said secondary cell group use a third synchronization signal on a new secondary downlink carrier in said new secondary cell as the timing reference.

38. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
    a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and a plurality of secondary cells;
    b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;
    c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :
        i) a plurality of cell groups; said plurality of cell groups comprising:
            (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
            (2) a secondary cell group comprising a first plurality of cells in said plurality of secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and
        ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

    wherein when said first secondary cell is deactivated, said wireless device selects a new secondary cell in said secondary cell group and all uplink transmissions in said secondary cell group use a third synchronization signal on a new secondary downlink carrier of said new secondary cell as the timing reference; and wherein said selection is according to a pre-defined rule known to said wireless device and said base station.

39. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; ; said plurality of cells comprise said primary cell and a plurality of secondary cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said

plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
      (2) a secondary cell group comprising a first plurality of cells in said plurality of secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and
   ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

   wherein when said first secondary cell is deactivated, said wireless device selects a new secondary cell in said secondary cell group and all uplink transmissions in said secondary cell group use a third synchronization signal on a new secondary downlink carrier of said new secondary cell as the timing reference; and wherein said selection is according to a pre-defined rule known to said wireless device and said base station; and

b) transmitting at least one time alignment command to said plurality of wireless devices, wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices.

40. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and at least one secondary cell;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell; and

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
      (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference;
   ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell in said secondary cell group, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and
   iii) a time alignment timer for said secondary cell group; said time alignment timer starts or restarts when said wireless device receives a timing advance command to adjust its uplink transmissions on said secondary cell group; and

d) activating a second secondary cell in said secondary cell group, wherein a deactivation timer for said second secondary cell is started after said second secondary cell is activated and said time alignment timer for said secondary cell group is running.

41. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
      (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said

secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference;

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell in said secondary cell group, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

iii) a time alignment timer for said secondary cell group; said time alignment timer starts or restarts when said wireless device receives a timing advance command to adjust its uplink transmissions on said secondary cell group;

b) activating a second secondary cell in said secondary cell group, wherein a deactivation timer for said second secondary cell is started after said second secondary cell is activated and said time alignment timer for said secondary cell group is running.

42. The method of claim 41, wherein said second secondary cell is the same cell as said first secondary cell.

43. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and at least one secondary cell;

b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell;

c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

wherein if PDCCH on an activated secondary cell in said secondary cell group indicates a PDDCH order to start a random access process for said activated secondary cell, or if PDCCH on another cell in said plurality of cells indicates a PDDCH order to start a random access process for said activated secondary cell, said wireless device restarts said deactivation timer associated with said activated secondary cell.

44. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated;

wherein if PDCCH on an activated secondary cell in said secondary cell group indicates a PDDCH order to start a random access process for said activated secondary cell, or if PDCCH on another cell in said plurality of cells indicates a PDDCH order to start a random access process for said activated secondary cell, said wireless device restarts said deactivation timer associated with said activated secondary cell; and

b) transmitting at least one time alignment command to said plurality of wireless devices, wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices.

45. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
    a) transmitting a first control message to a wireless device in said plurality of wireless devices on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said wireless device on said primary cell; said plurality of cells comprise said primary cell and at least one secondary cell;
    b) receiving a plurality of radio capability parameters from said wireless device on said first signaling bearer on a primary uplink carrier of said primary cell; and
    c) transmitting at least one control message to said wireless device on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring :
        i) a plurality of cell groups; said plurality of cell groups comprising:
            (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
            (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and
        ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

    wherein if PDCCH on an activated secondary cell in said secondary cell group indicates a PDDCH order to start a random access process for said activated secondary cell, or if PDCCH on another cell in said plurality of cells indicates a PDDCH order to start a random access process for said activated secondary cell, said wireless device stops said deactivation timer associated with said activated secondary cell; said deactivation timer is started from the point it was stopped or is restarted after a predetermined event is triggered for or after said random access process.

46. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise said primary cell and at least

one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to said wireless device in said plurality of wireless devices, said at least one control message configuring :
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
      (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and
   ii) said plurality of secondary cells; configuration for said plurality of secondary cells comprising a deactivation timer for each secondary cell; wherein when a packet is transmitted on a secondary cell, said deactivation timer corresponding to said secondary cell is restarted, and when said deactivation timer expires, said corresponding secondary cell is deactivated; and

   wherein if PDCCH on an activated secondary cell in said secondary cell group indicates a PDDCH order to start a random access process for said activated secondary cell, or if PDCCH on another cell in said plurality of cells indicates a PDDCH order to start a random access process for said activated secondary cell, said wireless device stops said deactivation timer associated with said activated secondary cell; said deactivation timer is started from the point it was stopped or is restarted after a predetermined event is triggered for or after said random access process; and
b) transmitting at least one time alignment command to said plurality of wireless devices, wherein said at least one time alignment command substantially aligns uplink transmissions in frames and subframes of said secondary cell group by said plurality of wireless devices.

47. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
   a) transmitting a first random access preamble on a primary uplink carrier of said primary cell to a base station; the timing of said first random access preamble is determined based on a first synchronization signal received on a primary downlink carrier of said primary cell from said base station;
   b) waiting for reception of a first random access response from said base station to align transmission timing on said primary uplink carrier; if no first random access

response from said base station is received during a waiting period, retransmitting said first random access preamble on said primary uplink carrier until said first random access response is received from said base station or a first maximum number of retransmissions is achieved;

c) if said first maximum number of retransmissions is achieved without receiving said first random access response, indicating a random access problem to an RRC layer in said wireless device, and said RRC layer determining a radio link failure and triggering a connection re-establishment process; and

d) if said primary uplink carrier is time aligned:

   i) receiving at least one control message from said base station on said primary downlink carrier; said at least one control message configuring a plurality of cell groups; said plurality of cell groups comprising:

      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use said first synchronization signal on said primary downlink carrier as the timing reference; and

      (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell;

   ii) receiving an activation command to activate a first secondary cell in said secondary cell group; said first secondary cell comprises a first secondary downlink carrier and a first secondary uplink carrier;

   iii) receiving a PDCCH order for transmission of a second random access preamble on said first secondary uplink carrier;

   iv) transmitting said second random access preamble on said first secondary uplink carrier to said base station; the timing of said second random access preamble is determined based on a second synchronization signal received on said first secondary downlink carrier; and

   v) waiting for reception of a second random access response from said base station to align transmission timing on said first secondary uplink carrier; if no second random access response from said base station is received during a waiting period, retransmitting said second random access preamble on said first secondary uplink carrier until said second random access response is received from said base station or a second maximum number of retransmissions is achieved; wherein if said second maximum number of retransmissions is achieved, said wireless device stops transmission of said second random access preamble on said first secondary uplink carrier at least until another PDCCH order is received from said base station.

48. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) starting a random access preamble transmission on a primary uplink carrier of said primary cell; if a first maximum number of retransmissions is achieved without receiving a first random access response, indicating a random access problem to an RRC layer in said wireless device, and said RRC layer determining a radio link failure and triggering a connection re-establishment process; and

b) after said primary cell is successfully configured:
   i) receiving at least one control message from said base station; said at least one control message configuring a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
      (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell;
   ii) transmitting a second random access preamble on a first secondary uplink carrier of a first secondary cell in said secondary cell group to said base station; the timing of said second random access preamble is determined based on a second synchronization signal received on a first secondary downlink carrier of said first secondary cell; and
   iii) if no second random access response is received during a waiting period, retransmitting said second random access preamble until said second random access response is received or a second maximum number of retransmissions is achieved; wherein if said second maximum number of retransmissions is achieved, said wireless device does not determine a radio link failure and stops transmission of said second random access preamble at least until another PDCCH order is received.

49. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) receiving a first control message from a base station on a primary downlink carrier of a primary cell in said plurality of cells to establish a first signaling bearer with said base station on said primary cell;
b) transmitting a plurality of radio capability parameters to said base station on said first signaling bearer on a primary uplink carrier of said primary cell;
c) receiving at least one control message from said base station on said primary downlink carrier; based at least in part on the information in said plurality of radio capability parameters, said at least one control message configuring:
   i) a plurality of cell groups; said plurality of cell groups comprising:
      (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) a time alignment timer for said secondary cell group; said time alignment timer starts or restarts when said wireless device receives a timing advance command to adjust its uplink transmissions on said secondary cell group; said secondary cell group is considered out-of-sync when said time alignment timer expires or is not running; and

d) transmitting a plurality power headroom reports according to a power headroom report triggering configuration received from said base station; wherein power headroom is not triggered for any of said at least one secondary cell in said secondary cell group, when said secondary cell group is out-of-sync.

50. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; said plurality of cells comprise said primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) receiving at least one control message from a base station, said at least one control message configuring:

i) a plurality of cell groups; said plurality of cell groups comprising:

(1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and

(2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) a time alignment timer for said secondary cell group; said time alignment timer starts or restarts when said wireless device receives a timing advance command to adjust its uplink transmissions on said secondary cell group; said secondary cell group is considered out-of-sync when said time alignment timer expires or is not running; and

b) transmitting a plurality power headroom reports according to a power headroom report triggering configuration received from said base station; wherein power headroom is not triggered for any of said at least one secondary cell in said secondary cell group, when said secondary cell group is out-of-sync.

51. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
    a) receiving at least one control message from a base station, said at least one control message configuring:
        i) a plurality of cell groups; said plurality of cell groups comprising:
            (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
            (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and
        ii) a time alignment timer for said secondary cell group; said time alignment timer starts or restarts when said wireless device receives a timing advance command to adjust its uplink transmissions on said secondary cell group; said secondary cell group is considered out-of-sync when said time alignment timer expires or is not running; and
    b) transmitting a plurality power headroom reports according to a power headroom report triggering configuration received from said base station; wherein a transmission of a power headroom report is triggered for an activated secondary cell in said secondary cell group, when out-of-sync status of said secondary cell group is terminated and said time alignment timer is started or restarted.
52. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
    a) receiving at least one control message from said base station on said primary downlink carrier; said at least one control message configuring:
        i) a plurality of cell groups; said plurality of cell groups comprising:
            (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
            (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said

secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

ii) a first time alignment timer for said primary cell group and a second time alignment timer for said secondary cell group; a time alignment timer of a cell group starts or restarts when said wireless device receives a timing advance command to adjust its uplink transmissions on said cell group, and said cell group is considered out-of-sync when said time alignment timer expires or is not running; and

b) when said primary cell group is out-of-synch, for each cell in said primary cell group and said secondary cell group:
   i) stopping transmission of all HARQ feedback in the uplink;
   ii) stopping all re-transmissions in the uplink in response to downlink HARQ feedback;
   iii) stopping all uplink transmissions comprising data packet transmissions and channel state information transmissions, except uplink transmission of a random access preamble; and

c) when said secondary cell group is out-of-synch, for each cell in said secondary cell group:
   i) continuing transmission of HARQ feedback in the uplink;
   ii) stopping all re-transmissions in the uplink in response to downlink HARQ feedback; and stopping all transmissions in the uplink; and
   iii) transmitting channel state information on said primary uplink carrier; and (optional) stopping triggering transmission of power headroom reports (optional).

53. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:

a) transmitting at least one control message to a wireless device in said plurality of wireless devices on said primary downlink carrier; said at least one control message configuring a plurality of cell groups; said plurality of cell groups comprising:
   i) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
   ii) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

b) transmitting a plurality of time alignment commands to said wireless device, said plurality of time alignment commands comprising at least one time alignment entity, each time alignment entity comprising:
   i) an amount of time adjustment for all uplink transmissions on a cell group; and
   ii) an index identifying said cell group;

   wherein frames and subframe transmission timing for all downlink carriers in said primary cell group and said secondary cell group of said base station are substantially time aligned with each other;
   wherein frames and subframe transmission timing for all downlink carriers in said primary cell group and said secondary cell group of said base station are substantially time aligned with frames and subframe transmission timing of all downlink carriers in said plurality of base stations;
   wherein frames and subframe transmission timing for all uplink carriers in said primary cell group of said wireless device are substantially time aligned with each other;
   wherein frames and subframe transmission timing for all uplink carriers in said secondary cell group of said wireless device are substantially time aligned with each other;
   wherein frames and subframe transmission timing for uplink carriers in said primary cell group of said wireless device are not necessarily time aligned with frames and subframe transmission timing for uplink carriers in said secondary cell group of said wireless device; and
   wherein said plurality of time alignment commands substantially aligns frame and subframe reception timing of signals transmitted by said plurality of wireless devices to said base station in said primary cell group and said secondary cell group.

54. A method for operating a base station in a communication network comprising a plurality of base stations, each base station communicating with a plurality of wireless devices and comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
   a) transmitting at least one control message to a wireless device on said primary downlink carrier; said at least one control message configuring:
      i) a plurality of cell groups; said plurality of cell groups comprising:
         (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
         (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; said secondary cell group comprising a first secondary cell with a first secondary downlink carrier and a first secondary uplink carrier; wherein all uplink transmissions in said secondary cell group use a second synchronization signal on said first secondary downlink carrier as the timing reference; and

b) transmitting a plurality of time alignment commands to said wireless device, said plurality of time alignment commands comprising at least one time alignment entity, each time alignment entity comprising:
   i) an amount of time adjustment for all uplink transmissions on a cell group; and
   ii) an index identifying said cell group;

   wherein frames and subframe transmission timing for all downlink carriers in said primary cell group and said secondary cell group of said base station are substantially time aligned with each other;
   wherein frames and subframe transmission timing for all downlink carriers in said primary cell group and said secondary cell group of said base station are substantially time aligned with frames and subframe transmission timing of all downlink carriers in said plurality of base stations;
   wherein frames and subframe transmission timing for all uplink carriers in said primary cell group of said wireless device are substantially time aligned with each other;
   wherein frames and subframe transmission timing for all uplink carriers in said secondary cell group of said wireless device are substantially time aligned with each other;
   wherein frames and subframe transmission timing for uplink carriers in said primary cell group of said wireless device are not necessarily time aligned with frames and subframe transmission timing for uplink carriers in said secondary cell group of said wireless device;
   wherein said plurality of time alignment commands substantially aligns frame and subframe reception timing of signals transmitted by said plurality of wireless devices to said base station in said primary cell group; and
   wherein said plurality of time alignment commands substantially aligns frame and subframe reception timing of signals transmitted by said plurality of wireless devices to said base station in said secondary cell group.

55. A method for operating a wireless device comprising a plurality of cells; said plurality of cells comprise a primary cell and at least one secondary cell; each cell comprising a downlink carrier and zero or one uplink carrier, and transmission time is divided into a plurality of frames, and each frame in said plurality of frames is further divided into a plurality of subframes, said method comprising:
   a) receiving at least one control message from said base station on said primary downlink carrier; said at least one control message configuring:
      i) a plurality of cell groups; said plurality of cell groups comprising:
         (1) a primary cell group comprising at least one cell comprising said primary cell; wherein all uplink transmissions in said primary cell group use a first synchronization signal on said primary downlink carrier as the timing reference; and
         (2) a secondary cell group comprising at least one secondary cell in said at least one secondary cell; and
      ii) a plurality of channel parameters for a plurality of channels comprising:
         (1) a PUSCH for each cell in said plurality of cells;

(2) a PUCCH for said primary cell; and
(3) a RACH for a first secondary uplink carrier in a first secondary cell in said secondary cell group;

b) receiving a PDCCH order for transmission of a random access preamble on said first secondary uplink carrier, said random access preamble is transmitted simultaneously with at least one of the following messages:
i) a message on said PUCCH;
ii) a message comprising UCI on at least one of said PUSCH;
iii) a message on said PUCCH and a message on said PUSCH of said primary cell;
iv) a message on at least one of said PUSCH; and
v) an sounding signal on a cell in said plurality of cells; and

c) scaling transmission power according to a predefined scaling rule before simultaneous uplink transmissions of said preamble along with said at least one message.

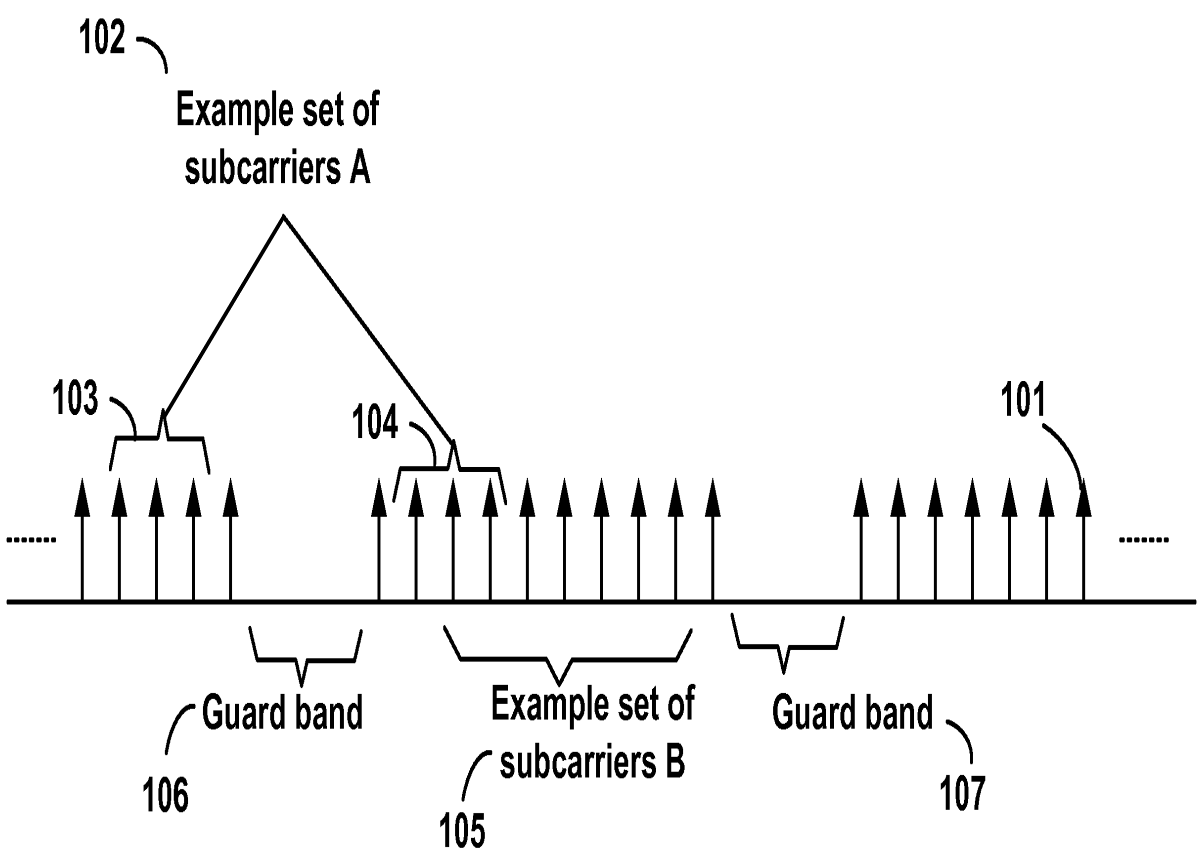
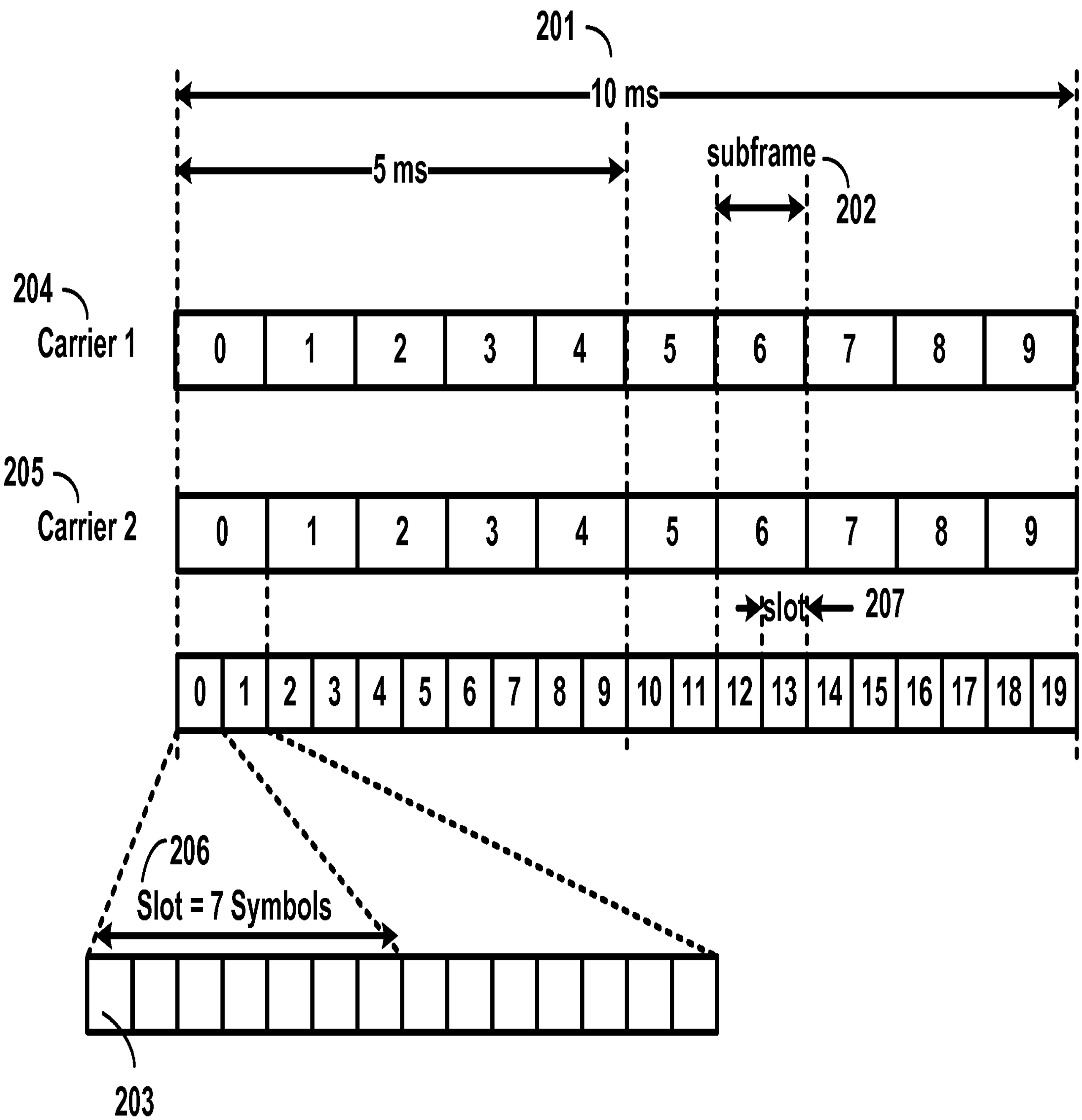

102
Example set of
subcarriers A
103
104
101
Guard band
106
Example set of
subcarriers B
105
Guard band
107

FIG. 1


201
10 ms
5 ms
subframe
202
204
Carrier 1
0
1
2
3
4
5
6
7
8
9
205
Carrier 2
0
1
2
3
4
5
6
7
8
9
slot
207
0
1
2
3
4
5
6
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12
13
14
15
16
17
18
19
206
Slot = 7 Symbols
203

FIG. 2

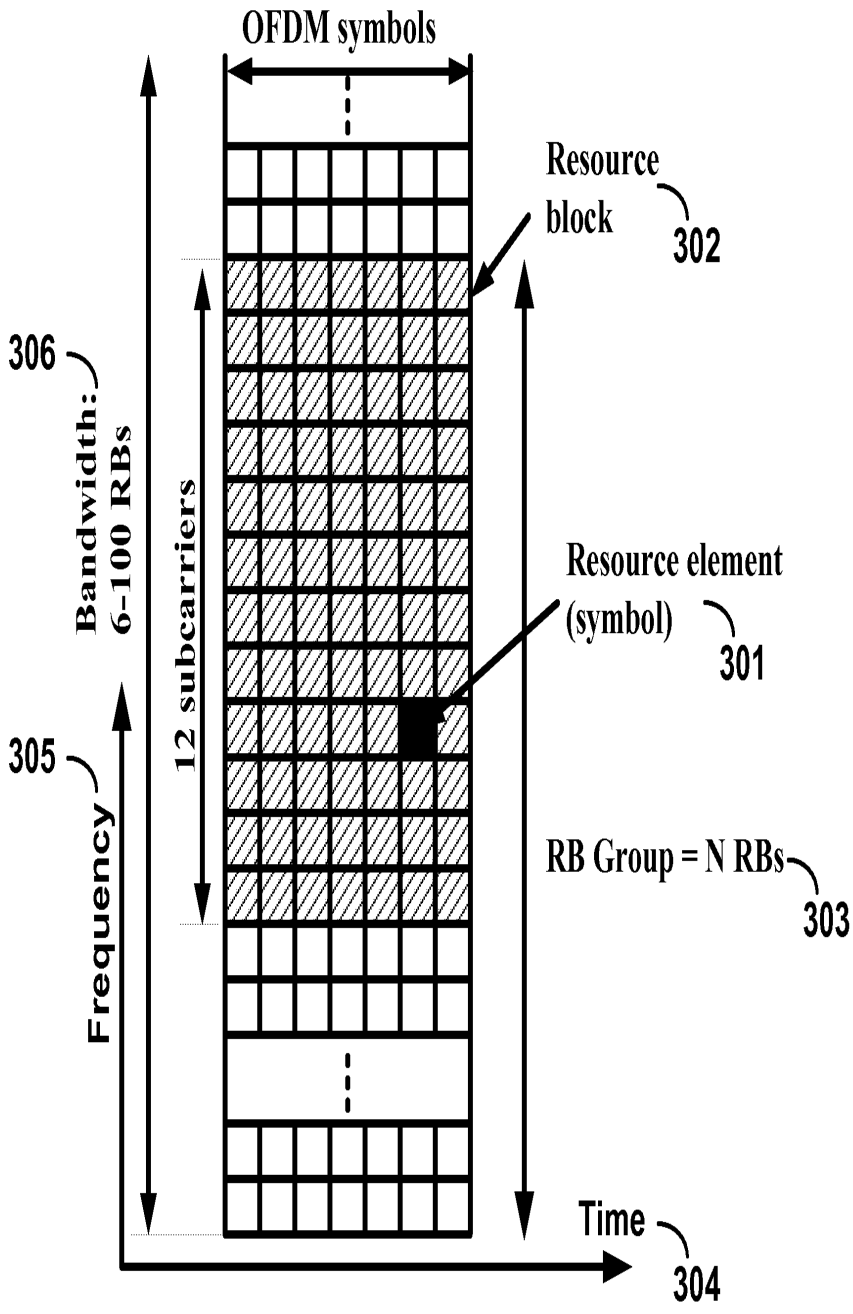
OFDM symbols
Resource block
302
306
Bandwidth: 6-100 RBs
12 subcarriers
Resource element (symbol)
301
305
Frequency
RB Group = N RBs
303
Time
304

FIG. 3

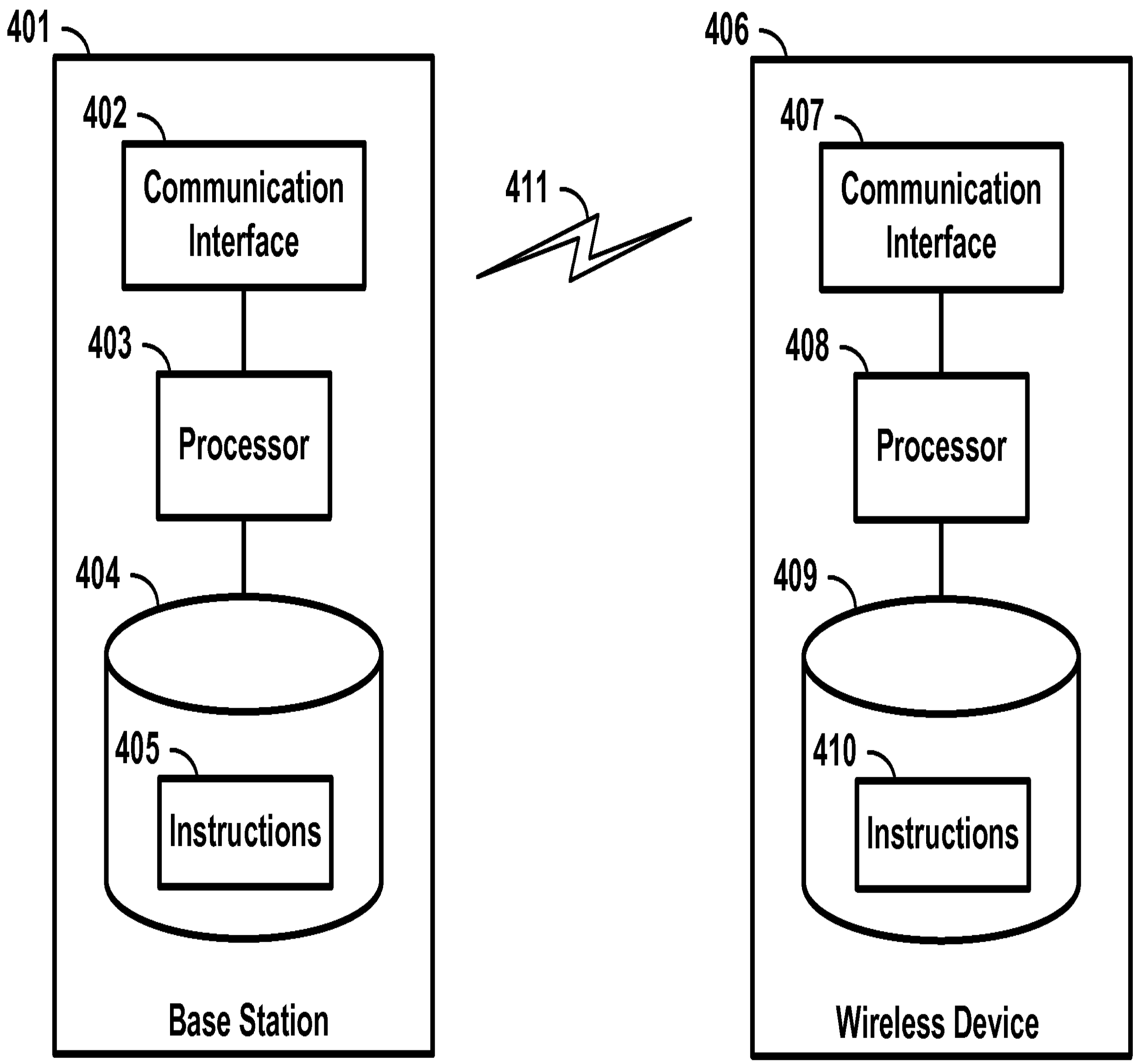
401
402
Communication Interface
403
Processor
404
405
Instructions
Base Station
411
406
407
Communication Interface
408
Processor
409
410
Instructions
Wireless Device

FIG. 4

Title: Carrier Groups in Multicarrier Networks
Inventor: Esmael H. Dinan
Docket No.: DD-12-1001P

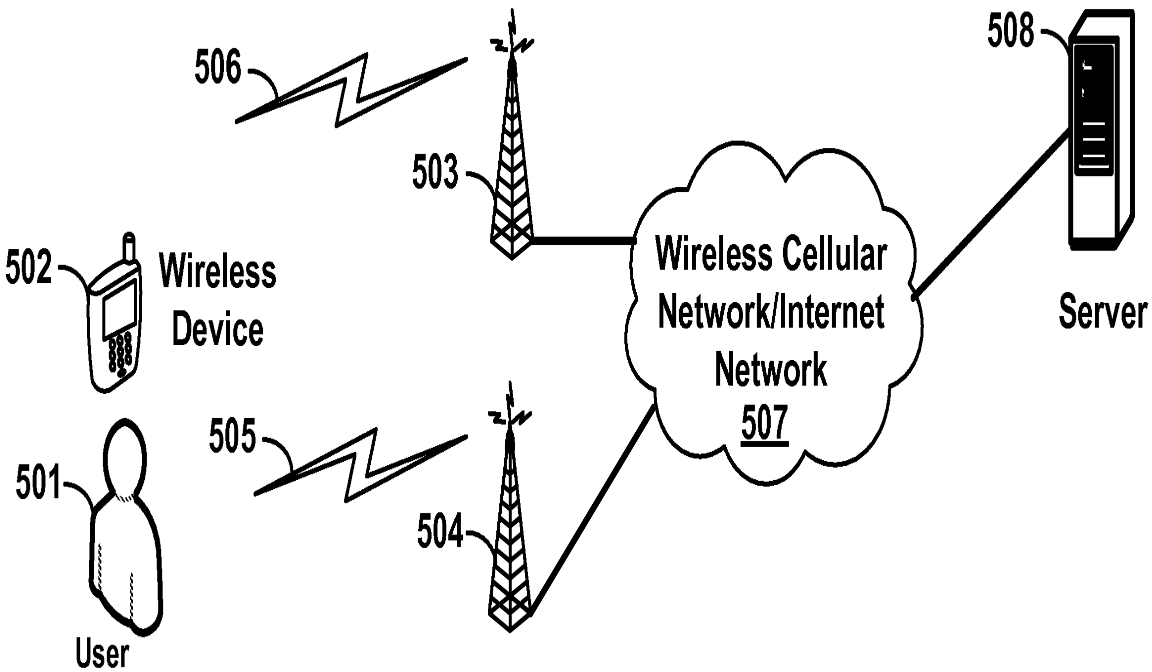

FIG. 5

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	Carrier Groups in Multicarrier Networks
First Named Inventor/Applicant Name:	Esmael Hejazi Dinan
Filer:	Esmail Hejazi Dinan
Attorney Docket Number:	DD-12-1001P

Filed as Small Entity

Provisional Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Provisional Application filing fee	2005	1	125	125
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**125**

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First Named Inventor/Applicant Name:	Esmael Hejazi Dinan
Customer Number:	92629
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Application Type:	Provisional

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Payment Type	Deposit Account
Payment was successfully received in RAM	$125
RAM confirmation Number	20839
Deposit Account	505124
Authorized User	

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1	Provisional Cover Sheet (SB16)	DD-12-1001P-ProvisionalSB.pdf	2071705 6c06d76054ce9a53ea31451152ba1e935eb7127f	no	3
Warnings:					
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3	Drawings-only black and white line drawings	Visio-DD-12-1001P-Drawings-Carrier-Groups-G.pdf	64029 d2e80ef50e89af708de466dc4dff606d93463587	no	5
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4	Fee Worksheet (SB06)	fee-info.pdf	29091 e5f2fe612cf38cde0d67c720bc291dc18ea915aa	no	2
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