CONSUMER ELECTRONICS APPLICATION AND COVERAGE CONSTRAINTS USING BLUETOOTH AND PROPOSED BLUETOOTH EVOLUTION TECHNOLOGIES

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ABSTRACT

This paper highlights key features of the Bluetooth physical layer standard. Typical link budgets and coverage plots are generated for an example residential environment. The results obtained for transmission of symmetric asynchronous data link (ACL) packets are used to discuss the bit rate capabilities of various time bounded and non-time bounded Bluetooth enabled consumer electronic devices. The need for higher bit rates in certain applications implies the need for a second Bluetooth standard.

INTRODUCTION

The Bluetooth radio interface operates in the unlicensed 2.45GHz Industrial, Scientific and Medical (ISM) band. Frequency hopping is used with terminals cycling through 79 1MHz hop channels at 1600 hops/s [1][2]. The current technology is capable of transmitting data and/or voice at raw half-duplex rates of up to 1Mb/s without the use of cables between portable and fixed electronic devices. Asymmetric and symmetric systems provide maximum half-duplex user data rates of 725kb/s and 433kb/s respectively. A narrowband Gaussian Frequency Shift Keying (GFSK) scheme is used with a BT product of 0.5. A software simulation of the Bluetooth baseband standard was carried out for symmetric and asymmetric data link packets [3]. Only symmetric data link packet results are presented and discussed in this paper.

SOFTWARE SIMULATION

In this paper, software simulated results are presented for symmetric Data Medium (DM) and Data High (DH) packets with 1, 3 and 5 time slot transmissions. Figure 1 shows the Packet Error Rate (PER) versus the ratio of energy per bit to noise power spectral density (Eb/No) in a quasi-static uncorrelated narrowband Rayleigh fading channel. As specified in the Bluetooth standard, the payload for all DM packets were encoded using a 2/3-rate shortened Hamming binary block code. The DH packets were not encoded. The simulation was repeated 5000 times for each type of packet and the average PER was calculated. Figure 2 shows the data throughput plot for all 6 symmetric ACL packets for Bluetooth.

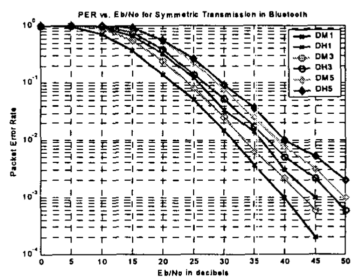

Figure 1: PER vs. Eb/No for symmetric ACL transmission in Rayleigh fading channel

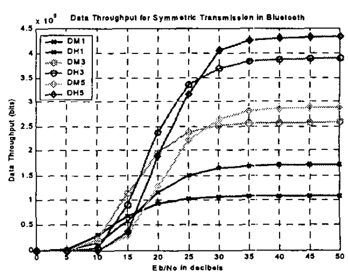

Figure 2: Data throughput for symmetric ACL transmissions in Bluetooth

INDOOR PROPAGATION MODELLING TOOL

A state of the art indoor propagation modelling tool based on the ray launching technique [4] was used to generate a map of the received signal strength in an example residential environment. Dipole antennas were used at the basestation and terminal. A transmit power of 0dBm (1mW) was assumed. Figure 3 shows a typical point-to-point indoor prediction. The test area is constructed predominantly from brick and has a concrete floor. The test area has dimensions $16x11m^2$ with 3m high ceilings. Figure 4 shows the received Eb/No for the test area quoted in dB. The received Eb/No was taken in steps of 3dB in the range 0-51dB. From Figure 2, the maximum achievable data rate and the types of packets involved were determined.

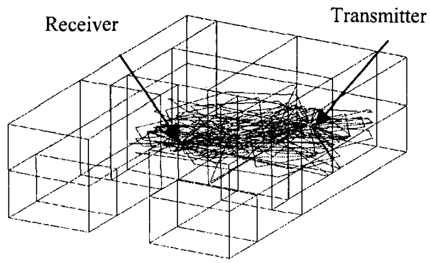

Figure 3: Ray geometry plot

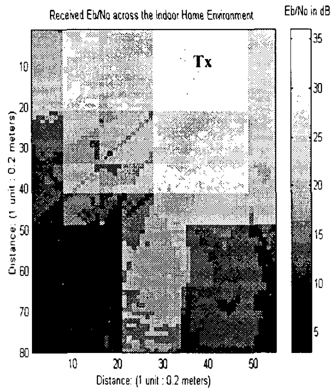

Figure 4: Coverage plot showing the received signal strength

RESULTS AND DISCUSSION

In Bluetooth, the receiver sensitivity is –70dBm at 0.1% bit error rate (BER) and the out-of-band spurious emission is defined at –20dBm during operation [5]. In Figure 4, the received Eb/No was calculated for points spaced at 0.2m over the entire test area. Figure 5 shows the available data rate for the entire test area. From Figure 2, it can be seen that at low Eb/No, the Data Medium packets (DM1&3) provide the best data throughput. Beyond 18dB, the Data High packets dominate (DH3&5). At low Eb/No, the environment is more susceptible to interference. Thus short duration transmissions (1 and 3 time slots as opposed to 5 time slots) coupled with encoding, provides a more reliable system. As the Eb/No increases, the packet error rate reduces such that high rate multi-slot transmission becomes more reliable whilst maximising the data throughput. From Figure 5, it can be seen that best throughput is achieved within a 10m radius of the basestation. Within this range, the maximum achievable data rate is 355kb/s. Hence, time bounded applications such as cordless telephones, CD players and video phones will be viable here. In addition, non-time bounded applications such as wireless computing links will operate successfully. As the receiver moves further from the transmitter, the data throughput decreases drastically (typically below 50kb/s). This is still sufficient for many non-time bounded applications (such as e-mail browsing). In summary, non-time bounded communication is possible in all but the most hostile regions (indicated as dark shaded areas). More demanding applications, such as low bit rate video communications, will cease to operate successfully at ranges greater than 10m.

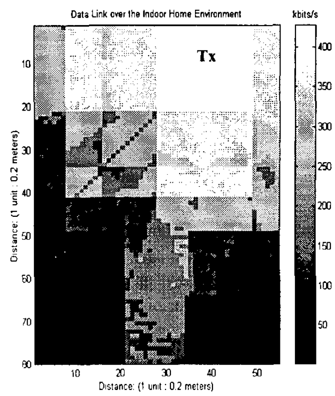

Figure 5: Map of available data rates

CONCLUSIONS

Date rates for Bluetooth enabled consumer electronic applications in a typical residential environment were investigated. It was found that time bounded applications were more unreliable due to the restricted bit rates achievable at greater than 10m radius. In the final paper, evolution technologies for a possible Bluetooth 2 standard covering higher level modulation schemes (QPSK and 16QAM) and variable rate error control coding will be proposed. The results presented will cover symmetric and asymmetric data link packet transmission over a multi-storey residential environment. The evolution technologies proposed will enable Bluetooth to be applied to a far broader range of consumer electronic products.

REFERENCES

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[2] Jennifer Bray and Charles F Sturman, "BLUETOOTH, Connect Without Cables"

[3] M.F. Tariq, P. Czerepiński, A. Nix, D.Bull and N. Canagarajah "Robust and Scalable Matching Pursuits Video Transmission using the Bluetooth Air Interface" IEEE Transactions on Consumer Electronics, August 2000, vol.46, pp 673-681

[4] B.S. Lee, A.R. Nix & J.P. McGeehan, "Indoor Space-Time Propagation Modelling Using A Ray Launching Technique"

[5] The complete guide to Bluetooth from TOSHIBA.