Chapter 1 Co-Channel Interference in Bluetooth™ Piconets

Introduction

1.1 Introduction

Several years ago, the telecommunications and computing industries recognized that a truly low-cost, low-power radio based cable replacement, or wireless link needed to connect different types of electronic devices was feasible. Such a ubiquitous link would provide the basis for small portable devices to communicate together in an ad-hoc fashion. In 1994, Ericsson Mobile Communications performed a study, and the technology code named "Bluetooth" began to be defined. The goal of the technology was to provide effortless connectivity between computers and peripheral devices by means of a small, short-range radio-based technology that is integrated into different devices.

Bluetooth, a promising technology to provide mobile devices with at least 10-meter connections, is predicted to explode into every world market, as many market analysts foresee that the number of Bluetooth devices will reach between 600 million and 1 billion in 2004. This year the InStat group (www.instat.com) projects that Bluetooth shipments will reach 955 million units by 2005. As the cost of adding the Bluetooth radio to devices falls to approximately $5, Bluetooth is expected to be present even in low-end devices such as set-top boxes, low-end mobile phones, and Internet appliances. To get an idea of where this industry is headed, consider that market analysts at IDC, a leading provider of technology intelligence, predict the global market for wireless handset semiconductors will exceed $38 billion by 2004.

This predicted explosion accelerates the connectivity of all types of mobile devices in the office environment. As cables become untangled and replaced with a Bluetooth wireless link the
question becomes will the bluetooth frequency band become crowded, resulting in poor communication quality? Performance analysis is needed to predict the effect of increasing numbers of bluetooth-equipped devices in the office environment.

1.2 Problem definition

Mobility is a fundamental feature of un-tethered communication networks. A wireless communication device significantly enhances the mobility of users, but also introduces problems that are not seen in wire line based communications such as interference. As signals are sent and received across the air mutual interference issues arise. Bluetooth-to-Bluetooth interference increases due to frequency reuse in a shared spectrum. Assuming 900 million Bluetooth-enabled devices are in existence 5 years from now, the dominant cause of bluetooth interference will be from other Bluetooth devices.

The research focus of this thesis is directed towards accurately determining and disseminating the result of co-channel interference analysis in the Bluetooth wireless network. Users of the Bluetooth network can experience interference from many sources, however the focus of this investigation is co-channel interference in Bluetooth networks from peripheral bluetooth devices located in proximity of the ten-meter range. The seamless wireless link concept will increase the number of users co-located in office buildings across the world. One potential problem of the Bluetooth network is the chance of interference grows as more users connect to neighboring Bluetooth networks in office cubicles, airports, and in the home within a ten-meter range. As each new user connects to a bluetooth network within the ten-meter range the probability of interference increases. Bluetooth efficiency can suffer a drastic drop when too many bluetooth devices are active in a small area due to collisions. Data collisions require
retransmits and with retransmits speed or data throughput is degraded. The source of the interference presented above is frequency reuse from co-located bluetooth devices.

A popular technique known as Frequency Hopping Spread Spectrum is applied to the Bluetooth network to combat interference from other devices operating on the same frequency for an extended period of time. The downside to this technique is the introduction of co-channel interference. As two bluetooth devices hop on the same channel, interference will occur if the signal to interference (SIR) threshold is not maintained. As the wireless cable link concept continues to evolve in terms of users, coverage, and services users will require the same system functionality characteristic of today’s wire line based high-speed networks for voice, data, audio, and video real time mobile communications. Although the Bluetooth concept has been explored the mutual interference between Bluetooth devices of single and mulitslot packets has not been investigated. Interference studies are essential because the effect of a crowded radio frequency within doors is unknown. Such studies will lead to statistical parameters that can be used to design efficient bluetooth wireless systems in the future.

1.3 Presentation Format of the Thesis

The thesis is organized as follows:

Chapter 2 describes the technical details of the Bluetooth wireless communication technology.

In Chapter 3 the analysis used to accurately determine co-channel interference is presented. The metrics and methodologies adopted to analyze the co-channel interference and the simulation model developed to move from the physical system to the software model are also presented in Chapter three.
The simulated bluetooth performance results are summarized in Chapter 4. Potential Tx-Rx distances interference can occur from co-located Bluetooth transmitters and the probability of interference are also presented.

Chapter 5 concludes the work of this thesis by outlining a possible direction for future bluetooth research.

1.4 Past Studies

In the past, studies were published that related to performance as Bluetooth and the 802.11 standard coexist. “Bluetooth voice and data performance in 802.11 Direct Sequence WLAN environments” investigates the impact of a WLAN system on BT performance [4]. However, the voice and data performance investigation ignores mutual interference between Bluetooth devices due to the distance between 802.11 access points and the low Bluetooth transmit power [4]. In “Reliability of IEEE 802.11 Hi Rate DSSS WLANs in a High Density Bluetooth Environment” the analysis is based solely on the use of single time slot packets [6]. The paper suggest that multi-slots reduce transmission time and results in longer gaps in bluetooth interference. Although the use of multiple time slot packets effectively reduces the bluetooth hop rate and increases throughput this study illustrates a higher probability for interference and increased data degradation due to the length of the packet. Our study indicates that multi-slot packets are actually worst-case scenario for interference. The issue of coexistence of the two standards is an important topic, as both types will exist in proximity of the other in the enterprise setting; however interference analysis of Bluetooth on Bluetooth devices located in adjacent offices using single and multi-slot packets has not been studied. In “Performance analysis of the
Bluetooth physical layer” the analysis omits the investigation into the performance of multi-slots, which have gone untouched until the publication of this research [7].