



Wi-Fi™ and Bluetooth™ - Interference Issues

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Introduction

Because both Wi-Fi™ and Bluetooth™ wireless technology share spectrum and will often be located in close physical proximity to one another, there is concern for how they may interfere with one another. Both are inherently resistant to other wireless devices by virtue of their use of spread spectrum techniques.

Both Wi-Fi and Bluetooth fail gracefully in the presence of interference. By this is meant that the communication protocols are very robust and include mechanisms for error checking and correcting, as well as requesting that corrupted packets be resent. Therefore the result of increasing levels of interference is almost always confined to a slowing of the data rate as more packets need to be resent. Only in extreme conditions, such as setting a Bluetooth-enabled cell phone down next to an operating microwave oven, is it likely that communications will cease altogether.

The Federal Communications Commission (FCC) qualifies devices that radiate radio frequency (RF) energy as either intentional or unintentional radiators. There are plenty of both in the crowded 2.4 GHz Industrial, Scientific, and Medical (ISM) bands that are shared by WiFi and Bluetooth.

Unintentional Radiators - Microwave Ovens

Unintentional radiators of RF energy include almost all electrical devices. The FCC sets practical limits on how much energy can be unintentionally radiated, and the engineering steps necessary to make products meet these limits are big business. Nonetheless, while the Electromagnetic Interference (EMI) from your PC will not disrupt your wireless device, a nearby microwave oven certainly can. The task then becomes how to design and live with inevitable interference. Remember that users of Part 15 devices are required to accept interference from other sources in these bands. Such is the price of operating largely unregulated.

The solution to operating successfully in the presence of unintentional radiators such as microwave ovens is to move them farther away or somehow provide further shielding. In a corporate environment an RF site survey should always be performed to identify sources of interference, so that they can be considered when planning the network.

Intentional Radiators - the Coexistence of Wi-Fi™ and Bluetooth™

Since Wi-Fi wireless local area networks (WLANs) and Bluetooth are complementary technologies, they will often be used in close proximity to one another. Neither Wi-Fi nor Bluetooth was originally designed with mechanisms in place to deal with the interference that each creates for the other.

Concern about the potential for interference between Wi-Fi and Bluetooth has IT managers considering options that range from ignoring the problem and accepting the possible degradation in data rate, to the outright banning of Bluetooth devices within the working area of a WLAN. Neither is desirable, and the industry is aggressively pursuing better solutions.

The time required to study this issue and develop recommendations has been another factor that has delayed getting Bluetooth products to market.

Engineering Studies

Many engineering studies have been done examining the effects of Bluetooth on Wi-Fi, and vice versa. These studies have been performed in rigorous controlled conditions and have quantified the degree of failure under repeatable conditions. Although there has been little real-world experience involving coexistence of Wi-Fi and Bluetooth, it is clear that interference of some degree will occur under certain scenarios. These studies have shown that until new mechanisms to facilitate coexistence of the two technologies are implemented, the only solution is to physically increase the space between the two networks or adjust signal levels to reduce interference.

How Bluetooth and Wi-Fi Interfere

Wi-Fi and Bluetooth both occupy a section of the 2.4 GHz ISM band that is 83 MHz-wide. Bluetooth uses Frequency Hopping Spread Spectrum (FHSS) and is allowed to hop between 79 different 1 MHz-wide channels in this band.

Wi-Fi uses Direct Sequence Spread Spectrum (DSSS) instead of FHSS. Its carrier does not hop or change frequency and remains centered on one channel that is 22 MHz-wide. While there is room for 11 overlapping channels in this 83 MHz-wide band, there is only room for three non-overlapping channels. Thus there can be no more than three different Wi-Fi networks operating in close proximity to one another.

When a Bluetooth radio and a Wi-Fi radio are operating in the same area, the single 22 MHz-wide Wi-Fi channel occupies the same frequency space as 22 of the 79 Bluetooth channels which are 1 MHz wide. When a Bluetooth transmission occurs on a frequency that lies within the frequency space occupied by a simultaneous Wi-Fi transmission, some level of interference can occur, depending on the strength of each signal.

Bluetooth Hops Away and Tries Again

When a Bluetooth device encounters interference on a channel, it deals with the problem by hopping to the next channel and trying again. In this manner it can attempt to avoid interference from a Wi-Fi network. When transmitting data on Asynchronous Connection-Less (ACL) links, the result will be a degradation of data throughput. However, when using Synchronous Connection Oriented (SCO) links to transmit time-sensitive information such as voice, packets can be lost because these links do not utilize Automatic Repeat Request (ARQ).

Wi-Fi Slows Down and Tries Again

Wi-Fi acts like a wireless Ethernet™, and it deals with interference like Ethernet does. If a transmission fails it assumes that a collision has occurred due to two stations trying to transmit simultaneously, and an ARQ is issued. In addition, many installations of 802.11b utilize the optional automatic data rate modification feature. This allows the data rate to fall back from 11 Mbps to 5.5, 2, or even 1 Mbps, in an effort to lower the Bit Error Rate (BER) due to poor signal-to-noise ratio (SNR).

In this scenario, if a Wi-Fi device encounters interference from a Bluetooth transmission and subsequently slows its transmission rate, it will then spend more time than before transmitting a packet on a frequency available to Bluetooth, thus having the effect of increasing the likelihood of interference between the two. Data is not lost, but the data throughput rate may slow to an intolerable level.

Efforts to Ensure Coexistence

The Bluetooth SIG and the IEEE 802.15 working group are collaborating on efforts to define mechanisms and recommended practices to ensure the coexistence of Bluetooth and Wi-Fi networks. *Coexistence* is defined¹ as “the ability of one system to perform a task in a given shared environment where other systems may or may not be using the same set of rules”. These practices fall into two categories:

Collaborative mechanisms

A *collaborative coexistence mechanism* is defined as one in which the wireless personal area network (WPAN™) and the WLAN communicate and collaborate to minimize mutual interference. The following collaborative techniques being considered require that a Wi-Fi device and a Bluetooth device be collocated (i.e. located in the same laptop).

TDMA (Time Division Multiple Access) techniques^{2,3} allow Wi-Fi and Bluetooth to alternate transmissions. Bluetooth can support piconets, but cannot support SCO links.

*MEHTA*²² (the Hebrew word for “Conductor”) is a technique for managing packet transmission requests. It grants permission to transmit a packet based on parameters including signal strength and the difference between 802.11 and Bluetooth center frequencies. It can support SCO links.

*Deterministic frequency nulling*⁴ is a mechanism used in conjunction with MEHTA that inserts a 1 MHz-wide null in the 22 MHz-wide 802.11 carrier that coincides with the current Bluetooth center frequency

Non-collaborative mechanisms

A *non-collaborative coexistence mechanism* is one in which there is no method for the WPAN™ and WLAN to communicate. Non-collaborative techniques being investigated are:

*Adaptive packet selection and scheduling*⁵ is a Bluetooth Media Access Control (MAC)-level enhancement that utilizes a frequency usage table to store statistics on channels that encounter interference. This table can subsequently be accessed by packet scheduling algorithms that schedule transmissions to occur only when a hop to a good channel is made.

*Adaptive frequency hopping*⁶ classifies channels and alters the regular hopping sequence to avoid channels with the most interference.

So Far So Good

While the use of Bluetooth devices is not yet widespread, early indications are that Wi-Fi and Bluetooth can happily coexist, even without coexistence mechanisms in place. This is largely due to early usage models that do not have both devices being used simultaneously, and to the fact that even when interference does occur, the consequences are not severe.

Efforts continue to alleviate interference problems under worst case scenarios. Both the Bluetooth SIG coexistence group and the IEEE 802.15.2 task group expect to publish recommendations for coexistence sometime in 2002.

References on the Web

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