Overview of Electromagnetic Interference Impact over Wireless Systems for Control and Data Acquisition Working on 2.4 GHz ISM Band

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Abstract – **Electromagnetic interference (EMI) causes a wide spectrum of difficulties including momentary, minor inconveniences to system failures in wireless electronic devices. This paper gives a review of the interference problem in 2.4GHz ISM Band. It examines several interference scenario examples and provides an overview of the expected performance deterioration which is resulting from interference based on several published results in literature.**
Keywords – **Electromagnetic interference, susceptibility, ZigBee, Wi-Fi, Bluetooth.**

I. INTRODUCTION

To support people mobile lifestyle, especially at work has become more intensely information-based, companies have been producing various portable and embedded information devices including laptops, tablets, smart phones, mobile POS terminals, active badges for access control etc. At the same time, recent advances in sensor accuracy, integration and electronic miniaturization have made it possible to produce sensing devices equipped with significant computing power and wireless communication capabilities to create smart environments in which remote sensors could coordinate to establish a communication network [1]. These wearable smart devices and ad-hoc environments demand unique requirements on the communication protocol design such as low power consumption, frequent make and break connections, resource discovery and utilization and have created the need for Wireless Personal Area Networks (WPANs) [1].

The constantly growing number of wireless systems and the scarcity for available spectrum necessitates highly efficient spectrum sharing among disparate wireless networks [11]. Due to its almost global availability, the 2.4 GHz Industry Scientific and Medical (ISM) unlicensed band constitutes an appropriate frequency band suitable for low cost radio solutions such as the ones which are meant for Wireless Personal Area Networks (WPAN) and Wireless Local-Area Networks (WLAN) [10]. Many of these solutions are heterogeneous in hardware capabilities, wireless technologies, or protocol standards, and are expected to overlap with each other in both frequency and space domain [10].

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Sharing of the spectrum among various wireless devices that can operate in the same environment may lead to severe interference and result in significant performance degradation [1]. For example, IEEE 802.11 - Wi-Fi, IEEE 802.15.1 - Bluetooth and IEEE 802.15.4 – ZigBee, they all share the same 2.4 GHz ISM frequency band. Cross Technology Interference (CTI) is a consequence of this coexistence that can lead to loss of reliability and inefficient use of the radio spectrum [5] [6] [9].

Fig. 1. Wireless devices sharing one medium.

The interferences can be divided into two classes depending on their usage of the spectrum. Devices that are based on the Direct Sequence Spread Spectrum (DSSS) technique represent one class of interferers that utilizes a fixed channel in the band. Usually this channel is 22 MHz wide, although the width of the signal depends on the transmitter's design. The second class of interferers is represented by devices using a type of Frequency Hopping (FH) mechanism. The IEEE 802.11 specifications include a frequency hopping technique that uses a predefined frequency pattern. However, Bluetooth specifications define a pseudo-random frequency sequence based on the Bluetooth device address and its internal clock [1]. While interference among systems from the same type such as Bluetooth on Bluetooth, or IEEE 802.11 on IEEE 802.11 interference can be significant, it is usually considered early on in the design stages of the protocol [1].

II. WIRELESS TECHNOLOGIES IN THE 2.4 GHZ BAND

This section gives an overview of the various radio technologies operating in the 2.4 GHz unlicensed ISM band.

The Wi-Fi Specifications / IEEE 802.11a/b/g/n.

Wireless fidelity (Wi-Fi) includes IEEE 802.11a/b/g/n standards for wireless local area networks (WLAN), which are commonly used today to provide wireless connectivity in the home, office, and some commercial establishments. Wi-Fi technology allows the electronic devices to exchange data remotely over a computer network, including highspeed Internet connectivity. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards". The IEEE 802.11a amendment to the original standard was ratified in 1999. The IEEE 802.11a standard uses the same core protocol as the original standard, operates in 5GHz band, and uses a 52-subcarrier orthogonal frequency-division multiplexing (OFDM) with a maximum raw data rate of 54Mbit/s [13]. The IEEE 802.11b and 802.11g are amendments to the IEEE 802.11 specification that extends throughput from 54Mbit/s to 600Mbit/s using the same 2.4GHz band as 802.11b. The IEEE 802.11b and 802.11g operate in total of 14 channels available in the 2.4GHz band, each with a bandwidth of 22MHz and a channel separation of 5MHz. WLAN output powers are typically around 20dBm and operate within a 100m range [4].

The Bluetooth Specifications / IEEE 802.15.1.

Bluetooth, described as IEEE 802.15.1 standard, is a RF technology standard for exchanging data over short distances from fixed and mobile devices. It operates in short-wavelength radio range transmitting data over the globally unlicensed Industrial, Scientific and Medical (ISM) band from 2400–2483.5MHz (including guard bands). Bluetooth radio transmitting method is based on frequency-hopping spread spectrum (FHSS). The transmitted data is divided into packets and each packet is transmitted on one of the 79 designated Bluetooth channels in a pseudo-random pattern. Each channel has a bandwidth of 1MHz. The first channel starts at 2402MHz and continues up to 2480MHz in 1MHz steps. It usually performs 1600 hops per second, with Adaptive Frequency-Hopping (AFH) enabled. Bluetooth can create personal area networks (PANs) with high levels of security. The Bluetooth standard is created by telecom vendor Ericsson in 1994 and operates in the range of 2400–2480MHz [4] [12].

The ZigBee Specifications / IEEE 802.15.4.

The IEEE802.15.4 is a part of the IEEE family of standards for physical and link layers, the standard is designed to address applications with requirements for low data throughput, low power, short transmitting range and low cost. The IEEE802.15.4 supports two PHY options implemented with DSSS (Direct sequence spread spectrum). The 2.4GHz PHY uses Q-QPSK modulation, whereas 780/868/915MHz uses BPSK (Binary Phase Shift Keying) modulation. Both of its 2.4GHz and 868/915 MHz can offer good Bit Error Rate (BER) performance at low Signal to Noise Ratio (SNR). The IEEE802.15.4 physical layer offers 31 channels, 4 in 780MHz band for China (IEEE 802.15.4c), 1 in 868MHz band for Europe,10 in 915MHz for North America, 16 in the 2.4GHz throughout of the world. The nominal radio data rates on these frequency bands are 20kbps, 40kbps, and 250kbps. ZigBee over IEEE 802.15.4, defines specifications for low-rate WPAN, provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime [4].

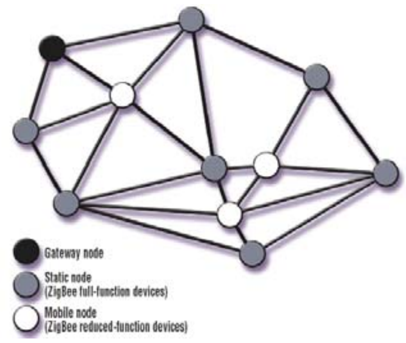

Fig. 2. ZigBee mesh topology.

A mesh network in which every node has a direct link to another node is a fully connected mesh network. In real wireless mesh network (WMN) only partially connected mesh networks are used, which means that there is no universal direct link between devices [2].

Other 2.4GHz Products

Today's high-power non Wi-Fi sources in the ISM band include surveillance cameras, baby monitors, microwave ovens, digital and analog cordless phones, and outdoor microwave links [8]. All these sources contribute for the "overcrowdedness" of the 2.4GHz ISM frequency band.

III. Coexistence

To illustrate the potential problems, an overview of the RF spectrums and available channels for Wi-Fi (802.11b/g) and ZigBee (802.15.4) is shown on the figure below [14].

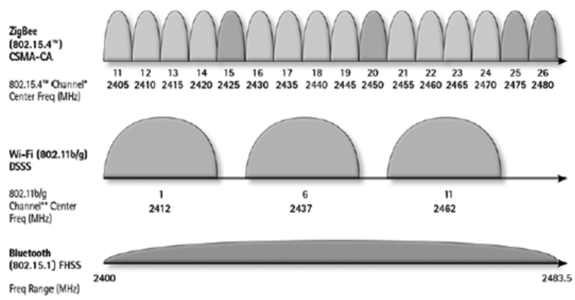

Fig. 3. Wi-Fi, ZigBee and Bluetooth Overlapping Channels in 2.4GHz ISM Band [14].

Since the RF channels in Wi-Fi, ZigBee and Bluetooth are overlapping there is a cause for concern [7]. The interference with Wi-Fi, caused by ZigBee, must be smaller than the interference with ZigBee, caused by Wi-Fi, the main reason is that ZigBee's bandwidth (2MHz) is much narrower than Wi-Fi's bandwidth (22MHz), ZigBee appears to be some kind of narrowband interference source to Wi-Fi [4].

Bluetooth adopts FHSS technology, which supports 79 channels with each 1MHz bandwidth. Its working frequency quickly hops 1600 times per second. Even if there are several kinds of 2.4GHz RF systems, the hopping system only interferes with other RF systems for a little time period, other RF systems can operate without influence in most of the time. ZigBee is a DSSS system, not a kind of frequency hopping system, so there is only one time channel overlap in 79 times, if a Bluetooth device transmits in a frequency that overlaps with the ZigBee channel, then the ZigBee device randomly backs off while the Bluetooth quickly hops to another frequency, so Bluetooth does not disturb ZigBee products in most instances, they can coexist very well [4].

The increase of ZigBee popularity and usage in different applications – home, industrial etc. area networks exert a new challenge for operating ZigBee in an environment in which Wi-Fi is already present. Sharing the spectrum between these two wireless technologies affect manly the functionality of ZigBee as it may cause a high packet error rate and significant drop in the throughput [3].

IV. Conclusion and Future Work

In this paper we focus on the problem of interference in the 2.4 GHz unlicensed ISM band. We have revised the problem and reviewed some of the results previously published in the literature on the evaluation of interference. Based on the results, the review has highlighted the most common coexisting interference causes. We have overviewed different interference scenarios between in Wi-Fi, ZigBee and Bluetooth coexistence.

In the future, we plan to extend our work by laboratory evaluations of working wireless systems and devices. Based on such laboratory evaluations we could research and propose software and/or hardware mechanisms for lowering the interference, between the systems increasing their performance and reliability in common medium.

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