ISSN 2395-1621

Performance of Bluetooth in the Presence of IEEE 802.11b

#1Ruchika A. Ghate, #2Prof. Mrs. S. A. Shirsat

[1]ruchikaghate@gmail.com
[2]sashirsat.scoe@sinhgad.edu

#1Dept. of Electronics and Telecommunication
#2Prof. Dept. of Electronics and Telecommunication

Sinhgad College of Engineering, Pune, India

ABSTRACT

The advancements in the wireless networks provide realistic distant communication of different areas of the world. Bluetooth, Wi-Fi and ZigBee wireless communication systems utilize the Industrial Scientific and Medical (ISM) Band, which results in a high mutual interference between these technologies since all these systems operate at the same or very close frequency bands. The interference problem increases with an in-device Co-existence. This is mostly due to the different characteristics of each technology such as access mechanism, frame structure, peak transmit power and frequency of operation. This work describes the interference between the Bluetooth, Wi-Fi and ZigBee wireless networks. The paper focuses on various types of mechanisms to solve the interference effect on Bluetooth (BT) due to Wi-Fi and ZigBee. It has also considered different techniques that attempt to avoid time and frequency collisions of Bluetooth with Wi-Fi and ZigBee. Also it conducts a comparative analysis of their respective performance, and discuss the trends and trade-offs they bring for interference levels. Bluetooth performance is measured in terms of packet loss, throughput. In this paper performance of Bluetooth is evaluated in the presence of Wi-Fi (IEEE 802.11b) and Bluetooth throughput is calculated as a function of distance with and without interference.

ARTICLE INFO

Article History

Received: 27th June 2016

Received in revised form :

27th June 2016

Accepted: 29th June 2016

Published online :

29th June 2016

Keywords: Bluetooth, ISM, Wi-Fi, WLAN, ZigBee

I. INTRODUCTION

The growth of wireless networks has changed our daily lives to such an extent that we cannot think of a life without devices like computers, mobile phones etc. These wireless networks that interconnect these devices are adding more and more nodes into it each minute. There are many popular standards developed by IEEE and such other groups which are used by these devices. The most popular among these communication standards are IEEE 802.11 or Wi-Fi and IEEE 802.15.1 or Bluetooth. Almost 75% either one of these or both equipped the whole mobile computing world. Also, ZigBee (IEEE 802.15.4) is establishing an enabling place for the Wireless Sensor Network (WSN) especially in the application of home automation network because of its low power and cost. The Industrial, scientific, and medical (ISM) band are most populated by various kinds of wireless devices. However, the Bluetooth (IEEE 802.15.1) and Wi-Fi (IEEE 802.11) share the same unlicensed band with the ZigBeeIEEE802.15.4) and experience mutual interference problems[3].Our objective is to minimize this mutual interference effect and thereby enhancing the throughput of Bluetooth. Also to investigate and classify different techniques and study their limitations in the presence of different types of interference, i.e. Bluetooth device interfering by other wireless transmission media like Wi-Fi and ZigBee.

II. TECHNOLOGY OVERVIEW

A quick overview of the three technologies is discussed here. Aspects of the three technologies that are necessary for the full comprehension of this study are also discussed such as the number of channels, the transmission power, modulation type and the access scheme.

2.1 Bluetooth

Bluetooth is a wireless technology which is designed for short-range wireless connections between devices in a wireless personal area network (WPAN)[4].It can support piconets of up to eight active devices; with a maximum of three synchronous connections oriented (SCO) links. Bluetooth also supports asynchronous connectionless (ACLs) data types that are used to exchange data in non-time critical applications. The Bluetooth uses frequency hopping spread spectrum (FHSS) at a rate of 1600 hops/sec as shown in Fig 2.1 and it uses Gaussian frequency shift keying (GFSK) modulation technique. Based on the applications that are considered for Bluetooth wireless technology, the majority of Bluetooth devices will transmit at a power level of about 1 mW with a raw data rate of 1 Mb/s. it utilizes 79 channels with each channel at 1Mhz occupying the entire ISM band. [5].

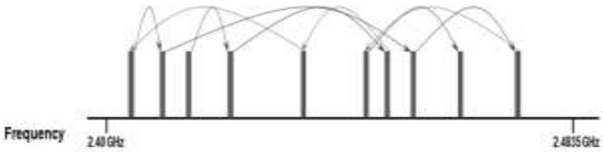

Fig 2.1 Frequency Hopping Spread Spectrum [5]

2.2 Wi-Fi

Wi-Fi (IEEE 802.11 standard) supports different multipoint networking with such data types as broadcast, multicast and unicast packets. The MAC address is built into every device allows unlimited number of devices to be active in a given network. These devices use carrier sense multiple access with collision avoidance (CSMA/CA) as media access technique. The Wi-Fi physical layer uses direct sequence spread spectrum (DSSS) at four different data rates as shown in Fig 2.2. It uses a combination of different shift keying methods such as differential binary phase shift keying (DBPSK) for 1 Mb/s, differential quaternary phase shift keying (DQPSK) for 2 Mb/s, and QPSK/complementary code keying (CCK) for the higher speeds, 5.5 and 11 Mb/s. The RF power level can vary typically between 30 and 100 mW in most commercial WLAN systems. A Wi-Fi system can use any of 11 22-MHz- wide sub channels across the acceptable 83.5 MHz of the 2.4 GHz frequency band [5].

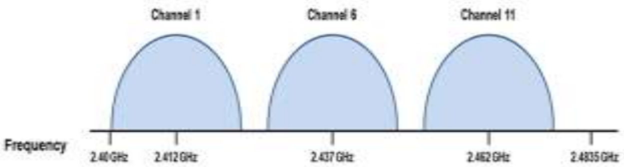

Fig 2.2 Direct Sequence Spread Spectrum [5]

2.3 ZigBee

This specification was developed for low cost, low power digital radios and it used in the areas like telecommunication services, health care, home automation and remote control etc. Same as Wi-Fi and the Bluetooth technologies, ZigBee also operates in the ISM band. Data transmission rate of 250 Kbps is used. ZigBee (IEEE 802.15.4 standard) technology specifies the PHY and MAC layers for lower rate wireless Personal area networks and can transmits up to 10 meters. 16 channels are defined for this specification in the 2.4 GHz band but with a narrower band of 2 MHz wide. So, up to sixteen ZigBee network can coexist in same area and at the same time. A latest ZigBee release “ZigBee Pro” Standard supports frequency hopping. This allows a ZigBee Personal area network to move from one channel to the other if overloading occurs in the former channel [6].

III. INTERFERENCE CASES

3.1 Bluetooth and Wi-Fi

Wi-Fi and Bluetooth both occupy the 83 MHz-wide section of the 2.4 GHz ISM band [7].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) and does not hop or change frequency and remains centered on one channel which is 22 MHz-wide. Even though this83 MHz-wide band can hold 11 overlapping channels, there is room for only three non-overlapping channels. Therefore at a time, there can be only three different Wi-Fi networks working together at close proximity [11].

If Bluetooth and Wi-Fi operate at the same time within the same frequency band, the single 22 MHz-wide Wi-Fi channel occupies the same frequency space as 22 1 MHz-Wide channels of the 79 Bluetooth channels. 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 [5]. Fig. 3.1 shows the FHSS and DSSS transmission collision.

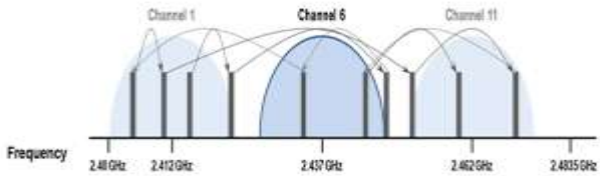

Fig 3.1 FHSS and DSSS transmission collision [5]

3.2 Bluetooth and ZigBee

Bluetooth and ZigBee technologies both use the 2.4 GHz ISM band for its operation. ZigBee uses DSSS modulation technique in which the data bits are spread to a larger bit stream, so that the data has a bigger bandwidth than the original data. This causes crowding of the spectrum and thus affects Bluetooth operation. As a result the coverage of Bluetooth is decreased [12].But unlike ZigBee, Bluetooth employs FHSS in which the carrier hops between the different channels. Bluetooth sends its data packet to its receiver in a particular channel and waits for its acknowledgement. If the acknowledgement is not received from the receiver then the carrier frequency is hopped to next frequency channel. In this way the transmission takes place in Bluetooth. The reason for the collision between ZigBee and Bluetooth is that both tend to access the same channel for transmission because the frequency band is same 2.4GHz. So if the transmission is already taking place in ZigBee and Bluetooth sends its data packets within the range of transmission of ZigBee then collisions is observed. This results in decrease in throughput.

IV. BLUETOOTH ADAPTIVE SOLUTIONS

4.1 Intelligent Frequency Hopping

Due to the fact that frequency hopping devices do not continually transmit at the same frequency, they have an inherent level of robustness. Hopping means that the probability of colliding with the transmission of another narrowband device at any particular time is very small. This can be easily concluded from Figure 4.1. Since the blue rectangles are very sparse in the time versus frequency plot, the probability of colliding with traffic in the band is quite small [14].

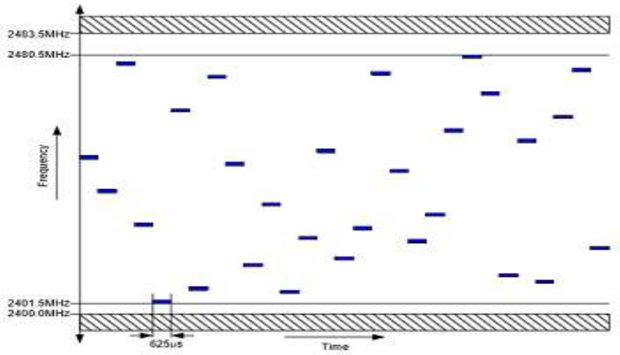

Fig 4.1 Bluetooth Frequency Occupancy [15]

If the hop sequences were designed to actively avoid other devices in the band, both the performance of Bluetooth devices and other devices in the band could be improved. For example, if a Wi-Fi device were active on Wi-Fi channel six, it would be advantageous for the Bluetooth device to never transmit in the frequency range 2.429 GHz to 2.445 GHz (see Fig 4.2), since any transmission in this range could result in a Bluetooth and/or Wi-Fi transmission error[15].

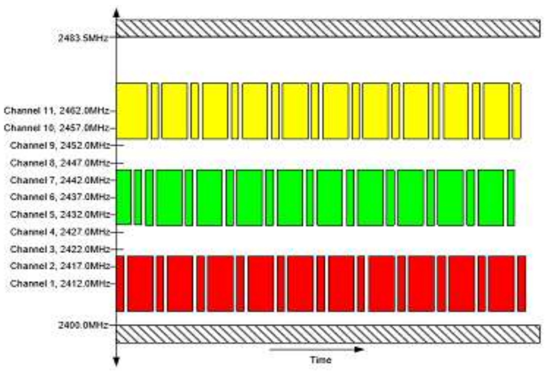

Fig 4.2 Frequency Occupancy of Three Wi-Fi networks [15]

There is intelligent frequency hopping schemes that would allow for enhancement in throughput. Such hopping sequences can be design based on the fact that it is better to have several non-interfered (good) hop frequencies in a row rather than alternating randomly between non-interfered and interfered (bad) hop frequencies. Since acknowledgements are embedded into Bluetooth packets, throughput can be improved by hopping through a sequence of non-interfered hop frequencies and thereby not needlessly retransmitting any data due to lost acknowledgements. Designing hop sequences that have runs of good hop frequencies and runs of bad hop frequencies; have been shown to significantly increase the performance of Bluetooth and Wi-Fi devices.

4.2 Transmit Power Control

When using a shared resource such as the 2.4GHz ISM band, it is important to not use it more than is actually required. This can be considered of as a golden rule for using congested bands. For example, if it is possible that two devices in the band can communicate by transmitting at a power level of 4 dBm, it is an over usage of the band to transmit at 20 dBm. By transmitting too much power in the band, the overall capacity per area is reduced and it would lead to interference with the communications of other users of the band.

Since the distance between devices does not change rapidly, the required transmit power does not tend to change rapidly either. This means that both Bluetooth and Wi-Fi devices can add dynamic power control without degrading the performance of either device. However, the fact that devices are no longer transmitting at their maximum power levels means that all devices in the area are more likely to be able to communicate with one another successfully [16].

V. EXPRIMENTATION

5.1 Experimentation is carried out in Matlab R2013a.

Table No.1 Simulation parameters for Bluetooth and Wi-Fi

	Bluetooth	Wi-Fi
Power	10mW	100 mW
Distance	10-15m	5 Km
Frequency Range	2.4 GHz	2.4 GHz
Modulation Technique	GFSK	QPSK
Data Rate	1Mbps	1-25 Mbps

In figure 5-1, the scenario can be observed in which only Bluetooth is present in the plane, According to Bluetooth standards, distance between Bluetooth transmitter and receiver should be less than 10m. Following fig shows the performance of Bluetooth transmitter and receiver as a function of distance.

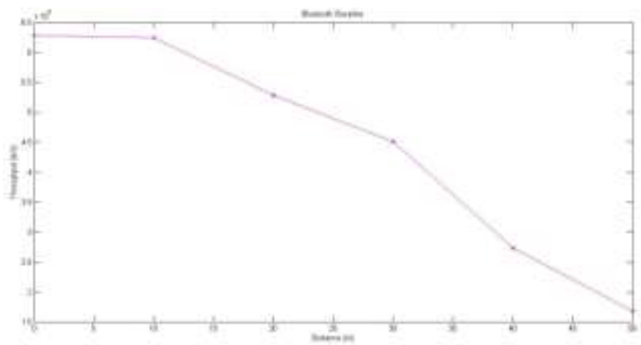

Fig. 5.1 Bluetooth Baseline Throughput

If the distance between Bluetooth transmitter and Bluetooth receiver is near about 10-15m, we get throughput about 0.64 Mb/s. As the distance between Bluetooth transmitter and receiver increases, Bluetooth throughput starts to decrease. At distance of 50 m get throughput 0.29 Mb/s.

Fig 5.2 shows Bluetooth performance in the presence of Wi-Fi (802.11b). Bluetooth performance is affected when there is interference caused by Wi-Fi. Bluetooth throughput is decreases to 0.48 Mbps at distance of 10m.

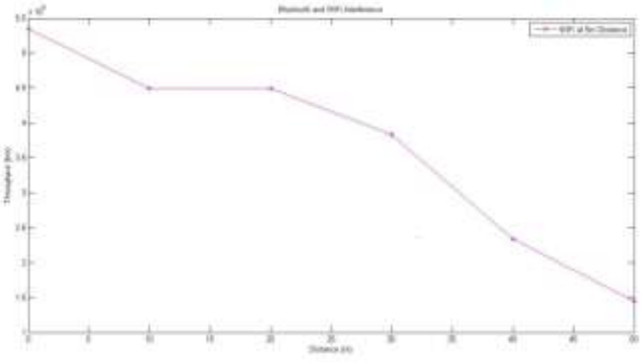

Fig 5.2 Bluetooth Throughput with Wi-Fi Interferer

VI. CONCLUSION

Different interference cases and adaptive solutions to mitigate interference and enhance the throughput of Bluetooth are discussed in this paper. Experimentation results show if the distance between Bluetooth transmitter and Bluetooth receiver increases throughput decreases. Bluetooth throughput performance is evaluated in the presence of Wi-Fi. Bluetooth throughput is decrease further.

VII. ACKNOWLEDGMENT

I greatly thank to my guide Prof. Mrs. S.A. Shirsat, Professor, E&TC Department, SCOE, for guiding me in preparation of this paper and for her valuable suggestions and help.

REFRENCES

[1] Oren Eliezer, Matthew Shoemake, “Bluetooth and Wi-Fi co-existence schemes strive to avoid chaos” RF wireless connectivity paper. November 2001. Pp. 66-72.

[2] S. Zurbes, W. Stahl, K. Matheus, and J. Haartsen, “Radio network performance of Bluetooth ,” in Proceedings of IEEE International Conference on Communications, ICC 2000, New Orleans, LA, June 2000, vol. 3, pp.1563–1567.

[3] R. Challooa, A. Oladeindea, N. Yilmazer, S. Ozcelik, L.Challoo “An Overview and Assessment of Wireless Technologies and Coexistence of ZigBee, Bluetooth and Wi-Fi Devices”, Complex Adaptive Systems, Publication 2, Conference Organized by Missouri University of Science and Technology 2012- Washington D.C.

[4] Jim Lansford, Adrian Stephens, and Ron Nevo, Mobilian Corporation “Wi-Fi (802.77 b) and Bluetooth: Enabling Coexistence”, September /October 2010.

[5] Bluetooth-Wi-Fi coexistences | A White Paper from Laird Technologies.

[6] Gurpreet Singh, Raghav Bhardwaj, Karamjeet Singh, Sahil Mehla , “ZigBee: A Review”, International Journal of Computer Science and technology, Vol. 3, Issue 1, Jan-March 2012.

[7] Matthew Loy, Raju Karingattil, Louis Williams, “ISM-Band and Short Range Device Regulatory Compliance Overview”, Texas Instruments, May 2005.

[8] Code of Federal Regulations, title 47, vol. 1, part 15, subpart C (Intentional Radiators), section 247, US Government Printing Office, in the Oct. 1, 1998revision of 47CFR15.247, the relevant pages are 690-92.

[9] C. F. Chiasserini, and R. R. Rao, “Coexistence Mechanisms for Interference Mitigation Between IEEE 802.11 WLANs and Bluetooth,” Proc. INFOCOM 2002, 2002, pp. 590–98.

[10] R.G. Garroppo, et al, “Experimental assessment of co-existence of ZigBee, Wi-Fi, and Bluetooth devices” in IEEE 2011 proceedings.

[11] Min Song &Sachin Shetty & Deepthi Gopalpet “Coexistence of IEEE 802.11b and Bluetooth: An Integrated Performance Analysis”, IEEE Transactions on Consumer Electronics, vol.50, no. 2,April 2008.

[12]Kuruvilla Mathew and Mujahid Tabassum, Member, IAENG, “Analysis of Bluetooth and Zigbee Signal Penetration and Interference in Foliage”, Proceedings of the International MultiConference of Engineers and Computer Scientists 2016 Vol II, IMECS 2016, March 16 - 18, 2016, Hong Kong.

[13] N. Golmie,“Bluetooth Adaptive Frequency Hopping and Scheduling,” Proc. MILCOM ’03, Boston, MA, Oct. 2003.

[14] AnujBatra, Jin-MengHo, “Proposal for Intelligent BT Frequency Hopping for Enhanced Coexistence”, IEEE 802.15-01/082, Jan 2001.

[15] Matthew B. Shoemake, Ph.D., “Wi-Fi (IEEE 802.11b) and Bluetooth Coexistence Issues and Solutions for the 2.4 GHz ISM Band”, Texas Instruments, Version 1.1, February 2001.

[16] Matthew B. Shoemake, Proposal for Power Control for Enhanced Coexistence, IEEE 802.15-01/081, Jan 2001.