AC 2007-1360: A STUDY ON THE PERFORMANCE OF BLUETOOTH AND IEEE 802.11B COEXISTENCE

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A study on the performance of Bluetooth and IEEE 802.11b coexistence

Abstract

There is potential for interference between IEEE 802.11 wireless local area networks (WLANs) and Bluetooth (BT) piconets as both of them are operating in the 2.4 GHz Industrial, Scientific, and Medical (ISM) radio band. With IEEE 802.11b and Bluetooth growing popular, a lot of research is being conducted to improve the coexistence of both technologies in the ISM band. Current research has not given much attention in studying the effect of multiple Bluetooth piconet (scatternet) on an IEEE 802.11b WLAN network and vice versa. This paper presents the analysis of performance degradation in the IEEE 802.11b WLAN due to the presence of Bluetooth scatternet, using a simulation model. The OPNET Modeler® tool from OPNET, Inc. along with SuiteTooth model was used to model the components of Bluetooth and IEEE802.11b WLAN. The results of this simulation demonstrated that Bluetooth scatternet has a severe impact on the performance of WLAN in comparison to the impact that of WLAN on Bluetooth.

Introduction

Since the beginning of the 21st century, two innovations in the wireless radio technology have taken hold of the markets and captured attention of the public; Bluetooth Wireless Personal Area Networks (WPAN) and IEEE802.11b Wireless Local Area Networks (WLAN). These wireless communication technologies showed great promise in transforming how people work and communicate with each other.

Bluetooth and IEEE 802.11 standards utilise the same 2.4GHz Industrial, Scientific, and Medical (ISM) frequency band. However, as both technologies operate in the same frequency band, an issue of growing concern is the coexistence of these technologies in the same environment.

"Coexistence" is defined as the ability for multiple protocols to operate in the same frequency band without severe degradation to either's operation. Bacuse of the rapid growth of these devices, this issue of coexistence has recently become a significant topic of analysis and discussion throughout the industry. The most important factor that is likely to affect the coexistence of these technologies operating in the same environment is interference.

Numerous studies of the interference in the 2.4 GHz ISM band range have been carried out with different focus areas. Several publications have addressed the issue of interference both theoretically and by simulation.

In the early stage of Bluetooth specification development, Ennis[1] studied the effect of interference based on a mathematical model rather than actual usage of models. Haartsen and Zurbes[2] combined analytical studies with simulation to provide an insight on the impact of 802.11 Direct-Sequence WLAN systems on Bluetooth data and voice links. Punnoose et al.[3] presented experimental results for the performance degradation of Bluetooth and IEEE 802.11b Direct Sequence Spread Spectrum (DSSS) devices due to mutual interference. These experiments were conducted in a large outdoor open space and also in a lab environment which focused on characterizing the performance of 802.11b devices in the presence of Bluetooth interference.

Several Studies have been conducted by Golmie et. al.[4-6] from the National Institute of Standards and Technology (NIST) with both the Bluetooth audio and data connections and also with varied 802.11b packet lengths. The results obtained were diverse due to the varying circumstances of interference in the 2.4 GHz band. The outcomes reflected the fact that there is some sort of interference that will occur depending on the different sources of interference.

As the Bluetooth and IEEE 802.11 continue to grow and gain popularity, it becomes apparent that more studies should be conducted to avoid the interference issue in the 2.4 GHz band. To achieve this, IEEE 802.15.2 Task Group has been formed specifically to consider proposals for mechanisms to improve the level of coexistence between Bluetooth and IEEE 802.11 devices and to come up with recommended practices derived from these.

Although different authors discussed the effect of Bluetooth on IEEE802.11b and vice versa, none of them have studied the effect of multiple Bluetooth piconets (scatternet) on IEEE 802.11b networks. This paper addresses this since the existence of multiple Bluetooth piconets and IEEE 802.11b networks is more likely.

This paper mainly intends to identify the effect of interference in terms of WLAN Data Drop, WLAN throughput and Bluetooth throughput. Through design and simulation of Wireless LAN and Bluetooth piconets, evaluation of the results will identify whether these technologies can coexist with each other without resulting in significant performance degradation.

Methodology

In this work, Computer simulation method is used for studying the effect of interference. Many successful performance evaluations have been conducted via software simulators. Simulators are widely available for many different platforms and protocols. One of the major advantages of simulators is their scalability, where it can provide simulations that involve a large number of networking devices without going to the expense of purchasing the real equipment.

However, the difficulties in choosing the right simulator for a given experiment were highlighted by Allman and Falk[7]. The majority of simulators are very difficult to use and understand. One of the biggest drawbacks of any simulator is the lack of modeling of non-networking events that may have impact on network performance. In the case of wireless networks, the user must try and replicate the exact environment conditions (e.g. atmospheric noise) that the network is used in.

Simulator

Two of the currently popular network simulators; within academia, commercial and industrial communities; that can perform analysis on Bluetooth are: Optimised Network Engineering Tools (OPNET Modeler)[8] from OPNET and Network Simulator (NS-2)[9] from the Virtual Internetwork Testbed project VINT.

In this work, OPNET Modeler 9.1 along with SuiteTooth Model was used for the network simulations. Few reasons for choosing OPNET over NS-2 were its features such as easier/Quicker Model Creation, flexible Model Development, Higher Simulation Performance, Large User Community etc. SuiteTooth (Bluetooth Simulation Model Suite) is

an open, modular framework for advanced PAN network performance engineering developed for OPNET simulation environment by Highland Systems.

SuiteTooth includes a generic ISM-band jammer as well as an adaptation of the standard OPNET 802.11b wireless LAN model. These models allow the effects of ISM band coexistence between the two wireless technologies to be quantified within a context of free space, indoor and user-defined path loss models. The custom RF pipeline models may be adapted to other ISM-band technologies.

Simulation Scenarios

Three scenarios were created in this work to study the coexistence between Bluetooth and Wireless LAN. All these scenarios consists of a WLAN station, a WLAN Access Point, and one or more Bluetooth devices In all these scenarios, the distance between Wireless LAN station and Access Point was fixed to 8 meters and the distance between Master and Slave was fixed to 2 meters. Table 1 shows the most important attributes used for the WLAN station, WLAN Access Point, Bluetooth Master Node and Bluetooth Slave Node.

Table 1: Important attributes of WLAN Station, WLAN Access Point, Bluetooth Master Node and Bluetooth Slave Node.

Device	Attribute	Value
WLAN Station	Data Rate	11 Mb/sec
	Power	10 mW
	Physical Characteristics	DSSS
	Access Point Functionality	Disabled
WLAN Access Point	Data Rate	11 Mb/sec
	Power	10 mW
	Physical Characteristics	DSSS
	Access Point Functionality	Enabled
Bluetooth Master Node	Data Rate	1 Mb/sec
	Power	1mW
	Bluetooth Radio Modulation	Bluehoc
	Sychnronous Connection Oriented (SCO) Packet type	HV3
Bluetooth Slave Node	Data Rate	1 Mb/sec
	Power	1mW
	Bluetooth Radio Modulation	Bluehoc
	Slave control Parameter	1 Ctrl

The network scenario 1 consists of a WLAN station, a WLAN Access Point, and two Bluetooth devices, one as master and another as slave as shown in figure 1.

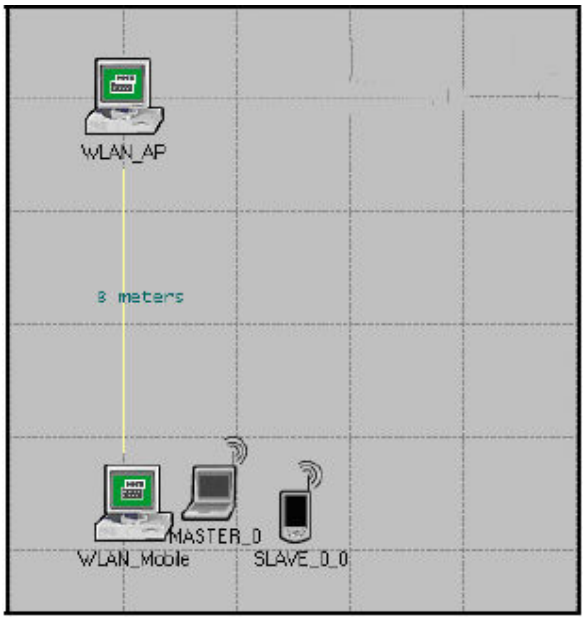

Figure 1. Scenario 1 – WLAN and PICONET with 1 slave

The network scenario 2 consists of a WLAN station, a WLAN Access Point , and eight Bluetooth devices, one as master and seven as slaves as shown in figure 2.

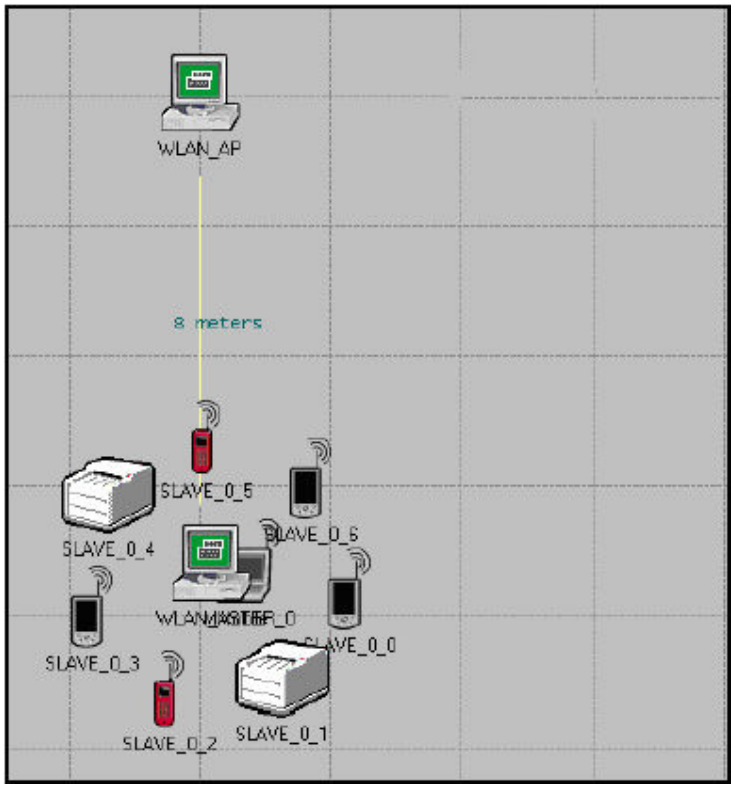

Figure 2. Scenario 2 – WLAN and PICONET with 7 slaves

The network scenario 3 consists of a WLAN station, a WLAN Access Point, and two Piconets (scatternet): two master and fifteen slaves as shown in figure 3.

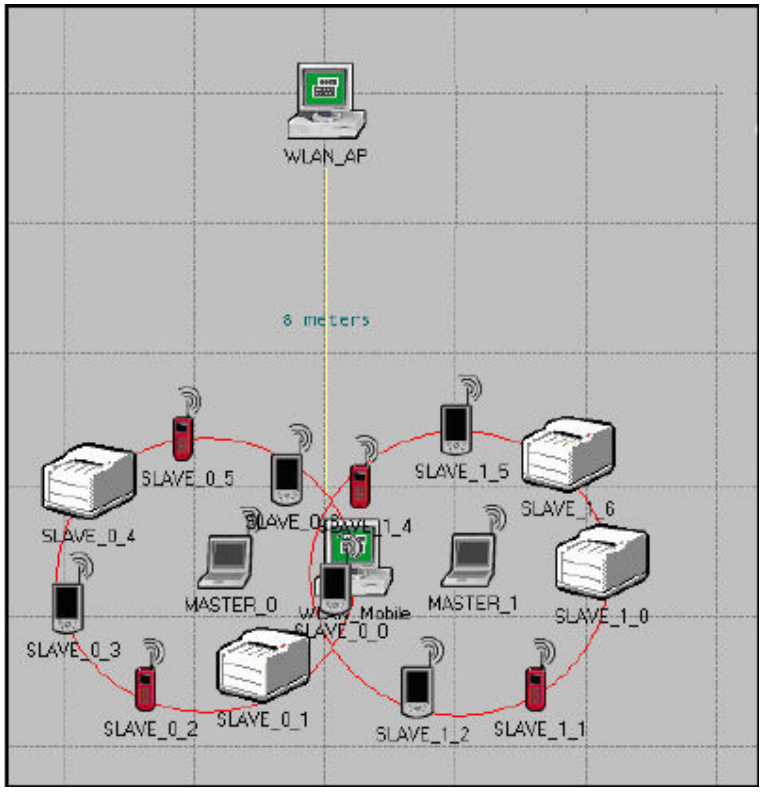

Figure 3. Scenario 3 – WLAN and Scatternet

Data Gathering

The performance of coexistence between Bluetooth and Wireless LAN can be analyzed using the various metrics such as Data Dropped, WLAN Delay, WLAN Throughput, Bluetooth FEC throughput, Bluetooth throughput etc. In this paper the results of WLAN Data Dropped, WLAN throughput and Bluetooth throughput were studied and presented. These measurements were conducted on all three scenarios by running the simulation for 180 seconds of time.

Results and analysis

In order to study the performance of WLAN in Bluetooth and vice versa, two types of statistic results were measured and are discussed.

Wireless LAN Data dropped

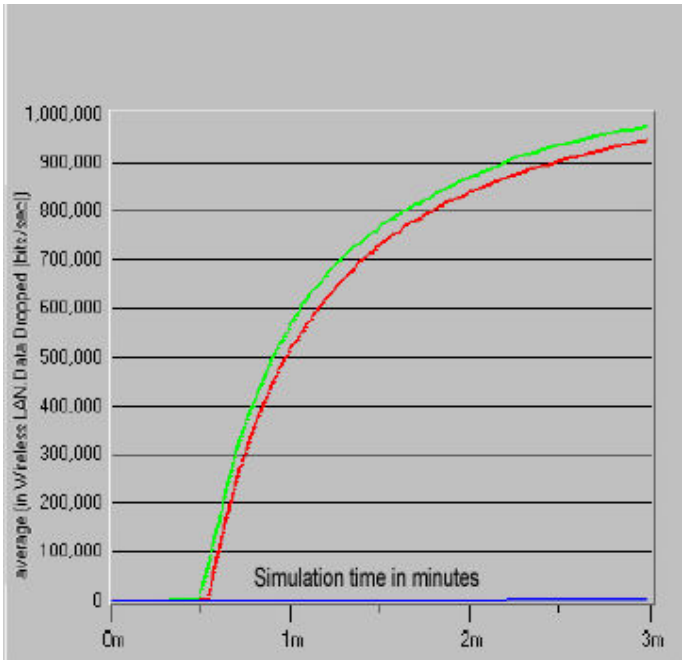

Figure 4. WLAN Data Dropped (bits/sec) comparison between the scenarios

Figure 4 shows the amount of data dropped in the wireless LAN for all the three scenarios. In Scenario 1, It can be seen that there is no data being dropped in the initial 2 minutes of the simulation. Thereafter there is a rise in the number of data being dropped. One can observe the drop of 10 bits/sec of data between 2 minutes and 2.5 minutes, then stabilizing for quarter of a minute and again the rise of data drop to 55 bits/sec at 2.75 minutes and holding at the same rate.

In scenario 2 and 3, there is no data being dropped in the initial 50 seconds of the simulation. Thereafter, there is a rise in the number of data being dropped. Between 50 seconds and 3 minutes time of the simulation, the drop of data is around 900000 bits/sec in the former case, while this is 990000 bits/sec in the later.

Wireless LAN Throughput

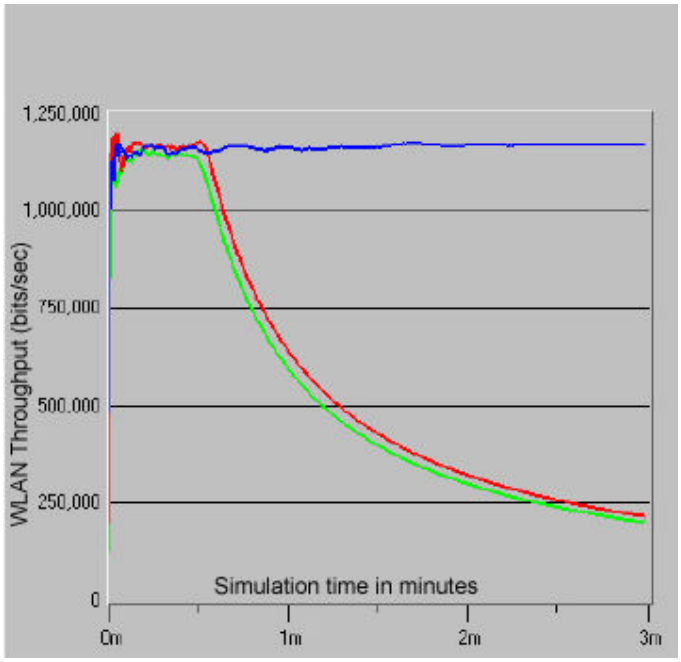

Figure 5. WLAN throughput (bits/sec) comparison between the scenarios

Figure 5 shows the WLAN throughput in the wireless LAN for all the three scenarios. In scenario 1, the Throughput on the wireless LAN was found to stabilize just after the initial start of the simulation to a value below 1250000 bit/sec.

In scenario 2 and 3, the Throughput was found to be below 1250000 bits/sec at the beginning of the simulation and it dropped just below 250000 bits/sec at the end of simulation.

Bluetooth Throughput

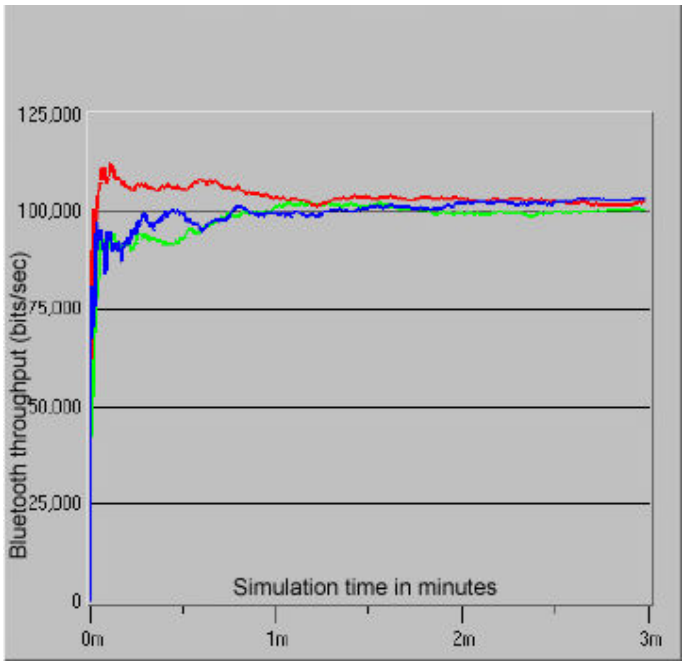

Figure 6. Bluetooth Throughput (bits/sec) comparison between the scenarios

Figure 6 shows the Bluetooth throughput in the wireless LAN for all the three scenarios. In all the three scenarios, the Bluetooth Throughput was found to stabilize just after the initial start of the simulation to a value around 100000 bit/sec. From the Bluetooth Throughput for all the three scenarios, It can be seen that there is no much difference in the throughput between the three scenarios.

From the figures 4 and 5, it is clear that the increase in number of Bluetooth devices has increased the wireless LAN data drop and decreased the WLAN throughput. This shows that as high throughput is required in a network, the presence of the multiple Bluetooth piconets poses a threat to the WLAN environment and solutions should be found to solve this problem.

It can be seen that there is not much difference in the Bluetooth throughput between the three scenarios. This is an indication that the WLAN has no effect in the throughput of the Bluetooth devices.

Discussions on educational value of the work

Since wireless access is growing in importance for many researches, teaching and other activities within the University, the community must aware that all equipment that operates in the frequency spectrum to be carefully installed, configured and monitored to avoid physical

and logical interference between components of different Network segments and other communication equipments.

A typical networking class student should be encouraged to analyze the impact of mutual interference and to propose the ways to minimize the potential for interference from those devices. Information Technology services should work with the University community to assist in phasing out other 2.4/5 GHz devices that are specifically used for digital communications in university-owned buildings.

Conclusions

Studying the interference that occurs between IEEE 802.11b networks and Bluetooth piconets is important because they operate in the same 2.4 GHz ISM frequency band. The possible interference will cause problems when both IEEE 802.11b and Bluetooth are used in the same physical location. A solution to the interference of these two technologies has become a more important area of research. The effect of Bluetooth and Wireless LAN technologies on each other has been investigated in this paper using OPNET simulation tool.

The significant effect of Bluetooth on an IEEE 802.11b network was that as the number of Bluetooth devices increased, there was degradation in the throughput and the data dropped increased. The more and more devices become Bluetooth ready and the IEEE 802.11b network multiply; the number of potential interferers could change rapidly and create greatly inconsistent throughputs.

It would be beneficial looking at studying the effect on various other metrics such as WLAN Delay, WLAN load, WLAN Media Access Delay, Bluetooth Data End –to-end Delay, Bluetooth Data Traffic etc. More information can be collected by simulating complicated scenarios with more than two WLAN devices, varying the distance between Access Point and WLAN, increasing the operating power of both WLAN and Bluetooth etc. Other future directions include exploring the physical characteristics for WLAN and Bluetooth and their respective performance in an interference-limited environment.

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