The coexistence of 802.11b/g and Bluetooth: An Experimental Comparison in LoS Conditions

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Abstract

In this paper we present experimental results for TCP throughput performance of the IEEE 802.11b/g standard in the presence of Bluetooth (BT) interference. The throughput of an IEEE 802.11b/g network is measured in a LoS environment. The results demonstrate that 802.11g is substantially more sensitive to BT interference than 802.11b.

1. Introduction

Currently, the trend towards indoor internet distribution in libraries, airports, hotels, conference centres and home environments is based on the use of Wireless Local Area Network (WLAN) technologies. The most widely used WLAN standards are developed by the IEEE and identified as the IEEE 802.11 standards for wireless connectivity. They are usually deployed as a wireless extension for broadband access to the network. IEEE 802.11b offers data rates up to 11 Mb/s [1] which makes it ideal for distributing audio files, still images, downloading games and VoIP phones. The IEEE 802.11g [2] standard offers data rates up to 54 Mb/s and is suitable for the distribution of real-time video and voice over WLAN.

Bluetooth (BT) technology [3] is regarded as a wireless personal area network (WPAN) system that provides wireless connectivity (up to 10 m) between mobile devices such as cellular phones, headsets, PDAs, digital cameras, laptop computers and other peripherals. The technology enables the design of low-power, small-sized, low-cost radios that can be embedded in existing portable devices.

These two systems (IEEE 802.11b/g WLANs and WPANs) both operate in the 2.4 GHz industrial, scientific and medical (ISM) frequency band, i.e., the unlicensed spectrum. WLANs and BT are complementary rather than competing technologies, and many applications require WLANs and BT to operate simultaneously and in close proximity. Under these conditions, interference conflicts between 802.11b/g and BT are unavoidable.

In order to investigate the effect of Bluetooth interference on the IEEE 802.11b transmission performance three experimental studies have been carried out in different interference scenarios. These experimental studies showed that the measured throughput performance of an IEEE 802.11b WLAN is degraded in the presence of Bluetooth interference. The amount of throughput degradation depends on the interference scenario and the distance between the 802.11b receiving device and the BT transmitting device. [4-6]. However, no studies have been published that quantifying the impact of BT interference on 802.11g. In this paper, we present new measurements of the IEEE 802.11g throughput for a Line of Sight (LoS) topology when there is BT interference.

2. Experimental Equipment

The IEEE 802.11b card (Intel PRO/Wireless 2011LAN PC Card) (mobile station) that was used in the experiments was made by Intel while the IEEE 802.11g Mobile Station (MS) (WG511) and the Access Point (AP) (WG 602) wireless LAN system were made by Netgear. The system was configured as an infrastructure network in which a single Access Point was placed in a given location. Two Bluetooth devices (F8T003 ver.2) made by Belkin were used as interference sources. Measurements were then made in particular locations using three laptop computers and one desktop computer. The computers are

identified as desktop, laptop1, laptop2, and laptop3. We used the default 802.11b/g configuration, with both the RTS/CTS (Request-to- Send/ Clear-to-Send) signalling and encryption disabled. The benchmark program which was used to measure the throughput in these experiments is Qcheck from NetIQ which is a simple utility for network benchmarking on widows platforms.

3. Test and Measurement Scenarios

To test the impact of Bluetooth interference on IEEE 802.11b transmissions in a LoS environment the IEEE 802.11b throughput without BT interference was measured first. The Qcheck application sends 1000 Kbytes using a TCP format from the access point (AP) to the mobile station (MS) (i.e. the down link). The distance *D* between the AP and MS was varied from 5m up to 30 m. Second, the 802.11b throughput was measured when a source of BT interference was placed at distance *d* equal 2, 5 and 10 m, respectively, from the 802.11b MS. The distance between the two BT devices R is kept constant at 2 m. Measurements of the 802.11b throughput were repeated 9 times and the average throughput determined. A schematic of the experimental arrangement is shown in Figure1. The measurements for the 802.11g MS were then made for the same operating environment.

4. Results and Discussion

Figure 2 shows TCP throughput performance of an 802.11b WLAN both in the absence and then in the presence of Bluetooth interference. In the absence of BT interference, the TCP throughput remains almost constant over the range investigated and achieves an average value of approximately 6.4 Mb/s. In the presence of BT interference, the TCP throughput falls to 5.7, 5.9, and 6 Mb/s when the distance *d* between the BT1 and MS devices is equal to 2, 5, and 10 m, respectively. The distance between the AP and MS *D* was varied between 5 and 30 m and over this range the TCP throughput generally decreased with increasing range. The worst TCP throughput performance is obtained when *d* is equal to 2 m and then slightly improves when *d* is equal to 5 m. At *d* equal to 10 m, the TCP throughput degrades slowly until *D* is equal to 25 m and then it degrades to 4.8 Mb/s at *D* equal to 30 m.

Figure 3 shows the TCP downlink throughput performance of 802.11g again using a LoS topology. The maximum TCP throughput (i.e. No BT) is 18 Mb/s and this degrades to 14.5 Mb/s at *D* equal to 30 m due to path loss. The results also show that when the BT device is 2 m away from the MS i.e. *d* equal to 2 m, the TCP throughput falls to 13.8 Mb/s at *D* equal to 5 m and as *D* increases the throughout decreases until it reaches 5.2 Mb/s at *D* equal to 30 m. At *d* equal to 5 and 10 m, the TCP throughput performances are similar. The throughput drops to approximately 14 Mb/s when is *D* equal to 5 m and decreases as *D* increases until it reaches 8 Mb/s at *d* equal to 5m and 9.5 Mb/s at *d* equal to 10 m when the distance between the AP and MS is equal to 30 m. From Figures 2 and 3 the percentage degradation in the throughput was calculated in order to quantify the difference between the 802.11b and 802.11g throughputs in the presence of BT interference. The results are presented in Table 1. It is clear from the results in Table1 that the 802.11g throughput is more sensitive to BT interference than 802.11b.

5. Conclusions

In this paper, we have presented the measured throughput performance of IEEE 802.11b/g devices when transmitting in the presence of Bluetooth interference using a LoS topology. The experimental results demonstrate the higher sensitivity of 802.11g to BT interference than 802.11b. At D = 10 m between AP and MS and d = 2 m between the BT and MS, the 802.11b throughput is degraded by 11% while the 802.11g throughput is degraded by 30%. The mitigation of interference effects in 802.11g is a topic of further study by the authors.

6. References

[1] Standard, IEEE 802.11-1999, Part 11, August 1999." Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications,"

[2] Standard, IEEE 802.11g Part 11. 2003 " Wireless LAN Medium Access Control

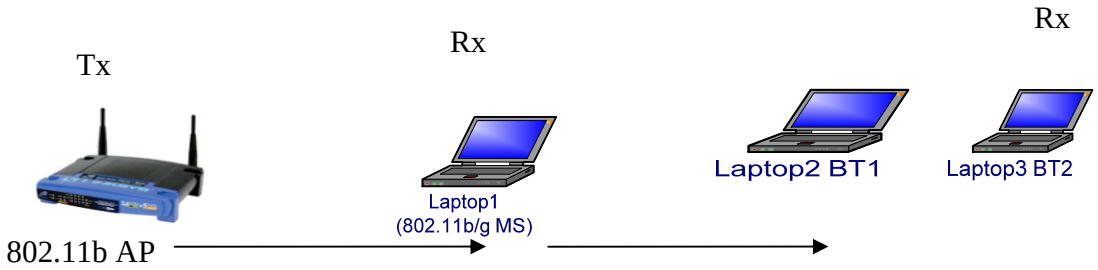
(MAC) and Physical Layer (PHY) specifications. Amendment 4: Further Higher data rate Extension in the 2.4 GHz band,"

[3] B. SIG, "Bluetooth Specifications." available online at: www.bluetooth.org/spec/

[4] J. del Prado and C. Sunghyun, "Experimental study on coexistence of 802.11b with alien devices," Vehicular Technology Conference, 2001. VTC 2001 Fall. IEEE VTS 54th Volume 2, pp.:977 – 98, 17-11 Oct 2001.

[5] J. M. Tomasz Keller, "Experimental Results of Testing Interferences in 2.4 GHz ISM Band," 33rd European Microwave Conference, pp.1034-1046 Munich, 2003.

[6] M. B. Shoemake, "White Paper: Wi-Fi (IEEE 802.11b) and Bluetooth," in Coexistence Issues and Solutions for the 2.4 GHz ISM Band: Texas Instruments, February 2001, Version 1.0. Available online at: http://wiki.unikonstanz.de/wiki/pub/Wireless/BlueTooth/Bluetoothcoexistence.pdf



D = Distance between AP and MS

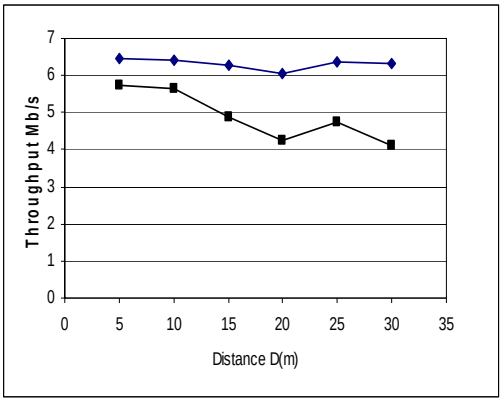
d = Distance between the BT transmitter and MS

R = Distance between the two BT devices

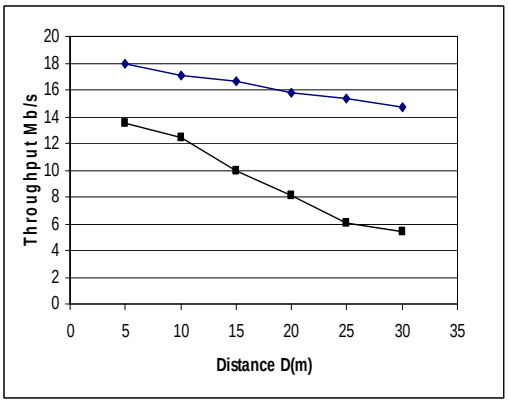
Fig.1. Schematic diagram of the interference scenario

D (m)	*d*=2m		*d*=5m		*d*=10m	
	11b	11g	11b	11g	11b	11g
5	10%	25%	8%	25%	5%	20%
10	11%	30%	6%	25%	5%	20%
20	30%	43%	30%	34%	20%	30%
30	33%	50%	28%	35%	23%	28%

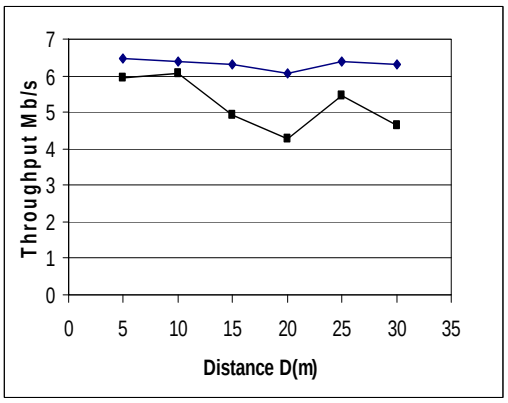
Table1. The percentage degradation in throughput of 802.11b/g due to BT interference



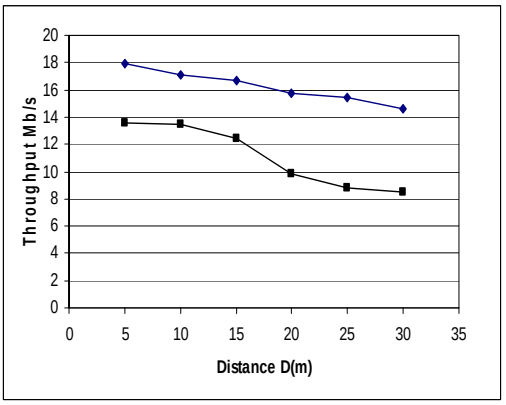
(a.i)



(b.i)



(a.ii)



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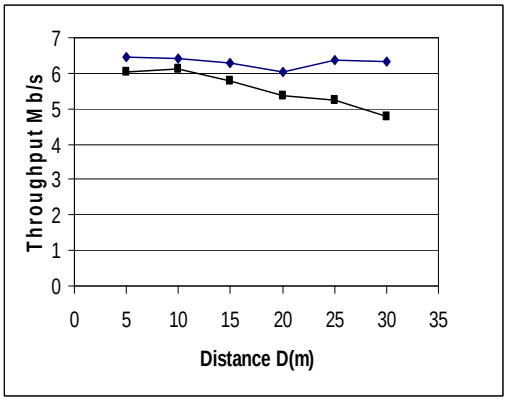

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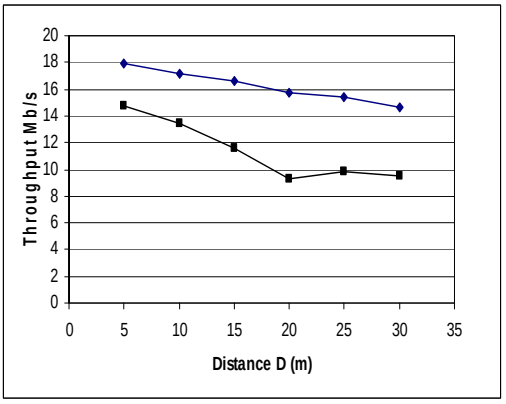

(b.iii)

Fig.2. TCP throughput performance of 802.11b with BT interference: (a.i) BT at 2m, (a.ii) BT at 5m and (a.iii) BT at 10m

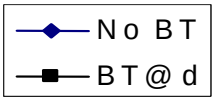

Fig.3. TCP throughput performance of 802.11g with BT interference: (b.i) BT at 2m, (b.ii) BT at 5m and (b.iii) BT at 10m