INDOOR DESIGN OF WIRELESS LOCAL AREA NETWORKS

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***Abstract*- Wireless local area networks (WLANs) are considered to be the fastest growing communication technology because of their low cost and high data rates. In this paper the effect of interference caused by Bluetooth devices and Microwave ovens on the performance of 802.11b WLANs is investigated. Results show that 802.11b WLAN are not affected severely while operating in the presence of a Bluetooth link and a Microwave oven. Furthermore, we use the signal level measurements to decide the number and locations of access points required to provide good WLAN coverage in a campus building at KFUPM.**

I. INTRODUCTION

The role of wireless communications in information exchange is growing rapidly because of the increased demand for portability and the low cost of wireless networks compared to wired networks. Emerging multimedia and Internet applications are requiring wireless networks to have high transmission rates with good quality. Several standards for wireless networks exist and are often classified according to their applications, distance ranges, transmission rates and networks topologies. For example, IEEE has adopted the 802.15 standard for wireless personal area networks (WPANs) appropriate for short-range applications (e.g., Bluetooth). For long-ranges, IEEE 802.16 standard was adopted for broadband applications. Cellular networks are considered more organized and centralized networks that can serve mobile and stationary users at wide ranges of distance. Wireless local area networks (WLANs) (IEEE 802.11 series) are standardized for medium-range networks with stationary users (as in offices and coffee shops).

Existing WLAN standards can provide a maximum transmission rate of 54 Mbps at the physical layer, where the actual data rates at the MAC layer are limited to 24 Mbps. Also, existing WLANs use the unlicensed spectrum (around 2.4 GHz), and hence they suffer from the interference caused by other wireless devices using the same spectrum. Recently, a lot of research in the literature was devoted to studying the interference effect of Bluetooth and Microwave oven on the performance of WLANs based on WLAN standards [1, 2]. It was shown through experimental measurements that Bluetooth and Microwave ovens do affect the performance of 802.11 WLANs. This was mainly due to the fact that the 802.11 is based on frequency-hopping spread-spectrum (FH-SS), which is affected by narrowband and wideband interference.

In this paper we present experimental procedures and results about the interference effects of Bluetooth and Microwave ovens on 802.11b WLANs. Furthermore, the signal strength level is used to measure the coverage area of an access point, which is in turn used to design the access point locations needed to provide a full WLAN coverage in a campus building.

The paper is organized as follows. We start with an overview of 802.11 and 802.11b WLAN standards in Section II. Experimental results about interference effects on WLAN performance are presented in Section III. In Section IV the design of a WLAN in a campus building is discussed. Conclusions are presented in Section V.

II. WLAN STANDARDS

A. IEEE 802.11

Probably the most commonly used and known wireless standard today is the IEEE 802.11 [4]. The 802.11x series refers to a family of specifications developed by the IEEE for WLAN technology. IEEE 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients. Basically WLAN is an ordinary LAN protocol which is modulated on high-frequency carrier waves. WLAN IEEE 802.11 is a natural extension to Ethernet LAN and the modulated protocol 802.3 Ethernet. There are three 802.11 standards that are based on frequency-hopping spread-spectrum (FH-SS), direct-sequence spread-spectrum (DS-SS) and Infrared technologies. IEEE 802.11 applies to WLANs and provides 1 or 2 Mbps data rates in the Industrial Scientific Medical (ISM) band at 2.4 GHz.

802.11 FH-SS standard hops randomly 2.5 times per second (very low compared to the Bluetooth hopping frequency at 1600 hops/second) [1]. DS-SS is another different spreading technique that carefully spreads the energy over a wide band in a controlled way. 802.11 DS-SS standard encodes data with 11-bit “chipping” sequence called Barker Sequence. Each 11-chip sequence corresponds to a single bit (0 or 1). These 11-chip sequences are then converted to a waveform (called a symbol) and are transmitted at a rate of 10^6 symbol per second (1 MSps) using binary phase shift keying (BPSK) modulation technique. BPSK switches the carrier phase between two different phases representing bits 1 or 0. Thus BPSK transmits one bit per symbol transmitted. Quadrature phase shift keying (QPSK) modulation is used to achieve 2 Mbps rate by using four different phases to transmit two bits per symbol.

B. IEEE 802.11b

There are several specifications and extensions to the IEEE 802.11 family, among which the 802.11b standard (also referred to as 802.11 high rate or Wi-Fi). The 802.11b achieves higher data rates than the original 802.11 standard by changing the coding technique from Barker sequence to complementary coding keying (CCK). The available data rates in 802.11b is 5.5 Mbps and 11 Mbps. CCK consists of a set of 64 eight-chip codewords. The receiver can accurately distinguish between different codewords, even in noisy and multipath environments due to the unique mathematical properties of these codewords. In the 5.5 Mbps and 11 Mbps data rates CCK is used to encode four and eight bits per symbol, respectively. Both speeds use QPSK as there modulation technique and 1.375 MSps. Just like the 802.11 standard the transmission band of 802.11b is 2.4 GHz, however 802.11b uses only DS-SS and, not both DS-SS and FH-SS as the 802.11 does. 802.11b is the most commonly used standard of the 802.11 family. Table I lists the data rates and modulation schemes available in 802.11 and 802.11b standards.

TABLE I
DATA RATES AND MODULATION SCHEMES IN 802.11 AND 807.11b STANDARDS

Data Rate	Code Length	Modulation	Symbol Rate	Bits/Symbol
1 Mbps	11 (BS)	BPSK	1MSps	1
2 Mbps	11 (BS)	QPSK	1MSps	2
5.5 Mbps	8 (CCK)	QPSK	1.375 MSps	4
11 Mbps	8 (CCK)	QPSK	1.375 MSps	8

An overall comparison of existing WLAN standards is summarized in Table II. IEEE 802.11a is another extension to the 802.11 WLAN standard and provides data rates varying from 6 to 54 Mbps in the 5 GHz band [5]. 802.11a uses OFDM for transmission in place of FH-SS or DS-SS. In the table HIPERLAN (High Performance Radio LAN) standard is also listed. HIPERLAN is a WLAN standard set by the European Telecommunications Standards Institute (ETSI) and is very similar to the IEEE 802.11a standard. It operates in the 5 GHz band, uses OFDM in the air-interface and provides similar data rates as 802.11a. Moreover, HIPERLAN is compatible with third-generation (3G) cellular networks and has different variations of the MAC-layer interface.

TABLE II
COMPARISON OF THE DIFFEREN T WLAN STANDARDS

	Bluetooth - IEEE-802.15	802.11b	802.11g	802.11a	HiperLAN2
Frequency	2.4GHz	2.4GHz	2.4GHz	5.2GHz	5GHz
Data rate	1Mbps	11Mbps	36Mbps	54Mbps	54Mbps
Max data rate at layer	721Kbps	5Mbps	22Mbps	32Mbps	32Mbps
Range	10m	Up to 100m	Up to 100m	100m	TBD
Communication Technique	FHSS	DSSS	OFDM	OFDM	OFDM
Timing	1999 December	1998 July	2001	2001	2003
Key Players	SIG members, IBM, Intel, Nokia,	Wi-Fi members, Lucent, Intersil,	Intersil, TI(Alantro)	Wi-Fi, Atheros, Intel Radiata,	Ericsson is promising HiperLAN 2 products at

III. Interference Effects

In this section the interference effects of Bluetooth and Microwave ovens are investigated. The WLAN cards are from Avaya Company as well as the measurement software, which provides measurement data about the packet loss rate and the signal-to-noise ratio (SNR). The WLAN cards are attached to a Remote-Outdoor-Router (ROR). Two of these RORs are used to study the effect of the Bluetooth and the microwave oven interference on the WLAN as follows.

The experimental setup used to study the effect of Bluetooth is shown in Figure 1. Initially, the WLAN devices and the Bluetooth devices were located on the same axis. Then, a 7 MB file was transferred between the Bluetooth devices. The packet loss rate and SNR were observed. In this scenario maximum packet loss rate was recorded to be 1%. Then we gradually moved the axis of the Bluetooth devices away from that of the WLAN equipment. The maximum packet loss rate decreased to zero in this case, which indicates that the effect of one Bluetooth link on the performance of 802.11b WLANs is negligible. This agrees with the results [1] where the effect of Bluetooth on the performance of 802.11b WLANs was also studied.

The experimental setup used to study the effect of Microwave ovens on the performance of 802.11b WLANs is shown in Figure 2. As in the case of Bluetooth results showed that the effect of Microwave ovens on the packet loss rate in a WLAN link is negligible. In [2] the effect of Microwave ovens on 802.11 WLAN was shown to be severe. We conclude that the 802.11b WLAN standard is more robust to interference. This robustness is due mainly to the use of DS-SS in 802.11b compared to FH-SS used in 802.11 standard, where it known that DS-SS is more robust to interference than FH-SS.

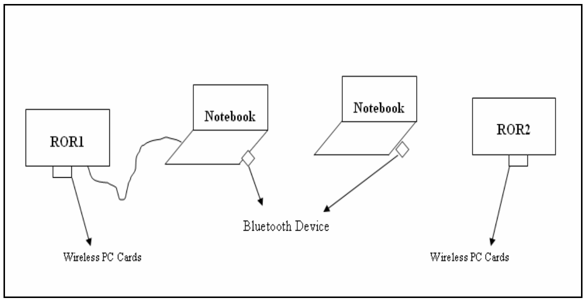


Figure 1: The setup for the Bluetooth interference test.

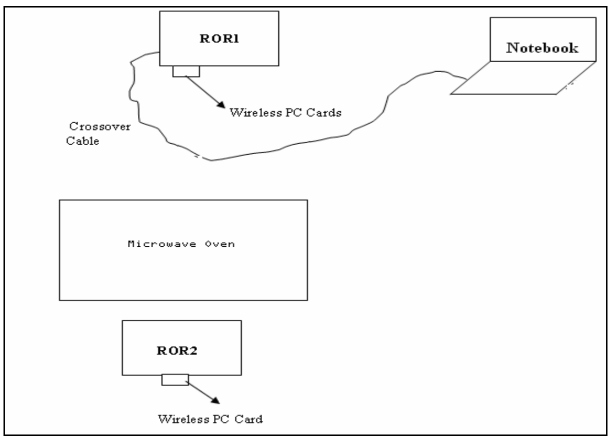
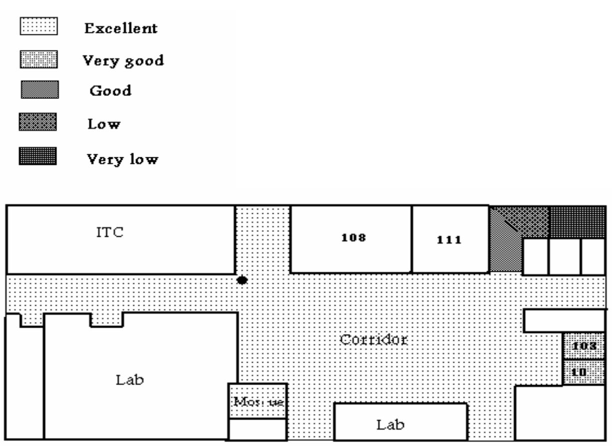


Figure 2: The setup for the microwave oven interference test.



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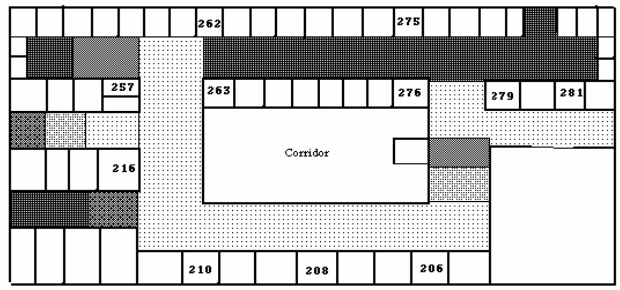


(b)

Figure 3: Building Layout with the access point located in the first floor. (a) First floor, (b) Second floor.

IV. WLAN DESIGN

The objective of this investigation was to determine the least number of access points needed to cover a building which houses many offices, lecture halls and classrooms. The SNR levels were measured and graded according to a five level scheme: Excellent, Very good, Good, Low, and Very Low.

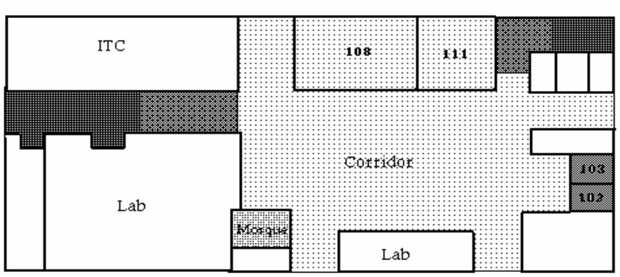
The experimental setup in this case is simple. An access point was placed at different points throughout the two-story building and the coverage in each case was noted based on the five levels mentioned above. A laptop with an 802.11b Wi-Fi card is used to measure the received signal quality.

Figure 3 shows the signal strength in both the first and second floor when the access point is located on the first floor between the left corridor and the open lounge area in the center of the building. In the figure, the access point is represented by a black dot. This configuration covers most areas in the first floor but corridors on the second level are not covered. Also, the right corner side of the first floor has poor signal levels.

Figure 4 shows what happens when the access point was located on the second floor next to room 208. In this case the corridors near the access point are well covered but the opposite corridor on the same floor has poor signal levels. Again, it seems that corners on either floor have problems receiving signals from the access point. If the access point on the second floor is placed on the opposite side near the second corridor then we have the signal levels shown in Figure 5. This configuration improved the signal level in the corridor but the rest of the building was poorly covered.

The tests have shown that the signal level drops significantly around corners. This meant that we had to allocate an access point for each corridor in the second floor. Also, our tests have shown that the big lounge in the first floor as well as all linked corridors will receive "Excellent" coverage if one access point is placed at the corner near the left corridor.

In conclusion, an access point has very good coverage inside the building in areas which are in the line-of-site coverage area of that access point even when walls are separating the two. However, if the line-of-site coverage is restricted by a few walls and the only access is through a sharp corner, the signal level will deteriorate significantly. It is therefore recommended to have an access point for each corridor if more than one exists. Figure 6 shows the final design of the access point layout in both floors.



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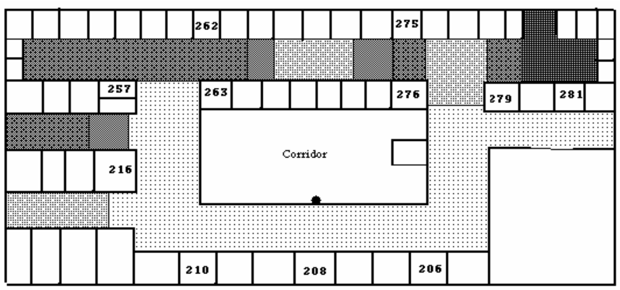

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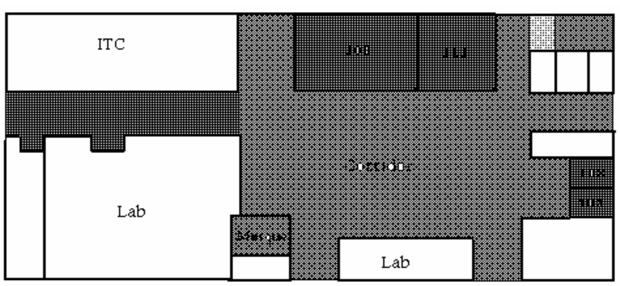
Figure 4: Building Layout with the access point located in the second floor. (a) First floor, (b) Second floor.



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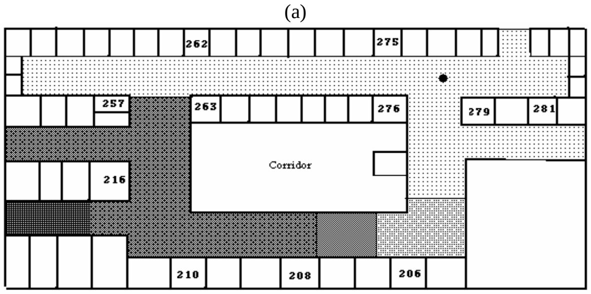

(b)

Figure 5: Building Layout with the access point located in the second floor. (a) First floor, (b) Second floor.

V. Conclusions

In this paper we presented experimental results about the interference effects of Bluetooth and Microwave ovens on the performance of 802.11b WLANs. It was shown that 802.11b standard is not affected severely when operating in the presence of a Bluetooth link and a Microwave oven. Moreover, we have demonstrated that a cheap design (less than $400) is enough to give good WLAN coverage in a typical campus building at KFUPM. We have also shown that corridors and corners are a major consideration when deciding the location of access points in a building.

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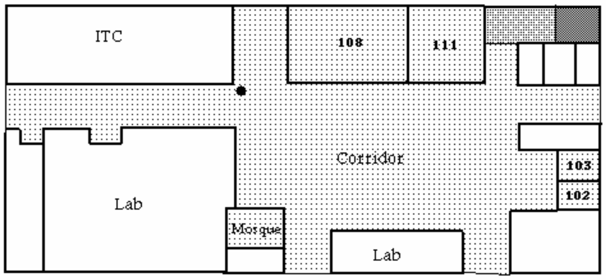

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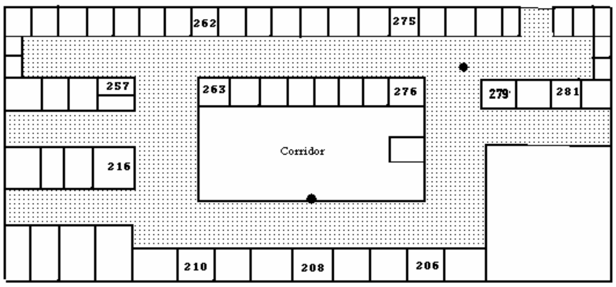

(b)

Figure 6: Building Layout with three access points and an excellent signal strength covering the whole building. (a) First floor, (b) Second floor.