Chapter 43
WI-FI Point-to-Point Links: Performance Aspects of IEEE 802.11a, b, g Laboratory Links

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Abstract Wireless communications using microwaves are increasingly important, e.g. Wi-Fi. Performance is a very relevant issue, resulting in more reliable and efficient communications. Laboratory measurements are made about several performance aspects of Wi-Fi (IEEE 802.11 a, b, g) point-to-point links using two types of access points from Enterasys Networks (RBT-4102 and RBTR2). Through OSI levels 3, 4 and 7, detailed results are presented and discussed, namely: latency, ICMP packet loss, TCP throughput, jitter, percentage datagram loss and FTP transfer rate.

Keywords WLAN · Wi-Fi · IEEE 802.11a · IEEE 802.11b · IEEE 802.11g · point-to-point links · wireless network laboratory performance measurements

43.1 Introduction

Wi-Fi (Wireless Fidelity) is a wireless communications technology whose importance and utilization have been growing for complementing traditional wired networks. Wi-Fi has been used both in ad hoc mode, for communications in temporary situations e.g. meetings and conferences, and infrastructure mode. In this case, an AP (Access Point) is used to permit communications of Wi-Fi devices with a wired based LAN (Local Area Network) through a switch/router. In this way a WLAN, based on the AP, is formed which is known as a cell. A WPAN (Wireless Personal Area Network) arises in relation to a PAN (Personal Area Network).

Point-to-point and point-to-multipoint configurations are used both indoors and outdoors, requiring directional and omnidirectional antennas. There are detailed

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studies about wireless communications, wave propagation [1,2] and WLAN practical implementation [3]. Studies have been made about long distance Wi-Fi links in rural areas [4,5].

Wi-Fi uses microwaves in the 2.4 and 5 GHz frequency bands and IEEE 802.11 a, 802.11 b and 802.11 g standards [6]. In ETSI (European Telecommunications Standards Institute) countries IEEE 802.11b and 802.11 g are used both in indoors and outdoors through 13 channels in the 2,400–2,485 MHz frequency band, permitting nominal transfer rates up to 11 and 54 Mbps, respectively. IEEE 802.11 a permits nominal transfer rates up to 54 Mbps. It is available in most European countries for indoor applications through four channels in both the 5,150–5,250 MHz and the 5,250–5,350 MHz frequency bands. In the same countries 11 channels are available in the 5,470–5,725 MHz frequency bands for both indoors and outdoors. As the 2.4 GHz band is increasingly used, leading to higher interferences, the 5 GHz band is interesting given lower interferences, in spite of larger absorption and shorter ranges. The standards mentioned use CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) as the medium access control. The 802.11 architecture has been studied in detail, including performance analysis of the effective transfer rate [7]. An optimum factor of 0.42 was determined for the effective transfer rate in 11 Mbps point-to-point links, giving an effective transfer rate of 4.6 Mbps. Studies are available about Wi-Fi performance in indoor crowded environments having significant obstacles to signal propagation [8].

Several measurements have been made at OSI levels 1, 3, 4 and 7 for point-to-multipoint and point-to-point configurations in the 2.4 GHz band [9, 10]. Results have also been reported for WiMAX [11], very high speed FSO [12] and Wi-Fi [13]. In the present work further results are presented and discussed for laboratory performance measurements of IEEE 802.11 a, b, g point-to-point links using different access points. We consider latency, ICMP packet loss, TCP throughput, jitter, percentage datagram loss, and FTP transfer rate.

The rest of the paper is organized as follows: Section 43.2 presents the experimental details i.e. the measurement setup and procedure. Results and discussion are presented in Section 43.3. Conclusions are drawn in Section 43.4.

43.2 Experimental Details

Two types of experiments were carried out, which are referred as Exp-A and Exp-B. In the measurements of Exp-A we used Enterasys RoamAbout RBT-4102 level 2/3/4 access points (mentioned as AP-A), equipped with 16–20 dBm IEEE 802.11 a/b/g transceivers and internal dual-band diversity antennas [14], and 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switches [15]. The access points had transceivers based on the Atheros 5213A chipset, and firmware version 1.1.51. They were parameterized and monitored through both the console using CLI (Command Line Interface) and a HTTPS (Secure HTTP) incorporated server. The configuration was for minimum transmitted power and equivalent to point-to-point, LAN to LAN mode, using the internal antenna. For the measurements of Exp-B we used Enterasys RoamAbout RBTR2 level 2/3/4 access points (mentioned as AP-B), equipped with 15 dBm IEEE 802.11 a/b/g cards [14], and 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switches [15]. The access points had RBTBH-R2W radio cards similar to the Agere-Systems model 0118 type, and firmware version 6.08.03. They were parameterized and monitored through both the console and the RoamAbout AP Manager software. The configuration was for minimum transmitted power i.e. micro cell, point-to-point, LAN to LAN mode, using the antenna which was built in the card.

Interference free channels were used in the communications. WEP (Wired Equivalent Privacy) encryption was not activated. No power levels above the minimum were required as the access points were very close. The results obtained in the present work were insensitive to AP emitted power level.

Both types of experiments, Exp-A and Exp-B, were made using the laboratory setup shown in Fig. 43.1.

For 7-echo UDP traffic injection (OSI level 4) the WAN Killer software was available [16]. Packet size was set to the default of 1,500 bytes. The traffic injector was the PC (Personal Computer) with IP 192.168.0.1, having the PC with IP 192.168.0.5 as destination. Latency was measured as the round trip time of ICMP (Internet Control Message Protocol) packets (OSI level 3) involving the PCs having IPs 192.168.0.2 and 192.168.0.6. Percentage packet loss was also measured for different ICMP packet sizes (32 and 2,048 bytes) through the same two PCs.

In addition, measurements were made for TCP connections and UDP communications, using Iperf software [17], permitting network performance results to be recorded. For a TCP connection, TCP throughput was obtained. For a UDP communication with a given bandwidth parameter, UDP throughput, jitter and percentage loss of datagrams were obtained. TCP packets and UDP datagrams of 1,470 bytes size were used. A window size of 8 kbytes and a buffer size of the same value were

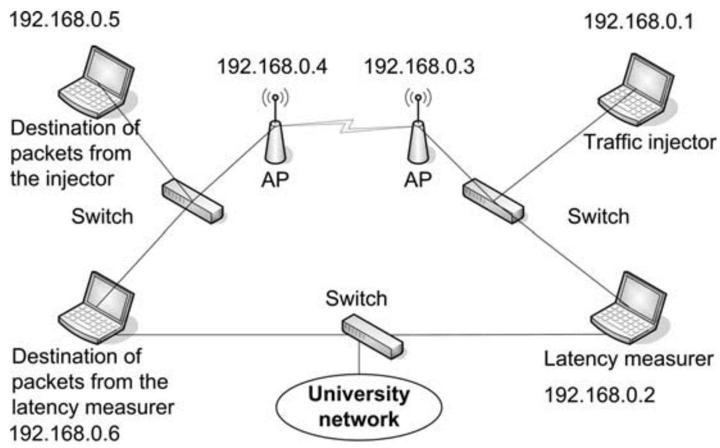

Fig. 43.1 Experimental laboratory setup scheme

used for TCP and UDP, respectively. A setup scheme similar to the one given in Fig. 43.1 was used, but having two PCs only. One, with IP 192.168.0.2 was the Iperf server and the other, with IP 192.168.0.6, was the Iperf client. Jitter, which can be seen as the smooth mean of differences between consecutive transit times, was continuously computed by the server, as specified by RTP (Real Time Protocol) in RFC 1889 [18]. This scheme was also used for FTP measurements, where FTP server and client applications were installed in the PCs with IPs 192.168.0.2 and 192.168.0.6, respectively.

Batch command files were written to perform the TCP, UDP and FTP tests. The results were obtained in batch mode and stored as data files in the client PC disk. Each corresponding PC had a second Ethernet network adapter to permit remote control from the official University network, via an additional switch.

43.3 Results and Discussion

Both access points AP-A and AP-B were configured, for every one of the standards IEEE 802.11a, b, g, with various fixed transfer rates. For every fixed transfer rate measurements were made, for both Exp-A and Exp-B, of latency and percentage packet loss for ICMP packet sizes of 32 and 2,048 bytes, with percentages of injected traffic varying from 0% to maximum values. In this way, data were obtained for comparison of the laboratory performances of IEEE 802.11 b (namely at 5.5 and 11 Mbps), 802.11 g and 802.11 a (namely at 12, 36 and 54 Mbps in both cases) links, measured at OSI levels 3 and 4 using the scheme of Fig. 43.1.

At OSI level 1 in Exp-B, for every one of the cases, the local and remote values of the signal to noise ratios SNR were recorded. The best SNR levels were observed for 802.11 g and 802.11a. The lowest noise levels were for 802.11 a. Similar trends were observed in Exp-A.

In each experiment type the measurements at OSI levels 3 and 4 permitted determination, for every standard and fixed transfer rate, of the maximum percentage of network utilization under quality conditions i.e. for values of latency and percentage packet loss less than 10 ms and 2%, respectively. Some sensitivity to AP type was observed. The average values obtained from Exp-A and Exp-B are shown in Table 43.1. We found that, for every standard, the maximum percentage of network utilization under quality conditions decreases with increasing fixed transfer rate. The best performance was, on average, for 802.11 a. The results obtained in Exp-A and Exp-B are illustrated for 802.11 a and 802.11 g at 36 Mbps in Figs. 43.2 and 43.3, respectively, where the data points were joined by straight lines.

Further measurements, using TCP connections and UDP communications at OSI level 4, were carried out for both Exp-A and Exp-B. In each experiment, for every standard and nominal fixed transfer rate, an average TCP throughput was determined. This value was used as the bandwidth parameter for every corresponding UDP test, giving average jitter and average percentage datagram loss. The results are shown in Figs. 43.4–43.6. In Fig. 43.4, polynomial fits were made for each AP

Table 43.1 Average maximum percentages of network utilization under quality conditions versus IEEE 802.11 a, b, g standards and fixed transfer rate (Mbps)

IEEE standard/ fixed transfer rate (Mbps)	5.5 (Mbps)	11 (Mbps)	12 (Mbps)	36 (Mbps)	54 (Mbps)
802.11b	70%	45%			
802.11g			60%	50%	40%
802.11a			65%	55%	40%

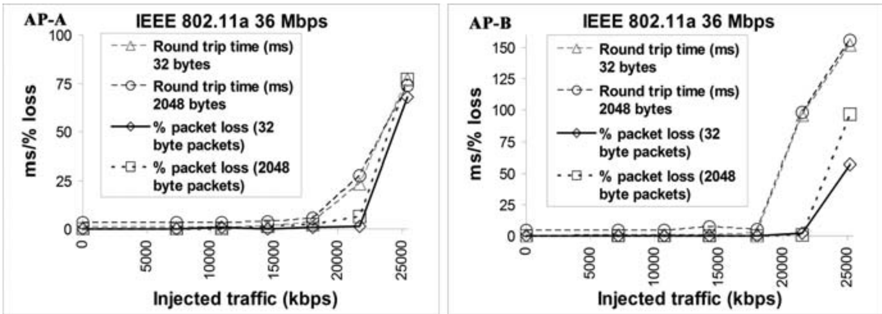

Fig. 43.2 Results for 802.11a, 36 Mbps; Exp-A and Exp-B

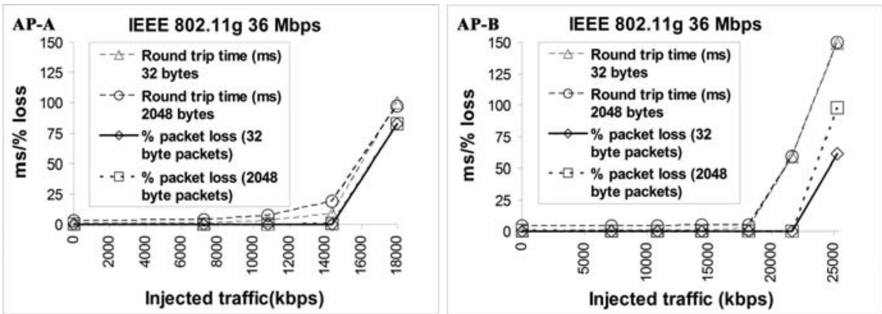

Fig. 43.3 Results for 802.11g, 36 Mbps; Exp-A and Exp-B

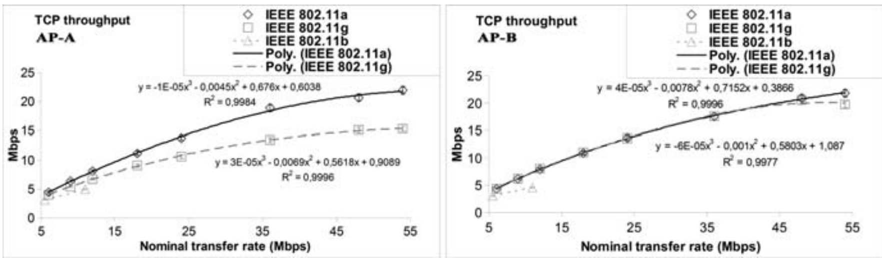

Fig. 43.4 TCP throughput results versus technology and nominal transfer rate; Exp-A and Exp-B

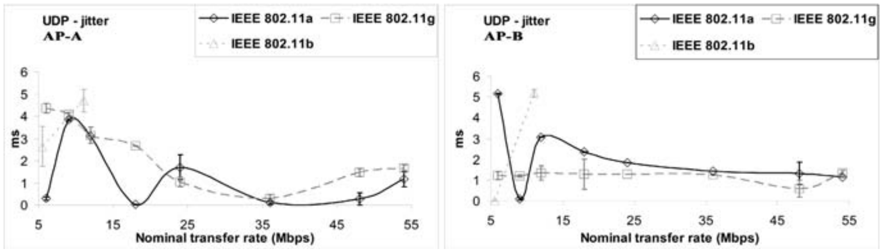

Fig. 43.5 UDP – jitter results versus technology and nominal transfer rate; Exp-A and Exp-B

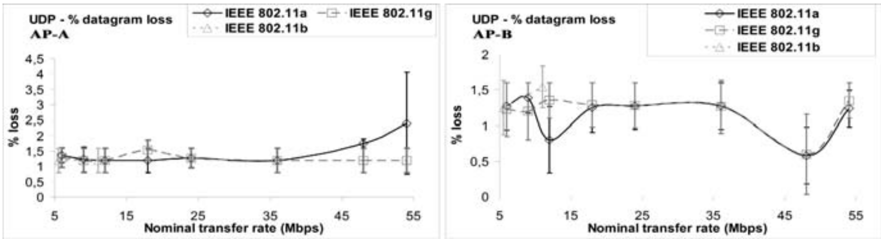

Fig. 43.6 UDP – percentage datagram loss results versus technology and nominal transfer rate; Exp-A and Exp-B

implementation of IEEE 802.11 a, g, where R^2 is the coefficient of determination. It follows that the best TCP throughputs are, by descending order, for 802.11 a, 802.11 g and 802.11 b. In Exp-A (Fig. 43.4), the data for 802.11 a are significantly higher (12–43%) than for 802.11 g. In Exp-B (Fig. 43.4), the data for 802.11 a are on average 2.5% higher than for IEEE 802.11 g. The best throughput performance was for AP-B. In Figs. 43.5 and 43.6, the data points were joined by smoothed lines. In Exp-A (Fig.43.5) the jitter data are rather scattered: jitter is, on average, higher for IEEE 802.11b (3.7 ms), g (2.3 ms). In Exp-B (Fig. 43.5), the jitter data show some fluctuations; jitter is, on average, higher for IEEE 802.11b (2.6 ms), a (2.1 ms). In both Exp-A and Exp-B (Fig. 43.6), generally, the percentage datagram loss data agree rather well for all standards. They are 1.3% and 1.2%, on average, respectively.

At OSI level 7, FTP transfer rates were measured versus nominal transfer rates configured in the APs for the IEEE 802.11b, g, a standards. Every measurement was the average for a single FTP transfer, using a binary file size of 100 Mbytes. The results from Exp-A and Exp-B are represented in Fig. 43.7. Polynomial fits to data are given. It was found that in both cases the best performances were, by descending order, for 802.11 a, 802.11 g and 802.11 b: the same trends found for TCP throughput. The FTP transfer rates obtained in Exp-A, using IEEE 802.11 b, were better than in Exp-B. The FTP performances obtained for Exp-A and IEEE 802.11a were slightly

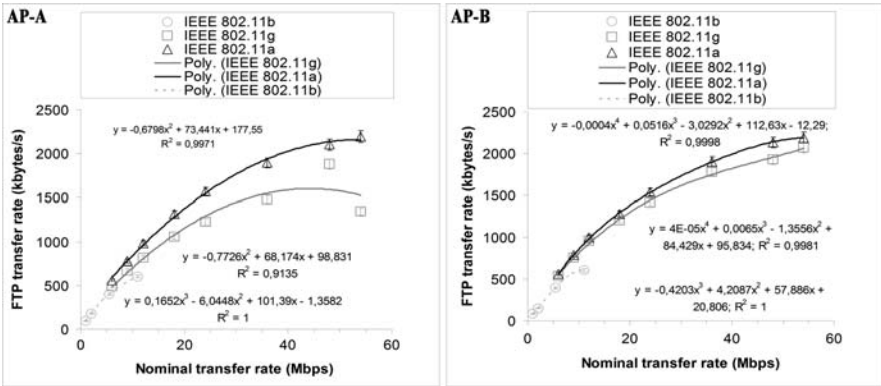

Fig. 43.7 FTP transfer rate results versus technology and nominal transfer rate; Exp-A and Exp-B

better in comparison with Exp-B. On the contrary, for Exp-A and IEEE 802.11 g, FTP performances were significantly worse than in Exp-B, suggesting that AP-B had a better FTP performance than AP-A for IEEE 802.11 g.

43.4 Conclusions

In the present work a simple laboratory arrangement was implemented that permitted systematic performance measurements of available access point equipments in IEEE 802.11 a, b, g point-to-point links. At OSI level 1, the best values of SNR were for 802.11 g and 802.11 a, while the lowest noise levels were for 802.11 a. At OSI levels 3 and 4, the measurements permitted to find the maximum percentages of network utilization under conditions of communications quality. Some sensitivity to AP type was observed. It was found that, for every standard, the maximum percentage of network utilization under quality conditions decreases with increasing fixed transfer rate. The best performance was, on average, for 802.11 a.

Through OSI level 4 the best TCP throughputs were found, by descending order, for 802.11 a, 802.11 g and 802.11 b. TCP throughputs were also found sensitive to AP type. The lower values of jitter were, on average, found for IEEE 802.11 a, and 802.11 g. For the percentage datagram loss, a reasonably good agreement was found for all standards. At OSI level 7, the measurements of FTP transfer rates have shown that the best performances were, by descending order, for 802.11 a, 802.11 g and 802.11 b: the same trends found for TCP throughput. FTP performances were also found sensitive to AP type. Additional performance measurements either started or are planned using several equipments, not only in laboratory, but also in outdoor environments involving, mainly, medium range links.

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