Laboratory Performance Comparison of Wi-Fi Point-to-Point Links: a Case Study

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Abstract —**Wireless communications are increasingly important. Performance is a very relevant issue. Laboratory measurements are made about several performance aspects of Wi-Fi IEEE 802.11a, b, g point-to-point links, using two types of access points from Enterasys Networks. Detailed results are presented and discussed, namely at OSI levels 4 and 7: TCP throughput, jitter, percentage datagram loss, and FTP transfer rate.**

I. INTRODUCTION

Wireless communications are increasingly important for their versatility, mobility and favourable prices. As a particular case, 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 arising e.g. from needs in meetings, conferences, laboratories 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 (Wireless LAN), based on the AP, is formed which is known as a cell. A WPAN (Wireless Personal Area Network) arises in relation to a Personal Area Network, where communications of personal electronic devices are involved.

Point-to-point and point-to-multipoint configurations are used both indoors and outdoors, requiring specific directional and omnidirectional antennas. Detailed studies are available about wireless communications, wave propagation [1,2] and WLAN practical implementation [3]. Studies have been reported about long distance Wi-Fi links in rural areas [4,5].

Wi-Fi uses microwaves in the 2.4 and 5GHz frequency bands and IEEE 802.11a, 802.11b and 802.11g standards [6]. In ETSI (European Telecommunications Standards Institute) countries, IEEE 802.11b and 802.11g are used both in indoors and outdoors through 13 channels in the 2400-2485 MHz frequency band, permitting nominal transfer rates up to 11 and 54 Mbps, respectively. IEEE 802.11a permits nominal transfer rates up to 54 Mbps. It is available in most European countries for indoor applications through 4 channels in both the 5150-5250 MHz and the 5250-5350 MHz frequency bands. In the same countries 11 channels are available in the 5470-5725 MHz frequency bands for both indoors and outdoors. As the 2.4 GHz band has been 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].

Performance is very important, leading to more reliable and efficient communications. Several measurements and performance studies 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 very high speed FSO (Free Space Optics) [11]. In the present work results are presented and discussed for laboratory performance measurements of IEEE 802.11a, b, g point-to point-links, using different APs.

The rest of the paper is structured as follows: Chapter II presents the experimental details i.e. the measurement setup and procedure. Results and discussion are presented in Chapter III. Conclusions are drawn in Chapter IV.

II. EXPERIMENTAL DETAILS

Two types of experiments were carried out, which we refer as Exp1 and Exp2. In the measurements of Exp1 we used Enterasys RoamAbout RBTR2 level 2/3/4 access points (mentioned as AP1), equipped with 15 dBm IEEE 802.11 a/b/g cards [12], and 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switches [13]. 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 as the access points were very close. For the measurements of Exp2 we used Enterasys RoamAbout RBT-

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4102 level 2/3/4 access points (mentioned as AP2), equipped with 16-20 dBm IEEE 802.11 a/b/g transceivers and internal dual-band diversity antennas [12], and 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switches [13]. 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.

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, Exp1 and Exp2, were made using the laboratory setup shown in Fig. 1. Measurements were made using TCP and UDP connections at OSI level 4, using Iperf software [14], 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 1470 bytes size were used. A window size of 8 kbytes and a buffer size of the same value were used for TCP and UDP, respectively. One PC (Personal Computer), 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 [15]. 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 enable the TCP, UDP and FTP tests. The results were obtained in batch mode and written as data files to the client PC disk.

III. RESULTS AND DISCUSSION

Both AP1 and AP2 access points were configured, for every one of the standards IEEE 802.11a, b, g, with several fixed transfer rates. For every fixed transfer rate, measurements were made, for both Exp1 and Exp. In this way, for each experiment type, data were obtained for comparison of the laboratory performances of IEEE 802.11 b (namely at 5.5 and 11 Mbps), 802.11g and 802.11a (at 6, 9, 12, 24, 36, 48 and 54 Mbps in both cases) links, measured namely at OSI levels 4 and 7 using the scheme of Fig. 1.

At OSI level 1 in Exp1, for every one of the cases, we recorded the local and remote values of the signal to noise ratios SNR of the point-to-point link. The best SNR levels were observed for 802.11g and 802.11a. The lowest noise levels were for 802.11a. Similar trends were observed in Exp2.

For both Exp1 and Exp2, and 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. 2-7. In Figs. 2-3, polynomial fits were made for each AP implementation of IEEE 802.11 a, g, where R^2 is the coefficient of determination. It is seen that the best TCP throughputs are, by descending order, for 802.11a, 802.11g and 802.11b. In Exp1 (Fig. 2), the data for 802.11a are on average 2.5% higher than for IEEE 802.11g. In Exp2 (Fig. 3), the data for 802.11a are significantly higher (12-43%) than for 802.11g. The best throughput performance was for AP1. In Figs. 4-7, the data points were joined by smoothed lines. In Exp1 (Fig. 4), the jitter data show some fluctuations; jitter is, on average, higher for IEEE 802.11b (2.6 ms), a (2.1 ms). In Exp2 (Fig. 5) the jitter data are rather scattered: jitter is, on average, higher for IEEE 802.11b (3.7 ms), g (2.3 ms). In both Exp1 (Fig. 6) and Exp2 (Fig. 7), generally, the percentage datagram loss data agree rather well for all standards. They are 1.2 % and 1.3 %, 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 thus obtained in Exp1 and Exp2 are represented in Figs. 8-9 respectively. Polynomial fits to data were made. It was found that in both cases the best performances were, by descending order, for 802.11a, 802.11g and 802.11b. The FTP transfer rates obtained in Exp2, using IEEE 802.11b, were better than in Exp1. The FTP performances obtained for Exp2 and IEEE 802.11a were slightly better in comparison with Exp1. On the contrary, for Exp2 and IEEE 802.11g, FTP performances were significantly worse than in Exp1, suggesting that AP1 had a better FTP performance than AP2 for IEEE 802.11g.

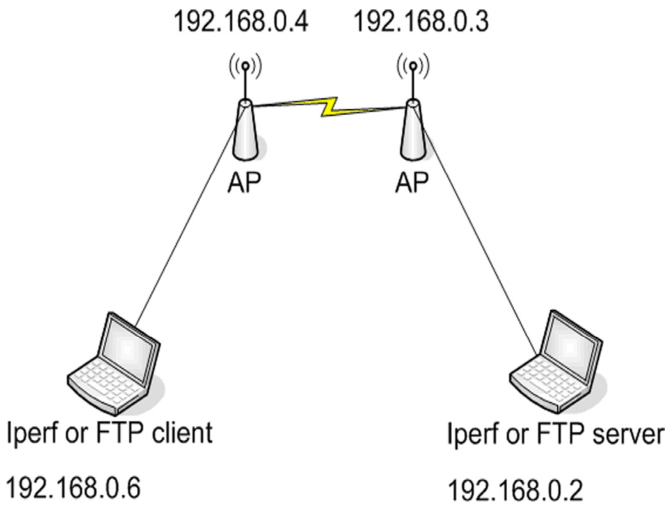

Fig. 1. Laboratory setup scheme.

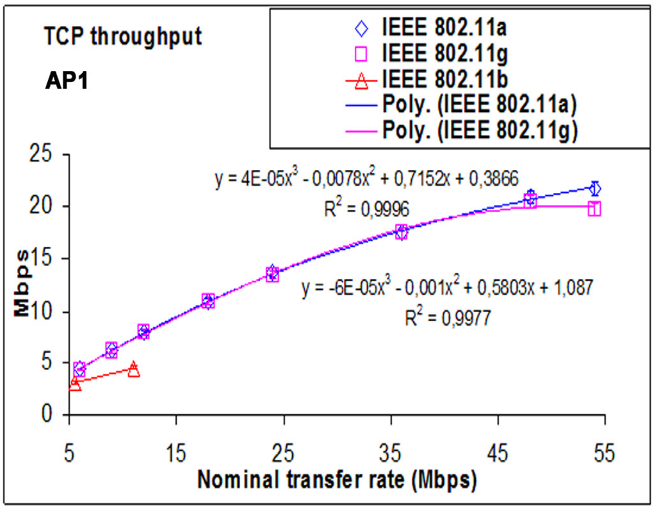

Fig. 2. TCP throughput versus technology and nominal transfer rate; Exp1.

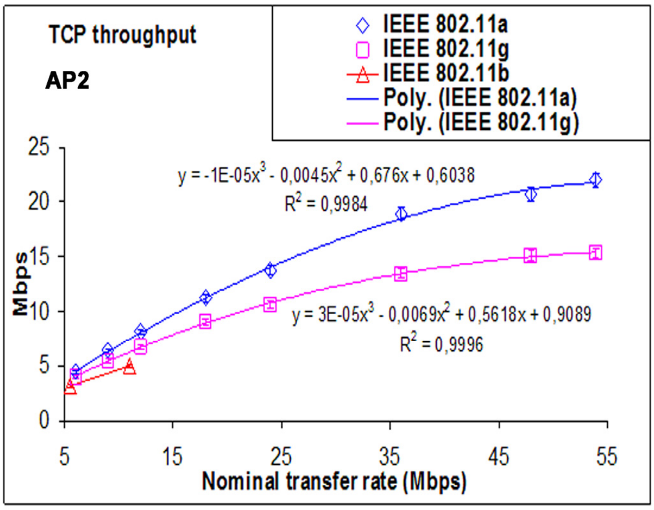

Fig. 3. TCP throughput versus technology and nominal transfer rate; Exp2.

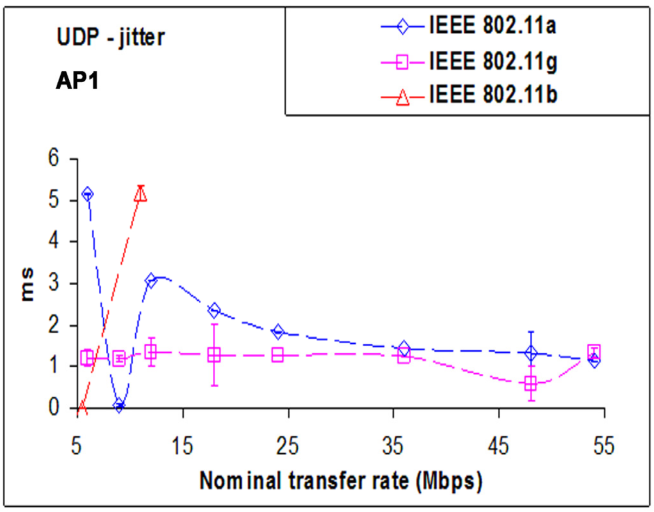

Fig. 4. UDP – jitter results versus technology and nominal transfer rate; Exp1.

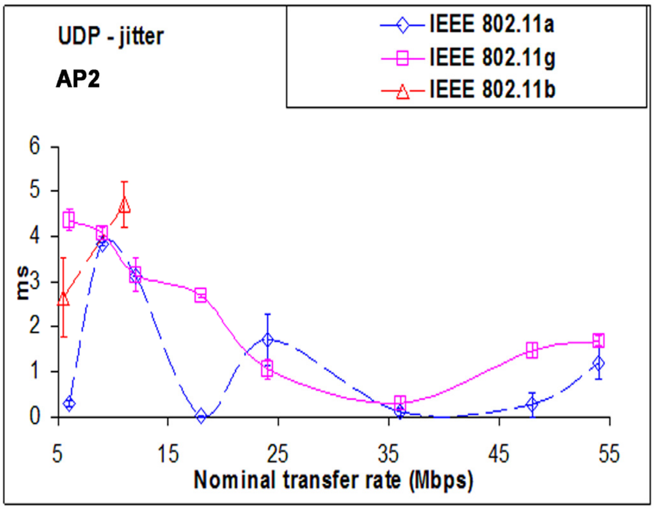

Fig. 5. UDP – jitter results versus technology and nominal transfer rate; Exp2.

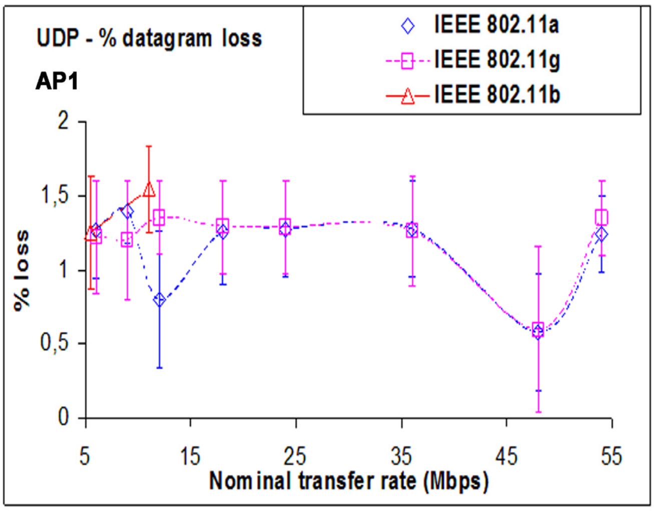

Fig. 6. UDP – percentage datagram loss results versus technology and nominal transfer rate; Exp1.

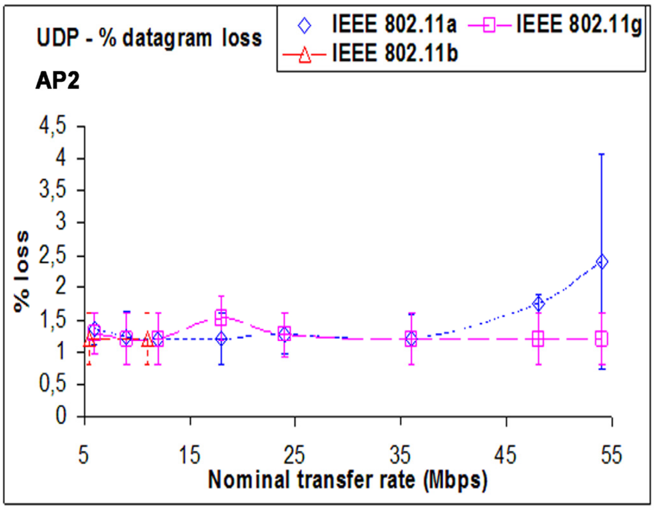

Fig. 7. UDP – percentage datagram loss results versus technology and nominal transfer rate; Exp2.

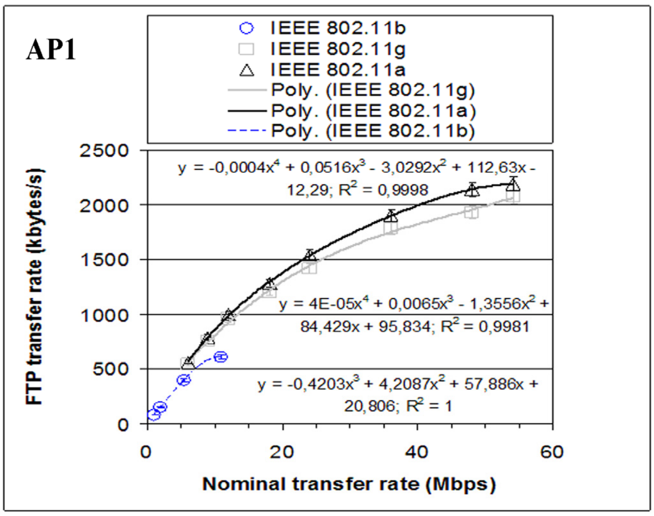

Fig. 8. FTP transfer rates versus technology and nominal transfer rate; Exp1.

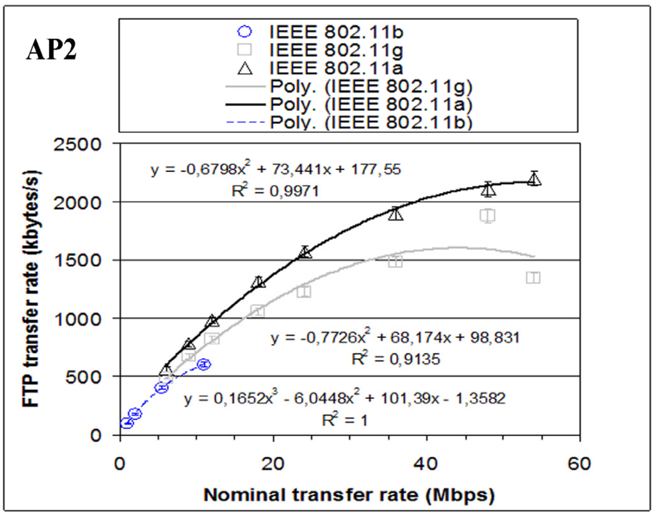

Fig. 9. FTP transfer rates versus technology and nominal transfer rate; Exp2.

IV. CONCLUSIONS

In the present work a simple laboratory arrangement was implemented that permitted systematic performance measurements of available equipments in IEEE 802.11a, b, g point-to-point links. At OSI level 1, the best values of SNR were for 802.11g and 802.11a, while the lowest noise levels were for 802.11a. Through OSI level 4 the best TCP throughputs were found, by descending order, for 802.11a, 802.11g and 802.11b. TCP throughputs were also found sensitive to AP type. The lower values of jitter were on average found for IEEE 802.11a, and 802.11g. 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 802.11a, 802.11g and 802.11b. 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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