# Comparative Performance Evaluation of Wi-Fi IEEE 802.11 B,G WEP Point-to-Point Links

J. A. R. Pacheco de Carvalho, H. Veiga, N. Marques, C. F. Ribeiro Pacheco, A. D. Reis

*Abstract*—**Wireless communications using microwaves are increasingly important, e.g. Wi-Fi. Performance is a crucial issue, leading to more reliable and efficient communications. Security is equally important. Laboratory measurements are made about several performance aspects of Wi-Fi (IEEE 802.11b, g) WEP point-to-point links. A contribution is given to performance evaluation of this technology under WEP encryption, using two types of equipments (RBT-4102 access points from Enterasys Networks and WRT54GL wireless routers from Linksys). Detailed results are presented and discussed, namely at OSI levels 4 and 7, from TCP, UDP and FTP experiments: TCP throughput, jitter, percentage datagram loss and FTP transfer rate. Comparisons are made and conclusions are drawn about the comparative performance of the links.**

*Index Terms*—**Wi-Fi; WLAN; IEEE 802.11b; IEEE 802.11g; WEP Point-to-Point Links; Wireless Network Laboratory Performance.**

## I. Introduction

Contactless communication techniques have been developed using mainly electromagnetic waves in several frequency ranges, propagating in the air. Examples of wireless communications technologies are Wi-Fi and FSO, whose importance and utilization have been growing.

Wi-Fi is a microwave based technology providing for versatility, mobility and favourable prices. The importance and utilization of Wi-Fi has been growing for complementing traditional wired networks. It has been used both in ad hoc mode and in infrastructure mode. In this case an access point, AP, permits communications of Wi-Fi devices with a wired based LAN through a switch/router. In this way a WLAN, based on the AP, is formed. Wi-Fi has reached the personal home, forming a WPAN, allowing personal devices to communicate. Point-to-point and point-to-multipoint configurations are used both indoors and outdoors, requiring specific directional and omnidirectional antennas. Wi-Fi uses microwaves in the 2.4 and 5 GHz frequency bands and IEEE 802.11a, 802.11b, 802.11g and 802.11n standards [1]. As the 2.4 GHz band becomes increasingly used and interferences increase, the 5 GHz band has received considerable attention, although absorption increases and ranges are shorter.

Nominal transfer rates up to 11 (802.11b), 54 Mbps (802.11 a, g) and 600 Mbps (802.11n) are specified. The medium access control is CSMA/CA. Wireless communications, wave propagation [2,3] and practical implementations of WLANs [4] have been studied. Details about the 802.11 architecture have been published, including performance analysis of the effective transfer rate, where an optimum factor of 0.42 was presented for 11 Mbps point-to-point links [5]. Wi-Fi (802.11b) performance measurements are given for crowded indoor environments [6].

Performance has been a most relevant issue, resulting in more reliable and efficient communications. New telematic applications are specially sensitive to performances, when compared to traditional applications. Requirements have been pointed out, such as: 1-10 ms jitter and 1-10 Mbps throughput for video on demand/moving images; jitter less than 1 ms and 0.1-1 Mbps throughputs for Hi Fi stereo audio [7].

Wi-Fi security is very important as microwave radio signals travel through the air and can be easily captured. WEP was initially intended to provide confidentiality comparable to that of a traditional wired network. In spite of presenting weaknesses, WEP is still widely used in Wi-Fi networks for security reasons. A shared key for data encryption is involved. In WEP, the communicating devices use the same key to encrypt and decrypt radio signals.

Several performance measurements have been made for 2.4 and 5 GHz Wi-Fi open links [8,9], as well as very high speed FSO [10]. In the present work new Wi-Fi (IEEE 802.11 b,g) results arise, using WEP, through OSI levels 4 and 7. Performance is evaluated in laboratory measurements of WEP point-to-point links using available equipments. Comparisons are made about the comparative performance of the links.

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 are referred as Expb and Expc. The measurements of Expb used

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(Fig. 1-(A), (C)) Enterasys RoamAbout RBT-4102 level 2/3/4 access points (mentioned as APb), equipped with 16-20 dBm IEEE 802.11 a/b/g transceivers and internal dual-band diversity antennas [11], and 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switches [12]. The access points had transceivers based on the Atheros 5213A chipset, and firmware version 1.1.51. The configuration was for minimum transmitted power and equivalent to point-to-point, LAN to LAN mode, using the internal antenna. Expc used (Fig. 1-(B), (C)) Linksys WRT54GL wireless routers [13], with a Broadcom BCM5352 chip rev0, internal diversity antennas, firmware DD-WRT v24-sp1-10011 [14] and the same type of level 2 switch [12]. The wireless mode was set to bridged access point (APc). In every type of experiment, interference free communication channels were used. This was checked through a portable computer, equipped with a Wi-Fi 802.11 a/b/g adapter, running NetStumbler software [15]. WEP encryption was activated in the APs, using 128 bit encryption and a shared key for data encryption composed of 13 ASCII characters. The experiments were made under far-field conditions. No power levels above 30 mW (15 dBm) were required, as the access points were close.

A laboratory setup has been planned and implemented for the measurements, as shown in Fig. 2. At OSI level 4 , measurements were made for TCP connections and UDP communications using Iperf software [16], 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 determined. 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, 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 indicates the smooth mean of differences between consecutive transit times, was continuously computed by the server, as specified by RTP in RFC 1889 [17]. The scheme of Fig. 1 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.

The server and client PCs were HP nx9030 and nx9010 portable computers, respectively, running Windows XP. They were configured to maximize the resources available to the present work. Batch command files have been 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. Each PC had a second network adapter, to permit remote control from the official IP University network, via switch.

## III. Results and Discussion

In each type of experiment Expb and Expc, the corresponding access points APb and APc, respectively, were configured for each standard IEEE 802.11 b, g with typical nominal transfer rates (1, 2, 5.5 and 11 Mbps for IEEE 802.11 b; 6, 9, 12, 18, 24, 36, 48, 54 Mbps for IEEE 802.11 g). For each experiment type, measurements were made for every fixed transfer rate. In this way, data were obtained for comparison of the laboratory performance of the links, measured namely at OSI levels 1 (physical layer), 4 (transport layer) and 7 (application layer) using the setup of Fig. 2. In each experiment type, for each standard and every nominal fixed transfer rate, an average TCP throughput was determined from several experiments. This value was used as the bandwidth parameter for every corresponding UDP test, giving average jitter and average percentage datagram loss.

At OSI level 1, noise levels (N, in dBm) and signal to noise ratios (SNR, in dB) were monitored and typical values are shown in Fig. 3 and Fig. 4 for Expb and Expc, respectively.

The main average TCP and UDP results are summarized in Table I. In Fig. 5 and Fig. 6 for Expb and Expc, respectively, polynomial fits were made to the 802.11b, g TCP throughput data, where $R^2$ is the coefficient of determination. It is seen that, for each AP type, the best TCP throughputs are for 802.11 g. APc shows, on average, a better TCP throughput performance than APb, both for 802.11 g (+49.0 %) and 802.11 b (+11.5 %). In Figs. 7-10, the data points representing jitter and percentage datagram loss were joined by smoothed lines. It follows that, on average, APb and APc present similar jitter performances for 802.11 b, within the experimental error. For 802.11 g APc shows a better average jitter performance (1.8 +- 0.1 ms) than APb (2.6+- 0.1 ms). Concerning percentage datagram loss data (1.2 % on average) there is a fairly good agreement for both APb and APc and for both standards.

At OSI level 7 we measured FTP transfer rates versus nominal transfer rates configured in the access points for the IEEE 802.11b, g standards. Every measurement was the average for a single FTP transfer, using a binary file size of 100 Mbytes. The average results thus obtained are summarized in Table I and represented in Fig. 11 and Fig. 12. Polynomial fits to data were made for the implementation of each standard. It was found that, for each AP type, the best FTP performances are for 802.11g. APc shows, on average, a better FTP performance than APb, both for 802.11g and 802.11b. These results show the same trends found for TCP throughput.

Generally, the results measured for WEP links were not found as significantly different, within the experimental errors, from corresponding data obtained for open links. Except for jitter, where the best performances were found for open links.


Fig. 1- Access point (A) [11], Wireless router (B) [13] and switch (C) [12].

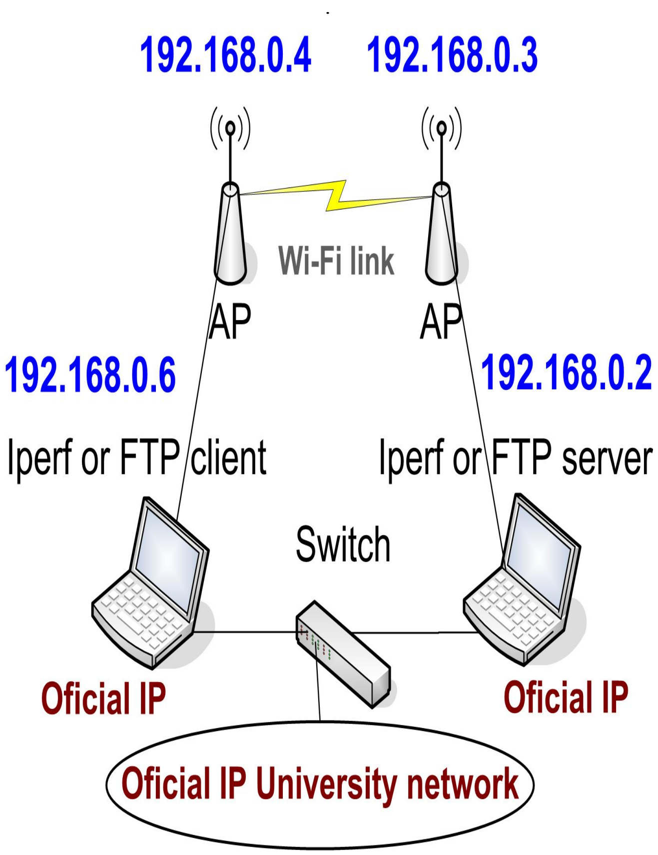


Fig. 2- Laboratory setup scheme.

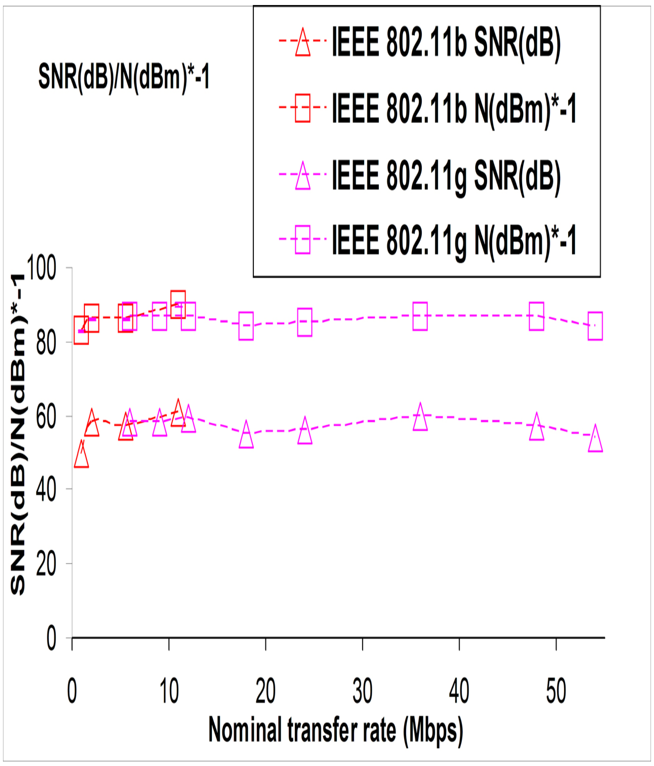


Fig. 3- Typical SNR (dB) and N (dBm); Expb.

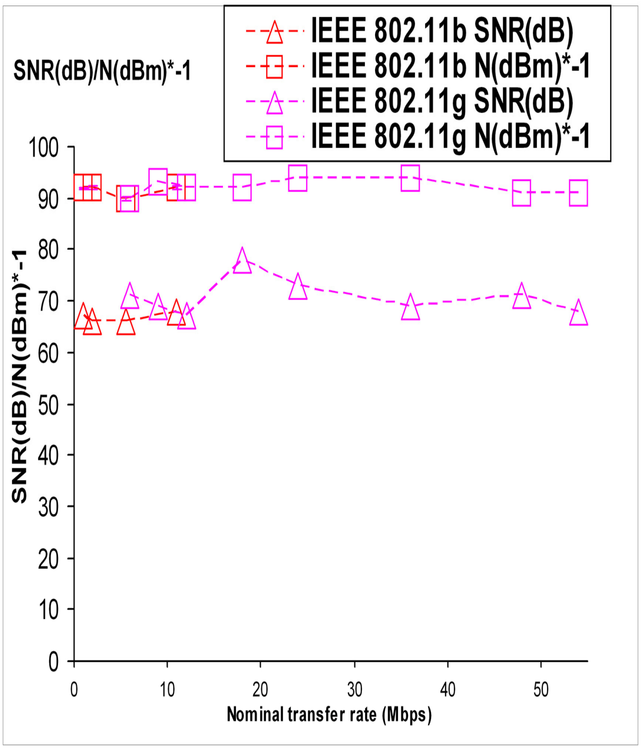


Fig. 4- Typical SNR (dB) and N (dBm); Expc.

TABLE I
AVERAGE WI-FI (IEEE 802.11 B, G) RESULTS; EXPB; EXPC

| **Exp type** | **Expb** | | **Expc** | |
|---|---|---|---|---|
| **Parameter/ IEEE standard** | **802.11b** | **802.11g** | **802.11b** | **802.11g** |
| TCP throughput (Mbps) | 2.6 +-0.1 | 9.6 +-0.3 | 2.9 +-0.1 | 14.3 +-0.4 |
| UDP-jitter (ms) | 4.8 +-0.3 | 2.6 +-0.1 | 5.1 +-0.3 | 1.8 +-0.1 |
| UDP-% datagram loss | 1.2 +-0.2 | 1.3 +-0.1 | 1.1 +-0.2 | 1.3 +-0.1 |
| FTP transfer rate (kbyte/s) | 300.5 +-9.0 | 1106.4 +-55,3 | 347.9 +-10.4 | 1557.7 +-46.7 |

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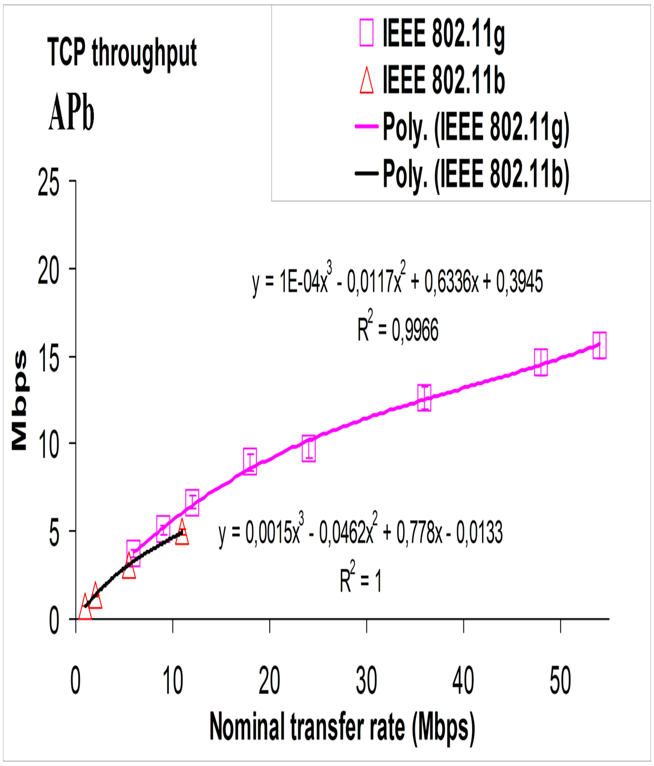


Fig. 5- TCP throughput versus technology and nominal transfer rate; Expb.

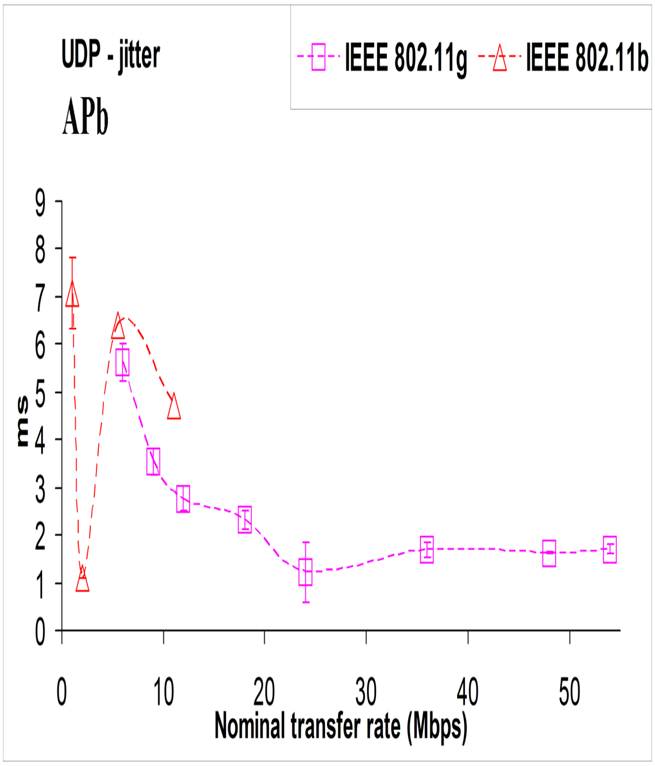


Fig. 7- UDP – jitter results versus technology and nominal transfer rate; Expb

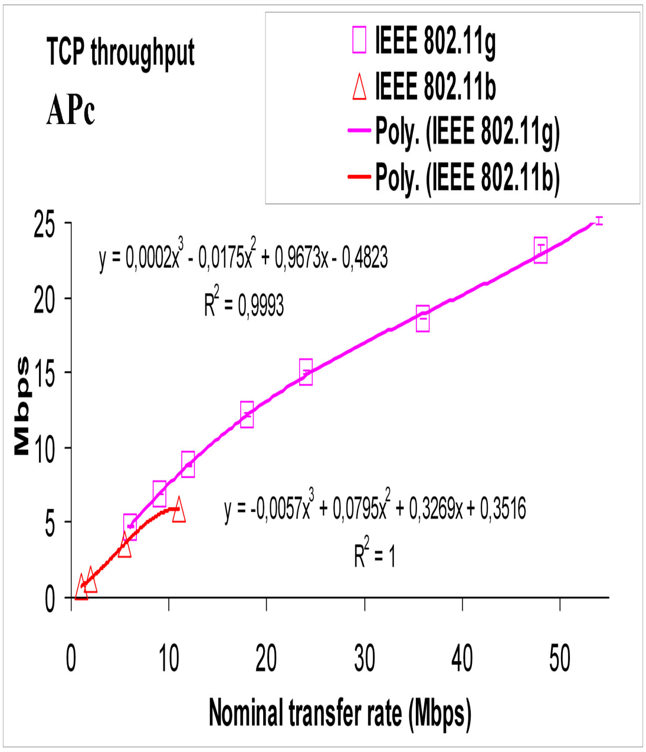


Fig. 6- TCP throughput versus technology and nominal transfer rate; Expc.

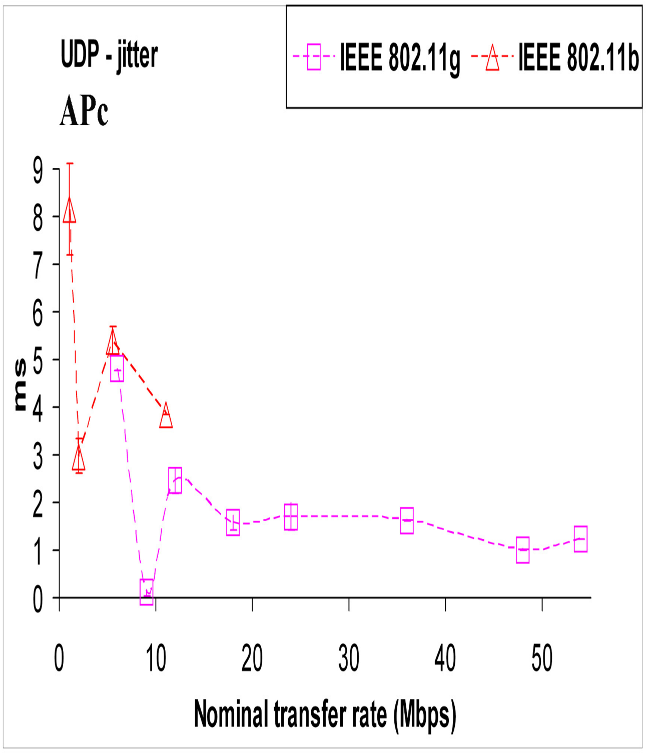


Fig. 8- UDP – jitter results versus technology and nominal transfer rate; Expc.


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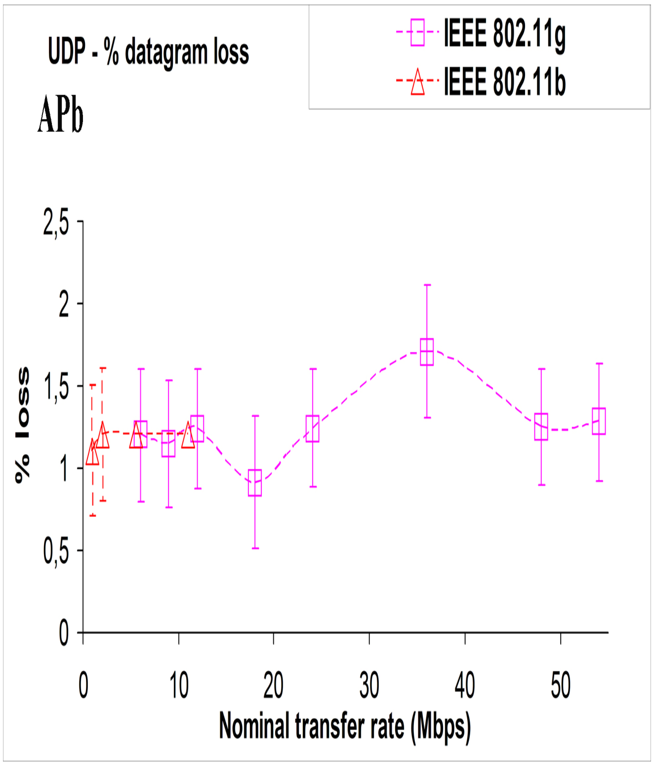


Fig. 9- UDP – percentage datagram loss results versus technology and nominal transfer rate; Expb.

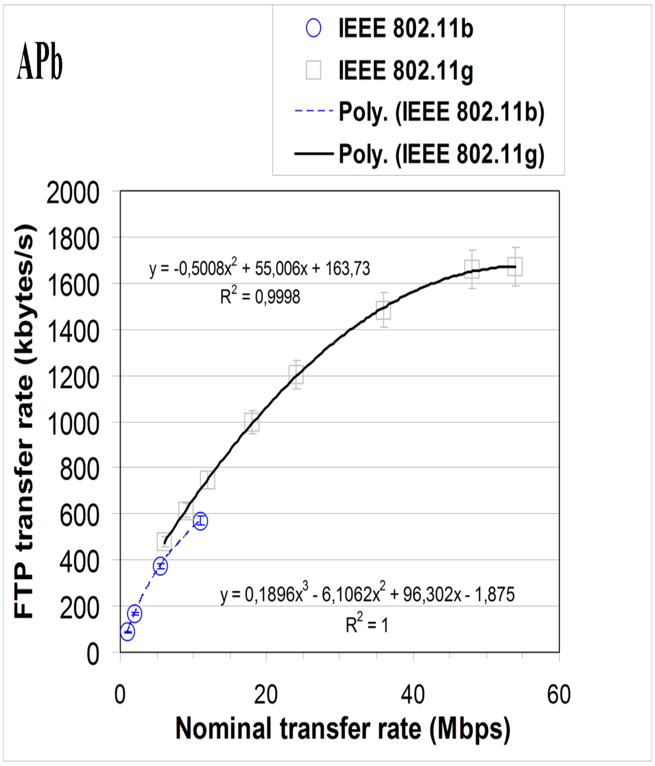


Fig. 11- FTP transfer rate versus technology and nominal transfer rate; Expb.

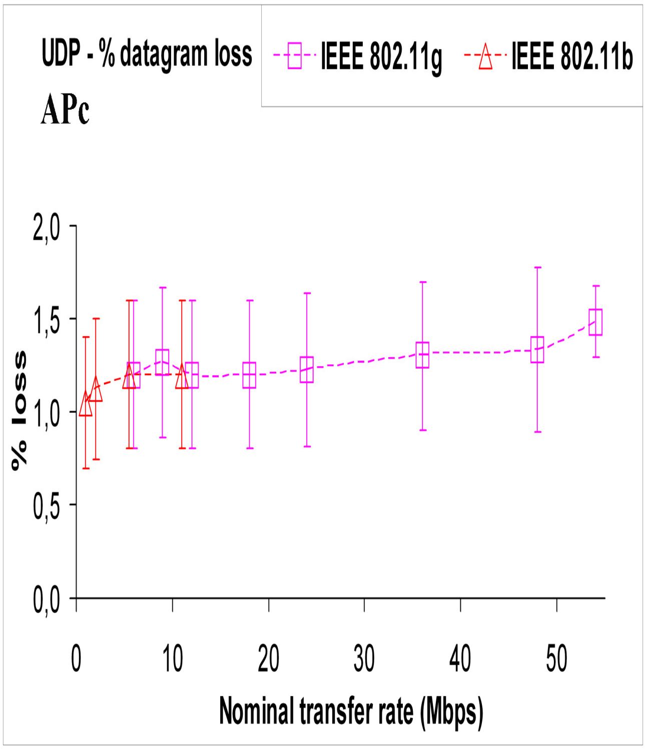


Fig. 10- UDP – percentage datagram loss results versus technology and nominal transfer rate; Expc.

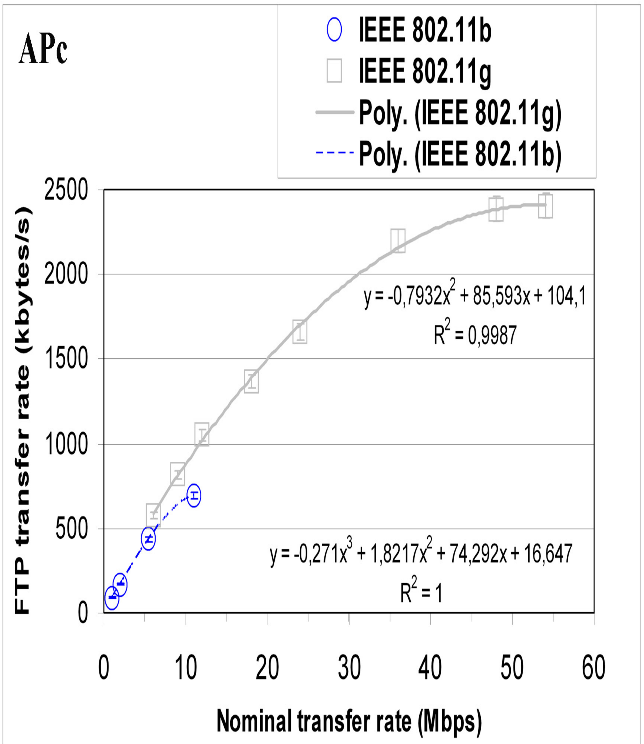


Fig. 12- FTP transfer rate versus technology and nominal transfer rate; Expc.

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## IV. CONCLUSION

A laboratory setup arrangement has been planned and implemented, that permitted systematic performance measurements of available wireless equipments (RBT-4102 access points from Enterasys Networks and WRT54GL wireless routers from Linksys) for Wi-Fi (IEEE 802.11 b, g) in WEP point-to-point links.

Through OSI layer 4, TCP throughput, jitter and percentage datagram loss were measured and compared for each standard. For each AP type, the best TCP throughputs were found for 802.11g. TCP throughput was found sensitive to AP type. For both AP types and 802.11 b, similar average jitter performances were found. For 802.11 g, jitter performance was found sensitive to AP type. Concerning average percentage datagram loss, fairly good agreements were found for both AP types and for both standards.

At OSI layer 7, the best FTP performances were, for each AP type, for 802.11g. FTP performance was found sensitive to AP type. These results show the same trends found for TCP throughput.

Generally, the results measured for WEP links were not found as significantly different, within the experimental errors, from corresponding data obtained for open links. Except for jitter, where the best performances were found for open links.

Additional performance measurements either started or are planned using several equipments and security settings, not only in laboratory but also in outdoor environments involving, mainly, medium range links.

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