Laboratory Performance Measurements of IEEE 802.11 b, g Open Four-node PTMP Links

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

***Abstract*—The importance of wireless communications, involving electronic devices, has been growing. Performance is a very relevant issue, leading to more reliable and efficient communications. Laboratory measurements are made about several performance aspects of Wi-Fi (IEEE 802.11 b, g) Open four-node-point-to-multipoint links. A contribution is given to performance evaluation of this technology, using available equipments (V-M200 access points from HP and WPC600N adapters from Linksys). New detailed results are presented and discussed, namely at OSI layers 4 and 7, from TCP, UDP and FTP experiments: TCP throughput, jitter, percentage datagram loss and FTP transfer rate. Comparisons are made to corresponding results obtained for Open point-to-point links.**

***Index Terms*—Wi-Fi, WLAN, IEEE 802.11b, IEEE 802.11g Open Four-node Point-to-Multipoint 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. Wi-Fi and FSO, whose importance and utilization have been recognized and growing, are representative examples of wireless communications technologies.

Wi-Fi is a microwave based technology providing for flexibility, mobility and favourable prices. The importance and utilization of Wi-Fi has been increasing 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 (such as a personal computer, a wireless sensor, a PDA, a smartphone, a video game console, a digital audio player) with a wired based LAN through a switch/router. In this way a WLAN, based on the AP, is formed. Wi-Fi has penetrated the personal home, where a WPAN permits personal devices to communicate. Point-to-point (PTP) and point-to-multipoint (PTMP) setups are used both indoors and outdoors, requiring specific directional and omnidirectional antennas. PTP and PTMP links use microwaves in the 2.4 and 5 GHz frequency bands and IEEE 802.11a, 802.11b, 802.11g and 802.11n standards [1]. The 2.4 GHz band is intensively used and is having increasing interferences. Therefore considerable attention has been focused on the 5 GHz band where, however, 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. There are studies on wireless communications, wave propagation [2,3], practical implementations of WLANs [4], performance analysis of the effective transfer rate for 802.11b point-to-point links [5], 802.11b performance in crowded indoor environments [6].

Performance has been a very important issue, resulting in more reliable and efficient communications. In comparison to traditional applications, new telematic applications are specially sensitive to performances. Requirements have been pointed out [7]. E.g. requirements have been quoted as: for video on demand/moving images, 1-10 ms jitter and 1-10 Mbps throughput; for Hi Fi stereo audio, jitter less than 1 ms and 0.1-1 Mbps throughputs.

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 used in Wi-Fi networks for security reasons, mainly in PTP links. More advanced and reliable security methods have been developed to provide authentication such as, by increasing order of security, WPA and WPA2.

Several performance measurements have been made for 2.4 and 5 GHz Wi-Fi open [8,9], and WEP links [10-11], as well as very high speed FSO [12]. In the present work new Wi-Fi (IEEE 802.11 b,g) results arise, using no encryption, mainly through OSI levels 4 and 7. The motivation of this work is to evaluate performance in laboratory measurements of Open four-node PTMP links using available equipments. Comparisons are made to corresponding results obtained for Open PTP links. This contribution permits to increase the knowledge about performance of Wi-Fi (IEEE 802.11 b,g) links [4-6]. The problem statement is that performance needs to be evaluated under several topologies. The solution proposed uses an experimental setup and method, permitting to monitor signal to noise ratios (SNR) and noise levels (N)

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and measure TCP throughput (from TCP connections) and UDP jitter and percentage datagram loss (from UDP communications).

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

II. Experimental Details

The measurements used a HP V-M200 access point [13], with three external dual-band 3x3 MIMO antennas, IEEE 802.11 a/b/g/n, software version 5.4.1.0-01-9867 and a 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switch [14]. Three PCs were configured having a PCMCIA IEEE.802.11 a/b/g/n Linksys WPC600N wireless adapter with three internal antennas [15], to enable four-node (4N) PTMP links to the access point. In every type of experiment, interference free communication channels were used (ch 8 for 802.11b,g). This was checked through a portable computer, equipped with a Wi-Fi 802.11 a/b/g/n adapter, running NetStumbler software [16]. No encryption was activated in the AP and the wireless adapters of the PCs. The experiments were made under far-field conditions. No power levels above 30 mW (15 dBm) were required, as the wireless equipments were close.

A new versatile laboratory setup has been planned and implemented for the PTMP measurements, as shown in Fig. 1. It involves three wireless links to the AP. At OSI level 4, measurements were made for TCP connections and UDP communications using Iperf software [17]. For a TCP connection, TCP throughput was obtained. For a UDP communication with a given bandwidth parameter, UDP jitter and percentage loss of datagrams were determined. Parameterizations of TCP packets, UDP datagrams and window size were as in [10]. One PC, with IP 192.168.0.2 was the Iperf server and the others, with IPs 192.168.0.6 and 192.168.0.50, were the Iperf clients (client1 and client2), respectively. Jitter, which represents the smooth mean of differences between consecutive transit times, was continuously computed by the server, as specified by the real time protocol RTP, in RFC 1889 [18]. Another PC, with IP 192.168.0.20, was used to control the settings in the AP.

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, 191.168.0.50, respectively.

Four-node PTMP experiments were made for simultaneous connections/communications between the two clients and the server. PTP was a particular case where the client was client1 and the server was the control PC.

The server and client PCs were HP nx9030 and nx9010 portable computers, respectively, running Windows XP Professional. They were configured to maximize the resources allocated to the present work. Batch command files have been re-written to enable the new TCP, UDP and FTP tests.

The results were obtained in batch mode and written as data files to the client PCs disks. Every PC had a second network adapter, to permit remote control from the official IP University network, via switch.

III. Results and Discussion

The wireless network adapters of the PCs were manually configured for each standard IEEE 802.11 b, g with typical nominal transfer rates (1, 2, 5, 11 Mbps for 802.11b; 6, 9, 12, 18, 24, 36, 48, 54 Mbps for 802.11g). For every fixed transfer rate, data were obtained for comparison of the laboratory performance of the 4N-PTMP and PTP links at OSI levels 1 (physical layer), 4 (transport layer) and 7 (application layer) using the setup of Fig. 1. For each standard and every nominal fixed transfer rate, an average TCP throughput was determined from a set of experiments. This value was fed in as the bandwidth parameter for every corresponding UDP test, resulting in average jitter and average percentage datagram loss. Both four-node PTMP and PTP results are represented for client1.

At OSI level 1, signal to noise ratios (SNR, in dB) and noise levels (N, in dBm) were measured. Typical values are shown in Fig. 2.

The main average TCP and UDP results are summarized in Table I, both for 4N-PTMP and PTP links. The statistical analysis, including calculations of confidence intervals, was carried out as in [19].

In Figs. 3 and 4 polynomial fits were made (shown as y versus x), using the Excel worksheet, to the 802.11b, g TCP throughput data for 4N-PTMP and PTP links, respectively, where R^2 is the coefficient of determination. It gives information about the goodness of fit. If it is 1.0 it means a perfect fit to data. It was found that, on average, the best TCP throughputs are for 802.11 g and PTP links (13.9+-0.4 Mbps).

In Figs. 5-8, the data points representing jitter and percentage datagram loss were joined by smoothed lines.

It was found that, on average, jitter performances are better for PTP (3.2+- 0.9 ms and 5.6+- 0.3 ms for 802.11g and 802.11b, respectively) than for 4N-PTMP links (3.0+- 0.3 ms and 12.8+- 2.2 ms for 802.11g and 802.11b, respectively).

Concerning average percentage datagram loss, performances were generally found as better for PTP than for 4N-PTMP links.

In comparison to PTP links, TCP throughput, jitter and percentage datagram loss were generally found to show performance degradations for 4N-PTMP links, where the processing requirements for the AP are higher so as to maintain links between the two client and server PCs.

Further corresponding results, not shown, obtained for 3N-PTMP links indicate smaller performance degradations than for 4N-PTMP links.

At OSI level 7 we measured FTP transfer rates versus nominal transfer rates, configured in the wireless network adapters of the PCs, for the IEEE 802.11b, g standards. The result for every measurement was an average of several experiments involving a single FTP transfer of a binary file with a size of 100 Mbytes. The FTP results have shown the same trends found for TCP throughput.

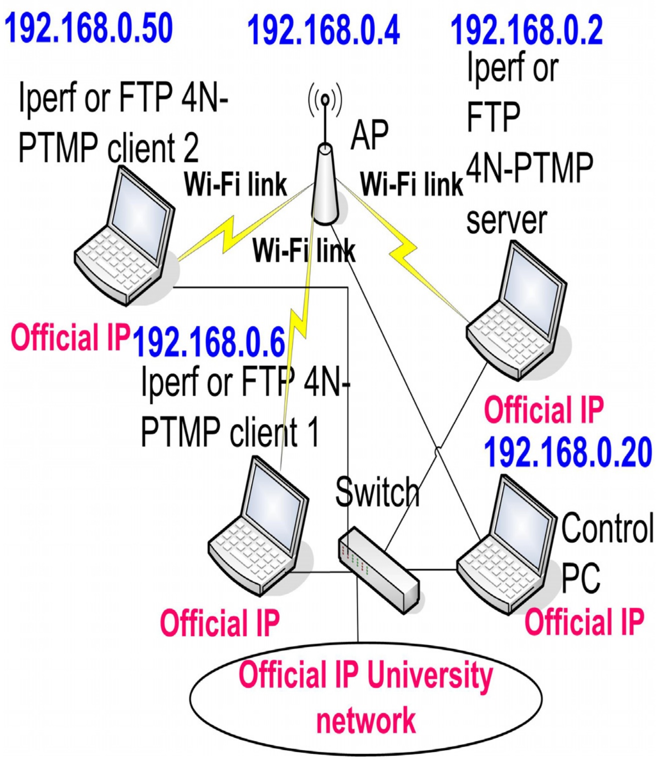

Fig. 1- Wi-Fi laboratory setup scheme.

TABLE I
AVERAGE WI-FI (IEEE 802.11 B, G) OPEN RESULTS; 4N-PTMP; PTP

Exp type	4N-PTMP		PTP	
Parameter / IEEE standard	802.11g	802.11b	802.11g	802.11b
TCP throughput (Mbps)	3.7 +-0.1	1.1 +-0.0	13.9 +-0.4	3.3 +-0.1
UDP-jitter (ms)	3.0 +-0.3	12.8 +-2.2	3.1 +-0.9	5.6 +-0.3
UDP-% datagram loss	2.6 +-0.6	1.6 +-0.4	1.5 +-0.1	1.2 +-0.2

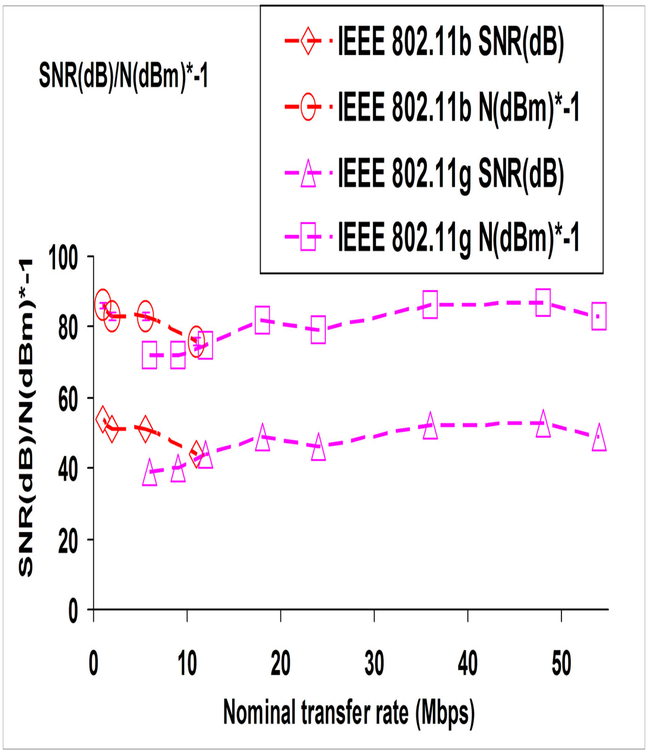

Fig. 2- Typical SNR (dB) and N (dBm) values. Four-node PTMP.

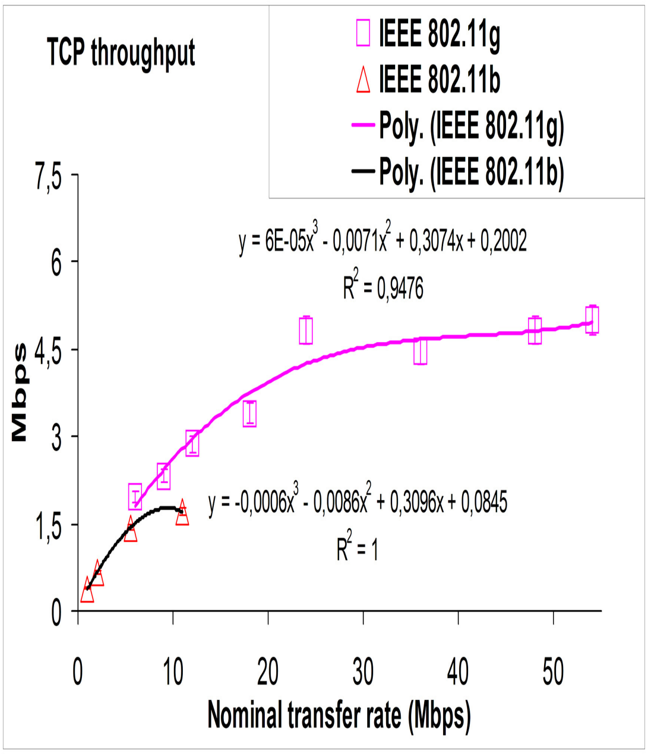

Fig.3- TCP throughput (y) versus technology and nominal transfer rate (x). Four-node PTMP.

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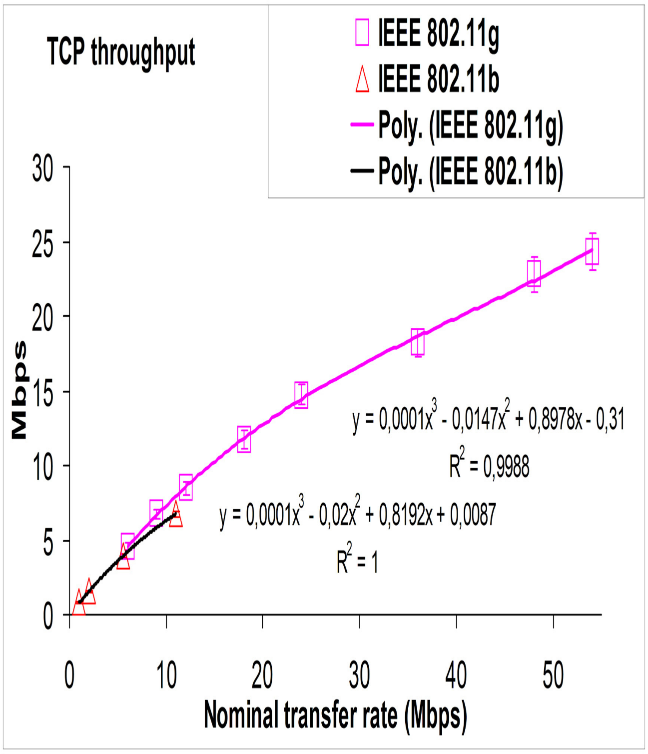

Fig. 4- TCP throughput (y) versus technology and nominal transfer rate (x). PTP.

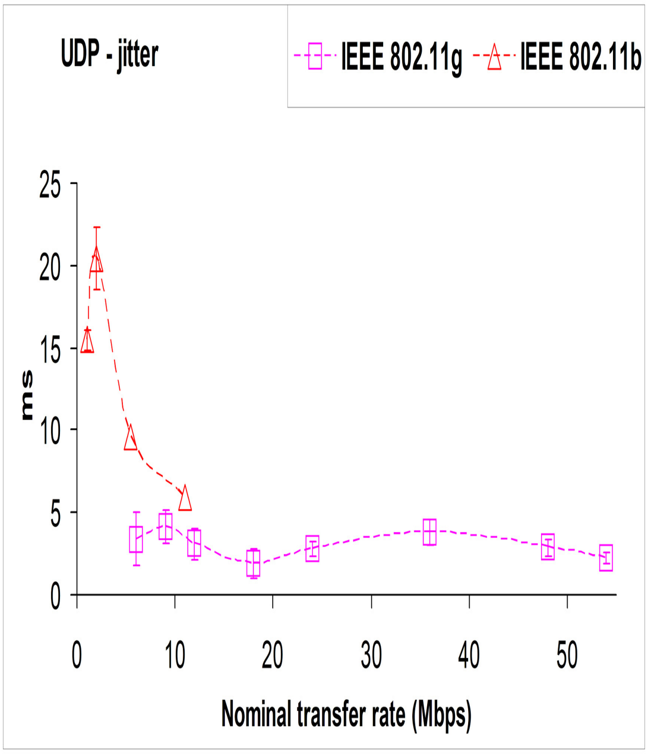

Fig. 5- UDP – jitter results versus technology and nominal transfer rate. Four-node PTMP.

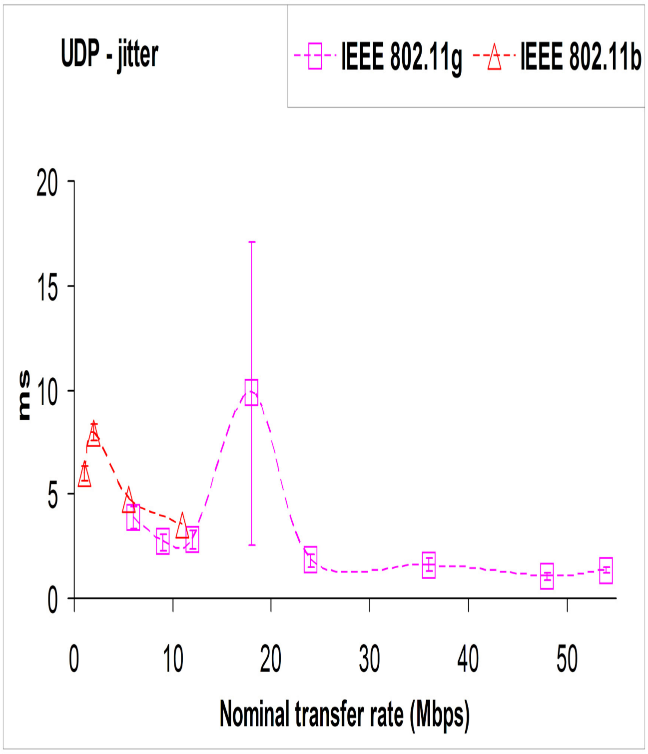

Fig. 6- UDP – jitter results versus technology and nominal transfer rate. PTP.

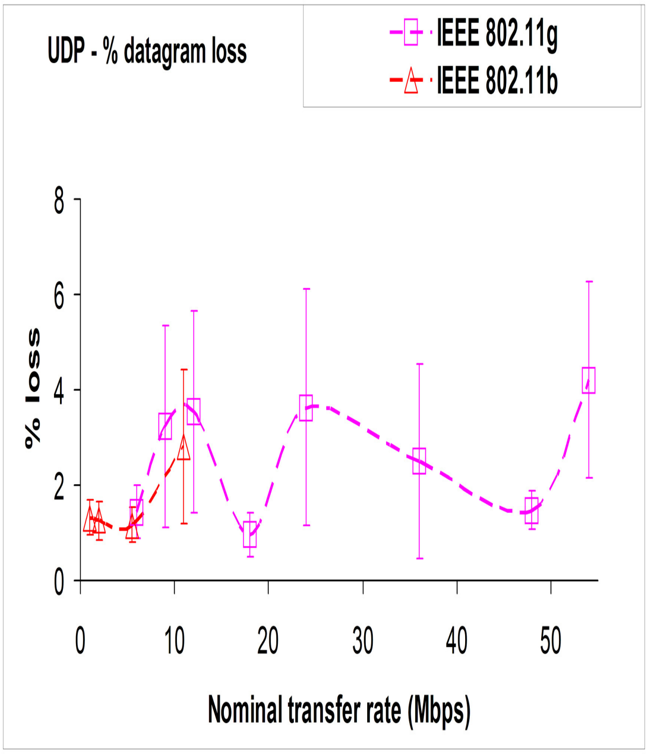

Fig. 7 - UDP – percentage datagram loss results versus technology and nominal transfer rate. Four-node PTMP.

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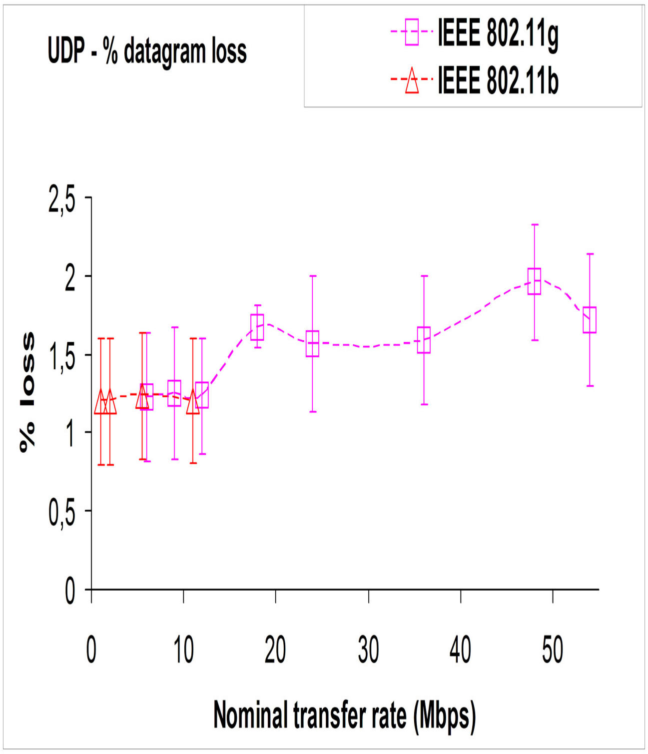

Fig. 8 - UDP – percentage datagram loss results versus technology and nominal transfer rate. PTP.

IV. Conclusion

In the present work a new versatile laboratory setup arrangement was planned and implemented, that permitted systematic performance measurements of new available wireless equipments (V-M200 access points from HP and WPC600N adapters from Linksys) for Wi-Fi (IEEE 802.11 b, g) in Open four-node PTMP links.

Through OSI layer 4, TCP throughput, jitter and percentage datagram loss were measured and compared for each standard to corresponding results obtained for Open PTP links. In comparison to PTP links, TCP throughput, jitter and percentage datagram loss were generally found to show performance degradations for 4N-PTMP links, where the AP experiments higher processing requirements so as to maintain links between PCs. Further corresponding results obtained for 3N-PTMP links indicate smaller performance degradations than for 4N-PTMP links.

At OSI layer 7, FTP performance results have shown the same trends found for TCP throughput.

Further performance studies are planned using several equipments, topologies, security settings and noise conditions, not only in laboratory but also in outdoor environments involving, mainly, medium range links.

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