Comparative Performance Studies of Laboratory WPA IEEE 802.11b,g Point-to-Multipoint Links

José A. R. Pacheco de Carvalho[1],

Cláudia F. F. P. Ribeiro Pacheco[2], Hugo Veiga[3], António D. Reis[4]

Abstract **–Wireless communications using microwaves are increasingly important, e.g. Wi-Fi. Performance is a very crucial issue, resulting in more reliable and efficient communications. Security is equally very important. Laboratory measurements are made about several performance aspects of Wi-Fi IEEE 802.11 b,g WPA point-to-multipoint links. A contribution is given to performance evaluation of this technology under WPA encryption, using available equipments (DAP-1522 access points from D-Link and WPC600N adapters from Linksys). Detailed results are presented and discussed, namely at OSI levels 4 and 7, from TCP, UDP and FTP experiments, permitting measurements of TCP throughput, jitter, percentage datagram loss and FTP transfer rate. Comparisons are made to corresponding results obtained for point-to-point links. Conclusions are drawn about the comparative performance of the links.**

Keywords – **WLAN, Wi-Fi, WPA Point-to-Multipoint Links, IEEE 802.11b, IEEE 802.11g, 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 versatility, mobility and favorable prices. The importance and utilization of Wi-Fi has been growing as it complements traditional wired networks. It has been used both in ad hoc mode and in infrastructure mode. In this case a WLAN arises based on an access point, AP, which permits communications of Wi-Fi electronic devices with a wired based LAN through a switch/router. Wi-Fi has penetrated the personal home, where a WPAN allows 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]. 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. Microwave radio signals can be very easily captured as they travel through the air. Therefore, several security methods have been developed to provide authentication such as, by increasing order of security, WEP, WPA and WPA2. WEP was initially intended to provide confidentiality comparable to that of a traditional wired network. A shared key for data encryption is involved. The communicating devices use the same key to encrypt and decrypt radio signals. The CRC32 checksum used in WEP does not provide a great protection. However, in spite of its weaknesses, WEP is still widely used in Wi-Fi communications for security reasons, mainly in point-to-point links. WPA implements the majority of the IEEE 802.11i standard [1]. It includes a MIC, message integrity check, replacing the CRC used in WEP. Either personal or enterprise modes can be used. In this latter case an 802.1x server is required. Both TKIP and AES cipher types are usable and a group key update time interval is specified.

Several performance measurements have been made for 2.4 and 5 GHz Wi-Fi open [8-9], WEP [10] and WPA [11] links, as well as very high speed FSO [12]. It is important to find the effects of network topology and WPA encryption on link

[1]José Pacheco de Carvalho is with the Remote Detection Unit and the Physics Department at the University of Beira Interior, R. Marquês d'Ávila e Bolama, 6201-001 Covilhã, Portugal, E-mail: pacheco@ubi.pt.

[2]Cláudia Pacheco is with the Remote Detection Unit at the University of Beira Interior, R. Marquês d'Ávila e Bolama, 6201-001 Covilhã, Portugal, E-mail: a17597@ubi.pt.

[3]Hugo Veiga is with the Remote Detection Unit and the Informatics Centre at the University of Beira Interior, R. Marquês d'Ávila e Bolama, 6201-001 Covilhã, Portugal, E-mail: hveiga@ubi.pt.

[4]António Reis is with the Remote Detection Unit and the Physics Department at the University of Beira Interior, and with the Department of Electronics and Telecommunications/Institute of Telecommunications, at the University of Aveiro, 3810 Aveiro, Portugal, E-mail: adreis@ubi.pt.

performance. Therefore, in the present work new Wi-Fi (IEEE 802.11 b,g) results arise, using personal mode WPA, namely at OSI levels 4 and 7. Performance is evaluated in laboratory measurements of WPA point-to-multipoint links using new available equipments. Comparisons are made to corresponding results obtained for point-to-point 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

The measurements used a D-Link DAP-1522 bridge/access point [13], with internal PIFA *2 antenna, IEEE 802.11 a/b/g/n, firmware version 1.31 and a 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switch [14].The wireless mode was set to access point mode. Two PCs were used having a PCMCIA IEEE.802.11 a/b/g/n Linksys WPC600N wireless adapter with three internal antennas [15], to enable 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]. WPA personal encryption was activated in the AP and the wireless adapters of the PCs, using AES and a shared key with 26 ASCII characters. 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 laboratory setup has been planned and implemented for the PTMP measurements, as shown in Fig. 1. 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 measured. 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 other, with IP 192.168.0.6, was the Iperf client. Jitter, meaning 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.

The server and client PCs were HP nx9030 and nx9010 portable computers, respectively, running Windows XP. They were configured to optimize the resources allocated 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

The access point and the wireless network adapter of the PCs were manually configured, for each standard IEEE 802.11 b, g, with typical fixed 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 WPA PTMP and PTP links at OSI layers 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 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, signal to noise ratios (SNR, in dB) and noise levels (N, in dBm) were monitored and typical values are shown in Fig. 2.

The main average TCP and UDP results are summarized in Table I, both for WPA PTMP and PTP links. In Figs. 3 and 4 polynomial fits were made to the 802.11b, g TCP throughput data for PTMP and PTP links, respectively, where R^2 is the coefficient of determination. It was found that, on average, the best TCP throughputs are for 802.11 g and PTP links. In Figs. 5-7, the data points representing jitter and percentage datagram loss were joined by smoothed lines. Concerning jitter it was found that, on average, the best jitter performances are for 802.11 g and PTP links. For percentage datagram loss no significant sensitivities were found on average, for both standards, to link type.

At OSI level 7 we measured FTP transfer rates versus nominal transfer rates configured in the access point and the wireless network adapters of the PCs for IEEE 802.11 b, g as in [10]. The results for WPA PTMP and PTP links show the same trends found for TCP throughput.

In comparison to PTP links, TCP throughput and jitter were found to show performance degradations for PTMP links.

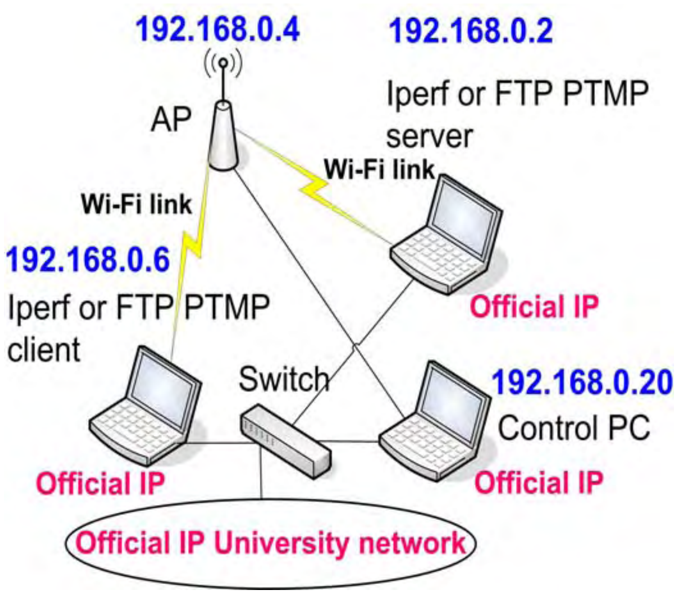

Fig. 1- Laboratory setup scheme.

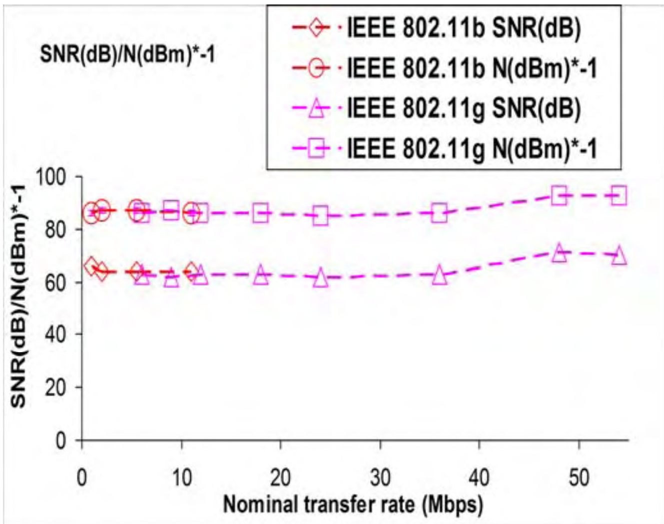

Fig. 2- Typical SNR (dB) and N (dBm).

TABLE I
AVERAGE WI-FI (IEEE 802.11 B,G) WPA RESULTS; PTMP AND PTP.

Link type	**PTMP**		**PTP**	
Parameter/ IEEE standard	**802.11b**	**802.11g**	**802.11b**	**802.11g**
TCP throughput (Mbps)	1.1 +-0.0	6.3 +-0.2	2.9 +-0.1	13.4 +-0.4
UDP-jitter (ms)	6.0 +-0.9	3.5 +-0.5	5.5 +-0.2	2.3 +-0.1
UDP-% datagram loss	1.2 +-0.2	1.7 +-0.1	1.2 +-0.2	1.8 +-0.2

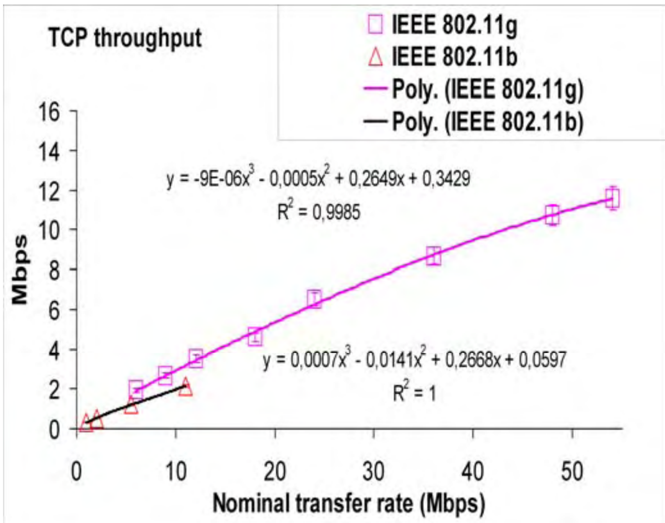

Fig. 3- TCP throughput versus technology and nominal transfer rate; PTMP.

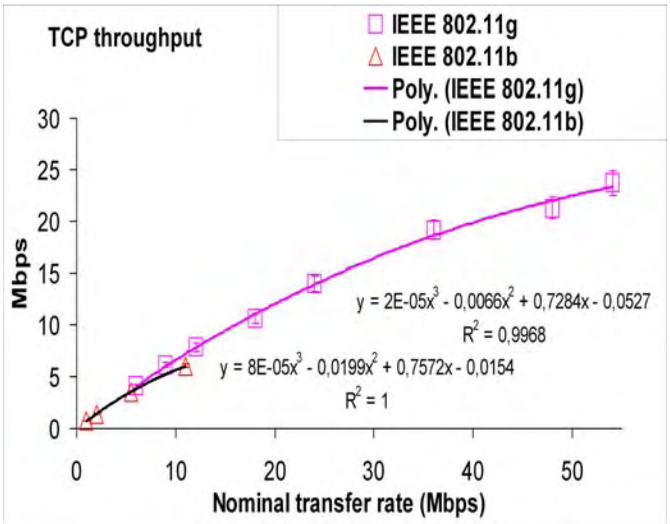

Fig. 4- TCP throughput versus technology and nominal transfer rate; PTP [11].

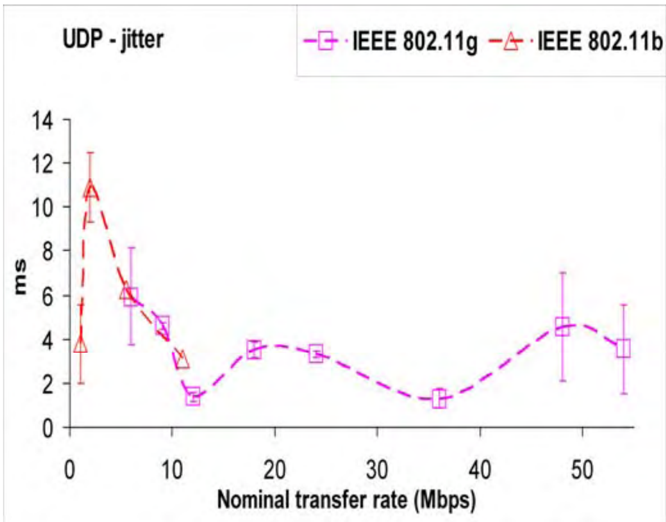

Fig. 5- UDP - jitter results versus technology and nominal transfer rate; PTMP.

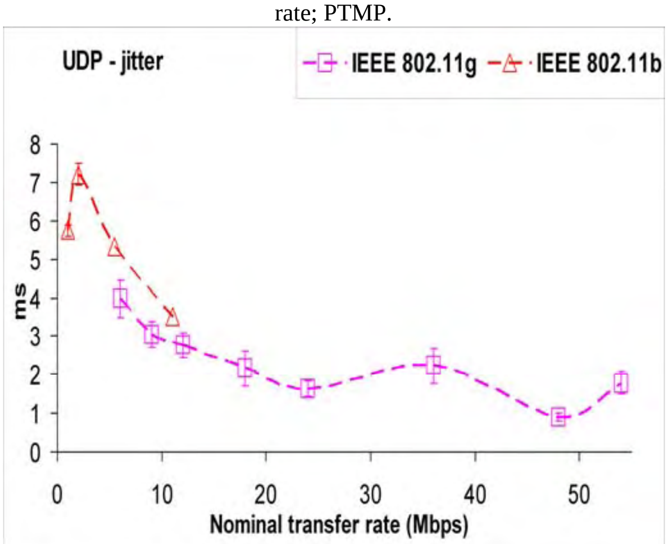

Fig. 6- UDP - jitter results versus technology and nominal transfer rate; PTP [11].

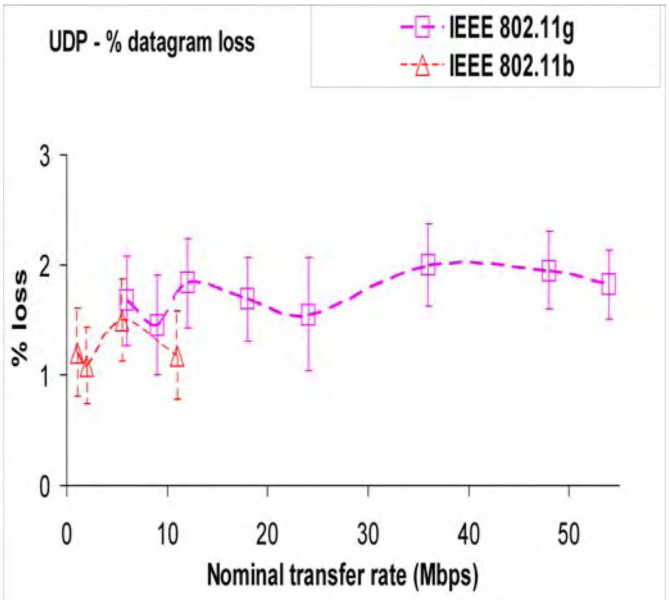

Fig. 7- UDP – percentage datagram loss versus technology and nominal transfer rate; PTMP.

IV. Conclusion

A new laboratory setup arrangement has been planned and implemented, that permitted systematic performance measurements of new available wireless equipments (DAP-1522 access points from D-Link and WPC600N adapters from Linksys) for Wi-Fi (IEEE 802.11 b,g) in WPA point-to-multipoint links.

Through OSI layer 4, TCP throughput, jitter and percentage datagram loss were measured and compared for each standard and WPA PTMP and PTP links. It was found that, on average, the best TCP throughputs are for 802.11 g and PTP links. On average, the best jitter performances were found for 802.11 g and PTP links. For percentage datagram loss, no significant sensitivities were found, within the experimental errors, to link type.

In comparison to PTP links, TCP throughput and jitter were found to show performance degradations for PTMP links, where the access point has to maintain links between PCs.

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

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

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