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Performance Studies of Wi-Fi IEEE 802.11 A,G WPA Point-to-Multipoint Links

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

***Abstract*—Wireless communications using microwaves are increasingly important, such as Wi-Fi. Performance is a most fundamental issue, leading to more reliable and efficient communications. Security is equally very important. Laboratory measurements were performed on several performance aspects of Wi-Fi (IEEE 802.11a, g) WPA point-to-multipoint links. Our study contributes to performance evaluation of this technology, using available equipments (DAP-1522 access points from D-Link and WPC600N adapters from Linksys). New 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 to corresponding results obtained for point-to-point links. Conclusions are drawn about the comparative performance of the links.**

***Index Terms*—Wi-Fi, WLAN, WPA Point-to-Multipoint Links, IEEE 802.11a, 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. 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 have 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 where a WPAN permits 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. CSMA/CA is the medium access control. Wireless communications, wave propagation [2,3] and practical implementations of WLANs [4] have been studied. Detailed information has been given about the 802.11 architecture, including performance analysis of the effective transfer rate. An optimum factor of 0.42 was presented for 11 Mbps point-to-point links [5]. Wi-Fi (802.11b) performance measurements are available for crowded indoor environments [6].

Performance evaluation is a crucially important criterion to assess the reliability and efficiency of communication. In comparison to traditional applications, new telematic applications are specially sensitive to performances. 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. Microwave radio signals travel through the air and can be easily captured by virtually everybody. 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. In WEP, 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. WPA implements the majority of the IEEE 802.11i standard [1]. It includes a MIC, message integrity check, replacing the CRC used in WEP. WPA2 is compliant with the full IEEE 802.11i standard. It includes CCMP, a new AES-based encryption mode with enhanced security. WPA and WPA2 can be used in either personal or enterprise modes. 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 [10,11] and WPA2

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J. A. R. Pacheco de Carvalho is with the Remote Detection Unit and the Physics Department, University of Beira Interior, 6201-001 Covilha, Portugal (phone: +351 275 319 703; fax: +351 275 319 719; e-mail: pacheco@ ubi.pt).

H. Veiga is with the Remote Detection Unit and the Informatics Centre, University of Beira Interior, 6201-001 Covilha, Portugal (e-mail: hveiga@ubi.pt).

C. F. Ribeiro Pacheco is with the Remote Detection Unit, University of Beira Interior, 6201-001 Covilha, Portugal (e-mail: a17597@ubi.pt).

A. D. Reis is with the Remote Detection Unit and the Physics Department, University of Beira Interior, 6201-001 Covilha, Portugal, and with the Department of Electronics and Telecommunications/ Institute of Telecommunications, University of Aveiro, 3810 Aveiro, Portugal (e-mail: adreis@ubi.pt).

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[12] links, as well as very high speed FSO [13]. In the present work new Wi-Fi (IEEE 802.11 a,g) results arise, using personal mode WPA, through 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.

In prior and actual state of the art, several Wi-Fi links have been investigated. Performance evaluation has been considered as a crucially important criterion to assess communications quality. The motivation of this work is to evaluate performance in laboratory measurements of WPA point-to-multipoint links using available equipments. Comparisons are made to corresponding results obtained for point-to-point links. This contribution permits to increase the knowledge about performance of Wi-Fi (IEEE 802.11 a,g) links [4-6]. The problem statement is that performance needs to be evaluated under security encryption and several topologies. The solution proposed uses an experimental setup and method, permitting to monitor, mainly, signal to noise ratios (SNR) and noise levels (N) 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: 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 [14], 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 [15]. 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 [16], to enable PTMP links to the access point. In every type of experiment, interference free communication channels were used (ch 36 for 802.11a; ch 8 for 802.11g). This was checked through a portable computer, equipped with a Wi-Fi 802.11 a/b/g/n adapter, running NetStumbler software [17]. WPA encryption was activated in the AP and the wireless adapters of the PCs, using AES and a shared key composed of 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 [18]. 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 [12]. 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 can be seen as 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 [19]. 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, respectively. 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 adapters of the PCs were manually configured for each standard IEEE 802.11 a, g with typical nominal transfer rates (6, 9, 12, 18, 24, 36, 48, 54 Mbps). For every fixed transfer rate, data were obtained for comparison of the laboratory performance of the WPA 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 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. 2.

The main average TCP and UDP results are summarized in Table I, both for WPA PTMP and PTP links. The statistical analysis, including calculations of confidence intervals, was carried out as in [20]. In Figs. 3 and 4 polynomial fits were made (shown as y versus x), using the Excel worksheet, to the 802.11a, g TCP throughput data for 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 a and PTP links. In Figs. 5-8, the data points representing jitter and percentage datagram loss were joined by smoothed lines. It was found that, on average, the best jitter performances are for 802.11 g and PTP links. Concerning percentage datagram loss, the best performance was for 802.11a and PTP links. In comparison to PTP links. TCP throughput, jitter and percentage datagram loss were found to show performance degradations for PTMP links.

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 the IEEE 802.11a, 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 show the same trends found for TCP throughput.

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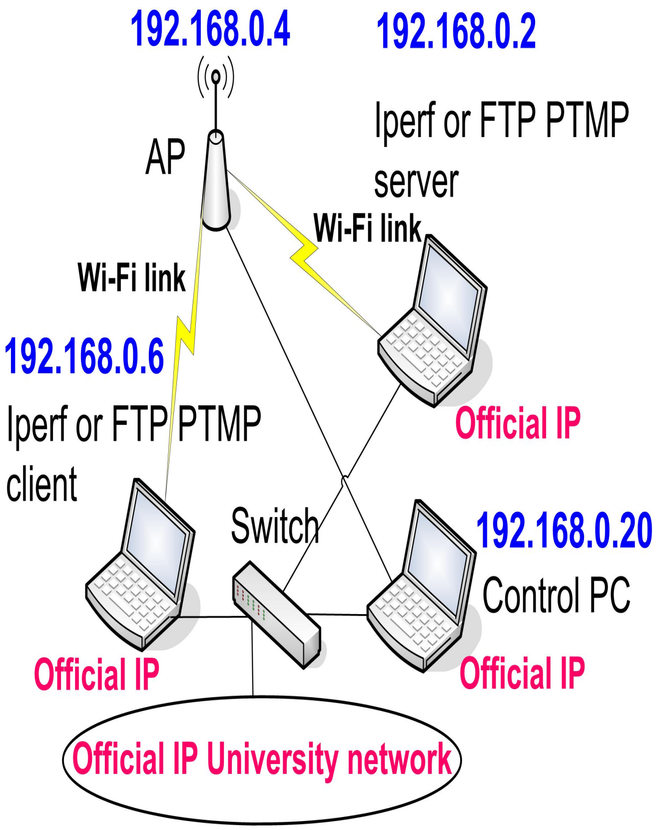

Fig. 1- Laboratory setup scheme; PTMP.

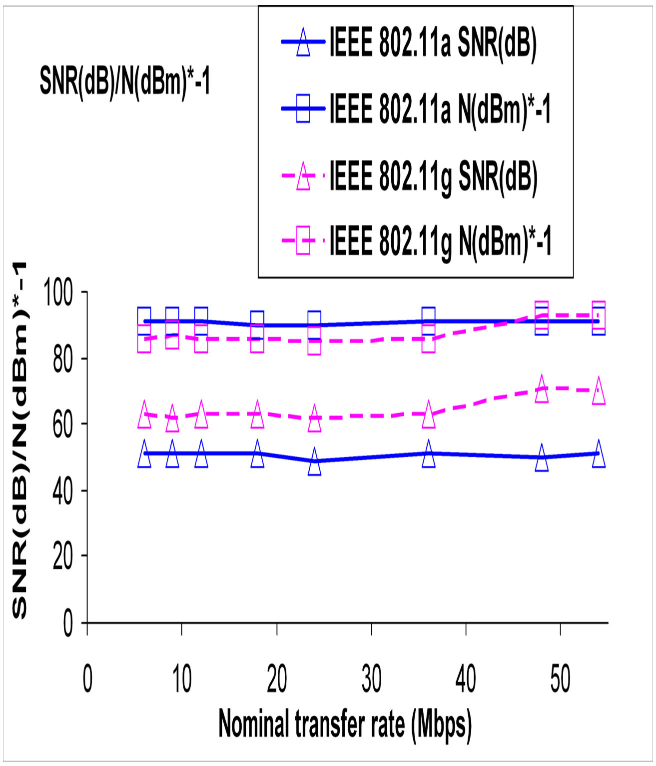

Fig. 2- Typical SNR (dB) and N (dBm).

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

Link type	PTMP		PTP	
Parameter/ IEEE standard	802.11a	802.11g	802.11a	802.11g
TCP throughput (Mbps)	7.5 +-0.2	6.3 +-0.2	15.9 +-0.5	13.4 +-0.4
UDP-jitter (ms)	3.3 +-0.7	3.5 +-0.5	2.5 +-0.5	2.3 +-0.1
UDP-% datagram loss	2.2 +-0.1	1.7 +-0.1	1.2 +-0.2	1.8 +-0.2

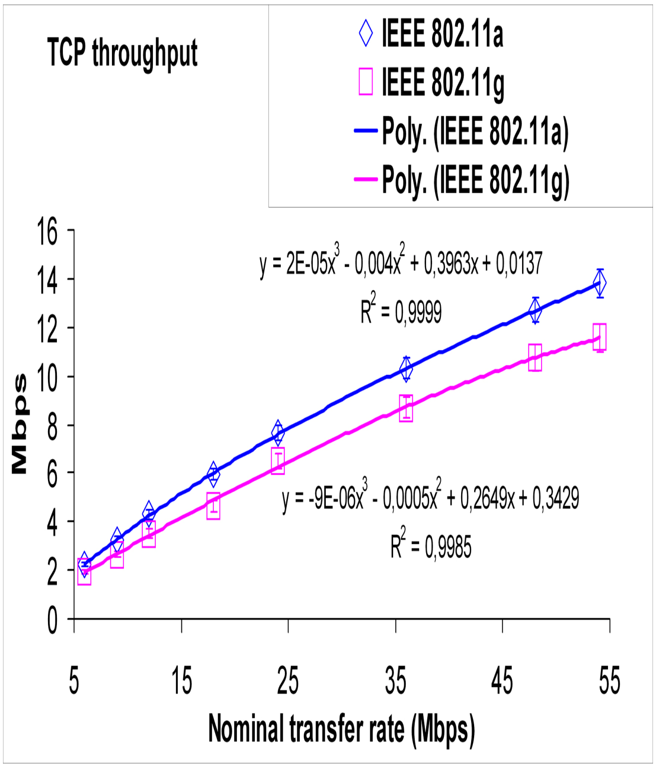

Fig. 3- TCP throughput (y) versus technology and nominal transfer rate (x); PTMP.

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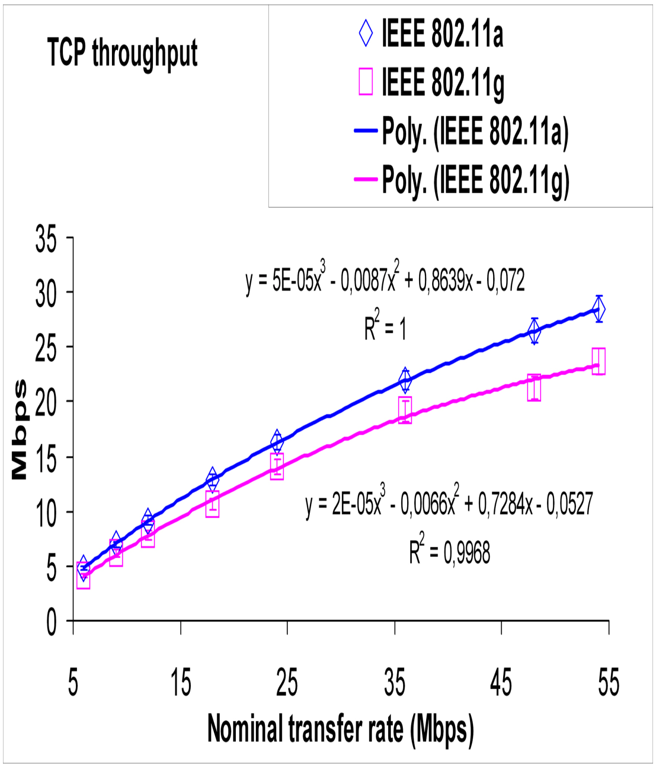

Fig. 4- TCP throughput (y) versus technology and nominal transfer rate (x); PTP.

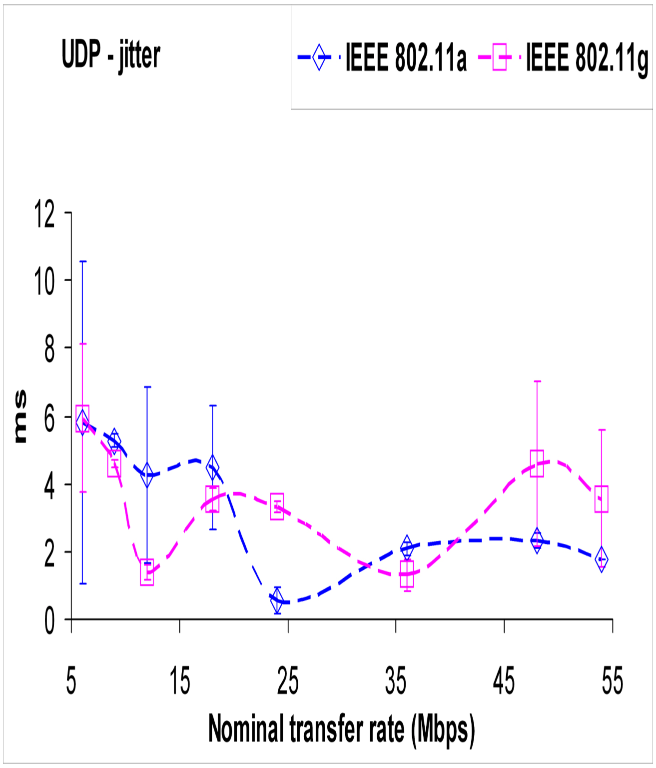

Fig. 5- UDP – jitter results versus technology and nominal transfer rate. PTMP.

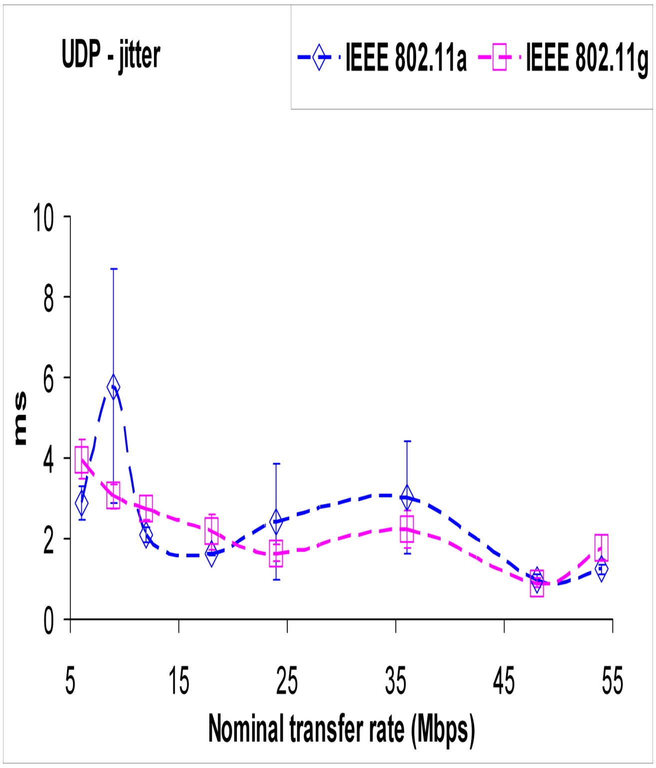

Fig. 6- UDP – jitter results versus technology and nominal transfer rate. PTP.

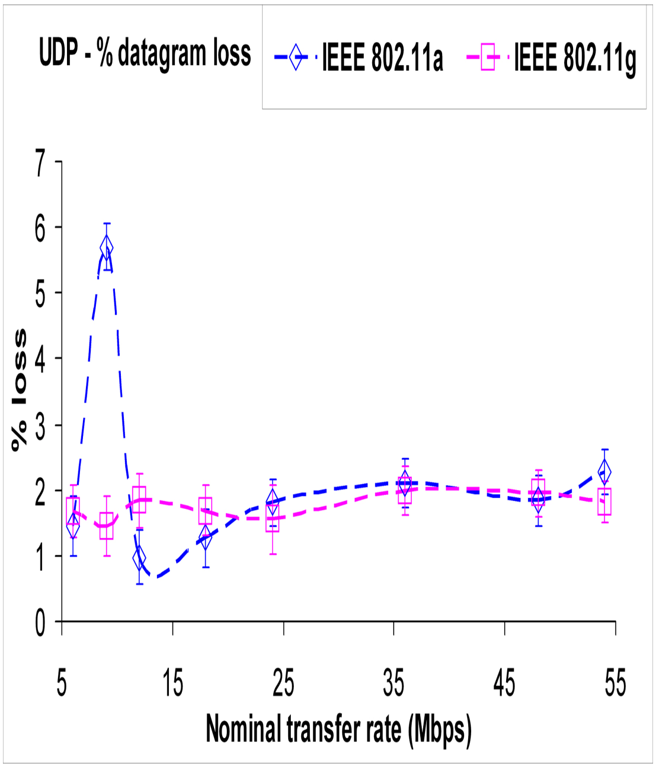

Fig. 7- UDP – percentage datagram loss results versus technology and nominal transfer rate. PTMP.

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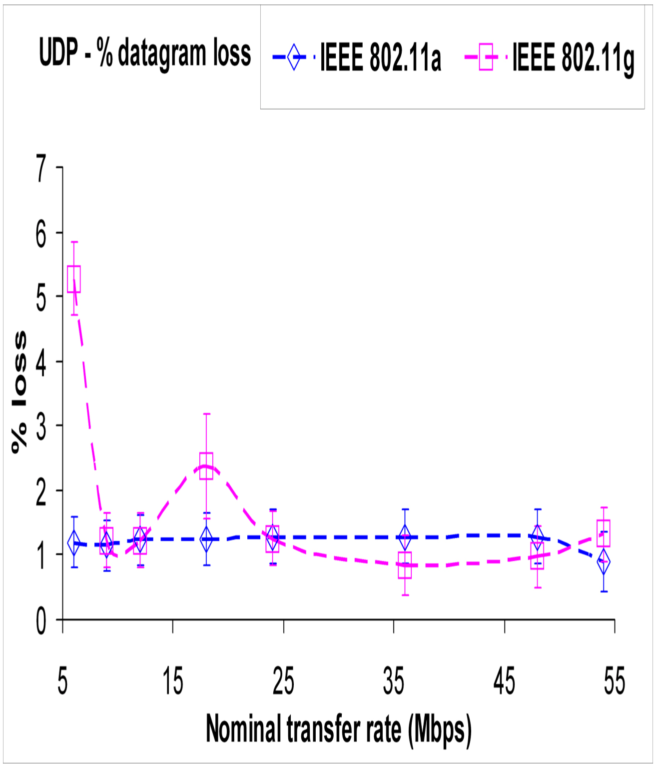

Fig. 8- UDP – percentage datagram loss results versus technology and nominal transfer rate. PTP.

IV. Conclusion

In the present work a new laboratory setup arrangement was 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 a, 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 a and PTP links. On average, the best jitter performances were found for 802.11 g and PTP links. Concerning percentage datagram loss, the best performance was for 802.11a and PTP links.

In comparison to PTP links, TCP throughput, jitter and percentage datagram loss 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.

Further 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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