Comparative Performance Studies of Laboratory WPA IEEE 802.11gPoint-to-Point Links

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Abstract – **Wireless communications using microwaves are increasingly important, e.g. Wi-Fi. Performance is a very important 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 802.11gWPApoint-to-point links. A contribution is given to performance evaluation of this technology under WPA encryption, using available wireless routers from Linksys (WRT54GL). 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, mainly, open links. Conclusions are drawn about the comparative performance of the links.**

Keywords –**WLAN, Wi-Fi, WPA Point-to-Point Links, IEEE 802.11g, Wireless Network Laboratory Performance.**

I. INTRODUCTION

Wireless communication technologies have been developed using electromagnetic waves in several frequency ranges, propagating in the air. It is the case of e.g. Wi-Fi and FSO, whose importance and utilization have been increasing.

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 electronic 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 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]. As the 2.4 GHz band becomes increasingly used interferences increase. There is a large base of installed equipments working in this band. The 5 GHz band has been receiving 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 where an optimum factor of 0.42 was presented for 802.11b point-to-point links [5]. Wi-Fi (802.11b) performance measurements are available for crowded indoor environments [6].

Performance evaluation is a fundamentally 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 everyone. 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 [8-10] and WEP links [11], as well as very high speed FSO [12]. It is important to find the effects of WPA encryption on link performance. Therefore, in the

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present work new Wi-Fi (IEEE 802.11 g) results arise, using personal mode WPA, through OSI levels 4 and 7. Performance is evaluated in laboratory measurements of WPA point-to-point links using available equipments. Comparisons are made to corresponding results obtained for, mainly, open 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 Linksys WRT54GL wireless routers [13], with a Broadcom BCM5352 chip rev0, internal diversity antennas, firmware DD-WRT v24-sp1-10011 [14] and a 100-Base-TX/10-Base-T Allied Telesis AT-8000S/16 level 2 switch [15]. The wireless mode was set to bridged access point. This was not possible to achieve with the firmware from the manufacturer. 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 [16]. WPA personal encryption was activated in the APs, using AES and a shared key composed of 9 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 was planned and implemented for the measurements, as shown in Fig. 1. At OSI level 4, measurements were made for TCP connections and UDP communications using Iperf software [17], 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 [18]. 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 allocated to the present work. 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. Each PC had a second network adapter, to permit remote control from the official IP Unit network, via switch.

III. Results and Discussion

The access points were configured for IEEE 802.11 g with typical nominal transfer rates (6, 9, 12, 18, 24, 36, 48, 54 Mbps). 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. 1. For 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 and Fig. 3 for WPA and open links, respectively.

The main average TCP and UDP results are summarized in Table I, both for WPA and open links. In Fig. 4 polynomial fits were made to the 802.11 g TCP throughput data for WPA links, where R^2 is the coefficient of determination. A fairly good agreement was found between the WPA data and the data for open links. Also, both data agree fairly well with those from recent WEP measurements. In Figs. 5-7, the data points representing jitter and percentage datagram loss were joined by smoothed lines. It was found that the best jitter performances are, by descending order, for open links, WEP and WPA. Increasing security encryption was found to degrade jitter performance. Concerning percentage datagram loss data (1.4 % on average) no significant sensitivities were found to link type.

At OSI level 7 we measured FTP transfer rates versus nominal transfer rates configured in the access points for IEEE 802.11 g, as in [11]. The average results thus obtained are summarized in Table I, both for WPA and open links. In Fig. 8 polynomial fits are shown to 802.11 g data for WPA links. The results show the same trends found for TCP throughput.

Generally, except for jitter, the results measured for WPA links were found to agree, within the experimental errors, with corresponding data obtained for WEP and open links.

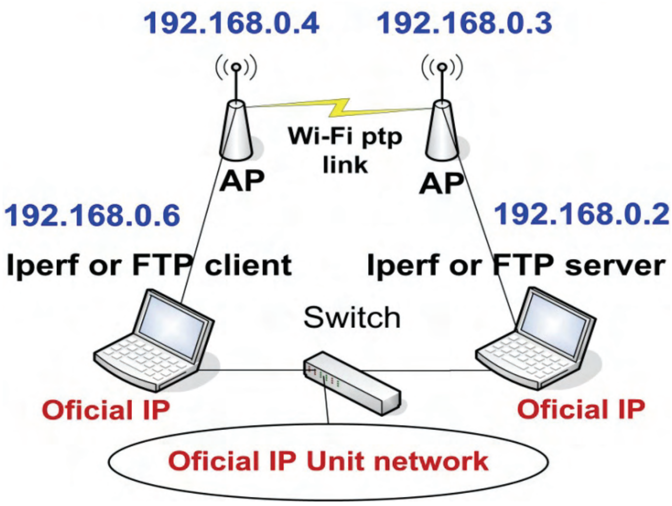

Fig. 1- Laboratory setup scheme.

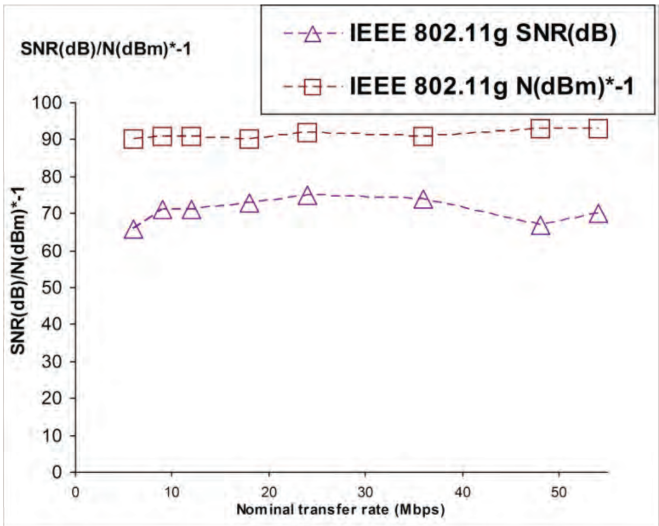

Fig. 2- Typical SNR (dB) and N (dBm); WPA links.

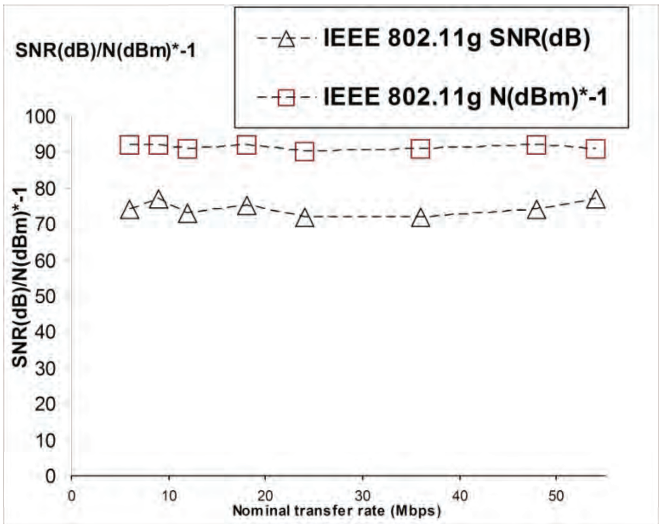

Fig. 3- Typical SNR (dB) and N (dBm); open links.

TABLE I
Average Wi-Fi (IEEE 802.11 g) results; WPA and Open links.

Link type	WPA	Open
TCP throughput (Mbps)	14.1 +-0.4	13.9 +-0.4
UDP-jitter (ms)	2.2 +-0.1	1.2 +-0.1
UDP-% datagram loss	1.2 +-0.1	1.6 +-0.1
FTP transfer rate (kbyte/s)	1527.0 +-45.8	1508.3 +-45.2

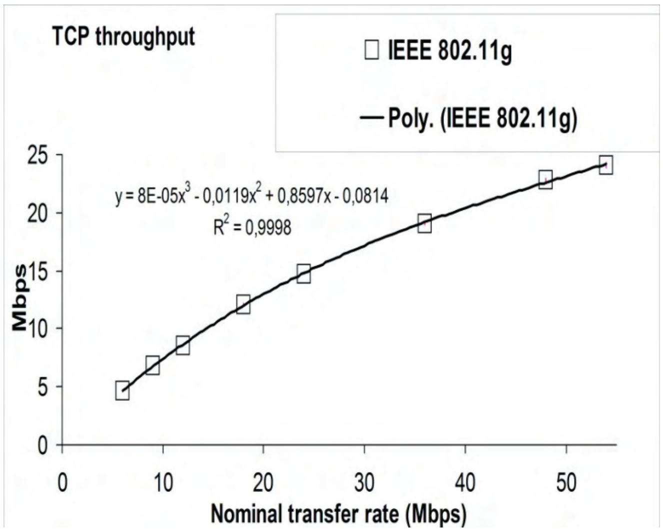

Fig. 4- TCP throughput versus technology and nominal transfer rate; WPA links.

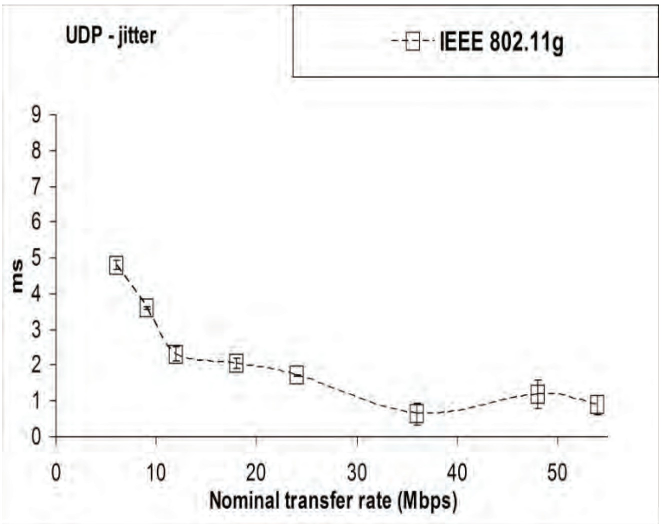

Fig. 5- UDP - jitter results versus technology and nominal transfer rate; WPA links.

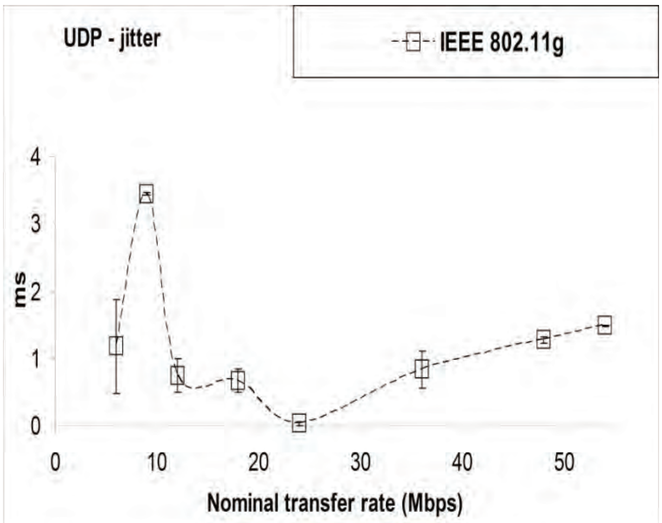

Fig. 6- UDP - jitter results versus technology and nominal transfer rate; open links.

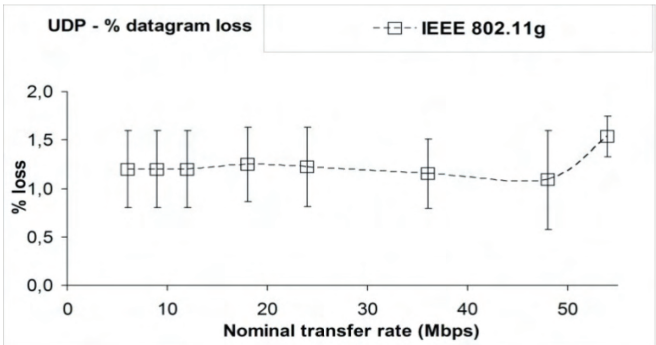

Fig. 7- UDP – percentage datagram loss versus technology and nominal transfer rate; WPA links.

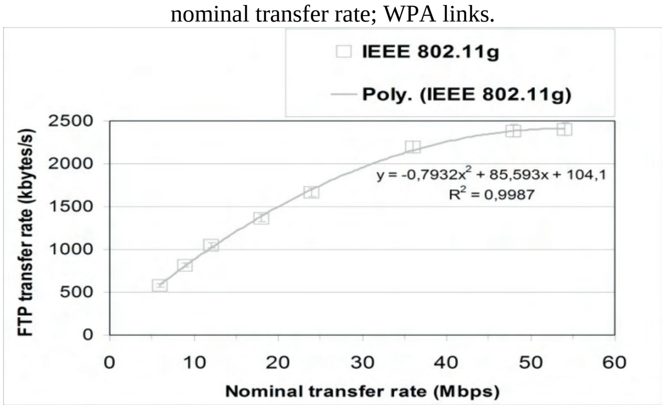

Fig. 8- FTP transfer rate versus technology and nominal transfer rate; WPA links.

IV. CONCLUSION

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

Through OSI layer 4, TCP throughput, jitter and percentage datagram loss were measured and compared for several link types. The average TCP throughput data were found to agree fairly well for WPA, WEP and open links. Concerning jitter, it was found that the best jitter performances are, by descending order, for open links, WEP and WPA. Increasing security encryption was found to degrade jitter performance. Concerning percentage datagram loss, no significant sensitivities were found to link type.

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

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

ACKNOWLEDGEMENT

Supports from Universidade da Beira Interior and FCT (Fundação para a Ciência e a Tecnologia)/POCI2010 (Programa Operacional Ciência e Inovação) are acknowledged.

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