Análisis del desempeño en un enlace descendente de redes basadas en los estándares IEEE 802.11b, IEEE 802.11n y WDS.

Performance analysis of down-link networks compliant with IEEE 802.11b, IEEE 802.11n and WDS standards.

Análise de desempenho para um downlink de redes baseadas em IEEE 802.11b, IEEE 802.11n e WDS.

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Resumen

En este artículo se analiza el desempeño del enlace descendente de redes basadas en los estándares IEEE 802.11b, IEEE 802.11n y WDS (*Wireless Distributed Systems)* al interior de un edifico. Para ello se plantean tres escenarios considerando fija la ubicación del transmisor en el primer piso y que el receptor varía su ubicación a las distancias de 3.6m, 7.2m y 10.8m desde el transmisor, existiendo un obstáculo entre cada distancia. En la obtención de resultados se emplea la técnica intrusiva de inyección de tráfico teniendo como principales métricas de desempeño al *throughput* normalizado, *delay*, *packetloss* y *jitter*. Los mejores resultados considerando el *throughput* normalizado como medida de eficiencia se obtuvieron con la red basada en el estándar IEEE 802.11n en el primer escenario con 78 %, mientras que en el segundo escenario WDS presenta una eficiencia de 52 %, finalmente en el tercer escenario con IEEE 802.11b se obtiene una eficiencia de 17 %.

Palabras clave: fluctuación de retardo, paquetes perdidos, retardo, rendimiento normalizado.

Abstract

This article analyzes the performance of the downlink based on IEEE 802.11b, IEEE 802.11n and WDS (Wireless Distributed Systems) in an indoor environment. We proposed three scenarios considering a fixed location of the transmitter on the first floor and the receiver varies its location at distances to 3.6m, 7.2m and 10.8m from the transmitter with obstacles among each distance. We used traffic injection as an intrusive technique, by considering the normalized throughput, delay, jitter and packet loss as main performance metrics. The best results in terms of efficiency related to the normalized throughput is obtained in the first scenario with the network based on IEEE 802.11n reaching 78 %, while in the second scenario WDS has an efficiency of 52 %, and finally in the third scenario with IEEE 802.11b we obtained an efficiency of 17 %.

Key words: jitter, packetloss, delay, normalized throughput.

Resumo

Este artigo descreve o desempenho do downlink com base em IEEE 802.11b, IEEE 802.11n e WDS (Wireless Sistemas Distribuídos) dentro de um edifício é analisado. Para fazer isso, considerando três cenários surgem local fixo no primeiro transmissor chão e o receptor muda a sua localização a uma distância de 3,6 m, 7.2m e 10,8 milhões a partir do transmissor, há um obstáculo entre cada distância. Na obtenção de resultados técnica de injeção de tráfego intrusivo com os principais indicadores de desempenho para processamento normalizado, delay, e packetloss jitter utilizada. Considerando o melhor rendimento medidas normalizadas dos resultados de eficiência foram obtidas com o padrão com base em IEEE 802.11n na primeira fase com a rede de 78%, enquanto que no segundo cenário WDS tem uma eficiência de 52%, finalmente, na terceira fase IEEE 802.11b com uma eficiência de 17% é obtido.

Palavras-chave: jitter, perda de pacotes, atraso, desempenho padrão.

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Introduction

Wireless technology has become one of the most used for access to the network, being the standard IEEE 802.11 with its technology Wi-Fi (Wireless Fidelity) as the most popular network of wireless local area network WLAN (Wireless Local Area Network) (Aman & Sikdar, 2012). Due to its high use from its inception, the standard IEEE 802.11b was approved in 1999, which counts with a 11Mbps maximum transfer rate and a 20MHz bandwidth, however, the rate of transmission is reduced when the receiver detects errors, due to interference or attenuation of the channel, causing a decline to 5.5Mbps, 2Mbps, and as little as 1 Mbps. Moderate speed and low cost of devices managed rapid growth of this technology on the market (Sendra, García Pineda, Turró Ribalta, & Lloret, 2011). Currently still there are devices that work with this standard, that is maintains existing despite the advances of the standard IEEE 802.11. On the other hand, the standard IEEE 802.11n was born as a proposal for amendment, in order to significantly improve the performance of the network. IEEE 802.11n is built on the basis of previous standards of the family of IEEE 802.11, adding the feature of MIMO (*multiple-input multiple-output*), which presented a theoretical maximum rate of 600Mbps with a 40MHz channel bandwidth (Hiertz, Denteneer, Stibor, Zang, Costa, & Walke, 2010). The standard IEEE 802.11n works with OFDM (*Orthogonal Frequency Division Multiplexing*) modulation and has 127 different transfer rates, presenting consumer products from 6.5Mbps, 13Mbps, 26Mbps, 52Mbps, 65Mbps, 117Mbps and 130Mbps. On the other hand, WDS (Wireless Distributed Systems) also known as Repeater mode, is a system that enables wireless interconnection between the AP (Access Point) of an IEEE 802.11 network, i.e., is used to extend the coverage of the network and use directions MAC instead of assignments IP to connect customers (Zaggoulos & Nix, 2008).

In the literature there are works that study the network performance analysis corresponding to the standard IEEE 802.11, as the of Sendra et to the. (2011) and Sendra, Fernandez, Turro and Lloret

(2010), who performed a comparison of IEEE 802.11a/b/g/n in indoor environments, for which used a surface with a length and a width of 12.5m by 6.68m. The building is made with walls of various thicknesses and materials, the tests are performed according to the Radio Signal Strength Indicator (RSSI), coverage area and measurement of Co-channel interference (CCI), they also performed an analysis taking into account different brands of routers, thus finding (Sendra et al., 2011) that the standard IEEE 802.11b possesses greater strength of signal at larger distances, while the standards IEEE 802.11g and IEEE 802.11n obtained lower signal strength, on the other hand (Sendra et al. 2010) came to the conclusion that the best standards to an indoor environment are IEEE 802.11b and IEEE 802.11n. In addition, Sendra, Lloret, Turro & Aguiar (2014), perform a comparison of IEEE 802.11a/b/g/n to determine the placement of wireless sensors in a building, based is in the intensity of the signal generated by an AP, obtaining that the best technologies for indoor environments are IEEE 802.11b and IEEE 802.11n, while the worst are IEEE 802.11 g and IEEE 802.11a, but when analyzing the intensity of the signal depending on the distance the higher intensity is IEEE 802.11b and the worst are IEEE 802.11g and IEEE 802.11n. On the other hand, with respect to WDS (Belghith, Tagar, & Braham, 2009) and (Tahar, Belghith, & Braham, 2009) multi-interface WDS studies are carried out to improve its performance, which is what is currently being used to extend Wi-Fi coverage. Finally, in our previous work (Lara-Cueva R. , Benítez, Fernández, & Morales, 2015) is the analysis of performance of Ad-Hoc, IEEE 802 Networks. 11b and WDS by *throughput*, *delay*, *jitter* and *packetloss* parameters considering scenarios in an interior of a building, obtaining that WDS —as the distance between the transmitter and the receiver increases— presents the best efficiency. No comprehensive study has been done about the performance analysis of a network based on WDS evaluated with the UDP protocol in an indoor environment.

In the IEEE 802.11 standard two operating modes, the Ad-Hoc mode and infrastructure are defined. will focus only on this item in infrastructure mode because it is the way most used in today's wireless networks because communication is via wireless links using Wi-Fi routers, for which it requires AP connecting all devices (Chen, Chan & Liew, 2003) and considering the analysis parameters normalized throughput, delay, jitter and packetloss, in an indoor environment with obstacles. For our case is analyzed only BSS (Basic Service Set English) (Jiang & Delgrossi, 2008), ie with AP and Client. To carry out this work three different scenarios are proposed, taking into account the distance and obstacles between the floors of a building, using intrusive techniques injection traffic, considering the parameters of throughput normalized, delay, jitter and packetloss of IEEE 802.11b networks, IEEE 802.11n WDS (as an extension of IEEE 802.11b).

This paper is organized as follows: section II materials used both hardware and software are detailed, plus a description of the proposed scenario and the necessary settings for traffic injection is performed. Section III performance analysis shows the results obtained parameters normalized throughput, delay, jitter and packetloss and an analysis of each of them. Finally, section IV is the discussion that the results obtained with other work and the conclusions that have been reached when performing this analysis are compared, as well as proposals for future work that can be performed from this Article.

MATERIALS AND METHODS

For this study, two laptop computers as terminals are used, the transmitter has a processor core i5 operating at 2.3 GHz with RAM 6GB and the receiver has a processor core i7 operating at 2.4 GHz with RAM memory of 8 GB, the same that have Linux (Ubuntu 12.04) operating system, as well as free software D-ITG (English Distributed Internet traffic Generator) for injecting traffic scenarios considered in this work, plus two routers are used with antennas internal PIFA type (Planar Inverted English-F Antenna), which have the characteristics shown in table I. Finally, the analysis of the acquired data is performed through mathematical tool MATLAB®.

Table 1. Router Features.

Parámetro	**Descripción**	
Protocolo 802.11	a/b/g/n	
Banda de Frecuencia (GHz)	2.4 y 5 de doble banda	
Velocidad Máxima (Mbps)	300 para 2.4 GHz 450 para 5 GHz	
Ganancia de Antenas (dBi)	Para 2.4 GHz	PIFA 1 <= 3.6
		PIFA 2 <= 3.8
		PIFA 3 <= 3.8
	Para 5 GHz	PIFA 1 <= 4.8
		PIFA 2 <= 5.3
		PIFA 3 <= 5.2
Tecnología de las antenas	MIMO 3x3	
Amplificadores Wi-Fi	2 SiGe 2528L045CA 2.4 GHz 3 SE2594L 5 GHz	
Sensibilidad de recepción	-87 dBm para IEEE 802.11b -68 dBm para IEEE 802.11n	

Stage

In Figure 1 the proposed scenarios are given to determine the maximum capacity of the channel with each of the standards, maintaining the transmitter fixed and varying the location of the receiver to 3.6m, 10.8m 7.2my transmitter, being these distances They are possessing each of the floors of the building. Tests were performed without obstacles, ie with line of sight.

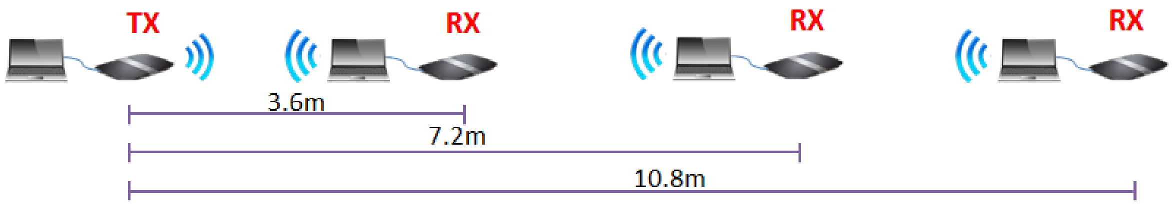
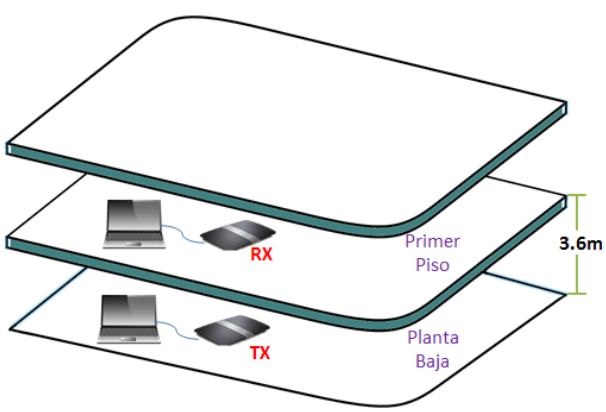


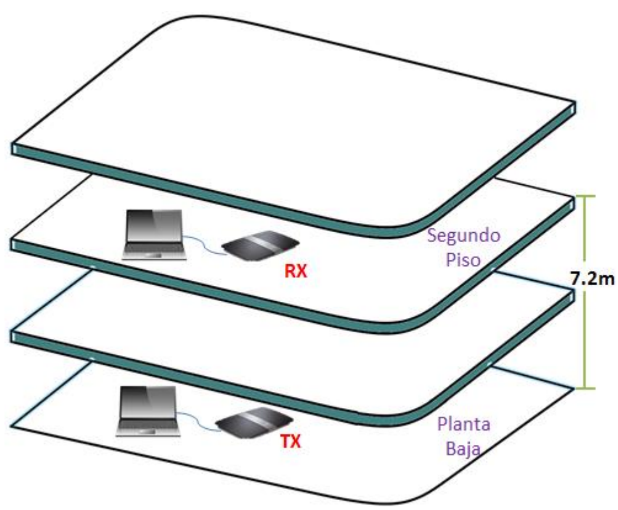
Figure 1.- Unobstructed test scenarios to determine the maximum channel capacity at certain distances.

Figure 2 shows the stages used for separate injections were performed the same as in an indoor environment at an average temperature of 21 ° C, with the obstacles floors of a building. For scenario A is taken as an obstacle a floor between the transmitter and receiver at a distance of 3.60 meters to stage B are considered two floors as obstacles, having a distance of 7.2 meters and scenario C have three floors network obstacle with a distance of 10.8 meters.

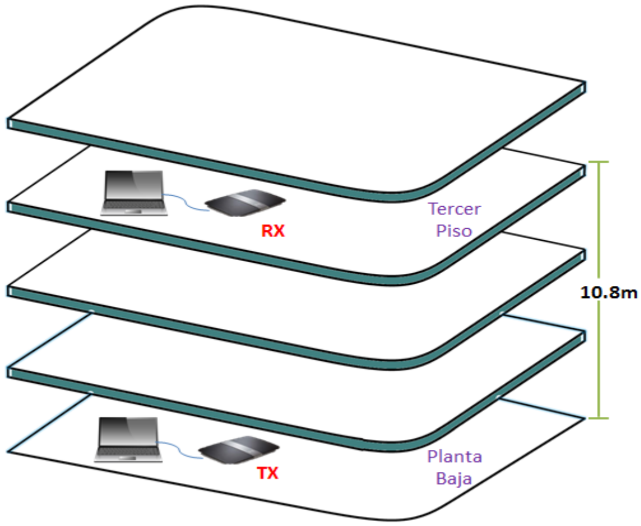
It should be noted that to carry out the tests, the building had an ideal environment, ie, there were people within the same or networks which could be interference, the material that is made each floor is concrete with a thickness of 30cm, each floor also has false ceiling. Given that the values of each injection are sensitive to vary from each other, five injections for each proposed scenario, thus achieving reduce uncertainty and the root mean square error, which is working with average values were performed performance parameters.



Escenario A



Escenario B



Escenario C

Figure 2.- Scenarios to evaluate the performance of networks.

Methods

One of the important aspects to consider is the timing, as this is to ensure that all network equipment work with a signal identical clock or as close in frequency and phase (Elson & Römer, 2003) and be synchronized computers ensures that there are no negative values or very outdated network. In this way it ensures that obtaining the value of the delay given by the D-ITG is correct. In this paper the synchronization is done via the NTP protocol (Network Time Protocol) (Mills, 1991), it is generally used to synchronize clocks on the Internet. In this case, the deployed network is not connected to the Internet, so the clocks are synchronized by creating your own server, for which you enter the /etc/ntp.conf file and the following changes are made.

At the transmitter the local clock is added as a server.

server 127.127.1.0,
fudge 127.127.1.0 stratum 10.

At the receiver it is assigned as the IP transmitter that local server is configured as a server.

server ip-servidor.

To synchronize the client to the server running the command:

$ sudo ntp -u ip-servidor.

To make traffic injection is required of a traffic generator, which is used to analyze and evaluate the performance of the network (Avallone, Guadagno, Emma, & Ventre, 2004). In this case, traffic injection is performed by means of the tool D-ITG (Botta, Dainotti, & Pescapé, 2012), the same used to generate traffic packet level, for which version 2.7 is used. 0-Beta2, this software has the advantage of presenting the parameters to be analyzed: normalized throughput, packetloss, delay and jitter (Srivastava, Anmulwar, Sapkal, Batra, Gupta, & Kumar, 2014). Values set at the transmitter side shown in Table II.

Table 2. Configuración de D-ITG

Parámetro	**Valor**
Métrica	*One way delay*
Duración (s)	30
Inicio del retardo (s)	0
Protocolo	UDP
Paquetes	470 / 930
Tasa de transmisión (Mbps)	2/ 4/ 6/ 10/ 11
Host de destino	IP receptor

In this case the UDP protocol (Pearson, 2001) is used, since it is a non-connection-oriented protocol also only unidirectional flow is analyzed, ie the downlink. Moreover it is working with the parameter One-way delay (Gurewitz, Cidon, & Sidi, 2006) because it only considered the time it takes a packet to be transmitted through the network from transmitter to receiver.

To determine how many packets should be sent, taken into account the percentage of packets lost in the various injections. First tests were conducted without hindrance, as shown in Figure 1, considering the distance of each stage to establish the maximum channel capacity to each standard, for which the size of packets to be transmitted are varied; first channel is flooded until a percentage of packets lost approximately 0%. Once the packets to be transmitted on each floor with each standard specific tests are performed using the scenario of Figure 2.

PERFORMANCE ANALYSIS

In this section the results obtained with respect to each of the parameters to be analyzed are presented.

In Table III the different traffic injections were performed to determine how many packets must be transmitted is. To carry out tests transmission rates to each working standard were considered.

Table 3. Determination of transmission rate set distances, depending on the percentage of lost packets.

Estándar	Distancia (m)	Paquetes	Tasa de Transmisión (Mbps)	Tasa de Recepción (Mbps)	Paquetes Perdidos (%)
IEEE 802.11b	3.6	1625	7	4.25	34.05
		1270	5.5	4.09	4.6
		930	4	3.8	0.01
	7.2	470	2	1.92	0.01
	10.8	470	2	1.93	0.01
IEEE 802.11n	3.6	35000	150	10.20	88.34
		12500	54	11.20	77.75
		4650	20	11.02	41.41
		2550	11	10.44	0.01
	7.2	2320	10	9.5	0.02
	10.8	1400	6	5.8	0.02
WDS	3.6	1400	6	5.82	0.02
	7.2	930	4	3.8	0.02
	10.8	470	2	1.89	0.02

Throughput normalizado

Throughput is the amount of information per unit of time is successfully delivered to the destination.

The efficiency is calculated using Equation 1(Lara-Cueva R. , Benítez, Caamano, Zennaro, & Rojo-Alvarez, 2014):

$$Ef = \frac{\eta}{RBR} \times 100 \, , \tag{1}$$

Where, η it is *throughput* received in the transmission and *RBR* is the net rate of transmission (del inglés *Raw Bit Rate).*

Different numbers of packages considering the maximum channel capacity shipped, so the RBR is different for each case. According to the standard indicating and marked on the equipment used for injections traffic RBR shown in Table IV were used.

Table 4. Network Efficiency

Escenario	Tipo de Red	RBR(Mbps)
A	IEEE 802.11b	5.5
	IEEE 802.11n	13
	WDS	11
B	IEEE 802.11b	5.5
	IEEE 802.11n	13
	WDS	11
C	IEEE 802.11b	5.5
	IEEE 802.11n	13
	WDS	5.5

Figure 3 shows the efficiencies of networks deployed with and without obstacles depending on the distance, which the IEEE 802.11n without obstacles has increased efficiency in all scenarios, achieving on stage A, at a distance of 3.6m , 80% and 78% with an obstacle, for the stage B at a distance of 7.2m it has an efficiency of 73% unhindered same decays significantly to 16% at present two obstacles; in the stage C at a distance of 10.8m it has the lower efficiency of 44% unhindered value is reduced to 8% with three obstacles.

The network has the second best efficiency without obstacles is deployed with IEEE 802.11b which has 69% efficiency in stage A, at a distance of 3.6m, value is reduced to 26% at present an obstacle; whereas in stage B at a distance of 7.2m, unobstructed efficiency 35% and 20% with two obstacles is obtained by; for stage C at a distance of 10.8m similar values are presented, having unobstructed efficiency 35% and 17% three obstacles.

Finally the WDS network deployed with lower efficiency presented unhindered, obtaining for the stage A, at a distance of 3.6m unobstructed efficiency 53%, it is maintained by having an obstacle in between, achieving an efficiency of 52 %; on stage B and C the same values unobstructed efficiency obtained with the deployed with IEEE 802.11b 35%, same as two obstacles were reduced to 29% and 15% three obstacles to network.

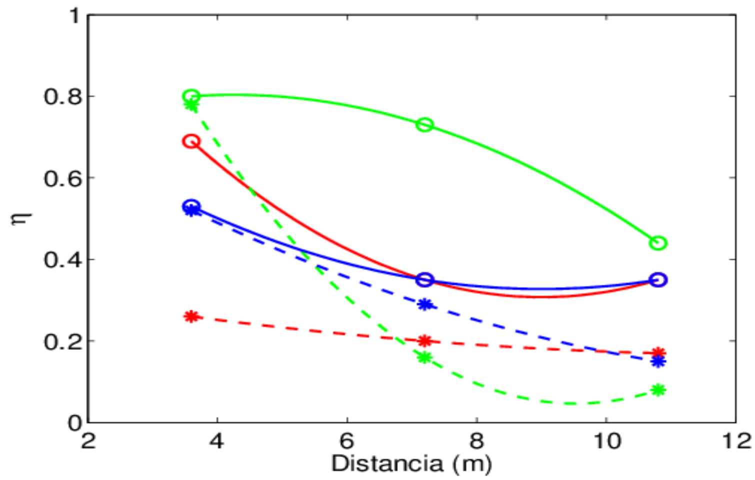
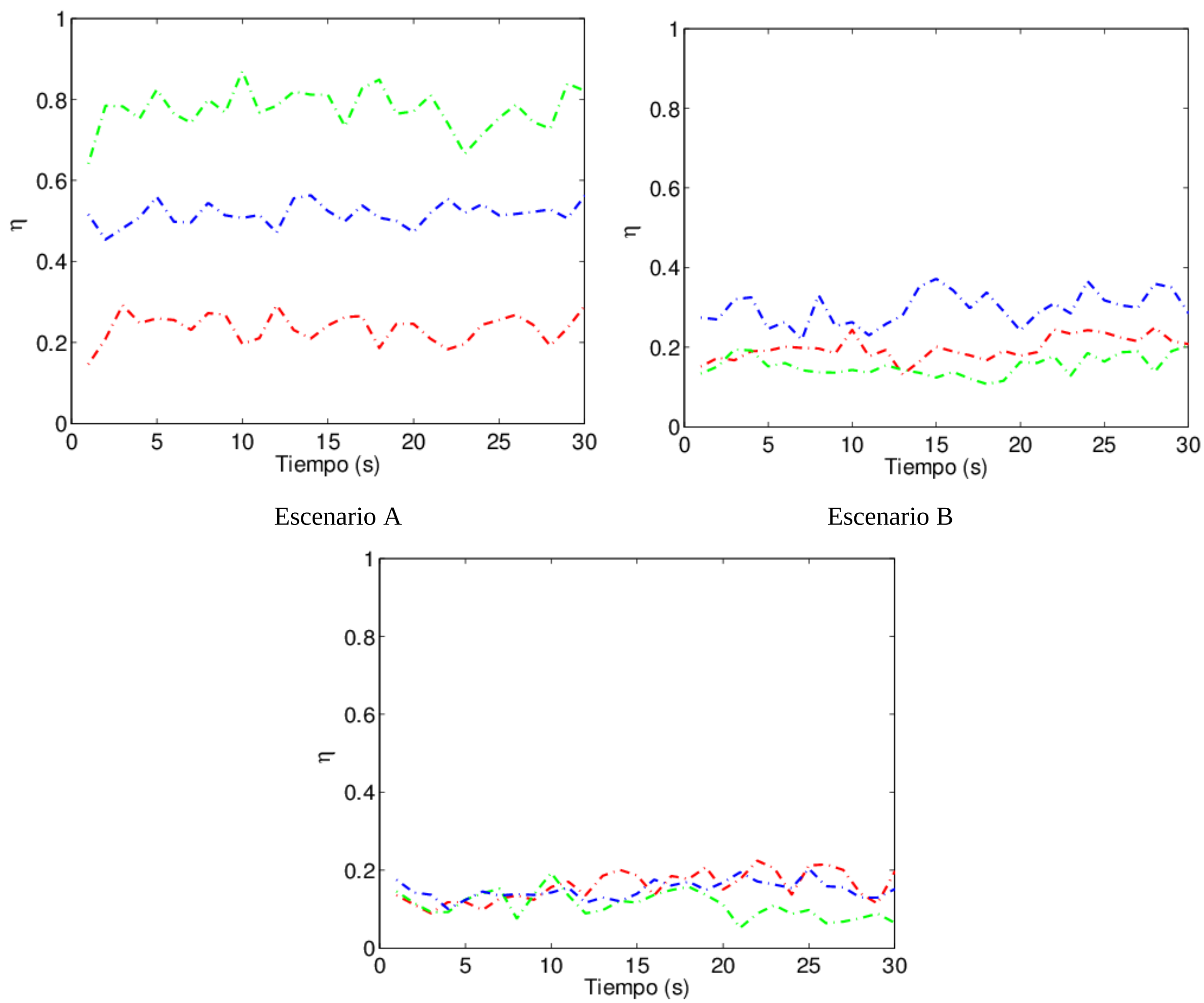


Figure 3. Efficiency of networks depending on the distance. The dashed line is efficiency considering the obstacles and the solid line without obstacles, where it is represented by red to IEEE 802.11b, green IEEE 802.11n and blue WDS.

Figure 4 shows the η function of time. It is observed in Figure 4.a that the greatest value is for IEEE 802.11n η having oscillatory values between 0.64 and 0.87 having an average value of 0.78, followed by WDS with values between 0.45 and 0.56 with a mean value of 0.52 and with lower performance network is the IEEE 802.11b network with values between 0.14 and 0.29, giving an average value of 0.26. While for the stage B and IEEE 802.11n networks have considerable decrease WDS decaying values between 0.11 and to 0.19, with a mean of 0.16 for IEEE 802.11n and values between 0.21 and 0.37 with a mean value of 0.29 for WDS; for IEEE 802.11b instead it has values between 0.13 and 0.25 having an average value of 0.20 as shown in Figure 4.b. the Furthermore, Figure 4.c. It presents approximate values in all cases, thus having values for IEEE 802.11n 0.19 from 0.05 with a mean value of 0.08, for WDS values between 0.1 and 0.2 with an average of 0.15, finally the network having the best performance in this scenario it is displayed with the IEEE 802.11b with values between 0.08 and oscillatory 0.22, giving an average value of 0.17.



Escenario A

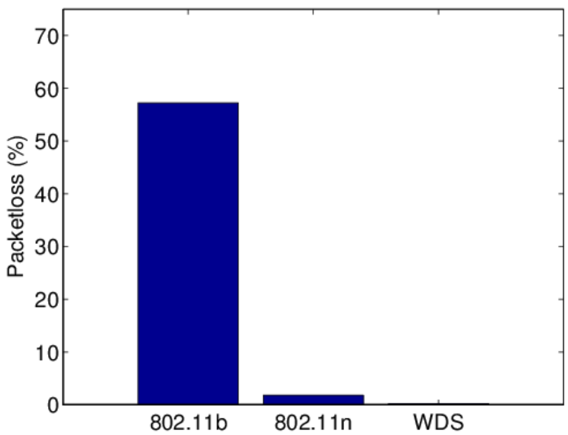
Escenario B

Escenario C

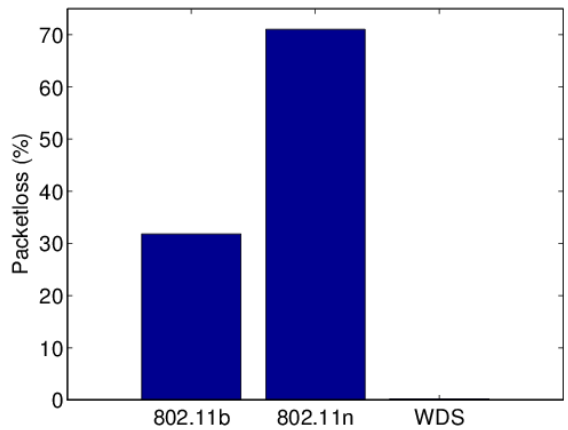
Figure 4 .- *Throughput* proposed standard versus time scenarios where red is represented by a IEEE 802.11b, green IEEE 802.11n and blue WDS.

Packetloss

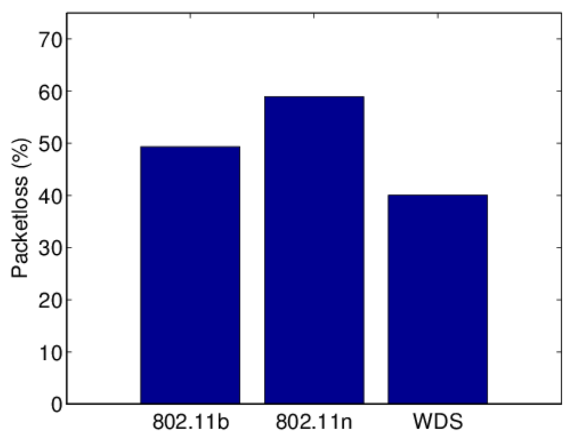
In Figure 5 the network packet loss in each of the proposed scenarios are observed. For scenario A, the network that has the highest percentage of lost packets is IEEE 802.11b 57 .24%, while other networks have less than 2% of lost packets, thus having 1.82% for IEEE 802.11n lower loss obtained is 0.22% for WDS. In scenario B lost packets increase considerably for the IEEE 802.11n network with 71%, while for IEEE 802.11b there is a decrease in packet loss, with 31.8%, while WDS remains constant with 0.21% of lost packets. For scenario C the percentage of lost packets is greater than 40% in all cases, for IEEE 802.11n the highest percentage of 58.95%, followed by IEEE 802.11b with 49.35% and the lowest value is obtained is obtained WDS 40 %.



Escenario A



Escenario B

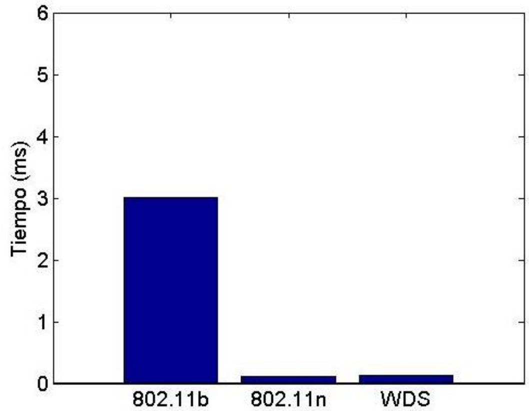


Escenario C

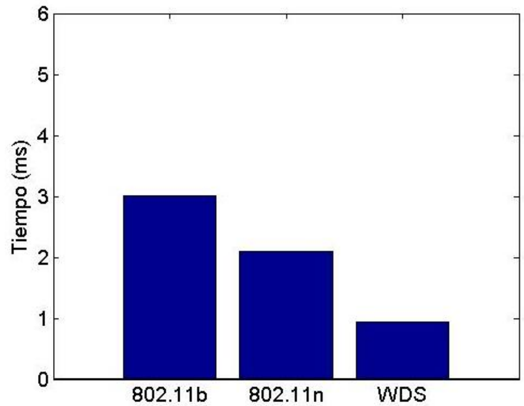
Figure 5.- Network packets lost in the different scenarios depending on the time.

Delay

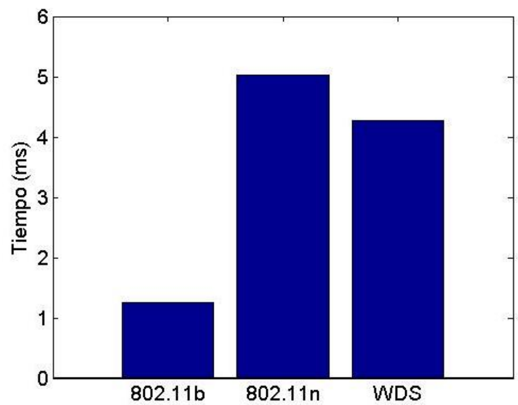
The delay values obtained are shown in Figure 6. For scenario A is have similar values for IEEE 802.11n networks and 0.11ms and 0.12ms WDS respectively, which are low values compared to the IEEE 802.11b that has 3ms. On the other hand, for the B stage in the WDS network deployed with the least delay of 0.93ms value is obtained by following the deployed with IEEE 802.11n network 2.1ms, while the delay network with IEEE 802.11b remains constant 3ms. Finally on stage C difference values are obtained for the other scenarios, the network that has less delay is the IEEE 802.11b 1.26ms, 4.27ms followed by WDS network and the more delay is the IEEE 802.11n 5.03ms .



Escenario A



Escenario B

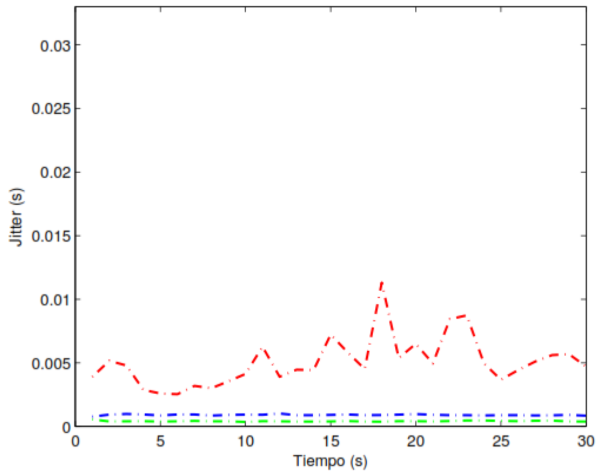


Escenario C

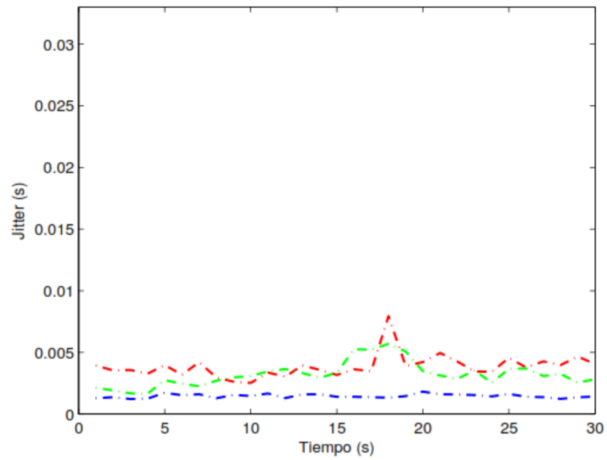
Figura 6.-.Delay de la red en los diferentes escenarios en función del tiempo.

Jitter

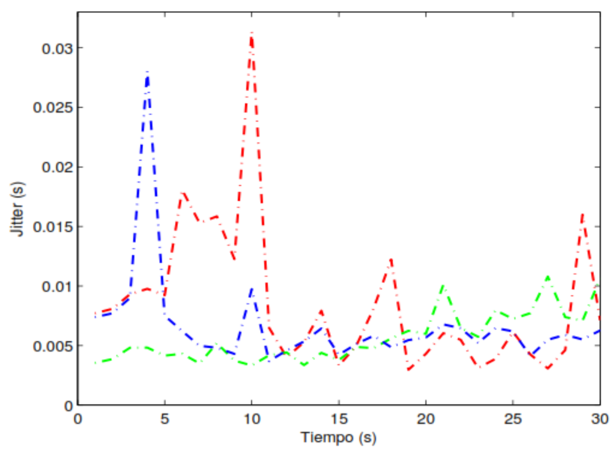
Figure 7 shows the jitter of each of the IEEE 802.11 standards. It is noted that the IEEE 802.11b standard oscillatory has values in the range of 2.5ms to 11.3ms for the stage A, having an average value of 4.8ms; in scenario B this value does not vary having an average value of 4.1ms, however, on stage C this value has great oscillations between 31.4ms 2.9ms to, obtaining an average value of 7.3ms. This value can be because there is a greater distance and the presence of obstacles between the teams. In the deployed with IEEE 802.11n for setting the average value A network is 1.9ms, while the stage B presents this value a slight increase 2.5ms, however, this value in stage C has an average value of 9.2ms. For network deployed with WDS shows that different values are presented on stage, and taking to the stage to an average value of 2.7ms, value increases in stage B to 7.3ms, finally on stage C presented with a average value of 6.4ms.



Escenario A



Escenario B



Escenario C

Figure 7.-. *Jitter* network in different scenarios depending on the weather, which is represented by red to IEEE 802.11b, green IEEE 802.11n and blue WDS.

Conclusions

In this paper the parameters of normalized throughput, delay, jitter and packetloss they were measured in an indoor environment with IEEE 802.11b, IEEE 802.11n WDS, getting that at a distance of 3.6m with a floor of an obstacle by the standard IEEE 802.11n has the best performance, but this is not a stable in the other scenarios standard, the efficiency drops considerably, so at a distance of 10.8m with three floors as obstacles networks deployed IEEE 802.11b WDS with they are those with the best performance. On the other hand, it was determined that the standard undergoes changes less in all scenarios and all performance parameters is deployed IEEE 802.11b, but their values are not the most optimal in all cases.

According to the analysis of all parameters of performance was established that the deployed with WDS network is the best in all cases have the lowest values of delay, jitter and the lowest percentage of packetloss also the efficiency with WDS to have the presence of obstacles is the highest except for the first stage which is overcome by IEEE 802.11n.

Moreover it determined based on a network WDS improves efficiency by IEEE 802.11b standard in 26% at a distance of 3.6m with concrete obstacle between the transmitter and receiver, and 9% at a distance of 7.2m with two obstacles between the transmitter and receiver, but for a distance of 10.8m with three obstacles between the transmitter and the receiver deployed with the IEEE 802.11b standard network is higher by 2% compared to WDS.

In analyzing the results obtained with the work previously described (Sendra et al., 2011), is presented to the IEEE 802.11n has lower performance, in no case exceed 5%, while IEEE 802.11b best efficiency was obtained obtaining average values of 25%, however these data are opposed to our work and that greater efficiency is obtained in IEEE 802.11n, but only to stage a with 78% efficiency, value declines to 8% in scenario C while deployed with IEEE 802.11b network is more stable in all cases obtaining an efficiency between 26% to 17%, comparable value to those obtained in the aforementioned articles. On the other hand (Sendra et al., 2014), when analyzing the signal intensity depending on the distance, they get deployed with the IEEE 802.11b network is more intense and the worst are IEEE 802.11g standards IEEE 802.11n, a result that resembles obtained in this work since the greater distance and with more obstacles IEEE 802.11n is the network that has the lowest efficiency.

Finally you want to perform a new analysis contrasting the performance of these networks in an outdoor environment, obtaining maximum coverage thereof, can also make a comparison with the new IEEE 802.11ac also it could perform the same analysis parameters normalized throughput, delay, and jitter packetloss using the TCP protocol since it can analyze the channel bidirectionally.

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