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Análisis de la calidad de servicio de una red WiMAX en conformidad con el estándar IEEE 802.16-2009 en escenarios exteriores

Analysis of the Quality of Service of a WiMAX network in accordance with IEEE 802.16 -2009 in outdoor scenarios

Análise da qualidade de serviço de uma rede WiMAX de acordo com o padrão IEEE 802.16-2009 em cenários externos

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Resumen

El desarrollo tecnológico de las comunicaciones inalámbricas ha hecho que distintos dispositivos se vayan posicionando cada vez más en la vida cotidiana de los usuarios, con lo cual surge la demanda de soportar las mismas aplicaciones que se tienen en una red cableada. Ante esta exigencia se presentan limitaciones de ancho de banda, como es el caso de las redes inalámbricas WiMAX (*Worldwide Interoperability for Microwave Access*). Por lo tanto, se impone la necesidad de brindar calidad de servicio (*QoS* del inglés *Quality of Service*) para garantizar el desempeño del sistema en esa red. En este contexto, el objetivo de este artículo es realizar un análisis de los parámetros de QoS en la tecnología WiMAX según el estándar IEEE 802.16-2009 dentro de una topología diversificada de escenarios exteriores, mediante la utilización de una técnica intrusiva de inyección de tráfico para la obtención de las métricas de desempeño, como el retardo, *jitter*, paquetes perdidos y eficiencia del enlace. En este sentido, se ha verificado que el sistema cumple con las especificaciones necesarias para soportar aplicaciones como televisión digital y VoIP en tiempo real.

Palabras claves: eficiencia del canal, jitter, paquetes perdidos, QoS, retardo, WiMAX.

Abstract

Technological development of wireless communications has made those increasingly positioned in the daily live for different users and with this, emerging the demand to support the same applications as in a wired network. Faced with this need, bandwidth limitations are presented, such as WiMAX (Worldwide Interoperability for Microwave Access) wireless networks, therefore the proposal to provide Quality of Service (QoS) to guarantee the performance of the system in said network. In this context, the main scope of this paper is to analyze the QoS parameters in WiMAX technology in conformance with IEEE 802.16 - 2009 standard, within a diversified topology in external scenarios, by using an intrusive injection traffic technique, in order to obtain performance metrics such as delay, jitter, lost packets and link efficiency. Being verified that the system fulfills the specifications to support applications, such as Digital TV, VoIP and interactive applications in real time that have been presented.

Keywords: channel efficiency, jitter, packets lost, QoS, delay, WiMAX.

Resumo

desenvolvimento tecnológico das comunicações sem fio tem feito vários dispositivos cada vez mais se posicionando no cotidiano dos usuários, apoiando assim a demanda para as mesmas aplicações que surgiram em uma rede com fio. Dada esta largura de banda exigência limitações surgem, tais como redes sem fio WiMAX (Worldwide Interoperability for Microwave Access). Portanto, a necessidade de proporcionar qualidade de serviço (QoS Inglês Quality of Service) para garantir o desempenho do sistema em que a rede é imposta. Neste contexto, o objetivo deste trabalho é uma análise dos parâmetros de QoS em WiMAX

IEEE 802,16-2.009 padrão de acordo dentro de uma topologia diversificada cenários ao ar livre, usando uma técnica invasiva para injecção de tráfego Obtenção de métricas de desempenho, como atraso, jitter, perda de pacotes e eficiência de link. A este respeito, verificou-se que o sistema atende as medidas necessárias para suportar aplicações como TV digital e as especificações em tempo real de VoIP.

Palavras-chave: eficiência do canal, jitter, perda de pacotes, QoS, delay, WiMAX.

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Introduction

Currently, technology advances at an accelerated pace, which generates new techniques and resources for the development of telecommunications systems. This is the case of wireless broadband networks based on WiMAX technology (Worldwide Interoperability for Microwave Access) in accordance with the IEEE 802.16 standard for the wireless transmission of information from a wide variety of applications.

The Institute of Electrical and Electronic Engineering (IEEE) defines with its work group 802.16 the need to implement Quality of Service (QoS) at the level of the physical layer and MAC (from the English Media Access Control) to guarantee the user's experience with the demand of these (Prakash and Pal, 2012), which offers the user the advantage of accessing services with mobility within the coverage of the network without being produce information losses (Berberana, 2014).

However, QoS is defined as the guarantee of quality of service through methods or techniques that apply to a specific technology; an example of this is WiMAX, which refers to the application of procedures to comply with the minimum requirements of metrics, such as jitter variation (j) or transmission rate, which guarantees a certain degree of user satisfaction. The WiMAX environment has a wide diversity of QoS (English schedulling) programming due to its variability with respect to the use of information in real time, such as the UGS (Unsolicited Grant Service), the configuration of its flows to send packets of fixed size in recurring intervals with the lowest latency and possible fluctuation from flows in schedulling classes such as rtPS (Real-time Polling Service), nrtPS (Non-real-time Polling Service), BE (Best Effort) and ErtPS (Extended Real- time Polling Service) (Tranzeo Wireless Technologies Inc., 2010), where the flows of UGS information packets are prioritized over the flows of rtPS, nrtPS, BE and ErtPS.

This means that the system starts processing packets of these schedulling only after it has finished transmitting all the pending UGS packets, where rtPS was designed to support real-time connections that generate packets of variable size, unlike nrtPS that does not present real-time requirements, BE that is used in application traffic that does not require QoS, and ErtPS that supports real-time applications with variable data rates, but that require minimum delay rates and minimum transfer speeds, that hits on the delay (δ) of the wireless network.

When using some type of QoS schedulling, there is the possibility of avoiding a loss of information packets in the transmission. Some applications do not require restrictions of δ, where their transmission of packets only needs an average quality of QoS, that is, schedulling can be used as BE or nrtPS, in which there is not a high robustness in the transmission of information as UGS has it to avoid the existence of service falls (Martínez, 2014).

In the traffic of the channel the schedulling UGS is used to avoid the normal request-grant mechanism, which allows the base station (BS of the English Base Station) to grant automatic priorities to a UGS flow. In other words, the latency in the propagation of information within a system with a WiMAX network is small (5-40 ms) compared to the latency of an IP service (100 ms), which ensures low latency to provide QoS to applications such as voice over IP (VoIP), digital television and interactive applications in real time (Asghar and Ravneet, 2014).

Several works have been carried out around the scientific community, such as Eklund, Marks, Stanwood and Wang (2002) to analyze the characteristics of the physical layer and MAC that are implemented in the IEEE 802.16 standard. In addition, Rosario, Martínez and Crespo (2013) describe the need to guarantee QoS in wireless environments through the evaluation of propagation techniques used in WiMAX technology. On the other hand, Cicconetti, Lenzini and Mingozzi (2006) focus on the mechanisms that are available in the IEEE 802.16 standard to support QoS, and whose effectiveness is evaluated through simulation.

Other authors such as Hsieh, Lee, Wu and Chien (2016) carry out the study on the use of patterns to guarantee the performance of the WiMAX service within a simulation program, while Moscoso (2010) considers the general analysis of the performance of the first amendment to the IEEE Standard 802.16 for wireless access systems for broadcasting, multi-hop switching belonging to the IEEE standards for local and metropolitan area networks, where it is shown that the network performance is 90% in the simulation. In addition, Jarrín (2012) present the design and implementation of the propagation model proposed by Yon Soo Cho, which allows to estimate the losses of the wireless channel for communications based on WiMAX, IEEE 802.16-2009 WirelessMAN Fixed OFDM.

These cited works, however, only theoretically study the application and simulation of QoS in WiMAX systems, so it can be said that there are no previous works in which a real-time examination of QoS in a WiMAX system can be evidenced. .

In this context, the objective of this work is to analyze the QoS in a WiMAX system in accordance with the IEEE 802.16-2009 standard within a diversified topology in external scenarios. This is to deepen the way in which the standard implements these mechanisms through a traffic injection analysis to obtain information in real time that serves to specify the QoS metrics for a detailed study, in which the development of the system is appreciated. in front of different types of scenarios, which consist of one to three jumps, respectively, within the network.

Method

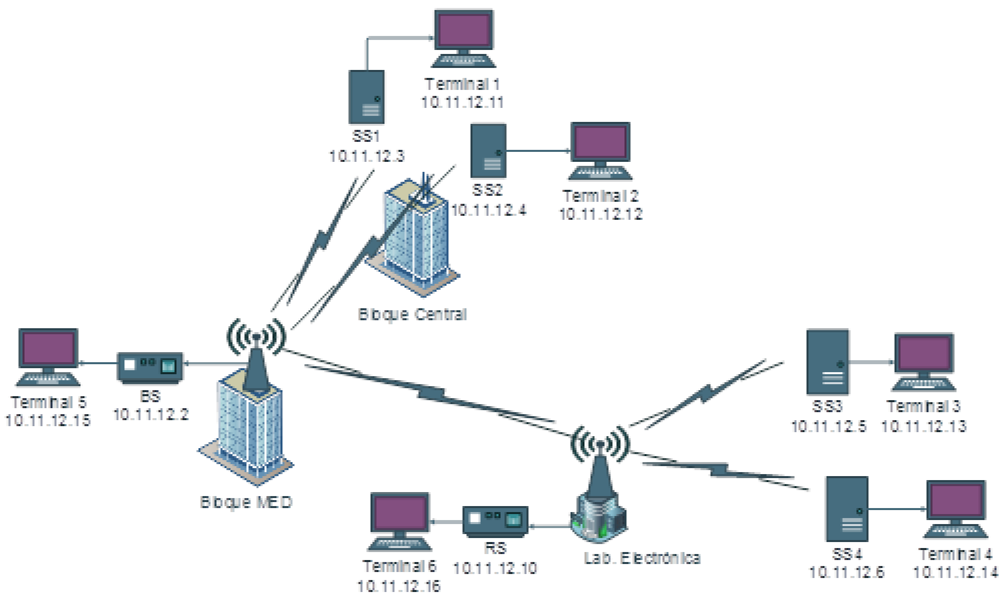
The tests were conducted on the campus of the University of the Armed Forces, ESPE, located in the valley of Los Chillos, in Sangolquí, 22 kilometers southeast of the Colonial Center of Quito, capital of the Republic of Ecuador, at an altitude of 2510 m s. n. m., and with temperatures that oscillate between 15 ° C and 30 ° C. The equipment with WiMAX technology was installed in accordance with the IEEE standard 802.16-2009 (Albentia Systems, 2017), which were located on different buildings of the university. We had a BS (Albentia Systems, 2009a) and a repeater (RS of the English Relay Station) (Albentia Systems, 2009b), which are characterized by using an OFDM modulation, working in the unlicensed frequency bands of 5.4 / 5.8 GHz , have a coverage radius of up to 30 km and allow to configure several types of QoS planning (such as UGS, ertPS, rtPS, nrtPS and BE). In addition to this, the communication between the BS and the rest of the equipment was placed in transparent mode to facilitate the interconnection at the MAC level within each link. There were also four user terminals (SS of the English Subscription Station) (Unidata Wireless Data and Internet Solution, 2009), with a real speed of 32 Mbps, distance of connection with line of sight (LOS of English Line of Sight) of up to 15 km from the BS and without line of sight (nLOS of the English Non Line of Sight) from 3 km to 5 km, to which the final users of the service were connected.

Configuration of scenarios

Figure 1 describes the topology implemented in the facilities of the University of the Armed Forces, ESPE, which was subdivided into three scenarios that were classified according to the number of jumps between transmitter and receiver to obtain a better contrast of the metrics of performance of the network of each of the links.

The BS was installed on the terrace of the postgraduate building (MED), where a 3 m tower was placed (with the approximate height of the building they added 24 m) to take advantage of a wide network coverage and a line of sight with the SS and RS (this guarantees a stable connection of the network). Something similar happened with the SS1 and SS2, which were located on the terrace of the central building (the SS1 had a height of 9 m, while the SS2 was installed at the height of the building).

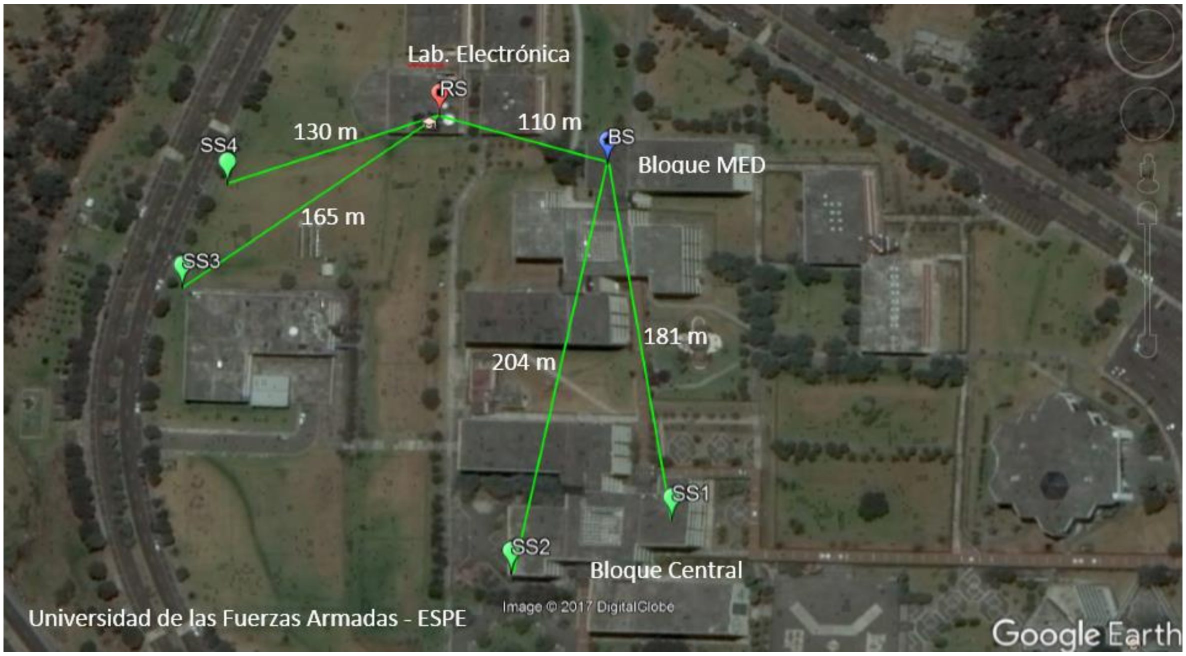
Figura 1. Topología de la red WiMAX implementada en la Universidad de las Fuerzas Armadas, ESPE



Fuente: Elaboración propia

Figure 2 shows the distances to which the network equipment was installed on campus: the SS1 and SS2 antennas with line of sight to the BS, while the SS3 and SS4 antennas pointed towards the RS.

Figura 2. Distancias entre los equipos implementados de la red WiMAX en las instalaciones de la Universidad de las Fuerzas Armadas, ESPE



Fuente: Elaboración propia a partir de Google Earth Pro

On the other hand, Figure 3 shows the first scenario of a jump, where information packets are sent from the SS1 to the BS. Likewise, a similar link for sending information is found in Figure 3 (b), which goes from the SS4 to the RS. In addition, the information was sent from the BS to the RS, where the main link is located. These teams contain the registry of the SS implemented in the network, as shown in Figure 3 (c).

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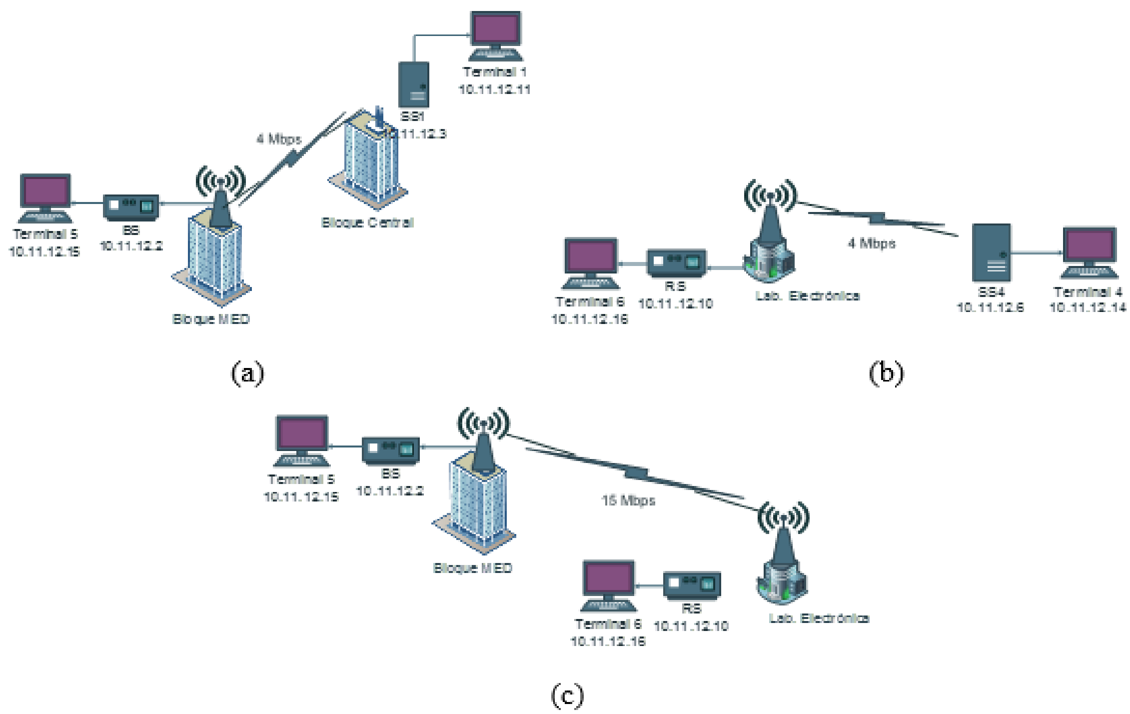
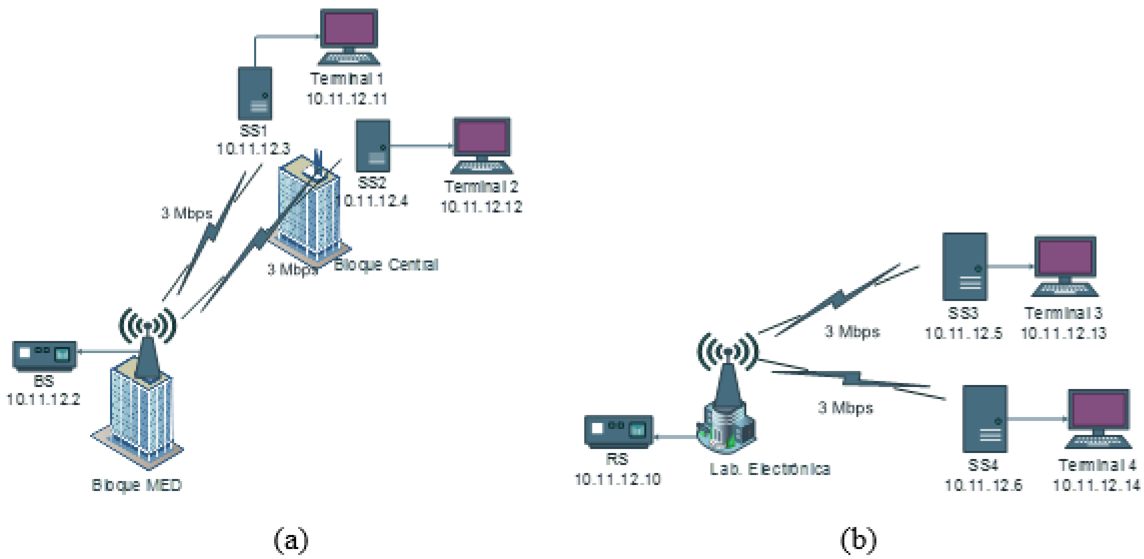
Figura 3. Escenario 1 correspondiente a los enlaces con un salto dentro de la topología de la red: a) envío de paquetes de información desde la SS1 con destino a la BS, b) envío de paquetes de información desde la SS4 con destino a la RS, y c) envío de paquetes de información desde la BS con destino a la RS



Fuente: Elaboración propia

Now, as shown in Figure 4, the second scenario has two jumps: in one, information packets are sent from SS1 to SS2, passing through BS (this contains the information and configuration of the parameters of the link), and in the second there is a similar link in which information is sent from SS3 to SS4 passing through the RS (see figures 4 (a) and 4 (b), respectively).

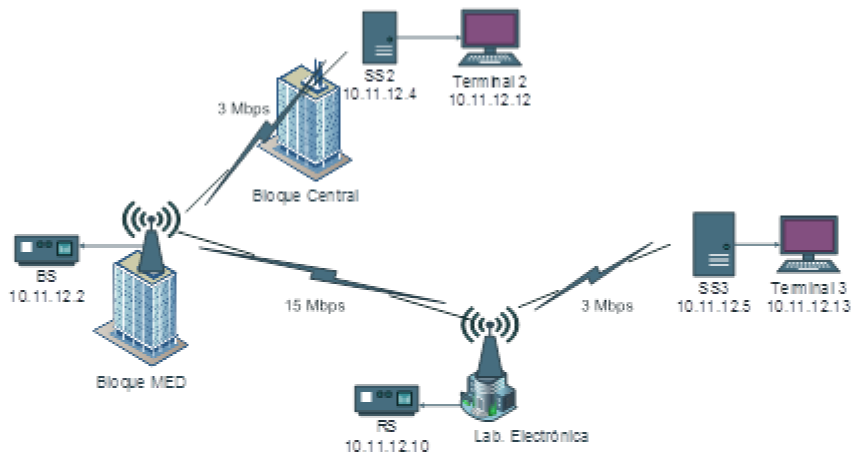
Figura 4. Escenario 2 correspondiente a los enlaces con dos saltos dentro de la topología de la red: a) envío de paquetes de información desde la SS1 con destino a la SS2, y b) envío de paquetes de información desde la SS3 con destino a la SS4



Fuente: Elaboración propia

Figure 5 shows the third scenario consisting of three hops, where information packets are sent from the SS2 to the SS3, passing through the BS and RS, in which the information and configuration of the information are stored. parameters of the link of both ends.

Figura 5. Escenario 3 correspondiente a un enlace de tres saltos dentro de la topología de la red. Envío de paquetes de información desde la SS2 con destino a la SS3



Fuente: Elaboración propia

Performance metrics

To evaluate the performance of the proposed scenarios, performance metrics were considered as δ, j, lost packages (PP) and the *throughput* (η), from which the efficiency is calculated (ξ) of the link, since these metrics are those delivered by the D-ITG software in order to determine the performance of the network.

The δ is the latency that can exist within a network in real time, which can be produced by the distance of the communication link that implies a certain δ on the arrival of messages. On the other hand, j is the variability of the execution time of the packages, which causes that some arrive too early or late to be able to deliver them in time, while PP is the percentage of information sent from the origin to the destination, but that never he came to him.

The amount of information delivered successfully per unit of time is called η, where we have the normalized throughput calculation equation (η_N), as detailed in equation 1 (Lara, Benítez, Caamano, Zennaro y Rojo, 2014).

$$\eta_N = \frac{\eta}{RBR} \quad (1)$$

Where the η it is divided for the net transmission rate (RBR of the English Raw Bit Rate); Therefore, the ξ of the channel corresponds to η_N in percent, as observed in equation 2 (Lara *et al*., 2014).

$$\xi(\%) = \eta_N \times 100 \ (2)$$

Configuration of the links

The links were configured with an RBR both in the uplink (UL of English Uplink) and for the downlink (DL of English Downlink), as shown in table 1.

Tabla 1. RBR configurada para cada enlace

Enlace		RBR (Mbps)	
		UL	DL
SS1	SS2	3	3
SS2	SS3	3	3
SS3	SS4	3	3
SS1	BS	4	4
SS4	RS	4	4
BS	RS	15	15

Fuente: Elaboración propia

For the configuration of the QoS parameters within the BS, UGS was placed as a schedulling with a priority of 1, where the BS prioritizes the UGS packets over the rest of the packets in the network to guarantee the transmission of information within each one of the links. In turn, in the Max Rate parameter (kbps), the value of each of the RBRs included in Table 1 was entered, since it was the maximum value that was configured for each of the links.

Configuration of the D-ITG software tool

To obtain the performance metrics, an intrusive traffic injection technique was used through the software D-ITG (Botta, Dainotti and Pescapé, 2012), which is a platform capable of producing traffic at the packet level, replicating exactly the Stochastic processes to represent a typical transmission channel.

Upon knowing the RBR for each link, the parameters such as the destination IP and the user datagram protocol (UDP of the User Datagram Protocol) were configured in D-ITG, which is a protocol oriented to work offline, that is, not It uses no synchronization between the source and the destination, as it provides a simple interface between the network layer and the application layer.

The number of packets per second injected and the size of the packets was 512 bytes (4 bytes are the IP protocol header and 508 bytes are estimated information for any type of application). Each traffic injection lasted 30 seconds with a sample of 1 second per sample. That is, for each injection of traffic, 30 samples were obtained from each performance metric, which tends to reduce the mean square error. The rest of the parameters were left with the default configuration, as shown in table 2, since only the parameters detailed above needed to be modified.

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Tabla 2. Parámetros de configuración en D-ITG para las pruebas de inyección de tráfico

PARÁMETRO	VALOR
Meter	One-Way-Delay
Inicio de retardo	0 seg
TOS/DS byte	0
TTL	64
Puerto destino	8999 (predeterminado)
Puerto origen	(Automático)
Aplicación capa de datos	Personalizado
Opción de tiempo	Constante
Opción de tamaño	Constante

Fuente: Elaboración propia

One of the important aspects to consider is the synchronization of PC clocks, which is to get all computers in the network work with an identical clock signal or the closest in frequency and phase. By being synchronized computers, it is guaranteed that there are no negative or outdated values in the network. In this way it is ensured that the value of the δ delivered by the D-ITG is correct.

In addition, synchronization was performed through the NTP (Network Time Protocol) protocol, which is generally used to synchronize clocks through the use of the Internet. In this case the implemented network was not connected to the Internet, so the clocks were synchronized creating their own server. For this, the file /etc/ntp.conf was entered and the following changes were made (Lara, Fernández and Morales, 2016): the local clock was added to the transmitter as a server using these commands:

server 127.127.1.0,

fudge 127.127.1.0 stratum 10.

In the receiver, the IP of the transmitter that is configured as a local server was assigned as server through the command line:

server ip-servidor.

Finally, to synchronize the client with the server, the command was executed:

$ sudo ntp -u ip-servidor.

After completing the configuration of the equipment and the D-ITG software, 10 injections of traffic were preceded in each of the links to obtain the performance metrics. Once this information was obtained, the respective analysis was carried out using the graphical tool of MatLab boxplot, which allows a more detailed and concise study about the distribution of the data. (MathWorks, 2017).

Results

Below, the figures with the results obtained in each of the scenarios described in the previous section are shown. It is worth noting that depending on each of these, there was a variation of configurations that influenced the QoS of the traffic injection through the D-ITG.

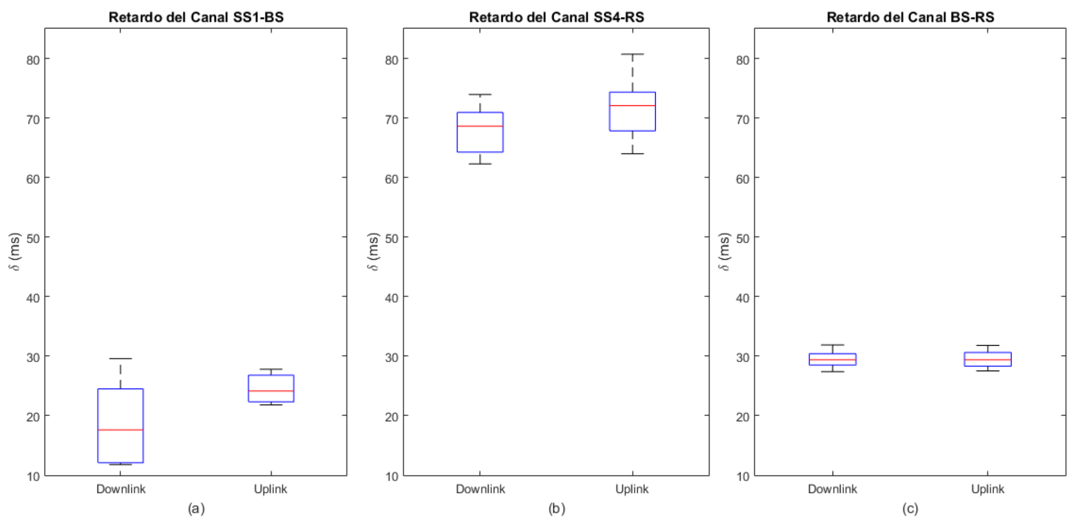
In figures 6, 7, 8 and 9 the performance metrics of scenario 1 are shown: in 6 (a) it has an average value in DL of 17.60 ms lower than in UL of 24.15 ms. It is observed that the extreme values in the DL channel have greater separation than the channels of 6 (a) (UL), 6 (b) and 6 (c), while in 6 (b) and 6 (c) they obey a similar trend in the δ. In 6 (b) there is a DL average of 68.61 ms lower than UL of 72.09, and in 6 (c) totally similar average values are perceived in the two channels, with DL values of 29.40 ms and UL of 29.39 ms.

In 7 (a) there is a DL of 3.33 ms lower than the UL of 5.23 ms, and it can be seen that the extreme values of the DL channel have a wide separation compared to the channels of 7 (a) (UL), 7 (b) and 7 (c). In 7 (b) and 7 (c) the average values of j are practically the same for the DL and UL channels, where in 7 (b) the value of DL is 1.93 ms and UL of 1.45 ms; in 7 (c) there is DL with 4.86 ms and UL with 4.75 ms.

In relation to the PP of 8 (a) and 8 (c) there is an average value for DL of 0.34% and UL of 0.30%, which are much lower than the average values of 8 (b) in DL of 0.51% and UL of 0.76%. The DL channel in 8 (b) has a greater separation at its upper end with a maximum value of 0.87%.

The average value of the ξ of the channel of 9 (a), 9 (b) and 9 (c) in DL is 89.52% and UL of 89.73%, in the two channels border 90% declared in the standard. In 9 (b) the separation of the lower end of the DL channel is greater than the others, unlike the UL channel in 9 (c), which has a wide separation of its ends with symmetrical shape.

Figura 6. δ del canal en el primer escenario: (a) enlace SS1-BS, (b) enlace SS4-RS, y (c) enlace BS-RS



Fuente: Elaboración propia

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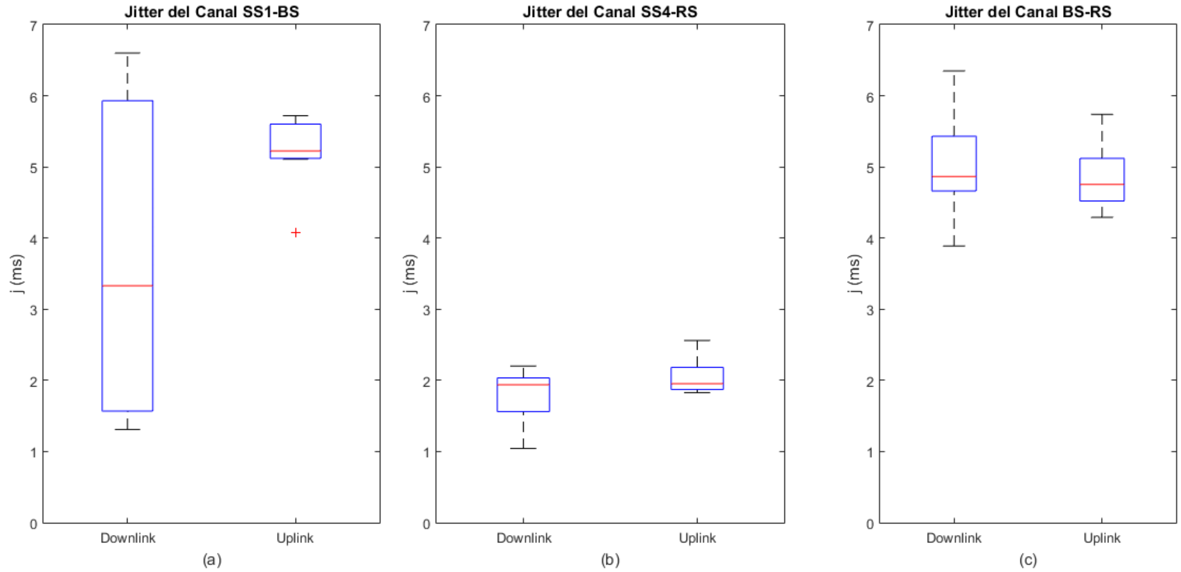
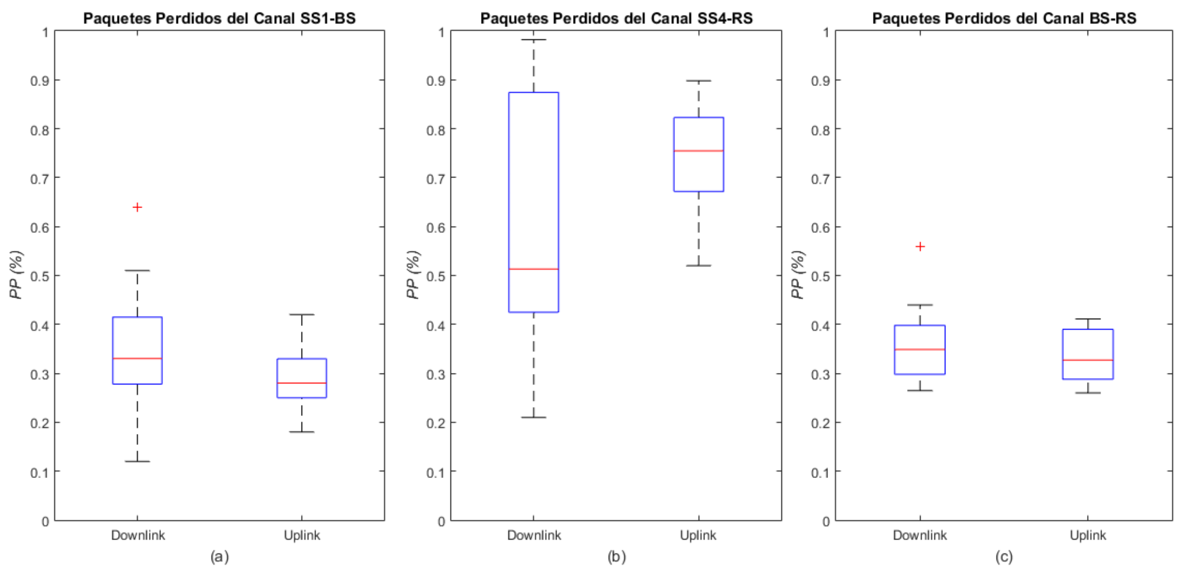
Figura 7. *j* del canal en el primer escenario: (a) enlace SS1-BS, (b) enlace SS4-RS, y (c) enlace BS-RS



Fuente: Elaboración propia

Figura 8. *PP* del canal en el primer escenario: (a) enlace SS1-BS, (b) enlace SS4-RS, y (c) enlace BS-RS



Fuente: Elaboración propia

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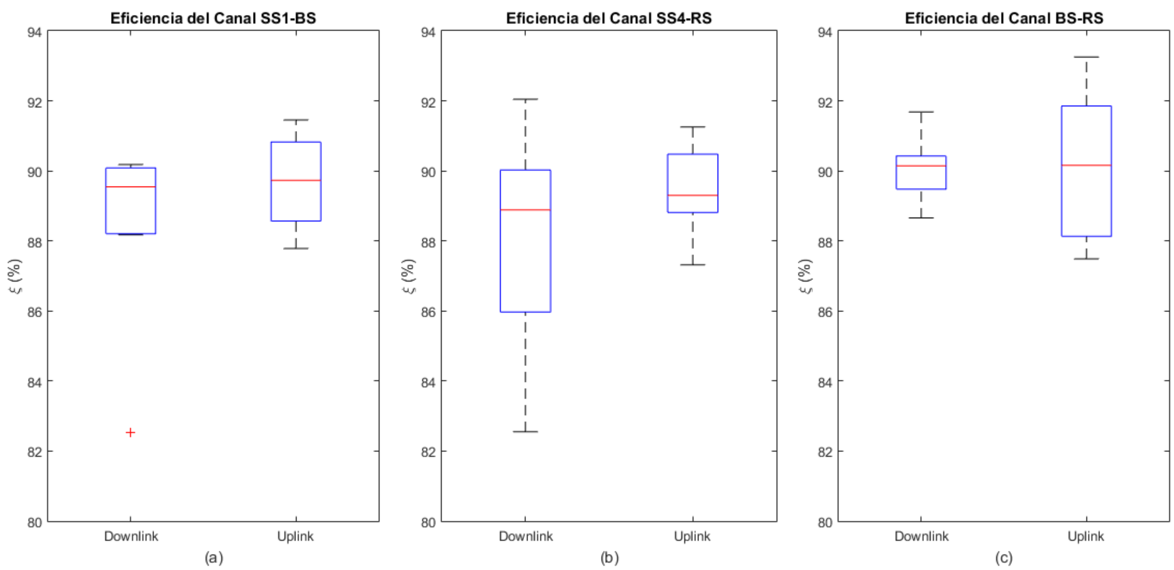
Figura 9. Parámetros de desempeño del escenario 1: (a) ξ del canal SS1-BS, (b) ξ del canal SS4-RS, y (c) ξ del canal BS-RS



Fuente: Elaboración propia

Figures 10, 11 and 12 show the performance metrics of scenario 2. In summary, a similar behavior was obtained from figures 10 (a) and 10 (c). In 10 (a) the δ of the DL channel has an average of 20.99 ms that is greater than the UL with 15.68 ms, in 10 (c) the j has the same tendency in DL with 1.63 ms greater than the UL of 1.11 ms.

In 10 (b) and 10 (d) the trends are in contrast to those described above. In 10 (b) the channel δ in DL has a mean of 8.32 ms lower than the UL with 68.08 ms and in 10d the average value of j in DL is 1.73 ms lower than the UL with 2.85 ms. The channel DL in 10 (d) has greater separation of its ends with respect to the rest of the channels in 10 (a), 10 (b), 10 (c) and 10 (d) (UL).

In 11 (a) and 11 (b) the values of PP on average in DL have a value of 0.67% and UL of 0.64%, in the two channels they are practically the same. In both figures it is observed that they have in their channels wide separations of their ends, with difference of the channel DL in 11 (b) that has symmetry in it.

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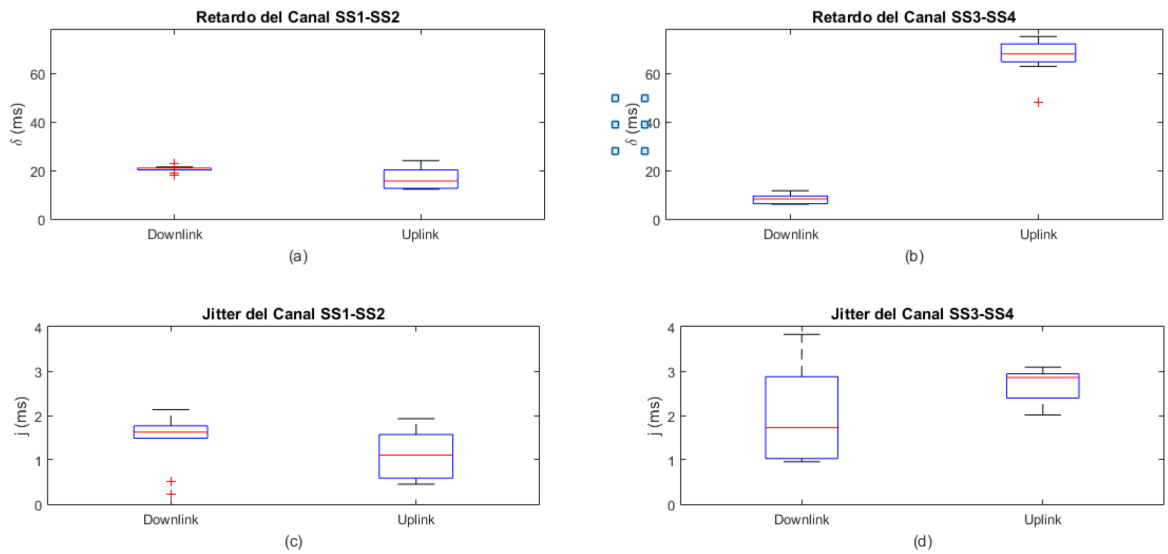
On the other hand, the performance of the channel in 12 (a) and 12 (b) has average values in DL of 89.24% and UL of 87.44%, which are so similar that they almost border on the theoretical value of 90%. In 12 (a) the separation and the upper and lower value in their channels are broad, respectively.

Figura 10. Parámetros de desempeño del escenario 2: (a) δ del canal SS1-SS2, (b) δ del canal SS3-SS4, (c) j del canal SS1-SS2, y (d) j del canal SS3-SS4



Fuente: Elaboración propia

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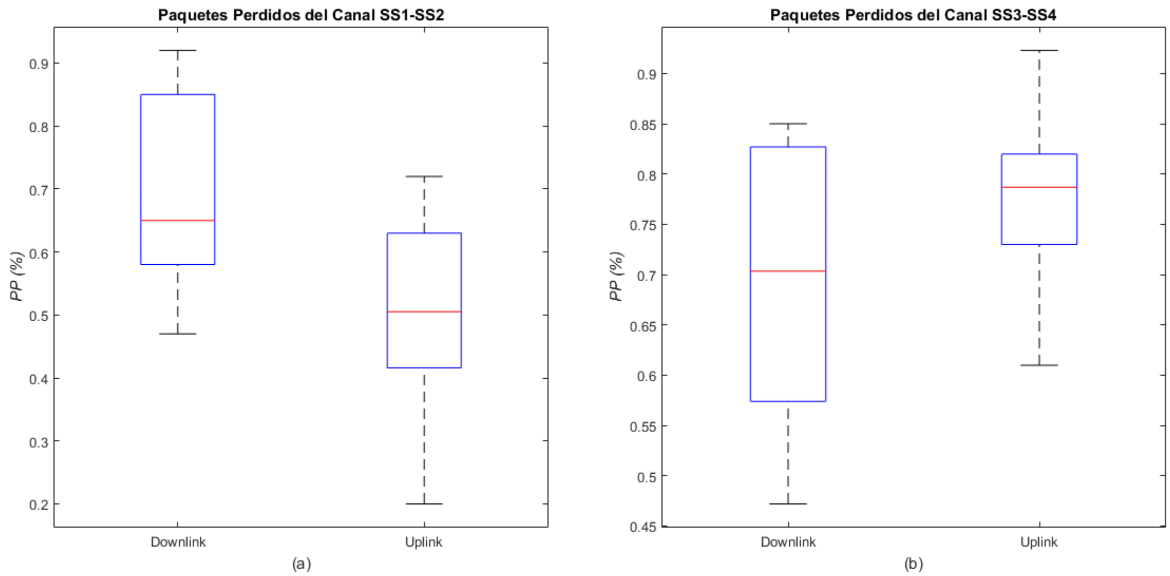
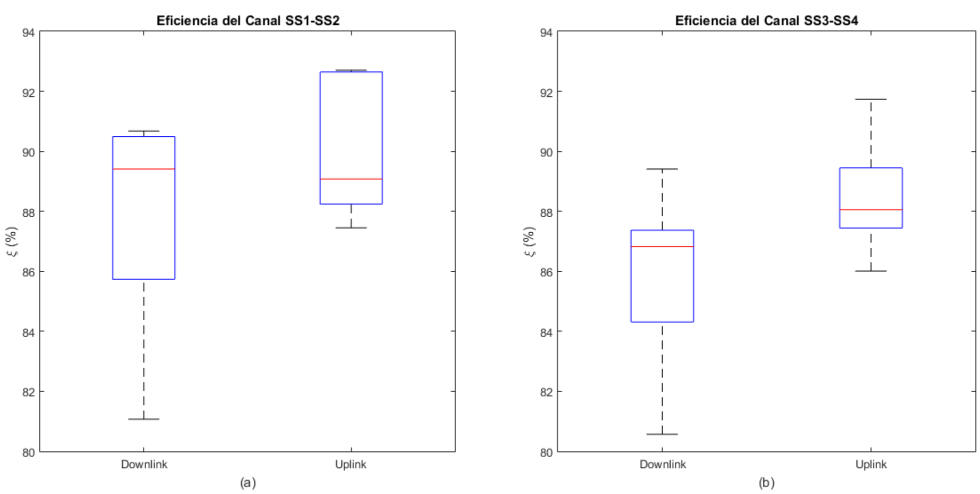
Figura 11. Parámetros de desempeño del escenario 2: (a) *PP* del canal SS1-SS2, y (b) *PP* del canal SS3-SS4



Fuente: Elaboración propia

Figura 12. Parámetros de desempeño del escenario 2: (a) ξ del canal SS1-SS2, y (b) ξ del canal SS3-SS4



Fuente: Elaboración propia

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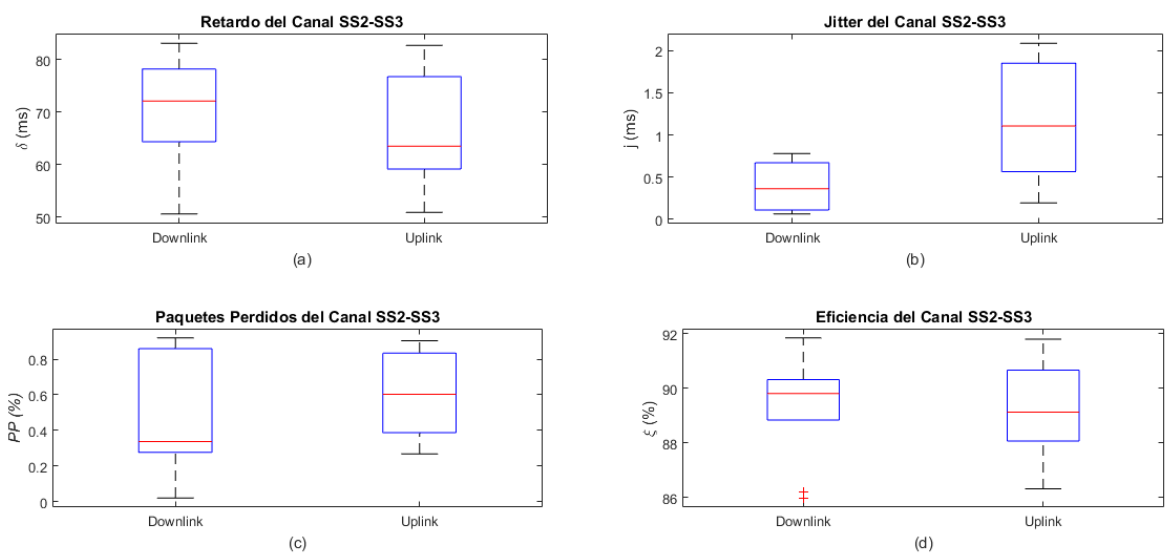
Figure 13 presents the performance metrics of scenario 3. In 13 (a) the DL channel has a greater δ compared to UL, with values of 72.12 ms and 62.53 ms, respectively, while in 13 (c), the PP of DL with 0.33% lower than UL with 0.60% and a very wide separation of its maximum value is observed with 0.84%.

In 13 (b) the value of j of DL and UL is extremely minimal, so the average of the two channels is 0.73 ms, where the UL channel has its extreme values separated from the DL channel, which tend to median. For the ξ of the channel in 13 (d) there is an average value of 89.47% of both channels.

Figura 13. Parámetros de desempeño en el enlace SS2-SS3: (a) δ del canal, (b) j del canal, (c) *PP* del canal, y (d) ξ del canal



Fuente: Elaboración propia

Discussion and Conclusions

As can be seen, the configuration of the ABs assigned to the DL and UL channels are the same, which is remarkable, since the sending of information depends a lot on it, because if it were the opposite, it could generate necks of bottle within the transmission, which would cause the loss of information.

The channel δ in the three scenarios does not exceed 100 ms demanded by applications over IP, in the DL and UL channels of figures 6 (a), 6 (c), 10 (DL) have values less than 30 ms unlike Figures 6 (b), 10 (b) (UL) and 13 (a), which are in a range of 62.53 to 73 ms, which makes the links in Figures 3 (a), 3 (c) and 4 (a) are more reliable for the minimum value of δ that was obtained in the tests, unlike the links in figures 3 (b), 4 (b) and 5, which consists of much longer times , as can be corroborated in the simulations carried out by Eklund, Marks, Stanwood and Wang (2002), which evaluate the WiMAX system.

Now, the j of both channels have values that do not exceed 5.23 ms in the three scenarios. This can guarantee any type of interactive application, VoIP and digital television, since they demand a maximum value of 10 ms, as described by Asghar and Ravneet (2014) in the QoS parameters.

The PP of each of the links does not exceed 1% of the standardized for the optimal functioning of VoIP applications. Therefore, there is an average DL of 0.48% and UL of 0.54%, which means that all scenarios are recommended for any type of application. In this way, it is verified what was demonstrated by Rosario, Martínez and Crespo (2013), who perform the analysis to guarantee the performance of the system in a WiMAX network.

The ξ of the channel in each of the scenarios on average borders 89.10% in DL and 89.24% in UL, where an error of 0.84% in DL and 1% in UL is obtained when compared with the theoretical value of 90% of ξ which determines the IEEE standard 802.16-2009. This is demonstrated by Cicconetti, Lenzini and Mingozzi (2006), who show the performance of the network through simulations. This guarantees the QoS within the implemented system.

From these data, it is concluded that WiMAX has a ξ 90% within each of the links. Likewise, the implemented QoS scheme allows guaranteeing the transmission of information without losses for all the aforementioned applications.

As future work could be specified the reproduction of this same implementation, but with varied climatic conditions, ie, compare the performance of the system in a warm, temperate and cold to see if it suffers or not some affectation.

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