



Performance Evaluation Using Smart: HARQ Versus HARQ Mechanisms Beyond 5G Networks

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Abstract

Since the basic objective of all communication systems is to provide a high-quality performance, the development of effective retransmission schemes with incremental redundancy has gained significant importance recently. In this regard, two retransmission mechanisms had been addressed the hybrid-automatic repeat request (HARQ) and the new smart hybrid-automatic repeat request (SHARQ); thus, SHARQ is integrated with an autonomous retransmission method, ensuring the transmission of a data packet regardless to the successful decoding of the packet at the receivers. That is to say, in order to make sure of having a maximum spectral efficiency, this mechanism determines the required optimal number of autonomous retransmissions. In other words, the developed system means to guarantee the benefits of the SHARQ mechanism based on the LTE-A network as well as the output improvement from the SHARQ. Furthermore, in this current research paper, according to a new proposed algorithm a comparison will provided between the most two basic newest retransmission mechanisms over the LTE-A. Thus, through the use of the OPNET Simulator 17.5, it found out that the SHARQ mechanism is much better for the system's operation, compared to the HARQ mechanism; not to mention that it is the best choice for all multimedia services as well as the overall network performance.

Keywords 3GPP · Cooperative communication · Decode and forward · Delay diversity scheme · Hybrid-ARQ · LTE-advanced · OPNET 17.5

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1 Introduction

Out of the several methods used to have reliable packet delivery, the retransmission of the packet over a number of unreliable channels is considered as a highly prominent approach in this regard. In this context, there are many wireless telecommunication technologies, such as the high-speed packet access (HSPA), the worldwide interoperability for microwave access (WiMAX), LTE and LTE-A. All of these various technologies mainly rely on boosting performance through several retransmission techniques, such as ARQ, the HARQ, and SHARQ mechanisms. Thus, through the improvement of successful packet delivery, these retransmission protocols increase the link throughput. For example, in the LTE-A, ARQ is utilized in the radio link control (RLC) layer, while HARQ is used in the lower media access control (MAC) and the upper physical layer (PHY). Thus, the system is provided with high reliability through the integration of these retransmission protocols; thus, through the use of the HARQ operation, any failure in the MAC layer is recovered by the RLC layer, using ARQ in acknowledged mode at the expense of extra experienced latency for the packet [1].

In this regard, a study was conducted in 2014 by N. Kuhn et al. for concerning the effect of the mechanisms of reliability applied at the link layer on the overall performance of the transport protocols within the context of 4G satellite links. In specific, they offered a software module that conducts a realistic analysis for the network performance through the use of real physical layer traces of a 4G satellite service. The results of this study showed that the use of the ARQ mechanism is considered to be the most beneficial for the improvement of TCP performance, when the throughput of the transport protocol is close to the channel capacity, taking into consideration all target TCP variants. On the other hand, when the physical channel's error rate is high, the hybrid-ARQ results show the best performance for all target TCP variants, with an improvement up to 22% compared to the other schemes. However, the weak point in this research is that authors focused only on one type of traffic the FTP and neglected other multimedia kinds after accumulated results the targeted improvement stilled not suitable for mobile networks with high coverage, fading effects and traffic congestion [2].

Furthermore, in 2014 D. Vukobratović et al. investigated a Radio access network method through the use of LTE-RNC at multiple access control (MAC) layer (MAC-RNC) for searching for a new set of possibilities for resource allocation and unequal error protection (UEP) which is necessary for efficient Wi-Fi multimedia transport in LTE. Still, the weak point that researches did not focus on various multimedia kinds and the behavior of the network performance under conditions of higher coverage and fading effects [3].

In addition, in 2015, H. Mukhtar et al. addressed the issue of optimizing the transmission power for multimedia applications within a constant high-speed transmission over wireless networks. They found out that it is possible to improve the process of power optimization, taking into account that for particular systems with HARQ, some performance metrics such as throughput, delay and peak signal-to-noise ratio (PSNR) may show a staircase behavior. In such cases, the corresponding metric remains fixed for a wide range of signal-to-noise ratios (SNRs). Hence, while the relevant metric remains almost unchanged, the transmission power is largely decreased. In addition, they applied this mechanism on a truncated HARQ with turbo product codes (TPC) and parallel concatenated convolutional codes (PCCC). The results of their study show that through the use of algorithms for power optimization, a large power saving up to 80% can be attained in some particular cases. The weak points in this paper could be summarized as: (i) authors have neglected other critical

parameters such as Bit error rate (BER), Packet loss ratio (PLR), uplink and downlink packet dropped. In addition, (ii) authors had been used there algorithms not to save power in the mobile not to ensure the quality of traffic transmitted by the network [4].

Moreover, in 2016, C. Zhu et al., an adaptive THARQ algorithm was applied to choose the best IL-FEC coded layered scheduling technique to minimize the video streaming distortion in accordance to a given number of transmitted time slots. The accumulated results showed that the proposed algorithm improved the video quality due to lower SNR values compared with the traditional scheme. The weak points in this paper mentioned as follows: (i) The case detailed the increase of SNR values in the inside of the network by using the proposed algorithm however, neglected the rest of a vital aspects to measure the quality of the communication as well as the information under many conditions such as high area coverage. Additionally, (ii) authors used the lowest quality video quality measurement and this is not standard for measuring the efficiency of the network [5].

Additionally in 2016, S. Hwan et al., a comparison assessment had been done between two-rate selection methods in wireless multicast systems were applied with an incremental network redundancy using the HARQ-IR scheme under the condition of Rayleigh block-fading channels. Also in this research, maximizing the long-term average transmission rate (LATR) issue has been discussed furthermore, reducing the computational load [6].

In this context, in 2017, Young-Ho Jung and Jihoon Choi proposed a new HARQ scheme with autonomous retransmission for use in multicast services. This algorithm showed larger spectral efficiency than the conventional HARQ scheme, and that is through a suitable tradeoff between the HARQ gain and the feedback overhead decrease. Also in this current paper, another spectral efficiency metric proposed taking into consideration both the downlink and the uplink; also designed a practical algorithm to adjust the number of autonomous retransmissions as a means to optimize the number of these autonomous retransmissions. The weakness points here the accumulated results showed that although the efficiency became larger a delay could occur in the transmission process, in addition, the research does not touch the effect of the proposed scheme on the multimedia [7].

More recently, in 2018, Zheng Shi et al. addressed the issue of the energy efficiency for three common HARQ schemes, including the following: Type I HARQ, HARQ with chase combining (HARQ-CC) and HARQ with incremental redundancy (HARQ-IR); thus, these schemes were analyzed and joined in power allocation and rate selection, in order to maximize the energy efficiency. They found out that the efficiency of this energy-efficient optimization was verified through extensive simulations. In addition, the results exhibited that the HARQ-CC could accomplish the best tradeoff between energy efficiency and the spectral efficiency among the three HARQ schemes [8].

This current research focuses on how to strengthen the weak points provided by using the HARQ mechanism in every retransmission process mentioned as follow: (I) *Throughput*: During the process of multimedia transmission, a high amount of data usually dropped resulting in a low quality of the received data; however, higher throughput rates could be achieved through the use of SHARQ mechanism based LTE-A; (II) *Delay Reduction*: The issue of higher delay ranges during the process of data transmission is present at all multimedia applications; nonetheless, the delay rates could be decreased under conditions of increasing the coverage and mobility, through the use of SHARQ and over LTE-A; (III) *Increasing Coverage Area*: delay issue could be solved providing high performance, through the use of SHARQ that enables us accessing multimedia anywhere and increasing the distance; and (IV) *Bandwidth*: The issue of bandwidth limitations faced by multimedia during the process of transmission could be solved through the use of SHARQ. That is to say, this proposed mechanism shall enable us to improve the multimedia QoS parameters,

and to increase the speed of multimedia access, with higher rates of SNR and lower rates of BER. In this regard, this current paper suggests a new approach represented in the proposed metrics for evaluating the QoS performance of the LTE-A network; and that is by covering the retransmission mechanisms in 4.5G networks that occur between the eNBs. Hence, the main objective of this current research is to analyze, characterize and differentiate between the performance of the SHARQ and the HARQ mechanisms based on the LTE-A network, resulting in the decrease of the packet loss during the process of transmission, as well as the improvement of the overall network performance through the use of SHARQ. The other sections of this paper are organized as follows: Sect. 2 introduces the previous re-transmission mechanisms. Section 3 discusses the proposed SHARQ algorithm used in our framework. Section 4 presents the system QoS Performance Metrics. Section 5 presents the simulation results discussion. Section 6 illustrates the general discussion. Moreover, Sect. 7 addressed a comparative study between the proposed system and other recent techniques. Finally, Sect. 8 provides concluding remarks and future directions.

2 Overview of the Pervious Re-transmission Mechanisms

After reviewing the previous retransmission mechanisms in the various multi-hop networks, we found out that they basically have the same principles as that of the single-hop deployments, as they depend on the same HARQ and ARQ mechanisms. Nonetheless, there is a difference at the conceptual level, represented either at the state machine that runs between the base station (referred to as MR-BS) and the mobile station (MS) logically by-passing relay stations (RS), or the independent state machines that exist for each link. On the other hand, as for the ARQ, the industry has adopted both end-to-end and hop-by-hop modes; for example, both of them are available in the 4.5 generation systems. That is to say, as previously mentioned, the difference is that either RS blindly stores and forwards ARQ enabling PDU without taking part in the ARQ protocol, or RS runs intermediate ARQ state machine [9].

In this regard, the HARQ shall be designed for cooperative relays, in order to achieve the required level of improvement in terms of the throughput. Particularly, it was evidently proven that the HARQ protocol with incremental redundancy provides strong robustness against the multipath fading channel. That is to say, the HARQ protocol shall improve the end-to-end performance highly through efficient retransmission schemes in a distributed system with cooperative relays, which in turn decreases the overall error rate in the system. On the other hand, a single-hop communication retransmits the packet with incremental redundancy, when a Negative Acknowledgement (NACK) is sent from destination to source. Nevertheless, as for the system shown in Fig. 1, the application of HARQ retransmissions is much more effective due to the presence of four independent links, corresponding to retransmissions between 4 pairs of transmitter and receiver [10].

3 The SHARQ Proposed Algorithm

3.1 The SHARQ Model

In this current paper, we used an SHARQ process that is asynchronous in the downlink and synchronous in the uplink. The asynchronous process shall enable the eNB to transmit

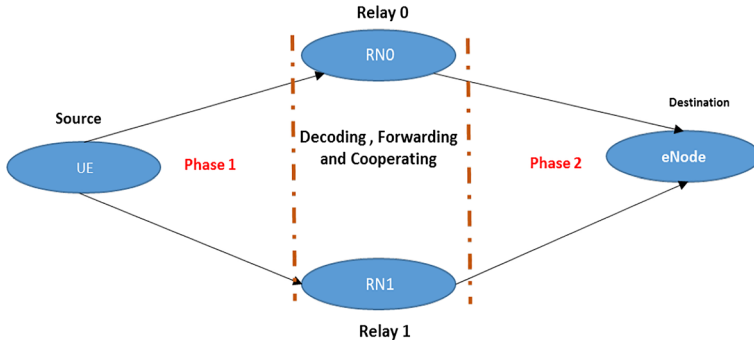


Fig. 1 SHARQ system representation

whenever it has the scheduled packet, while the synchronous SHARQ can only transmit in a fixed time slot. Given the SINR and MCS equation, we can conclude the BLER as follows [11–15]:

where:

$$BER = 0.2e^{\frac{-1.5\gamma}{M-1}}$$

where:

γ : SINR, valid from 0 to 30 dB Can be written as

$$\gamma = \frac{S}{N_0B} \tag{2}$$

S: Signal received power; N_0 =Noise density; and B = Bandwidth

M=Modulation Coding Scheme used where $M=2^n$

The efficiency of modulation code rate is given by

$$n = \log_2 M \tag{3}$$

3.2 The Proposed Algorithm

The SHARQ schemes are required in a cooperative system of distributed relays; thus, they could exploit the following benefits of the cooperative system, not to mention the enhancing capability of their inherent performance in decreasing the system’s block error rate, compared to the other retransmission mechanisms.

1. In this current paper, we propose an algorithm, in which the cooperative system of distributed relays establishes end-to-end link in two phases as follows: Phase (1) from source to relays and Phase (2) from relays to destination; thus, Phase (2) establishes the link even when just one relay decodes the signal. Hence, the HARQ scheme shall be designed in a smart way that starts retransmissions from the source only when the signal is decoded incorrectly at both relays.
2. The error performance shall be better in Phase (2) of the cooperative system when both relays forward and exploit the macro-diversity. That is to say, in case the destination has decoded the signal incorrectly, then, the following two cases are possible because of the presence of cooperative relays: one is to have retransmission in Phase (2), and

the other is to have retransmission in Phase (1), if the retransmissions in Phase (1) are not exhausted. According to these potentials, our proposed schemes depend mainly on the principal condition that the source starts the retransmissions only when it receives the Negative Acknowledgement (NACK) from both relays. In addition, we also used the Coordinated Multipoint Reception in order to facilitate the reception of NACKs from the relay nodes in the LTE-A network. Taking into consideration that the source will not retransmit if it receives the NACK from just one of the two relays in the system; however, it will wait for the ACK or the NACK from the other relay; and if it receives the ACK from that relay, it will not retransmit. On the other hand, if the source receives the ACK from both relays, it will automatically set the retransmissions counter to the maximum number, in order to shut Phase (1) for the transmission of that specific packet. Therefore, the SHARQ scheme shall be developed and schematically illustrated using the flowchart diagram shown in Fig. 2.

- Phase 2 in the illustrated system is depending on two kinds of states that can occur according to the decoding process at the two shown relays in phase 1. If the two relays are decoding correctly then the communications will take place in phase 2, if not when only one relay of the two relays in phase 1 decoded correctly so it will be a single forwarding scenario. As explained in Fig. 2, the operation of SHARQ is depending on having a retransmission process in phase 2 according to the incorrect destination decoding state. The initiation of retransmission in phase 2 takes place between the forwarding relay and the destination node. Then it continues until there is correct decoding occurred in the destination or the retransmission maximum number of processes were reached

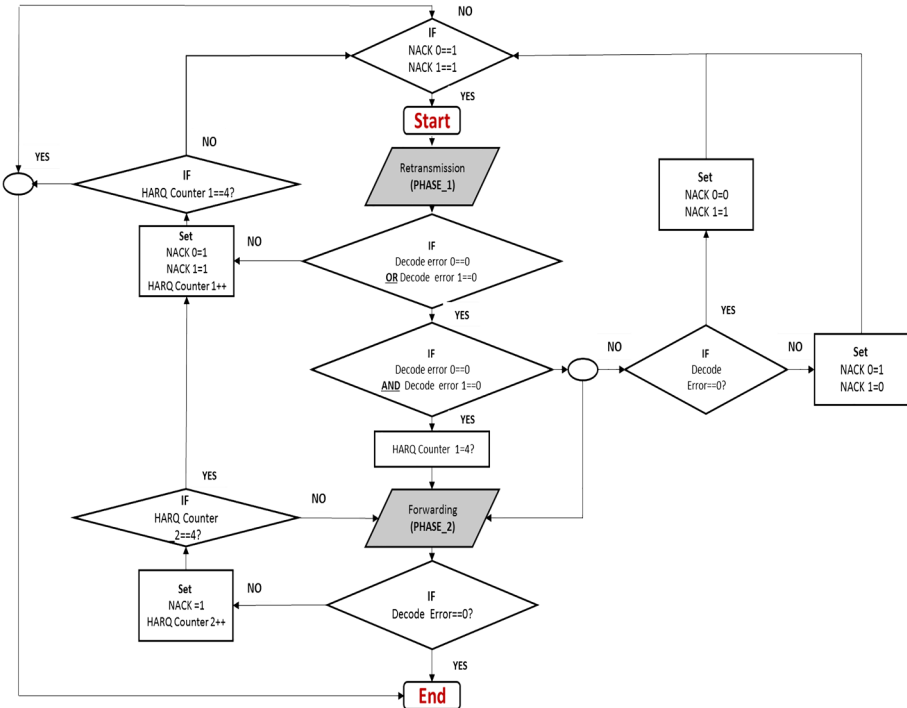


Fig. 2 SHARQ proposed algorithm

and exhausted. At this condition, it demands the retransmission process in phase 1 if the number of retransmission process were not exhausted. The benefit here, there is no need for retransmission in phase 1 if both relay nodes were forwarding in phase 2. Where decode error 0 and decode error 1 represent the decoding error at relay node 0 and relay node 1 respectively. In addition, NACK 0 and NACK 1 illustrate the negative acknowledgment of relay node 0 and relay node 1. NACK is indicating the destination negative ACK. Finally, the number of retransmission processes in phase 1 and phase 2 indicated using HARQ counter 1 and HARQ counter 2 respectively.

4 QoS Performance Metrics

4.1 End to End Delay (sec)

In this paper, the E2E delay is defined as the time taken by the packet to be transferred from the transmitter to the receiver. A reduced variety of delay does not directly affect the QoS for all multimedia traffic. Nonetheless, the delay for one way shall be less than 200 ms, as shown in Eqs. (4) and (5); otherwise, any end-to-end delay greater than 400 ms shall be considered as unacceptable [16–20].

$$d_{E2E} = N[d_{trans} + d_{prop} + d_{proc} + d_{queue}] \quad (4)$$

where: (I) $d_{end-end}$ = end-to-end delay; (II) d_{trans} = transmission delay; (III) d_{prop} = propagation delay; (IV) d_{proc} = processing delay; and (V) d_{queue} = Queuing delay

$$N = \text{Number of Links (Number of Routers - 1)} \quad (5)$$

(Note: we have neglected queuing delays).

4.2 Packet Delay Variation (sec)

Since there is a significant difference in a single-way delay of the packets over a definite time period, the PDV shall be calculated. In this regard, the packet delay variation shall be less than 60 ms; thus, the jitter is generally defined as the absolute value of the packet delay difference between some arbitrary packets [16–20].

In light of the above, if 'A' is the first packet and 'B' is the second packet, then, PDV can be derived according to Eq. (6) as follows:

$$PDV = |(R_{XA}) - (T_{XA}) - (R_{XB}) - (T_{XB})| = |(T_{XB}) - (T_{XA}) - (R_{XB}) - (R_{XA})| \quad (6)$$

Therefore, in order to calculate PDV, we need the following 4 parameters: (I) timestamp of the second transmitted packet; (II) timestamp of first transmitted packet; (III) timestamp of the second arriving packet; and (IV) timestamp of the first arriving packet. Thus, if the packet latency is constant, PDV equals 0 as the difference in latency does not exchange from packet to packet.

4.3 Mean Opinion Score

The MOS is defined as the numerical measure of the excellence of each voice and video telecommunication services; thus, its value shall range from 1 to 5, wherein 1 is the worst

satisfactory and 5 is the best quality, as illustrated in the following Eq. (7). In this context, we calculate the MOS as the arithmetic means over single ratings performed by human subjects for a given stimulus in a subjective quality assessment test.

$$MOS = \frac{\sum_{n=0}^N R_n}{N} \quad (7)$$

where R are the individual ratings for a given stimulus by N subjects.

Therefore, in order to obtain MOS rankings, we will need to hire many human assessors for various use cases such as codec development or service quality monitoring functions, wherein quality shall be anticipated repeatedly and routinely, a process that can be very time-consuming and expensive [16–20].

4.4 Throughput (packets/sec)

In light of the above, the throughput is defined as the measure of the total number of packets that have successfully reached the other destination node in a network. Since it directly affects the overall performance and the class of services stated in the WiMAX and LTE networks, the value of the throughput must always be high; thus, the suitable range for the throughput shall be from 221 to 5321 packets/sec. In this context, we could calculate the physical layer information throughput for some cases as described in Eq. (8) [21].

$$Throughput = \frac{\sum_i Packet\ Delivered}{\sum_i Packet\ Delivered - Packet\ Start\ Time_i} \quad (8)$$

4.5 Signal to Noise Ratio

The SNR is defined as the proportion between the strength of the original signal and the power for undesirable noise. In multimedia telecommunication services, noise behavior and the SNR are considered as essential parameters. In addition, it always used to identify the sensitivity overall performance of the destination; thus, Hence, the appropriate values for the SNR for signals shall be above 25 dB for the multimedia offerings as shown in Eq. (9) [22].

$$SNR(x) = \frac{P}{I + N} \quad (9)$$

where: ‘P’ refers to the strength of the incoming signal in question; ‘I’ refers to the interference power of the other (interfering) signals within the network; and ‘N’ refers to a few noise terms, which can be consistent or random.

4.6 Bit Error Rate

The BER is defined as the ratio between the total numbers of errors to the whole number of transmitted bits. It could be used in measuring the overall QoS and the system performance, regarding the source, destination and manipulate channels between the system’s two components. That is to say, if the channel between the supply and the destination is at a good state with better SNR, then the BER might be very small and can comprehend the

best quality and services; thus, the video and voice signals are in the best case as described in Eq. (10) [23].

$$BER = \frac{\text{number of errors}}{\text{total number of bits sent}} \tag{10}$$

5 Results and Discussion

5.1 Simulation of Scenarios

Due to the several variations in the received signal quality, the transmissions of data in wireless channels are vulnerable to errors. These errors can be handled to some degree through Link Adaptation.

5.1.1 Experiment Setup

In this current paper, we created two identical scenarios in order to differentiate between SHARQ and HARQ, based on the LTE-A network. In addition, we used one mobile user in these two scenarios, rotating with mobility feature and fading effects around 4 eNodes at the same time; thus, the simulation run time equals 490 s, as illustrated in Fig. 3.

5.1.2 Dataset

As shown in Tables 1, 2, 3 and 4, in both scenarios, the two retransmission mechanisms compared three types of applications, using Voice, FTP, and Video applications through

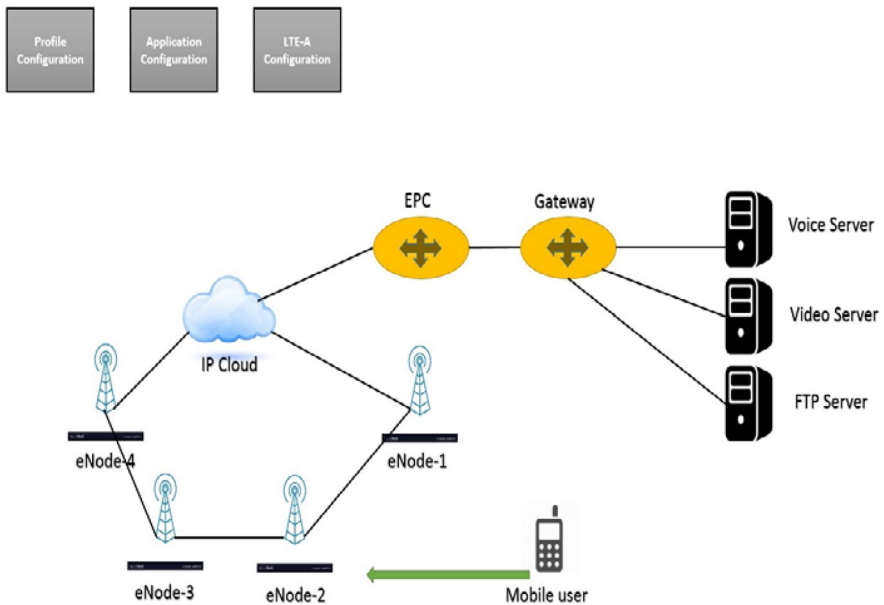


Fig. 3 Network topology for SHARQ and HARQ mechanisms

Table 1 Voice parameters

Attributes	Value
Silence Length (s)	Exponentially distributed, mean 0.62
Talk Spurt Length (s)	Exponentially distributed, mean 0.3512
Encoder Scheme	PCM
Voice Frames per Packet	2
Type of Service	Best effort (0)
De-Compression Delay (s)	0.0213

Table 2 LTE-A network parameters

ANTENNAS parameter	Value
Transmission power	26.2 dBm
SC-FDMA (UL) frequency	1710 MHz
Hybrid OFDMA (DL) frequency	2110 MHz
Bandwidth	Downlink 70 MHz– Uplink 40 MHz
Gain antenna	16.8 dBi
Antenna height	35 m
Radius coverage	19 km
Propagation model	Urban
Duration of simulation	490 s

Table 3 Video parameters

Attributes	Value
Frame interarrival time information	60 packets/sec
Frame size information (bytes)	128*240 pixels
Type of Service	Best effort

Table 4 SHARQ parameters

SHARQ parameter	Value
Efficiency mode	Physical layer enabled
Service class	Silver = rtPS
Multipath type	ITU Pedestrian A
Path loss type	Pedestrian
SHARQ parameters	UL Channels = 8 DL Channels = 16
Buffer size constant (K)	20 (16384 bits)
Maximum Number of retransmissions	3

the connected three application servers. Thus, the network consisted of four parameterized eNodes. As for the mobility, as previously mentioned, only one mobile user was used; as well as a structure, that includes Evolved Packet Core (EPC) elements, and a gateway that will communicate with the three-application server, as illustrated in Fig. 3.

5.1.3 Software Tools

The modeling of scenarios in this current study was conducted using the OPNET Modeler 17.5 (Version 8). Furthermore, performance matrices such as (End-to-End Delay, Packet Delay Variation, Jitter, MOS and Traffic Sent Received) were used in the Voice, FTP, and Video traffic; in addition to the Signal-to-Noise Ratio, Bit Error Rate, Throughput, Downlink and Uplink Packet Drop for the LTE-A network.

5.2 Simulation Results

5.2.1 Case-1: Voice

- MOS

As shown in Fig. 4, there is an immense variation in the voice quality according to the MOS value, which has a great influence on the quality of data. Thus, with the HARQ technique, the value of MOS is about 3.767 then there is a degradation down to 3.5 at the end of the simulation. However, it approximately equals 4.23 then it will decrease down to 4.1 after the use of the SHARQ technique. Therefore, based on the resulting high quality for voice, we conclude that SHARQ is preferred.

- Packet delay variation (sec)

On the other hand, another parameter, which has a huge effect on the quality of data received as illustrated in Fig. 5. In case of using the HARQ and SHARQ mechanisms, the variation of packet delays satisfies lower values that verify 0.000005 s in case of

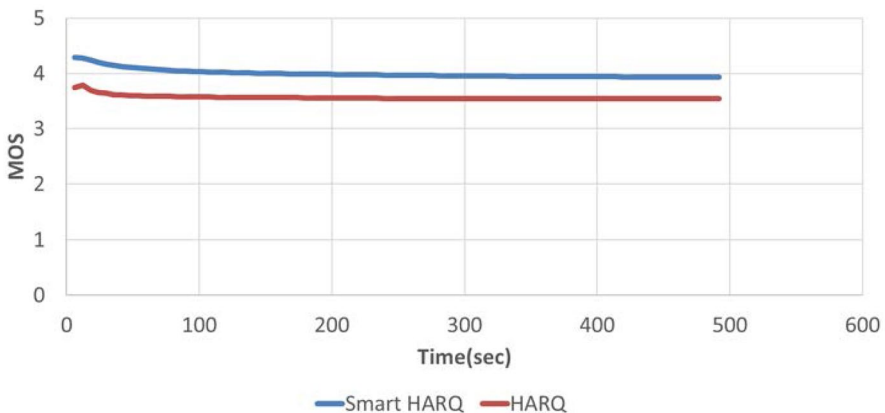


Fig. 4 MOS using SHARQ and HARQ mechanisms

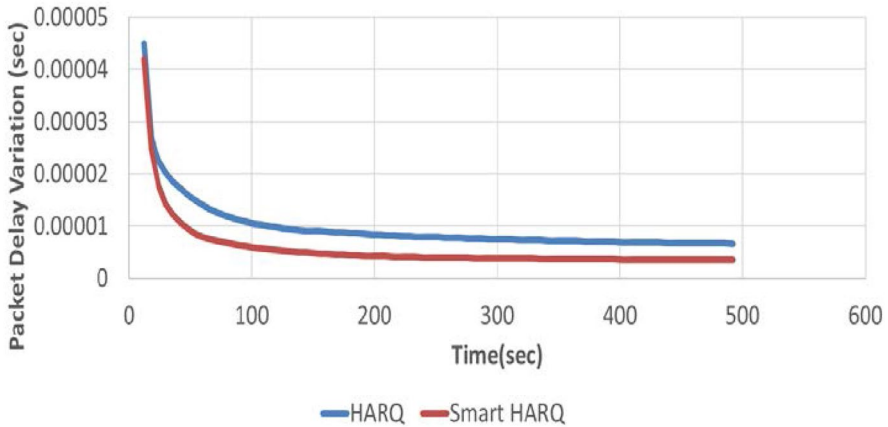


Fig. 5 PDV for SHARQ and HARQ mechanisms

using the SHARQ mechanism that is considered as a lower value and supports fast access for the service and 0.00001 s for the HARQ at the end of the simulation.

- Jitter (sec)

In addition in accordance to Fig. 6, there is a small voice jitter value that approximately equals zero, after the use of SHARQ, compared to 0.00000124 s with the HARQ; this shall in turn influence the overall transmitted voice traffic.

- End-to-end delay (sec)

Also, Fig. 7 illustrates that the value of the End-to-End Delay satisfies values start with 0.101 s, 0.1005 s then increase to 0.10346 s and 0.10123 s in case of using the HARQ and

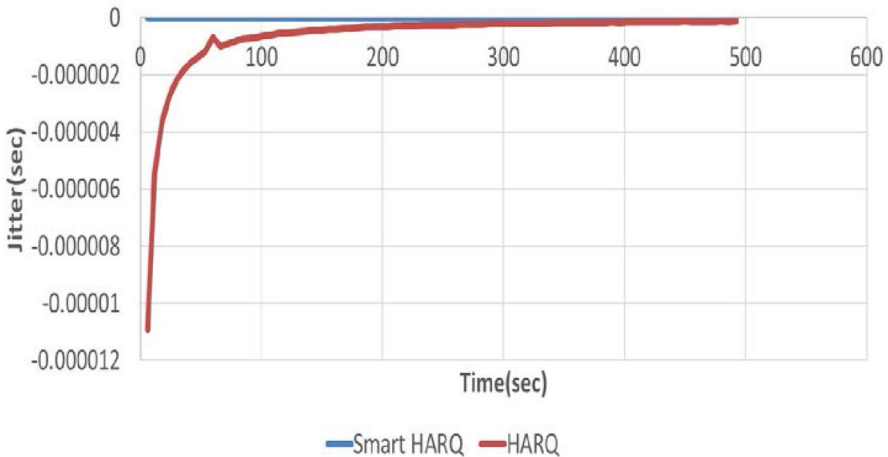


Fig. 6 Jitter for SHARQ and HARQ mechanisms

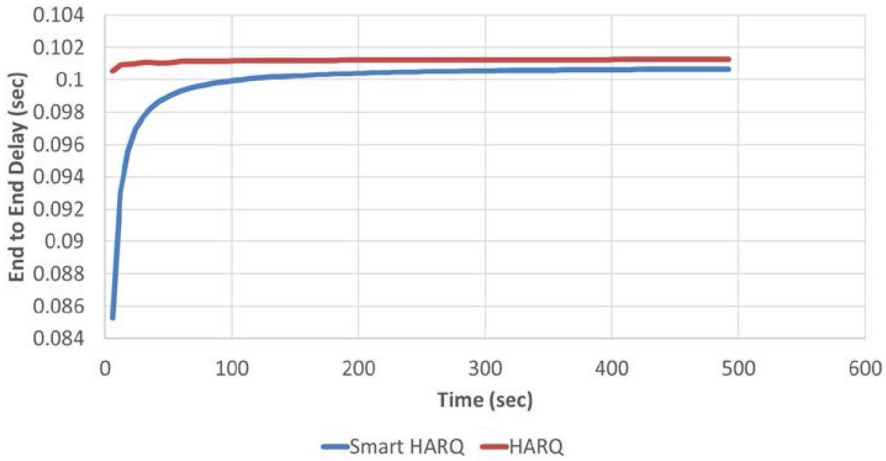


Fig. 7 End-to-end delay for SHARQ and HARQ mechanisms

SHARQ mechanisms respectively at the end of the simulation. Nonetheless, the voice traffic on HARQ has a higher End-to-End Delay value which impacts on the quality of voice received than that of the SHARQ mechanism.

- Traffic sent and received (packets/sec)

Moreover, Fig. 8 shows that the average packets sent per second by using the two SHARQ and HARQ mechanisms respectively equal 245 (packets/sec) at the end of the simulation. However, Fig. 9 illustrates that the traffic received through the use of SHARQ mechanism which equals approximately 245 (packet/sec). Nonetheless, in case of using the HARQ mechanism, there is a big packet drop in the traffic received; approximately 155 packets are dropped at the end of the simulation. Hence, the PLR can be accumulated for each type, which equals 0.01% and 63.26% for the SHARQ and HARQ mechanisms respectively at the end of the simulation according to the previous results illustrated.

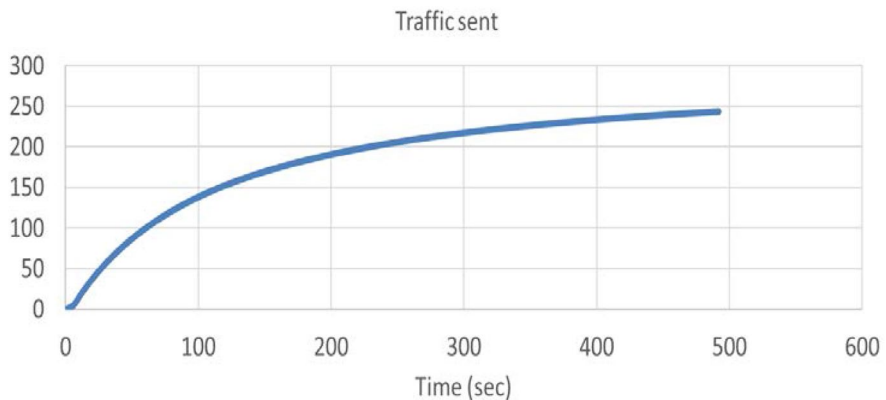


Fig. 8 Traffic sent over SHARQ and HARQ mechanisms (packet/sec)

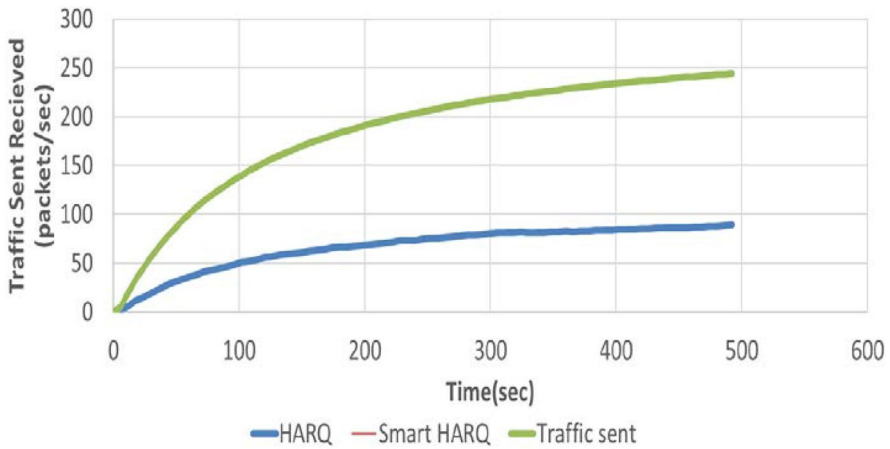


Fig. 9 Traffic received over SHARQ and HARQ mechanisms (packet/sec)

5.2.2 Case-2: Video Streaming

- End to end delay (sec)

In accordance to Fig. 10, End-to-End Delay satisfies acceptable values of no more than 500 ms by using video streaming after using the HARQ and SHARQ mechanisms respectively at the end of the simulation. However, the video End-to-End Delay with the HARQ mechanism has a higher value, which approximately equals 0.0721 s compared to the SHARQ value, which equals 0.0623 s from the beginning to the end of the simulation time.

- Packet delay variation (sec)

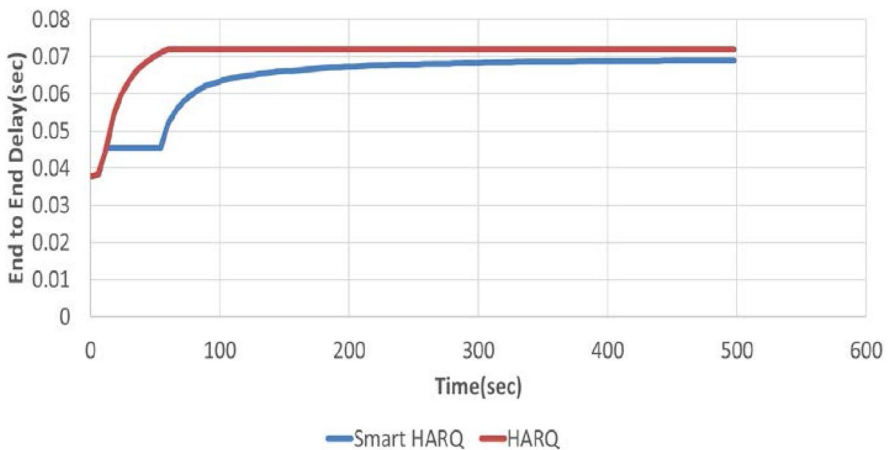


Fig. 10 End-to-end delay over SHARQ and HARQ mechanisms

In addition, as shown in Fig. 11, the variation of packet delays satisfies very low values in case of using the HARQ and SHARQ mechanisms. thus, at the end of the simulation time, the value is increased to 0.000003 s in case of using the SHARQ mechanism from the start of simulation to the end on the other hand, in case of the HARQ mechanism the value will increase to 0.00000852 s which will have a bad influence on the quality of video received.

- Traffic sent (packet/sec)

Furthermore, Fig. 12 shows that the video streaming traffic sent over the LTE-A network using the two SHARQ and HARQ mechanisms respectively equals 40 (packets/sec).

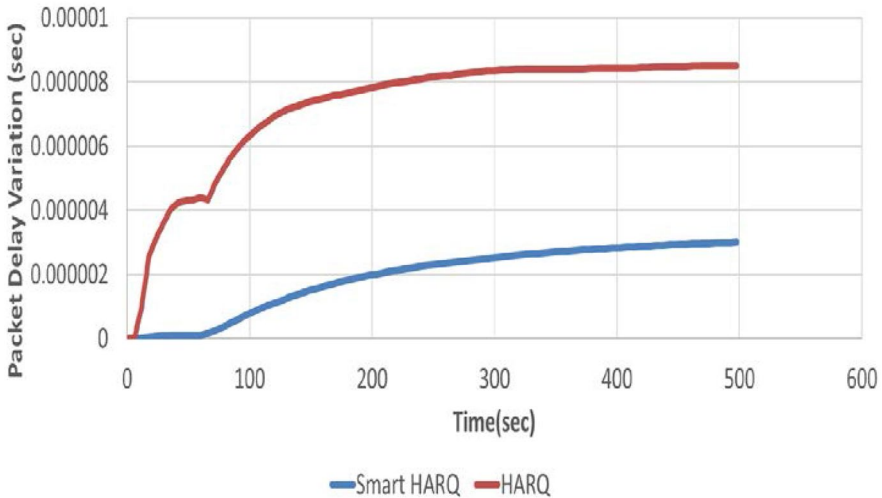


Fig. 11 Packet delay variation over SHARQ and HARQ mechanisms

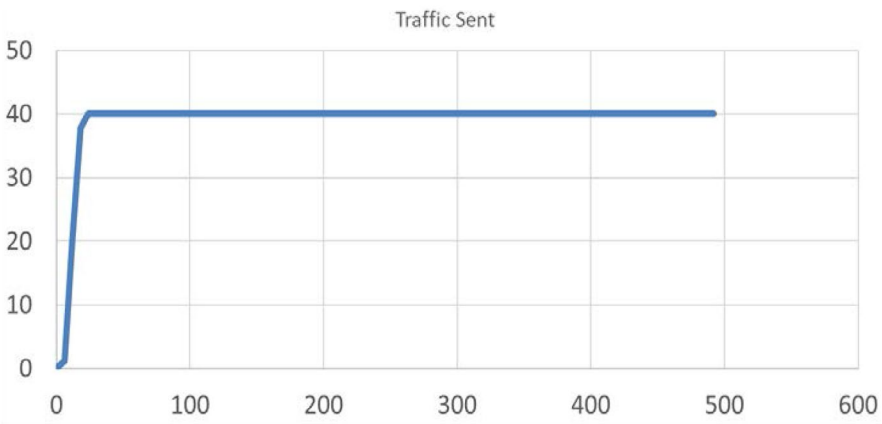


Fig. 12 Traffic sent over SHARQ and HARQ mechanisms (packets/sec)

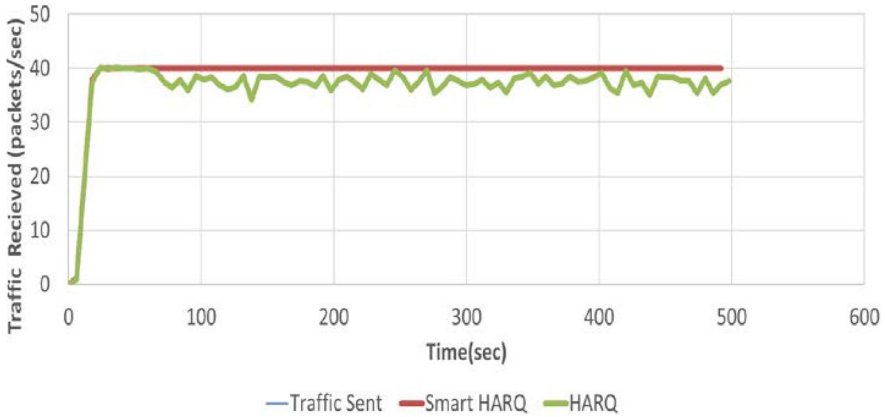


Fig. 13 Traffic received over SHARQ and HARQ mechanisms (packet/sec)

- Traffic received (packet/sec)

Moreover, as illustrated in Fig. 13 and according to the previous accumulated results, the traffic received using the SHARQ mechanism equals approximately 40 (packet/sec), as there are no packet losses. However, after the use of the HARQ, there is a big packet drop on the video traffic received, as about 12.5% of the packets dropped at the end of the simulation. Therefore, the metric of PLR calculated at second 200 PLR will equal 12.5% and 0.001% through the use of the HARQ and SHARQ respectively.

5.2.3 Case-3: FTP

- Download response time and object response time (sec)

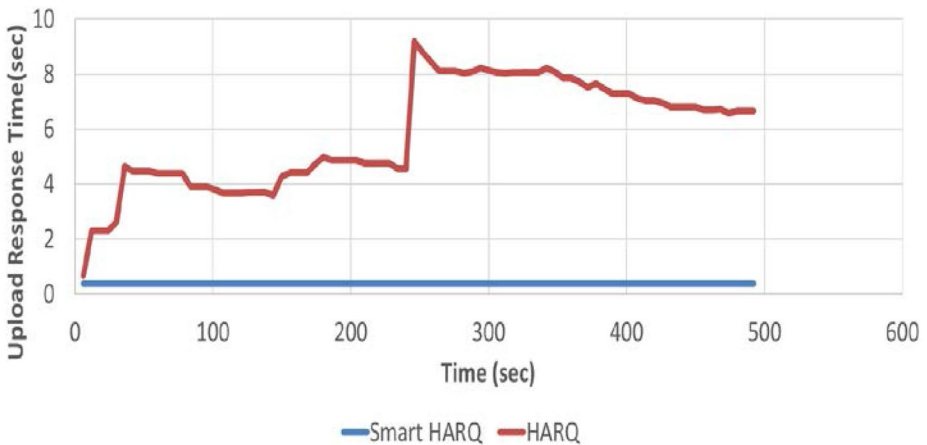


Fig. 14 Upload response time over SHARQ and HARQ mechanisms (sec)

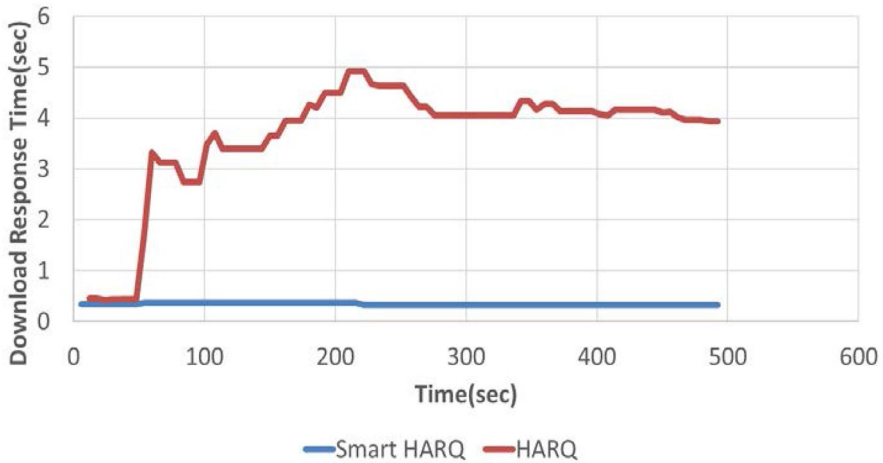


Fig. 15 Download response time (sec) over SHARQ and HARQ mechanisms

Figures 14 and 15 show respectively that the HARQ mechanism satisfied higher delay response values, compared to the SHARQ; thus, due to the higher delay values, there is a bad influence on the quality of the traffic received when using the HARQ.

- Traffic sent and received (packet/sec)

In addition, Figs. 16 and 17 show that a very high data drop occurred after the use of the HARQ mechanism, compared to the SHARQ mechanism. Furthermore, the Packet Loss Ratio could be accumulated for the two mechanisms; thus, at second 200, the PLR values equal 25.2% and 0.0012% for the HARQ and SHARQ mechanisms respectively.

5.2.4 Case-4: Network Performance

- Downlink packet drop (packets/sec)

According to Fig. 18, the overall packet drops because of the packet collisions with the signal mobility when using both mechanisms; thus, the use of the SHARQ verified a lower downlink packet drop; and the use of the HARQ mechanism caused higher packet drop approximately equals 11 packets per every second dropped over the downlink.

- BLER over downlink

Additionally, as shown in Fig. 19, based on the simulated system, the accumulated downlink values of BER in case of using the SHARQ mechanism are very small approximately equal 0.00005 over the downlink, compared to the HARQ mechanism, which verified up to 0.0006 at the end of the simulation.

- Throughput (packet/sec)

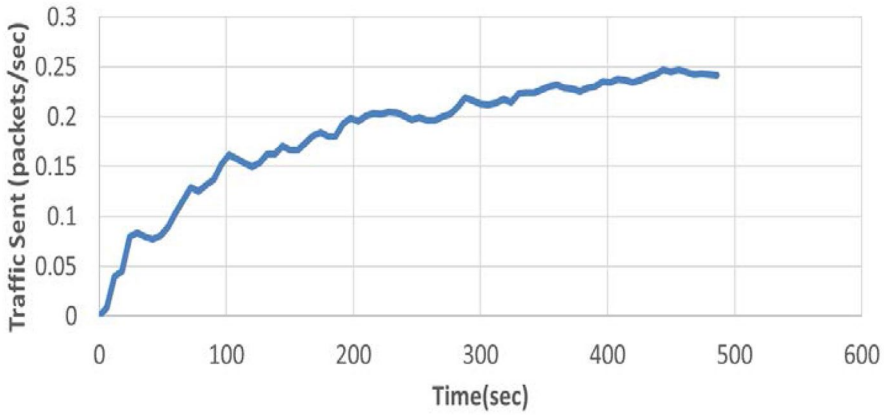


Fig. 16 Traffic sent over SHARQ and HARQ mechanisms (packets/sec)

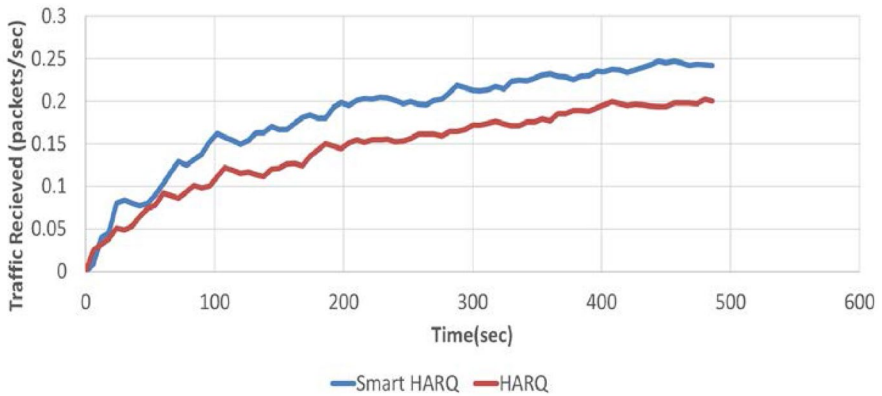


Fig. 17 Traffic received over SHARQ and HARQ mechanisms (packets/sec)

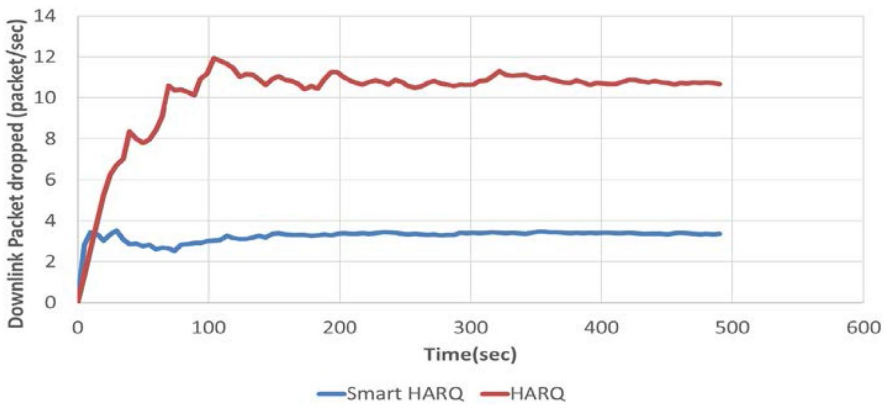


Fig. 18 DL Packet drop over SHARQ and HARQ mechanisms

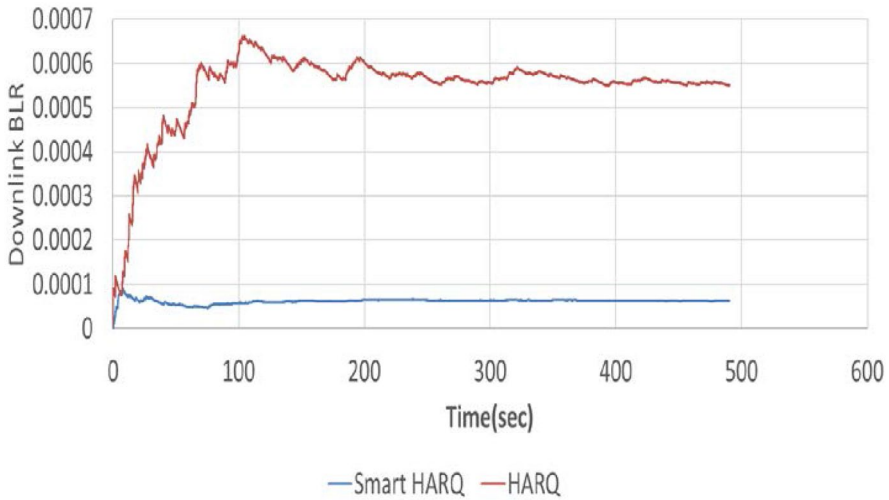


Fig. 19 DL BLER over SHARQ and HARQ mechanisms

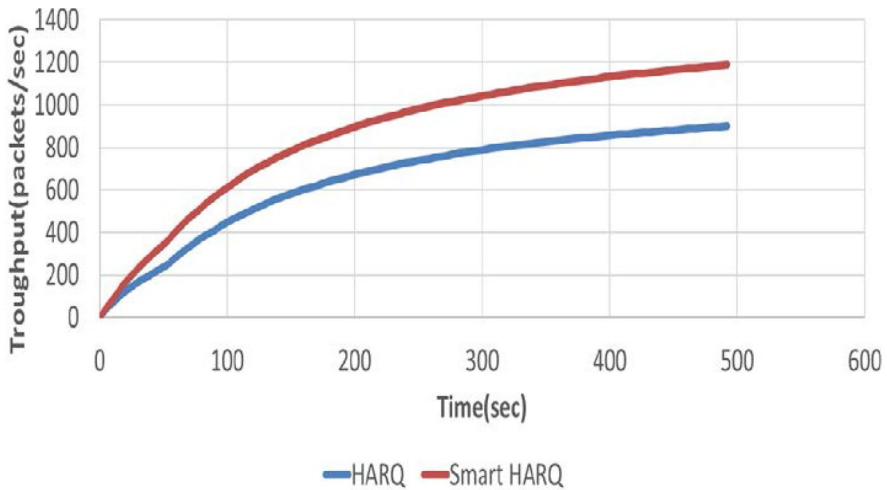


Fig. 20 Throughput over SHARQ and HARQ mechanisms (packets/sec)

As illustrated in Fig. 20, after using the SHARQ mechanism, there was a better throughput which verified a value equals 900 packets per second compared to the HARQ mechanism which equaled 700 (packets/sec). Hence, it can be concluded that by selecting the SHARQ mechanism would be the more appropriate choice compared to the other mechanism.

- Downlink SNR (dB)

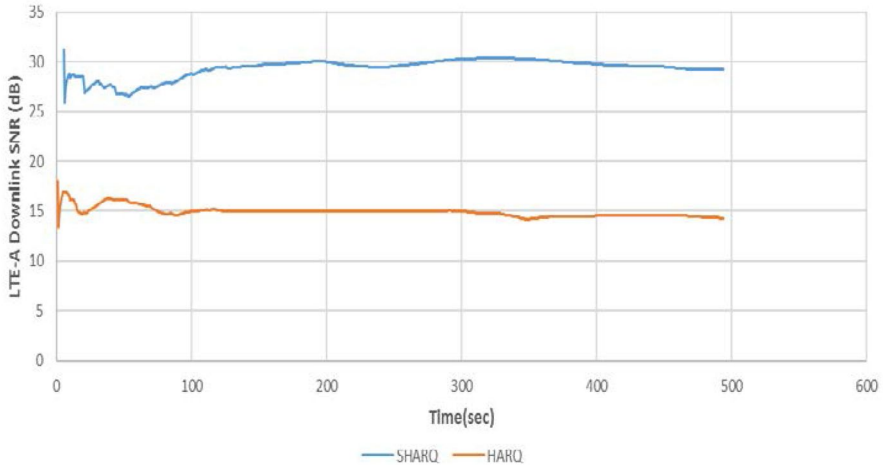


Fig. 21 Downlink SNR over SHARQ and HARQ mechanisms (dB)

The best acceptable values of the SNR for signals are approximately more than 23 dB by using the SHARQ mechanism on the network. The downlink SNR equaled 25.5 dB by using the SHARQ mechanism and 15 dB by using the HARQ mechanism as shown in Fig. 21.

6 General Discussion

In this current paper, two major retransmission mechanisms had been addressed, the HARQ and the SHARQ; thus, we have provided a complete comparison between these two types, so that we could conclude which type is better regarding multimedia data streaming and the total overall network performance. After analyzing the obtained results, usage of the SHARQ mechanism in network provides better MOS, lower E2E Delay, lower jitter, lower PDV, higher traffic quality and lower packet loss ratio across the network; hence, it improves the network overall performance significantly, including the voice and video quality as mentioned in Table 5. Furthermore, it found out that in addition to having a much lower object and page response time, the SHARQ mechanism also has a higher FTP traffic received quality and lower values of packet loss ratio; therefore, it evidently concluded that it is the better mode as illustrated in Table 6. Moreover, we also discussed the OPNET simulated networks, in order to illustrate the impact of using the SHARQ mechanism on data streaming across the LTE-A networks; thus, we have presented real-time scenarios in order to verify a good empirical value based on the protocols of this technology. In this sense, we have investigated more quality metrics through the simulation of more reliable streaming data using the OPNET 17.5 interface. The results of this simulation proved that the SHARQ mechanism increases the level of quality for the overall performance across the LTE-A networks as stated in Table 7.

Table 5 Video and voice result values

MOS	End to end (sec)		Packet delay variation (sec)		Jitter (sec)		Traffic sent (packet/sec)		Packet loss ratio (PLR %)		Traffic received (packet/sec)			
	HARQ	SHARQ	HARQ	SHARQ	HARQ	SHARQ	HARQ	SHARQ	HARQ	SHARQ	HARQ	SHARQ		
Voice	3.5	4.2	0.1035	0.101	0.00001	0.000005	0.000015	0	245	63.26	0.001	80	245	0.000015
Video	-	-	0.073	0.062	0.0000085	0.000002	-	-	40	12.5	0.0056	35	40	-

Table 6 FTP 2 types result values

Performance factor	HARQ	SHARQ
Download response time (sec)	5	0.001
Upload response time (sec)	4.52	0.5
Traffic sent (bytes/sec)	200	200
Traffic received (bytes/sec)	153	200
Packet loss ratio (PLR %)	25.2	0.0012

Table 7 LTE-A network result values

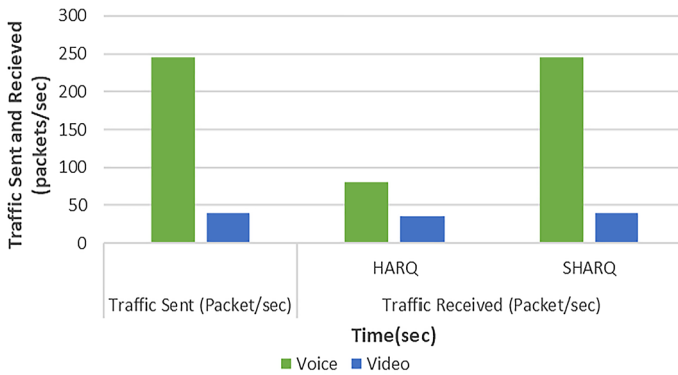
Performance factor	HARQ	SHARQ
Download packet dropped (packet/sec)	11	3.1
Throughput (packet/sec)	700	900
Path loss (dB)	124.85	123.95
Downlink BLER	0.0006	0.00005

7 Comparative Study

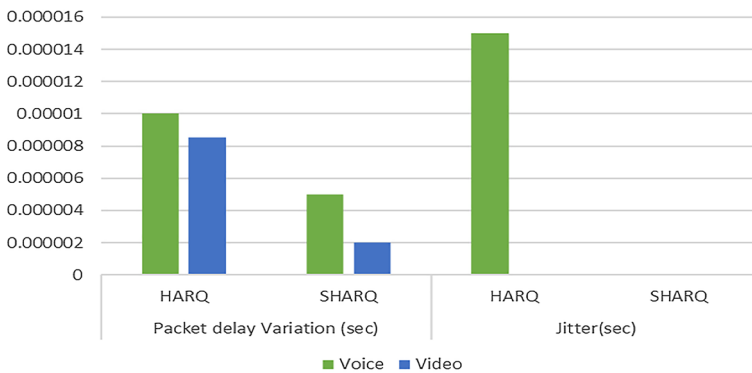
The rapidly processing of retransmission always has a great influence on the multimedia transferred and the performance of the overall network. In 2014, Kuhn et al. [1] Proposed some techniques to make compatibility between ARQ and HARQ between ARQ and HARQ Via file transfer protocol (FTP) multimedia service Independent on higher rates of network's coverage area and user's mobility; fading effects which essentially effect on each transmission processes. Kuhn et al. [2] used only three QoS metrics as (i) Throughput; (ii) SNR; and (iii) BER for investigating the overall performance of the network. However, the improvement in throughput was increased by using HARQ to 22% but still unappropriated value in the condition of heavy load traffic and high coverage faced by the mobile user due to every transmission process. SNR reached to 14 dB using ARQ and BER is 0.096 for the distribution scenarios then decreased to (5 up to 8) dB for bidirectional traffic and BER (0.01 up to 0.1) in which there is an unsatisfactory effect on FTP multimedia services. Otherwise, the HARQ scheme had higher SNR values and lower BER values but stilled under the standard values for acceptable SNR ranges, which must larger than 25 dB. The most important weakness point in [2] is the unavailability for other QoS metrics as MOS and Packet losses; so, it should build a new algorithm based on all performance metrics.

In 2017, Jung and Choi [7] proposed HARQ scheme to increase the spectral efficiency of the network over LTE network using parameter SNR only which satisfied 11 dB at it is un accepted value for SNR to realize high quality for the supported multimedia data. Finally, in 2018, Shi et al. [8] Discussed the investigation of energy efficiency through three common types of HARQ mechanisms as (i) type-1, type-2 with chase HARQ-CC; and (ii) HARQ with incremental redundancy (HARQ-IR) which used to define the overall performance for system energy. Nevertheless, the obtained results mentioned in [3] did not implement any multimedia services independent on any QoS metrics, which can be considered as an incomplete description of the overall efficiency of the network.

In this paper, the introduced proposed algorithm of the SHARQ would characterize all defects due to retransmission processes as follow: (i) the proposed algorithm developed under conditions of high coverage area over LTE-A network up to 20 km as a function of both factors higher pathloss fading effects and user mobility. Moreover, (ii) there are many QoS parameters discussed in this article to investigate the performance of three types of multimedia services dependent on the proposed system to make a complete characterization for performance as shown in Figs. 22, 23 and 24. In addition, (iii) starting with multimedia related to the SHARQ proposed algorithm. The obtained results by using voice, video streaming and FTP satisfies higher MOS and traffic received packets with lower Packet delay variation, PLR, End-to-End delays and jitter compared with other algorithms mentioned in [1, 2]. Finally, the overall network performance will be increased based on the proposed algorithm as higher rates for SNR greater than the standard values equivalent to 25 dB and lower BER values which can reflect on the downlink packet dropped and throughput values compared with other previous algorithms.



(a) Traffic sent and Received (packets /sec)



(b) PDV and Jitter (sec)

Fig. 22 Video and voice performance matrices results

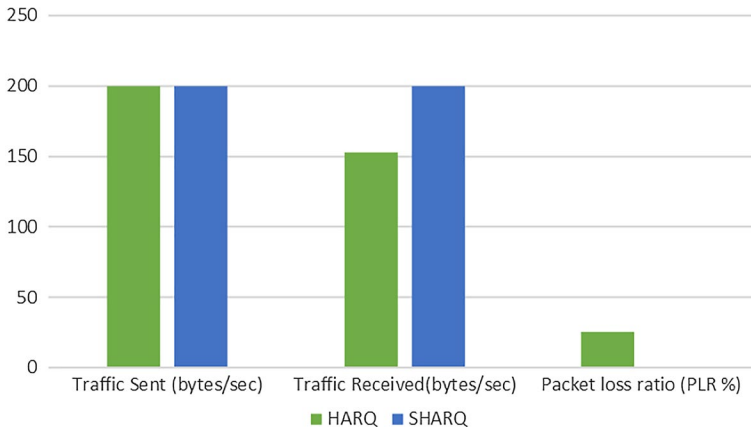


Fig. 23 FTP performance matrices results

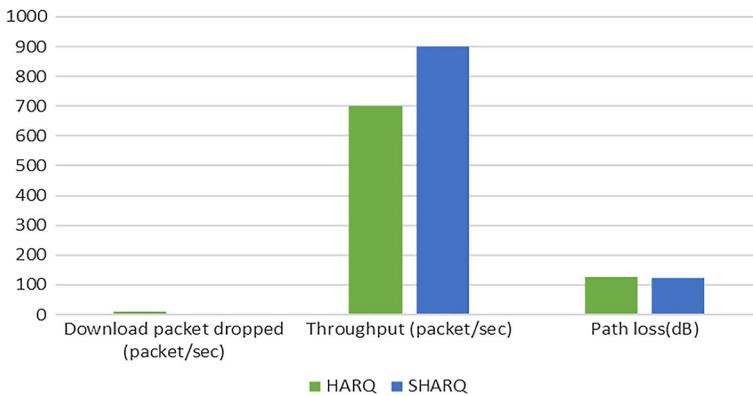


Fig. 24 LTE-A network performance matrices results

8 Conclusion

The transmission of packets for multimedia streams may involve a number of highly efficient problems regarding the adopted retransmission mechanisms; thus, a trade-off will be present between quality and delay. In this paper, we have presented a real-time simulation, and the results showed that the Mobile LTE-A network could deliver sufficient bandwidth, while guaranteeing that the packet delays and jitter will fulfill the required parameters of multimedia streaming. In other words, we have addressed the OPNET simulated networks in order to identify the impact of handover mechanisms across the LTE-A networks on multimedia streaming, with the objective of accomplishing a good empirical quality value on both multimedia and the overall performance. For this purpose, we have analyzed a number of critical parameters such as the end-to-end delay, packet delay variation, throughput, MOS, SNR, BER and PLR. After performing the said simulation, the obtained results proved that through the use of the SHARQ mechanism, a great influence on both the transmission quality and the overall performance was noticed; and that is in comparison to the

HARQ mechanism. Therefore, in light of this case study, we recommend conducting further future studies for more appropriate models for retransmission, as well as its effect on data streaming across the mobile 5G networks, taking into consideration the various types of network connections, and the impact of the several fading effects as well as the different paths between BSs and SSSs; thus, the different conditions of the network shall be studied in detail, with the main objective of providing the best quality at all times of the service's access.

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