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HARQ Scheme for different MCS users over LTE and LTE-Advanced Networks

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Abstract**—** In Long Term Evolution (LTE) and LTE-Advanced networks, due to multifold data traffic growth and unpredictable variation in the received signal strength, there is no guarantee for successful reception of data packets without any error. This becomes a challenging task for Mobile Network Operators (MNOs) to support more reliable data transmissions over the network. The LTE and LTE-Advanced networks uses Hybrid Automatic Repeat reQuest (HARQ) scheme to recovery of error data packets, however the received signal strength may vary from QPSK to 64QAM regions. Therefore the performance evaluation of different Modulation and Coding Scheme (MCS) users such as QPSK, 16QAM and 64QAM for different HARQ retransmissions under different data traffic condition is vital for MNOs to predict the per user throughput and recovery of error data packets of different MCS users for different HARQ retransmissions. Hence in this paper using QualNet 8.2 network simulator, the attempt has been made to study the performance of different MCS users for different HARQ retransmissions under different data traffic scenarios. Simulation results show that the data packets received with error are less as the cell load is within its capacity and less HARQ retransmissions are sufficient to recovery of error data packets, whereas in higher data traffic scenarios, for data intensive services maximum HARQ retransmissions are vital to fulfil QoS requirements.

Keywords**—** LTE, HARQ, MCS, NACK, Data Packets, MNOs

I. INTRODUCTION

The delay sensitive real time services such as video calling, video conference, webinars over LTE and LTE-Advanced networks connects telesurgeries, business community, academia, government organization and other communities to provide very essential services. However, the achieved QoS depends on IP packet connection robustness, setup success rate, latency, system throughput and mobility performances. The data transmissions over wireless channels are subject to errors due to variations in the received signal strength and data traffic [1, 2]. This may deteriorate the user QoE. To support reliable data transmission, the error correction scheme is crucial. The LTE and LTE-Advanced system use the HARQ scheme at MAC sublayer for fast error detection and corrections to provide ubiquitous data services. Further, this HARQ scheme brings several benefits for LTE and LTE-Advanced networks data users such as throughput maximization, latency control with time interlaced HARQ processes, and fine control of system resource usage [3].

The HARQ scheme uses receiver feedback on channel status using Acknowledge (ACK) and Negative ACKnowledge (NACK) signals to inform the transmitter about the status of received data packets. The Receiver feedback ACK signal for successful reception of data packets and for enormous data packet reception NACK signal is reported [4]. When the receiver feedback NACK signal, the HARQ scheme retransmits the same data packets repeatedly until an ACK signal has been received or maximum number of HARQ retransmissions is reached. The increase in HARQ retransmissions increases the received signal strength and Signal to Interference Noise Ratio (SINR) of the cell edge users and also robustness of the channel in both downlink and uplink [5]. Furthermore, the HARQ scheme increases the network capacity by adjusting latency target of eNB scheduler. The maximum number of HARQ retransmissions can be set for each service at eNB on both downlink and uplink to meet the user data rates and latency requirements. At higher data traffic for lower modulation scheme users, maximum number of retransmissions is necessary to provide data rates and latency constraint of service [6]. Hence, in this paper an attempt has been made to evaluate the performance of LTE and LTE-Advanced networks different MCS users such as QPSK, 16QAM and 64QAM under different data traffic to predict how many HARQ retransmissions are necessary for MNOs to recovery of error data packets to support reliable data transmissions to meet service requirements.

The rest of this paper is organized as follows. Section II outlines the related work in the literature. Section III describes the overview of HARQ scheme used in the LTE and LTE-Advanced networks. The simulation assumptions and models are described in section IV. Simulation results and discussions are illustrated in section V and section VI concludes the paper.

II. RELATED WORK

To optimize the performance of LTE and LTE-Advanced networks to provide high speed internet access for mobile data users several schemes have been proposed by the academia and industry on the design of LTE and LTE-Advanced networks using HARQ. The proposed channel coding and network coding techniques allow data retransmission for wireless unicast communication as the data packet received with an error [7]. The authors proposed the use of HARQ with Code Combining (HARQ-CC) scheme offers reliable communications over double Rayleigh channels [8]. The authors proposed the different ARQ schemes over Gaussian block fading channels to enhance the throughput of the network [9]. The authors proposed the ARQ protocols for error control. Using ARQ the corrupted data frames are retransmitted in several attempts for eventual error data packets recovery at the receiver to increase the efficiency of the network [10]. The HARQ scheme with one retransmission and Multiple Input Single Output (MISO) technique using two antenna elements at the transmitter side improve the capability of the system [11]. Motivated by the above proposed works using QualNet 8.2 network simulator an attempt has been made to predict the average unicast received throughput, average end-to-end delay and total transport blocks received with errors of different MCS users and how the error data packets are recovered with different HAQR retransmissions under different data traffic scenarios.

III. OVERVIEW OF HARQ SCHEME IN LTE AND LTE-ADVANCED NETWORKS

Nowadays the diversification of internet applications and services over LTE and LTE-Advanced networks may increase the data traffic exponentially and also due to unpredictable variations in the received signal strength the data packets may be received with an error [12]. To support reliable data transmissions and to offer ubiquitous high speed internet access for data users, the LTE and LTE-Advanced networks uses the HARQ protocol. The HARQ scheme uses a combination of Forward Error Correction (FEC) coding and retransmission technique to recovery of erroneous data packets.

Fig.1 show the HARQ retransmissions scheme used in LTE and LTE-Advanced networks. In HARQ scheme the stop and wait protocol is used at MAC layer to recovery of error data packets. In stop and wait protocol, after transmission of each data frames or Transport Block (TB), the transmitter stops data transmissions and waits for ACK or NACK. This leads to a reduction in system throughput and increase in end-to-end delay. Thus the LTE system uses HARQ scheme with multiple stop and wait protocols at MAC layer and are operates in parallel to avoid the waiting of acknowledgment from one process, the transmitter can transmit data to another HARQ process. After receiving a TB from the particular HARQ process the receiver makes an attempt to decode the TB and informs the transmitter about the delivery of TB through HARQ acknowledgment to specify whether the TB was correctly decoded or not. The receiver sends an ACK signal to indicate the successful reception of the data packets. Otherwise, the receiver sends an NACK signal to indicate that data packet is received with an error. The HARQ retransmits the same data packets repeatedly until an ACK signal has been received or maximum number of HARQ retransmissions is reached. The LTE allows simultaneous transmissions of 8 parallel stop and wait HARQ processes to improve the system throughput and to reduce the latency [13].

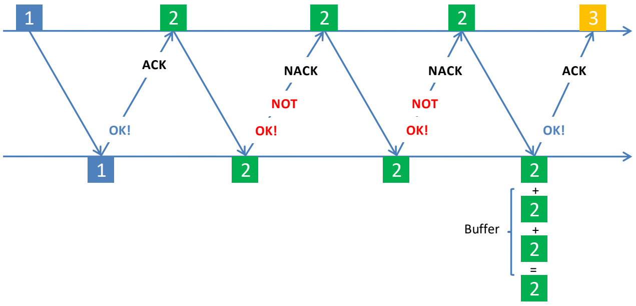


Figure 1. HARQ scheme in LTE

IV. SIMULATION ASSUMPTIONS AND MODELS

The error data packets recovery of different MCS users in the LTE and LTE-Advanced networks are evaluated using QualNet 8.2 network simulator. In the simulated environment, the designed scenario consists of an EPC subnet and macro eNB. The macro eNB is configured with 20MHz channel bandwidth and 2×2 Multiple Input Multiple Output (MIMO) antenna located at the centre of the terrain area of 10Km×10Km. The Proportional Fairness (PF) scheduling algorithm is used for packet scheduling. The simulation parameters considered for the simulation studies are listed in Table I.

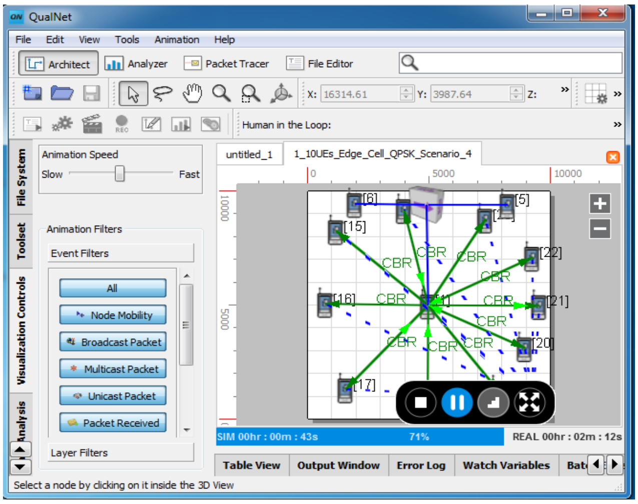
V. SIMULATION RESULTS AND DISCUSSIONS

The performance evaluation of the LTE and LTE-Advanced networks are necessary to validate the ideas before being implemented and to analyze the results to predict the QoS delivered by the network. The performance metrics such as per user unicast received throughput and end-to-end delay are usually measured to estimate the Quality of Service (QoS) of in-progress users.

Table 1. Simulation Parameters

Property	**Value**
Simulation Time	60 seconds
Downlink Channel Frequency	2.32 GHz
LTE Uplink-Channel-Frequency	2.3 GHz
Propagation-Model	Statistical
Path Loss Model	Two-Ray
Channel-Fading-Model	Rayleigh

Constant Shadowing of Mean (dB)		4
Item size (bytes)		512
Antenna Model		Omnidirectional
eNB	PHY- Tx-Power	46dBm
	PHY- Num-Tx-Antennas	2
	PHY- Num-Rx-Antennas	2
	Antenna-Height	15m
	Noise Factor	5
	MAC-Tx-Mode	OLSM
UE	PHY- Tx-Power	23dBm
	PHY- Tx-Antennas	1
	PHY- Rx-Antennas	2
	Antenna-Height	1.5m
	Noise Factor	10
	MAC- Scheduler-Type	Simple-Scheduler



Select a node by clicking on it inside the 3D View

Figure 2. Snapshot of the scenario designed for simulation studies

The snapshot of the scenario configured for simulation studies using QualNet 8.2 network simulator as shown in Fig. 2. In the configured scenario, initially 10 stationary User Equipments (UEs) are placed at 64QAM region and are connected to macro eNB with 100kbps Constant Bit Rate (CBR) downlink data rates. The simulation studies are carried out by setting one HARQ retransmission at LTE MAC. The performance metrics such as average unicast received throughput, average unicast end-to-end delay, average unicast jitter, total transport blocks received and forwarded to MAC, total transport blocks received but with errors are measured. The simulation studies are repeated with same simulation setup by changing the HARQ retransmissions to 2, 3 and 4.

The above performance evaluation process is repeated by changing the data rates to 300kbps, 500kbps, 1Mbps, 2Mbps, 3Mbps, 4Mbps, 5Mbps and 10Mbps. Furthermore, the entire above simulation process are repeated by placing the same 10 stationary UEs at 16QAM and QPSK regions to study the performance of different MCS users for different HARQ retransmissions under different data traffic scenarios.

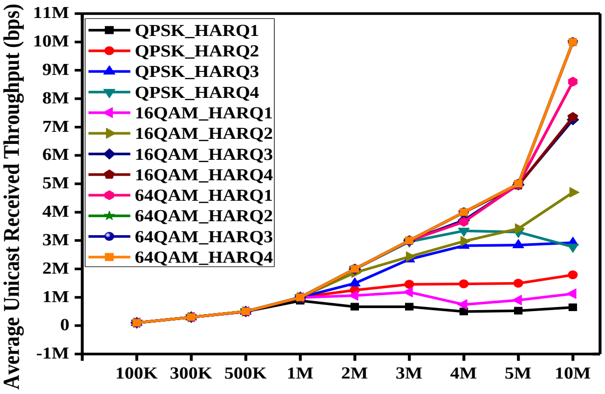


Figure 3. Average unicast received throughput performance of different MCS users for different data rates with different HARQ retransmissions

Fig. 3 illustrates the average unicast received throughput performance of different MCS users for different data rates with different HARQ retransmissions. It is evident from Fig. 3 that the average unicast received throughput of all MCS users is almost same for upto 1Mbps data rates. This is because the cell load is within its capacity and hence sufficient numbers of Resource Blocks (RBs) are availability for data transmissions. It is also evident from Fig. 3 that as the data rates exceed 2Mbps the average unicast received throughput of QPSK and 16QAM users are less with one HARQ retransmission. Because increase in data rates increases the data traffic and causes spectrum scarcity. Hence the UEs may not get sufficient numbers of RBs for data transmissions. Also one HARQ retransmission at the LTE MAC may not recovery the error data packets effectively. Further the QPSK and 16QAM schemes carries 2 and 4 bits per symbol and this significantly limits the user throughput. It is also depicted from Fig. 3 that as the data rates exceed 2Mbps, the increase in HARQ retransmissions increases the average unicast received throughput of all MCS users. This is because the increase in HARQ retransmissions increases the received signal strength, SINR and also robustness of the channel. It is also observed from Fig. 3 that the average unicast received throughput of 64QAM users are better compared to other regions users because 64QAM scheme carries 6 bits per symbol and also due to excellent received signal strength the data packets received with error are less [14].

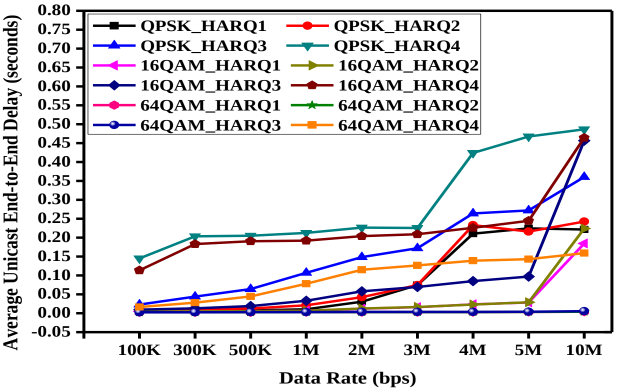


Figure 4. Average unicast end-to-end delay performance of different MCS users for different data rates with different HARQ retransmissions

Fig. 4 illustrates the average unicast end-to-end delay performance of different MCS users for different data rates with different HARQ retransmissions. It is depicted from Fig. 4 that the average unicast end-to-end delay of all MCS users increases noticeably with increase in HARQ retransmissions. This is due to the fact that the increase in HARQ retransmissions increases the system resource usage in turn to increase in network congestion, data packets transmission delay and queuing delay. It is also observed from Fig. 4 that the average unicast end-to-end delay of 64QAM users are less compared to QPSK and 16QAM region users, since 64QAM carries 6 bits per symbol and it radically reduces the transmission and queuing delays. However, the QPSK and 16QAM modulation schemes carries 2 and 4 bits per symbol leads to increase in network congestion, transmission delay and queuing delay. It is also observed from Fig. 4 that the average unicast end-to-end delay of all MCS users, increases with increase in data rates due to increase in data packets transmission delay and queuing delay [14].

Fig. 5 illustrates the average unicast jitter performance of different MCS users for different data rates with different HARQ retransmissions. It is observed from Fig. 5 that the average unicast jitter decreases for increase in data rates and HARQ retransmissions. Because increase in data rates and HARQ retransmissions maximizes the RBs usage and increases the robustness of the channel leads to reduction in the variation in the delay of received data packets [14].

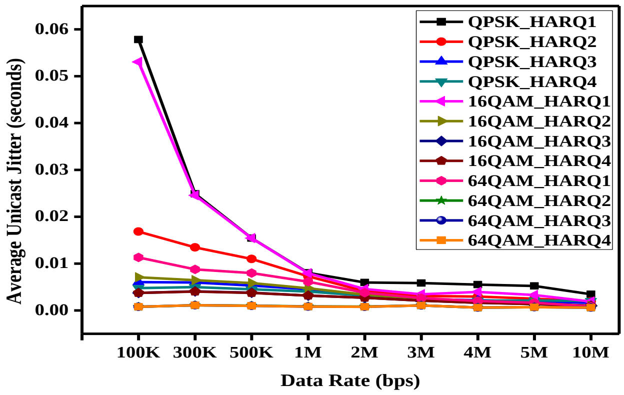


Figure 5. Average unicast jitter performance of different MCS users for different data rates with different HARQ retransmissions

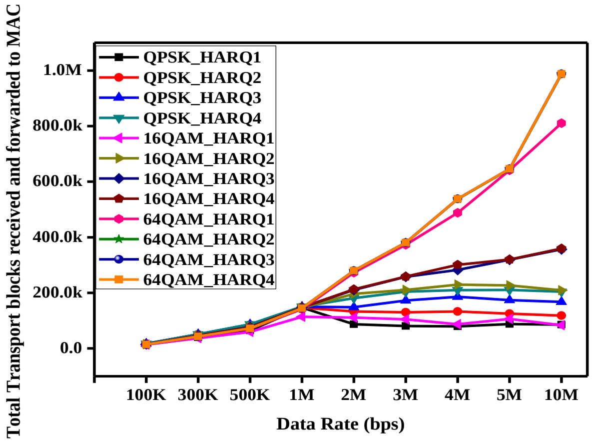


Figure 6. Total transport blocks received and forwarded to MAC for different MCS users for different data rates with different HARQ retransmissions

Fig. 6 illustrates the total transport blocks received and forwarded to MAC of different MCS users for different data rates with different HARQ retransmissions. It is depicted from Fig. 6 that the total transport blocks received and forwarded to MAC increases with increase in HARQ retransmissions. Because the increase in HARQ retransmissions provides more reliable channels for data transmission and also have a better control of system resource usage and latency. It is also observed from Fig.6 that the total transport blocks received and forwarded to MAC are better with higher order modulation scheme due to higher data rate information carrying capacity and lower latency. It is also depicted from Fig.6 that the total transport blocks received and forwarded to MAC are decreases with decrease in modulation order. This is because of poor channel condition each symbol carries less bits and more number of data packets are received with errors, and it significantly limits the transport blocks received and forwarded to MAC.

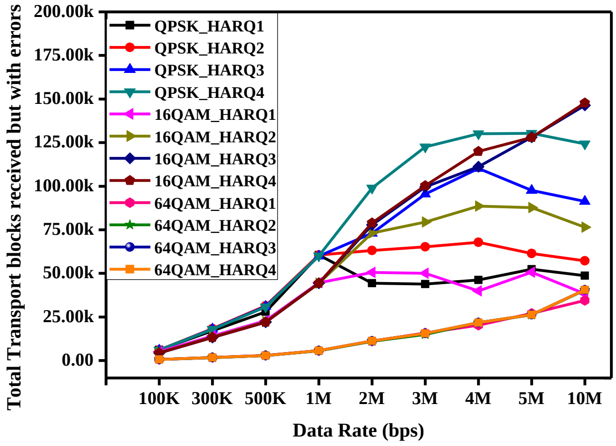


Figure 7. Total transport blocks received with errors of different MCS users for different data rates with different HARQ retransmissions

Fig. 7 illustrates the total transport blocks received but with errors of different MCS users for different data rates with different HARQ retransmissions. It is depicted from Fig. 7 that the total transport blocks received but with errors increases with increase in data rates due to increase in network congestion and scarcity of RBs that leads to more numbers of data packets received but with error. It is also observed from Fig. 7 that the total transport blocks received but with errors are less with higher order modulation scheme, since that carries more bits per symbol in turn to reduction in network congestion and hence more number of data packets successfully received. It is also observed from Fig.7 that the total transport blocks received but with error decreases with increase in HARQ retransmissions, because increase in HARQ retransmissions maximizes the RBs usage and robustness of the channel.

VI. CONCLUSION

Nowadays the diversification of internet applications and services over LTE and LTE-Advanced networks may increase the data traffic in multifold and also due to unpredictable variation in the received signal strength the data packets may received with error. The HARQ scheme may recovery the error data packets. However the received signal strength and data traffic may affects the QoS of end users. The received signal strength may vary from QPSK to 64QAM regions and hence different HARQ retransmissions are necessary for different MCS users to recovery of error data packets. Hence, in this paper using QualNet 8.2 network simulator the performance of different MCS users such as QPSK, 16QAM and 64QAM are evaluated with different HARQ retransmissions under different data traffic. The simulation results show that as the cell load is within its capacity the data packets received with errors are less for all MCS users and less HARQ retransmissions are sufficient to recovery of error data packets. As the data traffic increases the system performance is better with higher order modulation scheme. Furthermore, in higher data traffic scenarios, for lower order MCS and data intensive services maximum HARQ retransmissions are necessary to recovery of error data packets to suffice the service requirements.

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