Impact of Adaptive Modulation and Coding Schemes on Bit Error Rate for System Performance in the Uplink LTE System

Mohana H K
Department of Electronics, Seshadripuram First Grade College, Bangalore, India
E-mail: mohana1.amma@gmail.com

Mohankumar N M
Department of Electronic Science, Bangalore University, Bangalore, India
E-mail: mohan.nm87@gmail.com

Devaraju J T
Department of Electronic Science, Bangalore University, Bangalore, India
E-mail: devarajujt@bub.ernet.in

Abstract

Long Term Evolution (LTE) is a cellular network technology aims to render enriched data services to users at lower latency and higher (multi-megabit) throughput. The higher system throughput with more reliable transmission is achieved by the support of Adaptive Modulation and Coding (AMC) schemes, scheduling algorithms, multi-antenna techniques etc. The AMC schemes substantially increases the system throughput by reducing the Bit Error Rates (BER) and by adjusting the transmission parameters based on the link quality. The scheduling algorithms also enhance the throughput of individual users, as well as the cell throughput by allocating the resources among the active users. Hence in this paper, an attempt has been made to study and evaluate the effects of AMC schemes such as QPSK, 16-QAM and 64-QAM on uplink LTE system performance for Proportional Fair (PF) and Round Robin (RR) scheduling algorithms using QualNet 7.1 network simulator. The performance metrics considered for the simulation studies are BER, cell throughput, average delay and average jitter.

Keywords- LTE, uplink, BER, SC-FDMA, QPSK, 16-QAM, 64-QAM, PF, RR

1. Introduction

The cellular communication system requires the design of more robust and efficient radio access technology to provide spectrally efficient and flexible data rate to access new multimedia applications, voice and data services etc. Long Term Evolution (LTE) is a 3GPP (Third Generation Partnership Project) cellular network technology, which adapts AMC schemes such as QPSK (Quadrature Phase Shift Keying) or 4-QAM (Quadrature Amplitude Modulation), 16-QAM and 64- QAM to provide spectrally efficient and flexible data rates for mobile broadband services by adjusting the transmission parameters based on the link quality to reach the capacity limits of the channel. This AMC is also allows a wireless system to choose the highest order modulation schemes depending on the channel conditions to achieve higher system throughputs of the particular user based on the received signal quality by minimizing the BER, noise and interference. The coding scheme is also modified along the time to match the instantaneous channel conditions of each user. Thus in a LTE network AMC technique track the channel variations, changes the modulation and coding scheme to provide higher system throughput by transmitting information with higher data rates [1, 2]. The uplink LTE system employs SC-FDMA (Single Carrier-Frequency Division Multiple Access) scheme due to its robustness to multipath fading, high power efficiency, higher cell capacity, peak-to-average power ratio (PAPR) reduction ability and BER performances. The SC-FDMA is a single carrier modulation and frequency domain equalization technique, which converts multipath frequency selective fading channel into several flat fading sub-channels to deliver low PAPR and it significantly, increases the power efficiency, spectral efficiency and terminal costs of the User Equipments (UEs). The SC-FDMA also provides orthogonal access to multiple users simultaneously to minimize intra cell interference and maximize cell capacity [3, 4 and 5]. LTE network also support the scheduling algorithms to distribute the resources among the active users by selecting the user with higher order modulation schemes and it improves the throughput of each user and the throughput of the entire cell [6]. Thus the integrated study of AMC schemes and scheduling

ISSN:2229-6093

algorithms in the LTE network becomes crucial. Hence in this paper, the performance of uplink LTE system is evaluated for AMC schemes namely QPSK, 16-QAM and 64-QAM by considering the RR and PF scheduling algorithms.
The rest of the paper is organized as follows. Section 2 and 3 gives a brief insight of AMC schemes and BER analysis. Section 4 gives a brief explanation of SC-FDMA scheme. Simulation studies and results are given in section 5 and Section 6 concludes the paper.

2. Adaptive Modulation and Coding (AMC) Schemes

In cellular communication systems, the quality of a signal received by a UE depends on the distance between the desired and interfering base stations, multipath or shadow fading, noise etc,. In order to improve system capacity, peak data rate and coverage reliability of the cellular systems, the signal transmitted to and by a particular user is modified to signal quality variation to provide maximum system throughput and flexible data rate for services. This can be achieved by adapting AMC schemes. The AMC scheme adjust the modulation and coding scheme to the channel state conditions (CSCs) to accomplish the highest spectral efficiency at all times by overcome the fading and other interference. As per Release 8 LTE network supports QPSK or 4-QAM, 16-QAM and 64-QAM modulation schemes in order to provide different data rates for different kind of mobile broadband services by reacting dynamically to the channel fluctuation. The users closer to the eNB (enhanced Base Station) exploits the 64-QAM scheme to provide higher data rates for services, but the modulation order and/or code rate will decrease as the distance from eNB increases. The AMC schemes are generally represented by M-QAM, where M represents the modulation order or number of conditions or constellation points are available to provide high transmission data rates by transmitting more bits per symbol with high spectral efficiency [7].
In a cellular network M-QAM conveys digital bit streams, by changing the amplitudes of the carrier waves using the amplitude-shift keying (ASK). The M-QAM uses finite number of phases and amplitudes (minimum 2 each) to encode the bits per symbol. In M-QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, since the data are binary, the number of points in the grid is a power of 2 (i.e., 2, 4, 8 …). The most common forms of M-QAM modulation orders are 4-QAM (QPSK), 16-QAM, 64-QAM and 256-QAM. For M-QAM the number of points in the constellation is defined as, $\mathbf{M = 2^k}$ where k is the number of bits in each constellation symbol and is an even number. Thus by increasing a modulation order or constellation point, it is possible to transmit more bits per symbol to enhance the system throughput.
In general the constellation points for M-QAM can be generated as [8, 9]

$$\propto_{\mathbf{MQAM}} = \{\pm(\mathbf{2m-1}) \pm (\mathbf{2m-1})\mathbf{j}\},$$

$$\text{where } \mathbf{m} \in \left\{\mathbf{1,2,..,\frac{\sqrt{M}}{2}}\right\}$$

For QPSK modulation scheme $\mathbf{m\in\{1\}}$ and hence the constellation symbols $\{\mathbf{-1-j, -1+j, 1+j, 1-j}\}$ are used to transmits the information.
For 16-QAM scheme $\mathbf{m\in\{1,2\}}$, hence the constellation symbols $\left\{\begin{matrix}\mathbf{\pm1\pm1j}, & \mathbf{\pm1\pm3j},\\ \mathbf{\pm3\pm3j}, & \mathbf{\pm3\pm1j}\end{matrix}\right\}$ are used to transmits the information.
For 64-QAM scheme $\mathbf{m\in\{1,2,3,4\}}$, thus the constellation symbols $\left\{\begin{matrix}\mathbf{\pm7\pm7j} & \mathbf{\pm7\pm5j} & \mathbf{\pm7\pm3j} & \mathbf{\pm7\pm1j}\\ \mathbf{\pm5\pm7j} & \mathbf{\pm5\pm5j} & \mathbf{\pm5\pm3j} & \mathbf{\pm5\pm1j}\\ \mathbf{\pm3\pm7j} & \mathbf{\pm3\pm5j} & \mathbf{\pm3\pm3j} & \mathbf{\pm3\pm1j}\\ \mathbf{\pm1\pm7j} & \mathbf{\pm1\pm5j} & \mathbf{\pm1\pm3j} & \mathbf{\pm1\pm1j}\end{matrix}\right\}$ are used to transmits the information.
In M-QAM modulator, the data stream is divided into I and Q bit streams, each encoded onto a separate axis using identical Gray coding mapping blocks. The distance between two adjacent signal points is given by [10]

$$\mathbf{d} = \sqrt{\frac{\mathbf{3E_b\log_2(M)}}{\mathbf{2(M-1)}}}$$

, where E_b is the energy per bit.

The constellation diagrams show the different position for the states within different forms of M-QAM. The data rates of AMC techniques depends on its constellation points and is calculated by using the equation,

$$\mathbf{k = \log_2(M)\ bits/sec/Hz.}$$

Where, M is modulation order or possible signal (symbol) and hence M-QAM constellation can encode $\mathbf{\log_2(M)}$ bits per symbol i.e., each symbol consists of **k** bits. Thus by increasing modulation order M-QAM it is possible to transmit more bits per symbol to achieve higher system throughput with the same system bandwidth [11, 12].
The QPSK uses four constellation points and hence the data rate of each symbol or constellation point is $\mathbf{k=\log_2(M)=\log_2(4)=2}$ bits/sec/Hz. Correspondingly the symbol data rate of 16-QAM and 64-QAM schemes are $\mathbf{k=\log_2(16)=4}$bits/sec/Hz and

ISSN:2229-6093

$k=\log_2(64)=6$bits/sec/Hz. Hence in LTE network the higher order modulation scheme able to carries more data bits per symbol to provide higher data rates for services and are less flexible to noise and interference. Also by using different M-QAM modulation schemes it is possible to provide diversity of data traffic requirements for mobile broadband network to access different kind of services such as multimedia applications, traditional voice and data traffic etc [11, 12].

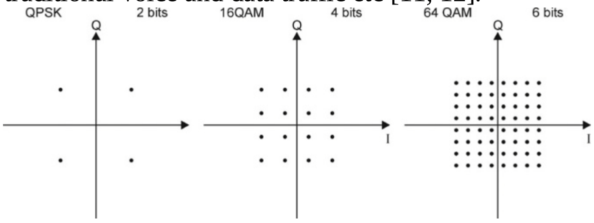

Figure 1: Constellation diagrams of AMC Schemes

The Spectrum efficiency of the modulation schemes is measured by the achievable data rate per unit bandwidth [13]

i.e. $\frac{R_b}{B}$

In general, bandwidth required to pass M-QAM signal is approximately given by

$$B=\frac{1}{T_s}$$

$$\text{But, } R_b=\frac{\log_2(M)}{T_s}=\text{bit rate}$$

Then, the bandwidth efficiency may be expressed as

$$\rho=\frac{R_b}{B}=\log_2(M) \text{ bits/sec/Hz}$$

Hence, as **M** increases the bandwidth efficiency of **M-QAM** increases

Table1. Data rate of AMC Schemes

Modulation Schemes	Symbol time (sec)	Bandwidth (Hz)	Bits Per Symbol/ Data Rate
QPSK	T	1/T	2
16-QAM	T	1/T	4
64-QAM	T	1/T	6

3. BER Analysis for M-QAM

In a digital transmission, BER is the percentage of bits that have errors relative to the total number of bits that have been transmitted, received or processed over a given time period [14]. Hence Bit error rate (BER) is a parameter which gives an excellent indication of the system performance and is given by,

$$BER=\frac{\text{Number of Error bits}}{\text{Total number of bits sent}}$$

In cellular network AMC techniques allows to maintain the BER below a predefined target value by modifying the signal transmitted to a particular user according to the instantaneous received signal quality to provide higher data rates.

In LTE network each symbol consists of **k** bits, the symbol to noise ratio is equal to **k** times the bit to noise ratio [8].

i.e., $$\frac{E_s}{N_0}=k\frac{E_b}{N_0}$$

Then the relationship between bit error and symbol error is given as,

$$P_b\approx\frac{P_s}{k}$$

Hence the higher order modulation scheme renders higher system throughput in a LTE network by reducing the BER [15].

The symbol error rate for 4-QAM (QPSK) is given as [8],

$$P_s\,4QAM=\operatorname{erfc}\left(\sqrt{\frac{E_s}{2N_0}}\right)$$

The symbol error rate for 16-QAM modulation is given as [8],

$$P_s\,16QAM=\frac{3}{2}\operatorname{erfc}\left(\sqrt{\frac{E_s}{10N_0}}\right)$$

In general symbol error rate for M-QAM constellation point (where $M=2^k$ and **k** is even) is given by [8],

$$P_s\,MQAM=2\left(1-\frac{1}{\sqrt{M}}\right)\operatorname{erfc}\left(\sqrt{\frac{3E_s}{2(M-1)N_0}}\right)-\left(1-\frac{2}{\sqrt{M}}+\frac{1}{M}\right)\operatorname{erfc}^2\left(\sqrt{\frac{3E_s}{2(M-1)N_0}}\right)$$

Where, erfc (.) is the complementary error function.

4. Single Carrier-FDMA Scheme in Uplink LTE System

The SC-FDMA is a multiple access scheme used in the uplink LTE system to provide high power efficiency, higher cell capacity, low peak-to-average power ratio (PAPR) and bit error rate (BER) performances. The transmitter and receiver structure of SC-FDMA as shown in figure 2. At the transmitter side, the information bits can be modulated using one of the possible modulation techniques such as QPSK, 16-QAM, 64-QAM, etc. The complex modulated signal undergoes discrete Fourier transformation (DFT) to produce a frequency domain representation of the input

ISSN:2229-6093

symbols. The number of DFT points (M) is defined by the number of symbols to be transmitted. The DFT outputs are then mapped on to different sub-carrier by using either Localized Mapping (LFDMA) or Distributed Mapping. The number of sub-carriers (N) allocated for the entire users is given by the following equation

$$N = M \times Q$$

Where, M represents the number of DFT points and Q represents number of users [16]. The output is then applied to consecutive inputs of a size-N Inverse DFT (N > M) where the unused input of IDFT are set to zero, the output of the IDFT is a signal with 'single carrier' properties, i.e. a signal with low power variations, and with a bandwidth that depends on N. If they are equal (N=M), they simply cancel out and it becomes a conventional single user single carrier system with frequency domain equalization. The SC-FDMA is single carrier, not single frequency. The data signal of each user consists of a lot of frequency. DFT of SC-FDMA is used to filter the frequency items and maps them into IDFT to reform single user waveform. This causes the reduced peak-to average lower ratio (PAPR) in the IDFT output. Prior to transmission the transmitter also inserts a set of symbols referred to as cyclic prefix (CP) in order to provide a guard time to prevent inter-block interference (IBI) due to multipath propagation and linear filtering operation referred to as pulse shaping in order to reduce out-of-band signal energy.

The receiver transforms the received signal into the frequency domain via DFT, de-maps the subcarriers, and then performs frequency domain equalization. Because SC-FDMA uses single carrier modulation, it suffers from inter-symbol interference (ISI) and thus equalization is necessary to combat the ISI. The equalized symbols are transformed back to the time domain via IDFT, and detection and decoding take place in the time domain [17, 18].

The system choose the highest order M-QAM modulation scheme depending on the channel conditions to achieve higher throughputs or better spectral efficiencies of the particular user according to the instantaneous received signal quality by minimizing the interference and bit error ratio (BER). When the channel is in good condition, the data transmission is performed with 64-QAM modulation scheme to achieve higher data rates for services and when the channel is in poor condition, the transmission is performed with QPSK modulation scheme and hence the data rate is lowered due to its less information carrying capacity and low-rate codes. The channel side information is feedback to transmitter in order to control transmit constellation, the coding rate and transmit power

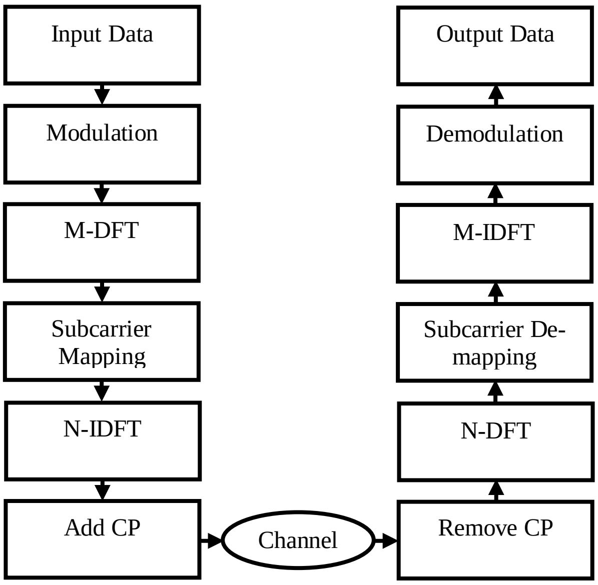

Figure 2: Transmitter and Receiver structure of SC-FDMA scheme

5. SIMULATION STUDIES AND RESULTS

In the uplink LTE system, the effects of AMC schemes such as QPSK, 16-QAM and 64-QAM on system performance is evaluated by considering an eNB and a 20 UEs for rayleigh fading model in an simulation area 5Km x 5Km using QualNet 7.1 network simulator. The remaining simulation parameters considered for the simulation studies are listed in Table 2.

The snapshot of the scenario designed for simulation studies using QualNet 7.1 simulator as shown in figure 3. In the designed scenario, 20 UEs which are placed in the QPSK region and are connected to an eNB with uplink Constant Bit Rate (CBR) connections of data rate 500Kbps by considering PF scheduling algorithms. The simulation studies are carried out by considering the performance metrics namely BER, cell throughput, average delay and average jitter. Simulation studies are repeated by changing the data rate of each CBR connections to 1Mbps, 5Mbps, 10Mbps, 15Mbps, 20Mbps and 25Mbps. The simulation studies are also repeated by placing the 20 UEs at 16-QAM and 64-QAM regions. Further, the simulation studies are repeated for RR scheduling algorithms

ISSN:2229-6093

IJCTA

MOHANA H K ET AL, INT.J.COMPUTER TECHNOLOGY & APPLICATIONS,VOL 6 (5),803-809

Table 2. Simulation Parameters

Property			Value
Simulation-Time			50S
Terrain Area			5Km X 5Km
Propagation-Channel-Frequency[0]			2.4GHz
Propagation-Channel-Frequency[1]			2.5GHz
Propagation-Model			Statistical
Pathloss Model			Two Ray
Shadowing Means			4dB
Fading Model			Rayleigh
Channel Bandwidth			10MHz
Antenna Model			Omni directional
Antenna Gain(dB)			0
eNB	MAC-Scheduler-Type		PF/RR
	PHY-Tx-Power (dB)		23
	Antenna Height		15meters
	MAC Transmission Mode		Single antenna scheme
	Receive Diversity (SIMO)	PHY- Num-Rx- Aneanna	2
UE	MAC-Scheduler-Type		Simple-Scheduler
	PHY-Tx-Power (dB)		23
	Antenna Height		1.5meters
	PHY-Num-Tx-Aneanna		1

Figure 4 shows BER performance of AMC schemes for PF and RR scheduling algorithms with varying date rates. It is depicted from figure 4 that the BER is less for higher order M-QAM, since the higher modulation scheme deliver less symbol error rate and are less flexible to noise and interference [15, 8]. Figure 4 also illustrate that the BER performance of RR is better than PF scheduling algorithms, since RR scheduling algorithm does not have an additional overhead of allocating resources dynamically depending on channel conditions which is present in PF scheduling algorithm [19]. It is also evident from figure 4 that the BER is less for higher data rate due to its less flexibility of noise and interference [15].

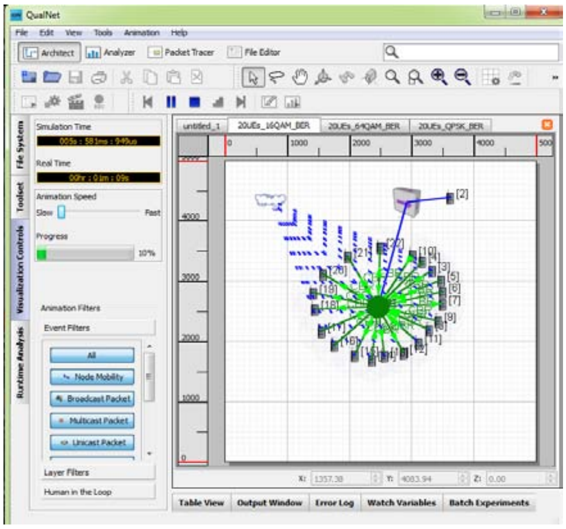

Figure3. Snapshot of the Scenario designed for simulation study

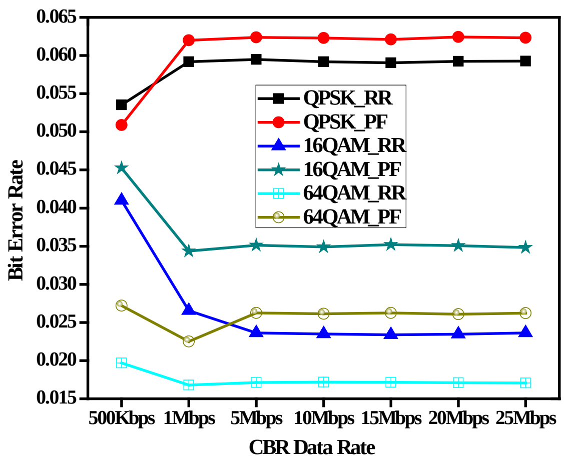

Figure4: BER performance of AMC schemes for various date rates

Figure 5 depicts the cell throughput performance of AMC schemes for PF and RR scheduling algorithms with varying date rates. It is observed from figure 5 that the cell throughput performance is better for higher order M-QAM, because its carries more bits per symbol and it significantly increases the data rates to accomplish the higher cell throughput [7, 8]. The data rates per symbol of the AMC schemes as shown in table 1. It is evident from figure 5 that the cell throughput of PF is better than RR algorithm for higher order M-QAM. Because the PF algorithm provides a good tradeoff between system throughput and fairness among all users by selecting the user with higher order modulation scheme, this renders higher data rates for services. But RR provides resources in turn (one after another) to the users without considering

ISSN:2229-6093

channel conditions. Thus the users are equally scheduled and it significantly degrades the cell throughput [19, 20].

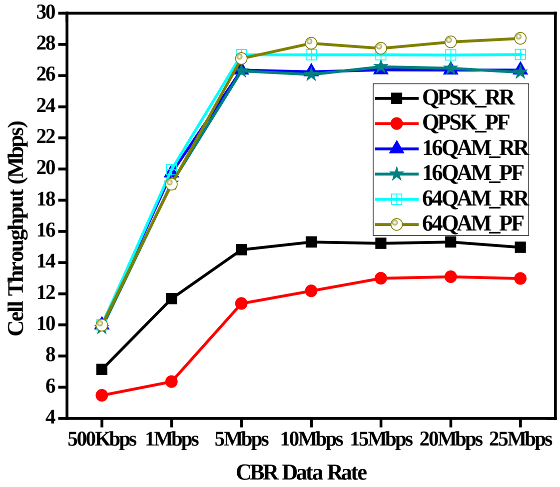

Figure 5: Cell throughput performance of AMC schemes for various date rates

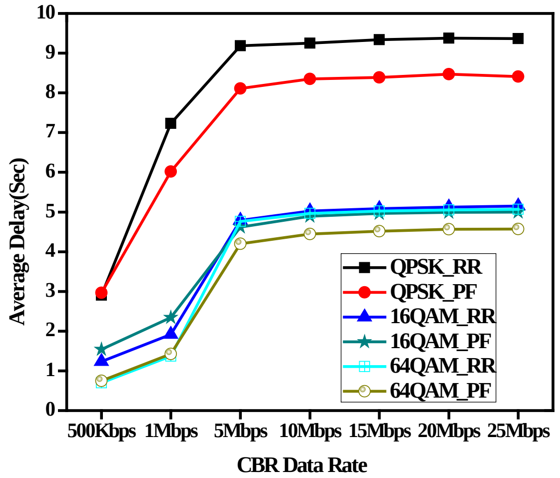

Figure 6: average delay performance of AMC schemes for various date rates

Figure 6 illustrates the average delay performance of AMC schemes for PF and RR scheduling algorithms with varying date rates. It is evident from figure 6 that the average delay for higher order M-QAM is less, because the higher order modulation schemes carries more bits per symbol and it radically reduces the queuing delay [21]. It is also depicted from figure 6 that the average delay is less for PF algorithm, since it allocate the more resources to users with relatively better channel quality. However, the RR algorithm assigns resources cyclically to the users without taking channel conditions and it causes more delay [22]

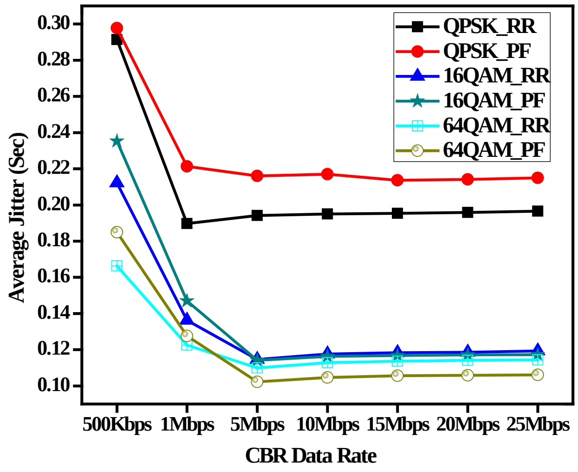

Figure 7: average jitter performance of AMC schemes for various date rates

Figure 7 shows the average jitter performance of AMC schemes for PF and RR scheduling algorithms with varying date rates. It is illustrated from figure 7 that the average jitter performance is less for higher order M-QAM, since the increased modulation order increases the symbol rate by carrying more bits per hertz [21]. From figure 7 it is also depicted that the average jitter is less for higher data rates, because the higher data rates reduces the queuing delay of constellation point for resources and it substantially reduces the jitter [14].

6. CONCLUSION

In this paper, the effects of AMC schemes such as QPSK, 16-QAM and 64-QAM on uplink LTE system performance for Proportional Fair (PF) and Round Robin (RR) scheduling algorithms is evaluated using QualNet 7.1 network simulator. The system performance metrics considered for the simulation studies are Bit Error Rate (BER), cell throughput, average delay and average jitter. The simulation result shows that the uplink LTE system performance is better with 64-QAM scheme for both PF and RR scheduling algorithms as compared to 16-QAM and QPSK modulation schemes due to its higher information carrying capacity.

ACKNOWLEDGMENT

One of the Authors of this paper would like to thank Director of Studies and Management of Seshadripuram Educational Trust (SET), Bangalore for their support. Authors would like to thank UGC for providing Junior Research Fellowship under 'At Any One Given Time Basis Scheme' to carry out the research work.

ISSN:2229-6093

References:

[1] Sami H. O. Salih, Mamoun M. A. Suliman "Implementation of Adaptive Modulation and Coding Technique using"

[2] M.A.Mohamed, H. M. Abd-ElAtty, M. E. A. AboEl-Seoud, W.M.Raslan "Performance Analysis of LTE-Advanced Physical Layer", IJCSI International Journal of Computer Science Issues, Vol. 11(1), 2014

[3] Raad Farhood Chisab, Member IEEE *and Prof. (Dr.) C. K. Shukla*, "Performance Evaluation of 4G-LTE-SCFDMA Scheme under SUI and ITU Channel Models" International Journal of Engineering & Technology Vol:14(01)

[4] Sandeep Shukla, Saurabh Shukla, Neetesh Purohit "PAPR Reduction in SC-FDMA Using NCT Technique", International Conference on Computational Intelligence: Modeling Techniques and Applications (CIMTA), 2013

[5] Mayada Faris Ghanim1, Mohammad Faiz Liew Abdullah2 and Aws Zuheer Yonis3 "Software Implementation and Comprehensive Performance of Uplink Channel on Mobile 4th Generation Technology" International Journal of Smart Home Vol. 7(3), 2013

[6] Yaser Barayan and Ivica Kostanic, "Performance Evaluation of Proportional Fairness Scheduling in LTE", Proceedings of the World Congress on Engineering and Computer Science, Vol 2, 2013

[7] Ronell B. Sicat, Professor Tareq Y. Al-Naffouri, "Bit Error Probability Computations for M-ary Quadrature Amplitude Modulation".

[8] Krishna Pillai, "Symbol error rate for M-QAM modulation and Modulation roundup: error rates, noise, and capacity"

[9] Sahasha Namdeo, Reena Rani " Designing and Performance Evaluation of 64 QAM OFDM System", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834. Vol 5(6), 2013, PP 97-105

[10] Laleh Najafizadeh, Chintha Tellambura "Exact BER Analysis of an Arbitrary Square/Rectangular QAM for MRC Diversity with ICE in Non-identical Rayleigh Fading Channels"

[11] Wasan K. Saad, Mahamod Ismail and Rosdiadee Nordin, "Survey of Adaptive Modulation Scheme in MIMO Transmission", journal of communications, vol. 7(12), 2012.

[12] Sonia Rathi, Nisha Malik, Nidhi Chahal, Sukhvinder Malik, "Throughput for TDD and FDD 4 G LTE Systems", International Journal of Innovative Technology and Exploring Engineering (IJITEE) Volume-3(12), 2014

[13] MeixiaTao, "Principles of Communications"

[14] Manish Trikha, Neha Sharma, Manas Singhal, Ritu Rajan, Pankaj Bhardwaj "BER Performance Comparison between QPSK and 4-QA Modulation Schemes" MIT International Journal of Electrical and Instrumentation Engineering, *Vol. 3(2), 2013, pp. 62–66*

[15] M.A.Mohamed, H.M.Abd-ElAtty, M.E.A.AboEl-Seoud and W.M.Raslan "Performance Analysis of LTE-Advanced Physical Layer" , IJCSI International Journal of Computer Science Issues, Vol. 11(1), 2014

[16] Prittu Ann Thomas, Prof M.Mathurakani, "Effects of Different modulation schemes in PAPR reduction of SC-FDMA System for Uplink Communication", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3(4), 2014

[17] Renu Rani, Garima Saini, Anuj Kumar "Peak-to-Average Power Ratio Analysis of SCFDMA Signal by Hybrid Technique" *International Journal of Computer Applications (0975 – 8887) Vol. 69(15), 2013*

[18] Hyung G. Myung, Jung-Lin Pan, Robert Olesen, and Donald Grieco "Peak Power Characteristics of Single Carrier FDMA MIMO Precoding System"

[19] Claude Simon and Geert Leas "Round-Robin scheduling for time varying channel with limited feedback", IEEE 10th workshop on signal processing advances in wireless communication, 2009, ISBN-978-1-4- 4244-3695-8, DOI: 10.1109/SPAWC.2009.5161781, Pp(s): 231-234

[20] Ronak D. Trivedi1 , M. C. Patel2, Comparison of Different Scheduling Algorithm for LTE, International Journal of Emerging Technology and Advanced Engineering, Volume 4(5), 2014

[21] J.G. Proakis "Digital Communications" McGraw-Hill, New York, 2001.

[22] Mohammad T. Kawser, Hasib M. A. B. Farid, Abduhu R. Hasin, Adil M. J. Sadik, and Ibrahim K. Razu "Performance Comparison between Round Robin and Proportional Fair Scheduling Methods for LTE" , International Journal of Information and Electronics Engineering, Vol. 2(5), 2012