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MULTICELL ENVIRONMENT : TOOL FOR CAPACITY ENHANCEMENTOF LTE SPECTRUM USING ADAPTIVE MODULATION

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Abstract: Due to increasing demand for data and connectivity, it has become necessary to enhance the data capacity of the existing 4G LTE network. In order to achieve this fit , the use of adaptive modulation and coding with involvement in finding the best combination of modulation scheme and code rate that best maximizes the throughput of the network momentarily for a given signal to noise ratio (SINR)available to the User equipment (UE). A method has been presented in this research work which is based on adaptive modulation and coding (AMC) switching which uses an algorithm that considers a certain given block error rate (**BLER**) requirement before deciding the best combination of modulation scheme, code rate and transmission mode that is most appropriate for a given available SINR from the UE. Field measurements were carried out to reveal the exact values of SINR values obtainable from a UE in a typical LTE cell. The SINR values were then simulated for different modulation schemes (QPSK, 16QAM, 64QAM and 256QAM, code rates) varying from 0.13 to 0.92 depending on the modulation scheme and Transmission modes (TM7, TM8 and TM9) to generate the BLER and throughput performance for each unique combination of the stated parameters (modulation scheme, code rate and TM mode). The generated table served as a database to determine the best combination of modulation scheme, code rate and TM mode that best maximizes the throughput for a given input SINR and maximum BLER requirement.

Keywords: 4GLTE, BLER, SINR, Adaptive Modulation and Coding;

INTRODUCTION

Due to the spread of smart phones and tablets in the general tier and technological innovation such as IoT, the use of the Internet and the demand for data is on the increase (Andrew, Buzzi, & Choi, 2014). The wireless communication channel is dynamic in nature leading to poor utilization of the network resources whenever they are available. Adaptive systems aim to solve this problem by creating a system that is opportunistic in nature utilizing the network resources whenever they are available. This leads to better utilization of the network resources. In adaptive modulation and coding (AMC), parameters such as the modulation scheme and the code rate are adaptively selected based on the instantaneous channel condition. Due to the tradeoff relationship between system throughput and block error rate (BLER) the selection of modulation scheme and code rate is in such manner as to increase the throughput of the system for a given channel quality and still be able to achieve a given acceptable block error performance. Setting higher modulation order increases information bits to be transmitted thus raising spectral efficiency but such higher order modulation schemes has poor block error rate performance. Forward error correction (FEC) using error correction codes can compensate for such errors bits by using additional redundant bits.

The error correction capability can be controlled via its redundancy, i.e. coding rate. In which case, the maximum throughput deteriorates in inverse proportion to the coding rate (Kojima, Maruta, & Ahn, 2018). The concept of AMC and its implementation have been widely recognized and employed in the 3G cellular networks (Goldsmith & Chua, 1998)(3GPP, n.d.) as well as in 4G wireless standards, such as WiMAX (IEEE Standard 802.16e, 2006) and Long-Term Evolution (LTE) (3GPP TS 36.211, n.d.). However, the implementation of AMC brings a challenge that in order to select the appropriate modulation and coding scheme, the scheduler must be aware of the channel quality. In some practical implementation of the AMC scheme, the channel state information (CSI) will have to be estimated at the receiver and then fed back to the transmitter. Uncertainty about the accuracy of the estimated CSI is one of the key constraints in such AMC systems (Zhenhuan, 2011).

LITERATURE REVIEW

Motivated by the increasing demand for mobile broadband services with higher data rates and Quality of Service (QoS), 3GPP started working on two parallel projects, Long Term Evolution (LTE) and System Architecture Evolution (SAE), which are intended to define both the radio access network (RAN) and the core network of the system, and are included in 3GPP Release 8. LTE/SAE, also known as the Evolved Packet System (EPS), represents a radical step forward for the wireless industry that aims to provide a highly efficient, low-latency, packet-optimized, and more secure service (Varshney, 2019).

In 4G, the majority of the traffic is data and multimedia as opposed to voice only. Through a common wide-area radio-access technology and flexible network architecture LTE has enabled convergence of mobile and fixed broadband networks (Singh & Singh, 2016). At present, the most widely used frequency of LTE is 1800 MHz, and the second is 2.6 GHz, 800 MHz frequency band (Yang, 2013).

Long Term Evolution (LTE) is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards. The goals of LTE were to increase the capacity and the speed of wireless data networks, by utilizing a new Digital Signal Processing (DSP) techniques and modulations. Third Generation Partnership Project Long Term Evolution (3GPP LTE) promises high peak data rates for both uplink and downlink transmission, spectral efficiency, low delay and latency, low bit error rates, flexible bandwidth deployment to mention but a few. LTE leverages on a number of technologies to achieve these targets, namely Multi Input Multiple Output (MIMO) antennas, Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiplexing Access (OFDMA) at the downlink, Single Carrier Frequency Division Multiple Access (SCFDMA) at the uplink, support for Quadrature Phase Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (16QAM), and 64QAM. Adaptive modulation and coding is used to increase the network capacity or data rates in LTE (Yamindi, Hong, & Wu, 2012)

LTE ARCHITECTURE

The overall LTE architecture is called the Evolved Packet System (EPS). Network architectures used to design LTE significantly reduce transfer latency compared to the 3G architectures. Other features in LTE network architecture which makes them superior to that of the previous generations are new routing techniques, efficient solutions for sharing dedicated frequency band, increased mobility and bandwidth capacity. The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum.

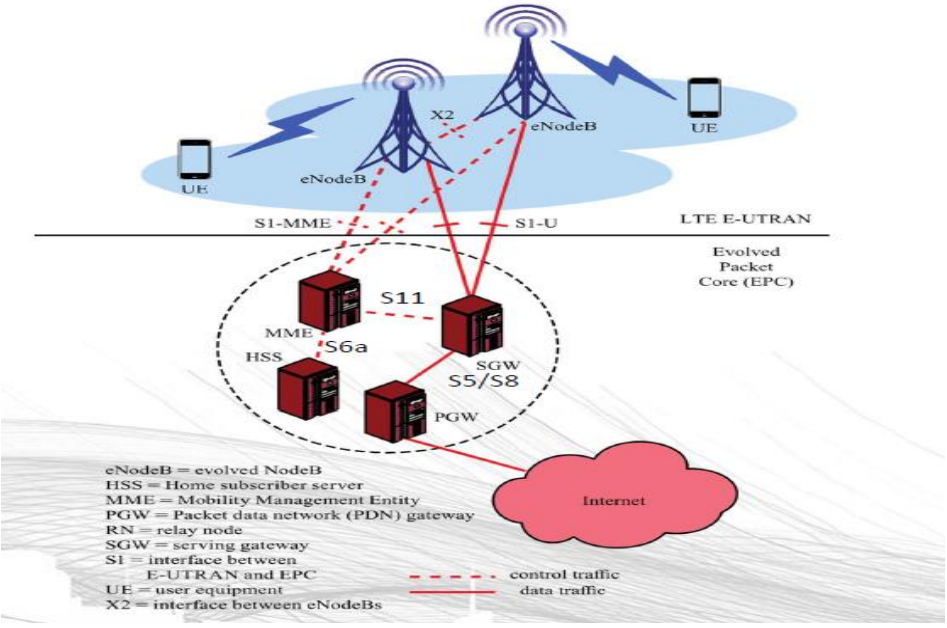

Fig 1: LTE Architecture or the Evolved Packet system (Xerandy, 2018)

DEFAULT BEARER IN LTE

When LTE UE attaches to the network for the first time, it will be assigned default bearer which remains as long as UE is attached. Default bearer is best effort service. Each default bearer comes with an IP address. UE can have additional default bearers as well. Each default bearer will have a separate IP address. QoS class indicator, QCI 5 to 9 (Non-guaranteed bit rate – non-GBR) can be assigned to default bearer.

ADAPTIVE MODULATION AND CODING

The ever-increasing demand for all types of services, voice, data and above all, multimedia services, requires the design of increasingly more intelligent and nimble communication systems, which are capable of providing access to spectrally efficient and flexible data rate.

These systems are able to adapt and adjust the transmission parameters based on the link quality, hence improving the spectrum efficiency of the system, and in this way, reaching the capacity limits of the underlying wireless channel.

RELATED WORKS

The concept of adaptive communication started with adaptive modulation in late eighties (Abdullah, et al., 2018). In this way the modulation scheme was chosen according to the CSI. For example, if channel conditions are good then a relatively higher-order modulation scheme like 64QAM, 128QAM or 256QAM may be used and if channel conditions are poor then a lower-order modulation scheme like binary phase shift keying (BPSK) may be used. So, when a range of such modulation schemes is available, then some criteria must be there to govern how to choose the optimum modulation scheme for a given CSI.

In (Romano, Marabissi, Tarchi, & Habib, 2009) the author proposed an efficient adaptive modulation and coding techniques to be used in WiMAX based wireless networks, that will allow improvement in network performance for the case of Non Line-of-Sight communications. He presented two switching algorithms, The Maximum Throughput (MT) and The Target BLER (TBLER) algorithm. The MT algorithm aims to maximize the system throughput without constraints on target Block Error Probability.

According to (Fakhri, Nsiri, Aboutajdine, & Vidal, (2006) have taken a more general look at throughput by considering its definition for a packet-based scheme and how it can be maximized based on the channel model being used. The throughput is defined as the number of bits per second correctly received. His research focused on the transmission of data as opposed to that of voice. Even in his work, however, the analysis is mostly done with system specific parameters Zhenhuan, (2011) proposed a more efficient and accurate means of channel estimation which resulted in better SNR estimation based on previous channel fading characteristic and thereby maximizing the throughput of the AMC system. He proposed use of layered multi-step finite-state Markov chain model (FSMC) for channel estimation and also selectively assist the system in selecting the optimal modulation and coding scheme as well as the power.

RESEARCH GAP

In most of the above reviewed works, the interest was either to maximize throughput while compromising BLER or to minimize BLER while compromising throughput with no interest in finding the best trade off that will maximize the throughput for every BLER requirement. Even those that set a BLER requirement simply assumed a given fixed BLER requirement and used it to generate a static switching table for selection of modulation and code rate. Since BLER and data rate requirement is different for different QoS classes, there is need to formulate a more flexible switching algorithm that generates the best choice of the modulation scheme and code rate that maximizes throughput for every BLER requirement and available SINR.

METHODOLOGY

An empirical measurement was carried out in a 4G drive test experiment over eighteen LTE cells. The field experiment revealed different possible SINR values available to a UE at various points within the cell. The SINR values was then simulated under AWGN and Rayleigh fading channel using the MATLAB 2019a LTE toolbox to generate their block error performance and throughput. The SINR was simulated under different modulation schemes (QPSK, 16-QAM, 64-QAM and 256-QAM), different code rates and for different TM modes (TM7, TM8 and TM9). This simulation generated a table of throughput and BLER values for each combination of modulation scheme, code rate and TM mode.

A desktop application was developed which for every input SINR searches the table to find the best combination of modulation scheme, code rate and TM mode that maximizes the throughput while still satisfying the maximum BLER requirement of that QoS class.

Theoretical Channel Capacity of the LTE Network System

The Shanon’s formular for the theoretical capacity that can be achieved with a communication channel is given in equation 3.1

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$$C = BNRLog_2(1 + SINR) \qquad 3.1$$

Where,
C = Channel capacity in Mbps
N = Number of bits per signal point of the modulation scheme
R = code rate
SINR = Signal to noise plus Interference ratio

Method of data collection

The primary source of data for this research was obtained from field measurement from eighteen LTE cells in the city of Enugu. This measurement revealed different possible SINR values obtainable from a typical UE in an LTE cell.
The secondary source of data is the data generated from the simulation which was carried out using the MATLAB LTE Toolbox

Experimental Test Bed

The study was carried out on a total of eighteen enodeB's on the Airtel network located inside the city of Enugu, comprising of new heaven, Otigba junction, government house and independence layout Enugu state, Nigeria

Experimental set up for 4G drive test

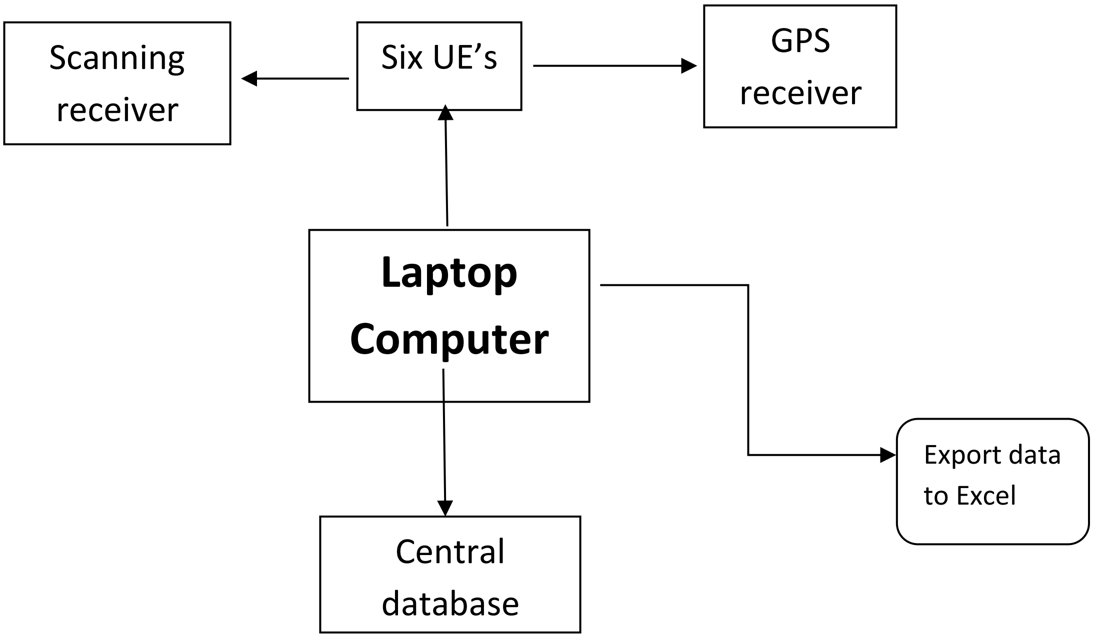

Fig2 Block Diagram of the drive test

The six UE's, all having a 4G configured sim on the Airtel network were all connected to the laptop computer via WLAN connection while the scanning receiver and the GPS receiver are both connected to the laptop via a USB connection established using a USB cord. The UE's through its built in devices measures the received signal strength and other parameters, the scanning receiver picks up sources of interference that degrades the network while the GPS receiver is used to map each measured value to a given coordinate point which is then translated to a physical location by the Google map software.

RESULTS AND DISCUSSION

Drive Test Result

From the excel spread sheet export from the software, it was discovered that minimum recorded SINR during the drive test on 18 eNodeB's located at Enugu is -5.6dB while the maximum recorded SINR is 26.8dB. The frequency band of the measurement is Band 3 (1800MHz)
Fig3 shows the visual representation of the drive test result in a map-like form with the SINR information.

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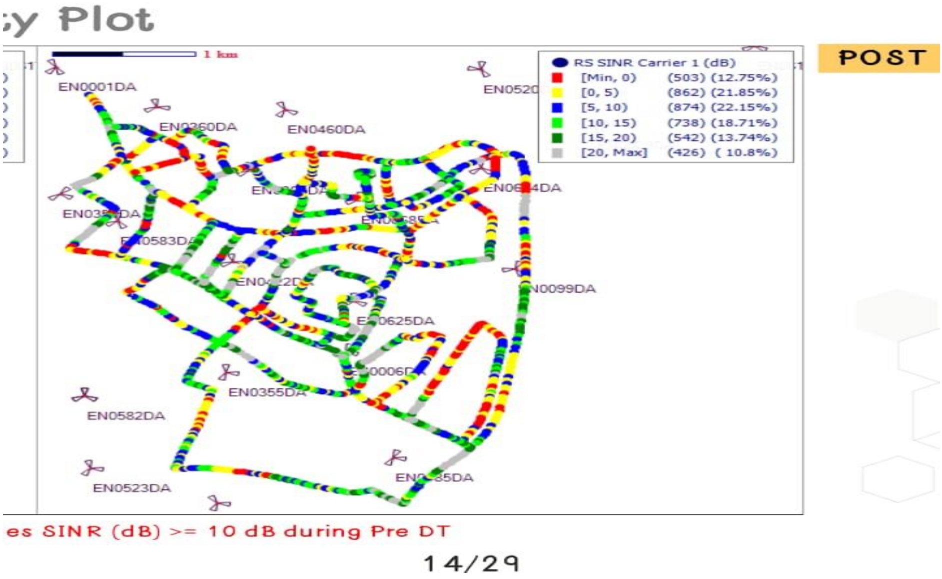


Fig 3: Visual representation of SINR distribution across the LTE cells

Looking at Fig3, we see that various SINR values at different points in the eighteen LTE cells are represented using various colours with each colour representing a given unique SINR range as indicated by the key. This only serves as a visual summary of the measured data.

4.2 Simulation Result

The SINR values were simulated under AWGN and Rayleigh fading channel to generate their block error performance and throughput using the MATLAB LTE toolbox.

Table 1: Simulation Data Output Generated for TM7, QPSK for Varying SINR and Code Rate Values

TM7, QPSK															
	Code rate: 0.13			Code rate: 0.27			Code rate: 0.41			Code rate: 0.55			Code rate: 0.69		
SINR	**BLER**	**TPUT(%)**	**TPUT (Mbps)**	**BLER**	**TPUT(%)**	**TPUT (Mbps)**	**BLER**	**TPUT(%)**	**TPUT (Mbps)**	**BLER**	**TPUT (%)**	**TPUT (Mbps)**	**BLER**	**TPUT (%)**	**TPUT (Mbps)**
-5.6	0	100	0.2534	0	100	0.5623	0	100	0.8633	0.00817	89.899	1.0894	0.03044	52.5253	0.8029
-5	0	100	0.2534	0	100	0.5623	0	100	0.8633	0.000817	98.9899	1.1995	0.023964	62.6263	0.9573
0	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286
5	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286
10	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286
15	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286
20	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286
25	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286
26.8	0	100	0.2534	0	100	0.5623	0	100	0.8633	0	100	1.2118	0	100	1.5286

Looking at Table 1 for TM7, QPSK, it would be seen that throughput was maximum (100%) for every SINR input except for -5dB or less at code rate of 0.55 and 0.69. Even though the throughput was 100%, the total data bits transmitted per second is very low at 0.2534Mbps for code rate 0.13, 0.5623Mbps for code rate 0.27, 0.8633Mbps for code rate of 0.41, 1.2118Mbps for code rate of 0.55 and 1.5286 Mbps for code rate of 0.69. This was because of the high level of redundancy and low order modulation scheme used.

BLER was at zero (best) for every SINR input, except for SINR of -5dB or less for code rate of 0.55 or higher. That is, every 100% throughput indicates a 0 BLER. Therefore, low order modulation scheme together with low code rate is suitable to preserve the fidelity of the transmitted data bits but not to maximize the throughput (Mbps).

Also note that the higher the SINR the lower the BLER and the higher the throughput for given code rate and TM mode. This can be seen clearly from the plots.

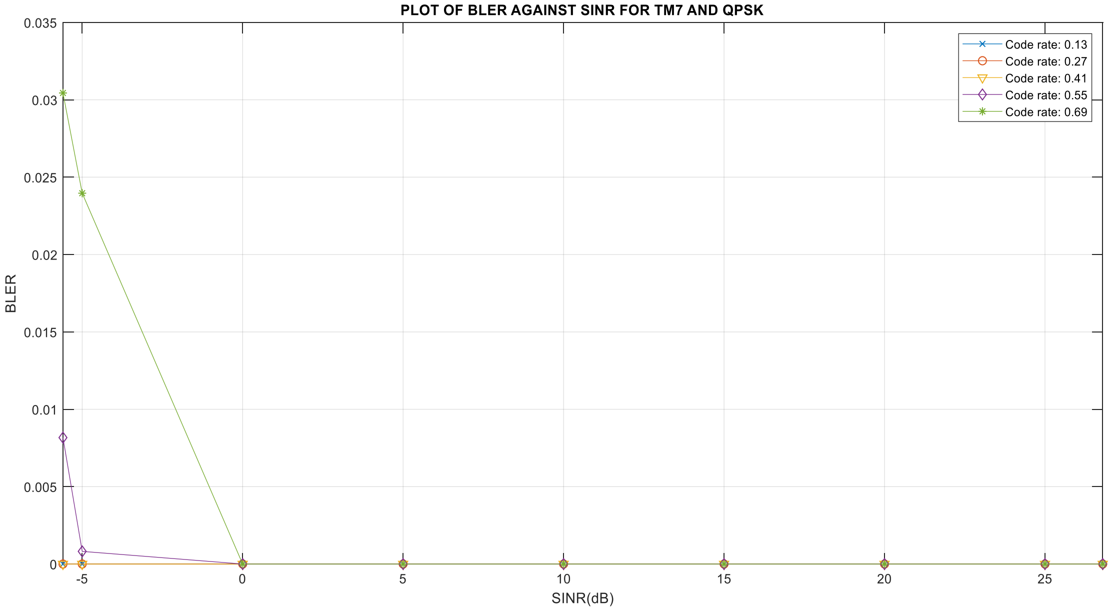
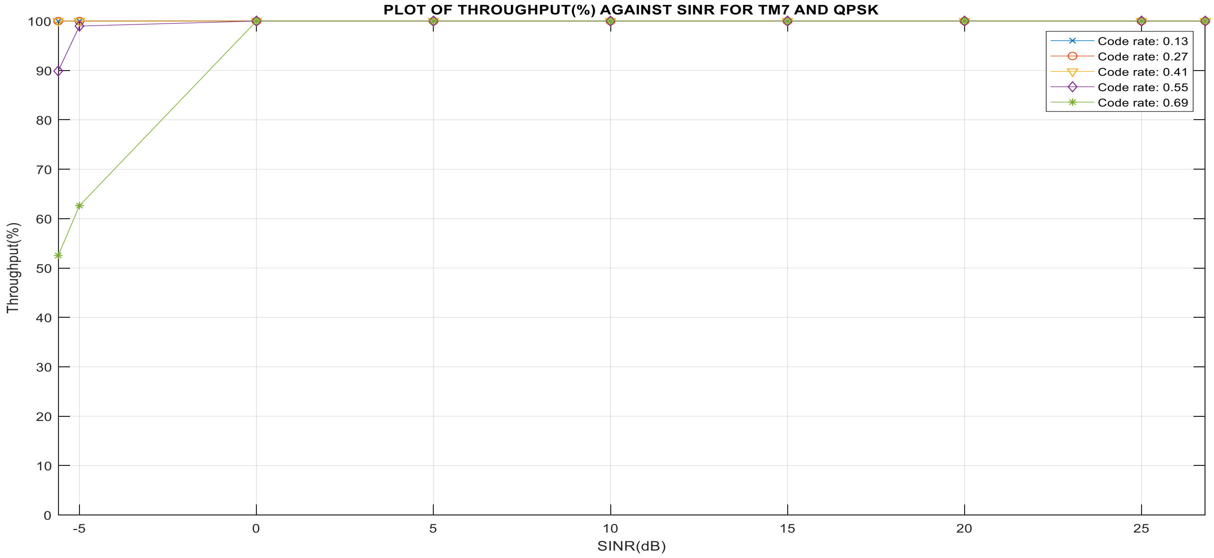


Fig 3.: Plot of BLER against SINR for TM7, QPSK

From Fig 3 it can be seen that as the code rate values is increased, the BLER becomes more pronounced because of less redundancy and hence less error correction capability in the higher code rate values. Therefore, it can be stated that for a fixed SINR value, the higher the code rate the higher BLER. More so, for a fixed code rate value, the higher the SINR the lower the BLER.



Fig

Fig4: Plot of Throughput (%) against SINR for TM7, QPSK

From Fig 4 it can be seen that for a fixed code rate, the higher SINR value the higher the throughput (%). For fixed SINR value, the higher the code rate values the lower the throughput (%). This is because higher code rate values have less redundancy bits and hence less error correction ability and because of this, more data blocks are likely to encounter errors causing them to be dropped and consequently leading to decrease in the percentage throughput. Whereas lower code rate values have more redundancy bits and more error correction ability, hence there is less likelihood of block error and less likelihood of a block being dropped as a result of error; therefore lower code rate values would lead to increase in percentage throughput.

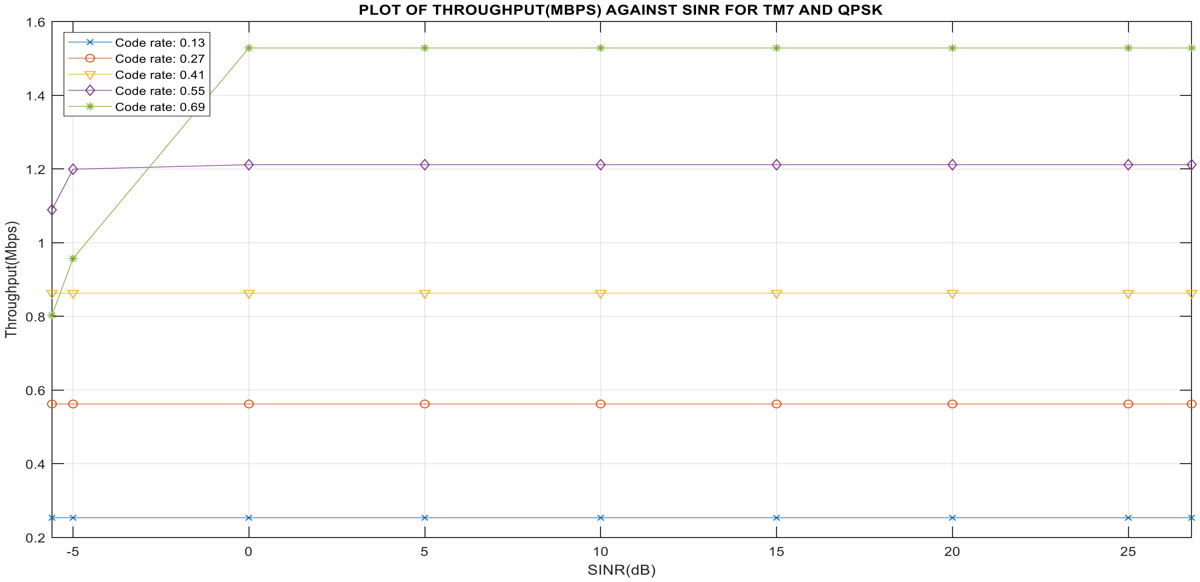


Fig 5: Plot of Throughput (Mbps) against SINR for QPSK, TM7

From Fig 5, it can be seen that for a fixed code rate value the higher the SINR the higher the throughput (Mbps

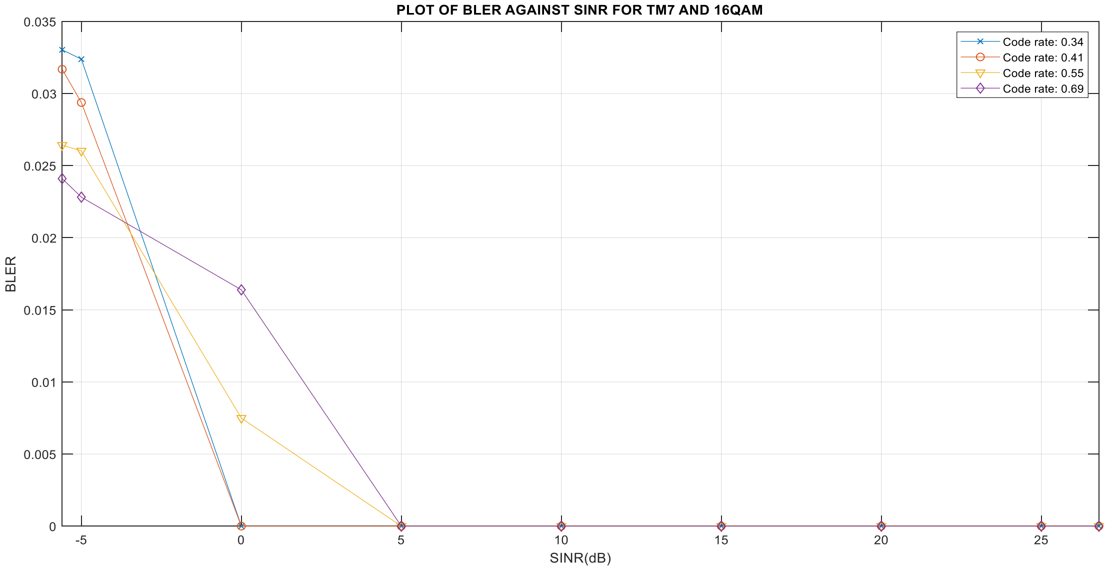


Fig 6: Plot of BLER against SINR for TM7, 16QAM

It can also be seen that as the code rate values is increased, the BLER values becomes more pronounced because of less redundancy in the higher code rate values. Therefore, we still maintain that for a fixed SINR value, the higher the code rates the higher BLER. For a fixed code rate value, the higher the SINR the lower the BLER.

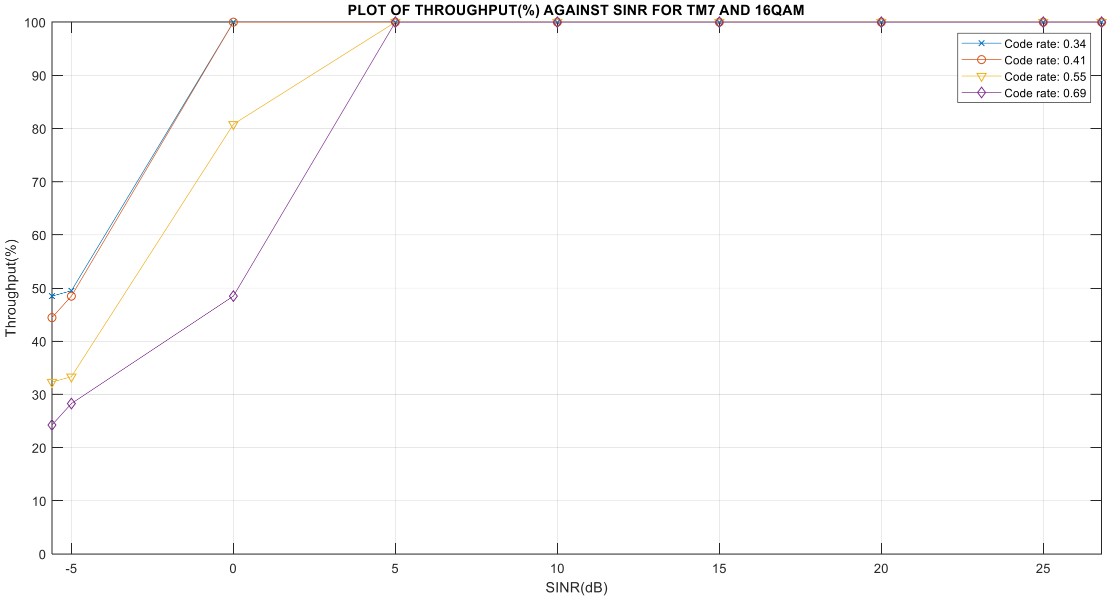


Fig 7: Plot of Throughput (%) against SINR for TM7, 16QAM

It can also be seen that for a fixed code rate, the higher SINR value the higher the throughput (%). For fixed SINR value, the higher the code rate values the lower the throughput (%).

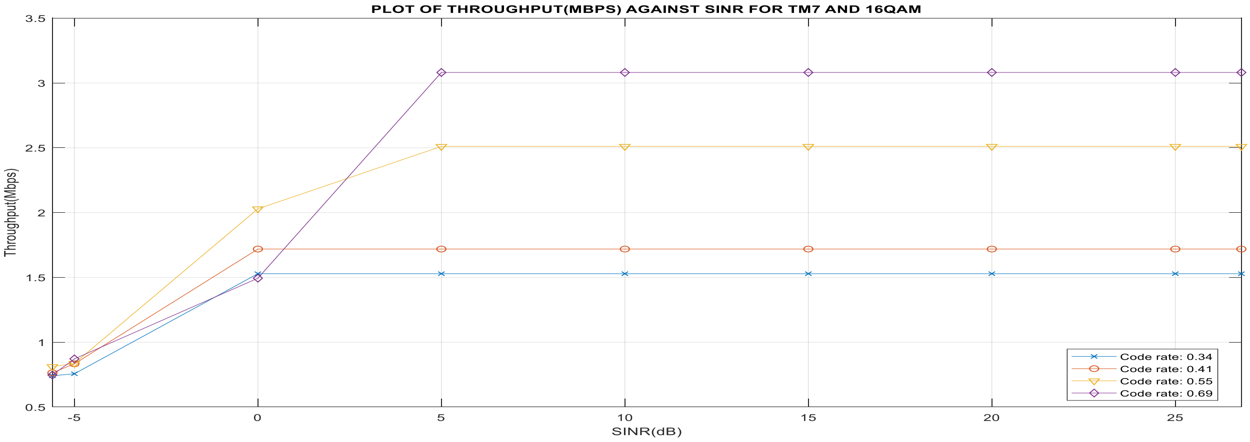


Fig 8: Plot of Throughput (Mbps) against SINR for TM7, 16QAM

CONCLUSION

Having tested the output of the desktop application for different set of inputs and comparing them with the manual look up from the table, it is established that the desktop application is producing the desired outputs. Therefore, this algorithm can be fully implemented at the eNodeB to optimally select the best choice of modulation scheme and code rate for any given SINR feedback received from the UE through the Physical Uplink Control Channel (PUCCH) and to also satisfy BLER requirement of the bearer class. This algorithm resulted in a more efficient utilization of the scarce radio resources and consequently result in an increase in the overall throughput and hence capacity of the network.

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