JEAS

JOURNAL OF ENGINEERING AND APPLIED SCIENCES

Journal of Engineering and Applied Sciences, Volume 15, Number 1, December 2019, 151-161

Simulative Methods of Estimating and Modifying Deployed 4G LTE Network Capacity in Terms of Throughput Performance

Ogbuokebe .S.K[1],Idigo V.E[2], Alumona T.L[3], and Okeke R.O[4]
[1]PhD. Scholar, Dept. of Electronic & Computer Engineering,NnamdiAzikiwe University, Awka[2,3]Dept.of Electronic & Computer Engineering Nnamdi,Azikiwe University,Awka
[4]Dept. of Electrical Engineering, University of Port Harcourt, Rivers
*Corresponding Author's E-mail: ogbuokebekc@googlemail.com

Abstract
Telecommunication network and system is fast replacing all other sectors of economy as the bedrock upon which every business thrives today. Oil and gas industries, national security, financial institutes, agricultural sector, learning institutes etc., cannot effectively function without efficiently enabling telecommunication infrastructure for purposes of remote data acquisition, exchange of information, data storage and integrity, precision agriculture, facility monitoring and management, instrumentation, exploration, crude oil refining, distribution chain, automated metering and billing, digital reports etc. Though Nigeria launched 4th generation Long Term Evolution (4G LTE) network in 2013 to be able to support ever demanding and reliable network architecture capable of enabling high speed data rate greater than 20 Mbps (Mega Bits Per Second), however,Nigeria has a poor communication networks which has contributed to decline of economic growth in recent years. Identifying and solving telecommunication problem in Nigeria is major task of this paper which presented simulative methods of estimating and modifying deployed 4G network considering factors that improves the network capacity and performance. End to end system level simulation was carried out using MATLAB tool box facilitated by empirical data of SPECTRANET LTD, Abuja which is used as a case study in this paper. Bit Error Rate (BER) testing, Signal to Noise Ratio (SNR) performance test and User Equipment (UE) propagation model proved to be powerful techniques of investigating transmission of digital bits over 4G LTE network and results obtained demonstrated that lower modulation order scheme, Quadrature Phase shift Key (QPSK) presented stronger BER performance (10^{-4}) with -3dB energy per bit to noise power spectral density ratio while 16QAM (Quadrature Amplitude Modulation) and 64QAM had same BER performance(10^{-4}) with energy per bit to noise power spectral density ratio (Eb/No) of 2dB and 4dB respectively, however, LTE Physical downlink shared channel (PDSCH) throughput conformance test carried out, proved that signals received in Frequency Division Duplex (FDD) system demonstrated better SNR performance than received signals in Time Division Duplex (TDD) system by 1.2%.

Keywords: 4G, LTE, Throughput, BER, SNR, Modulation, FDD, TDD.

1. Introduction

4th Generation cellular network in Nigeria currently have more than six licenced operators. Long term evolution (LTE) is the next step forward in cellular network of third generation (3G) services already provided by mobile network operators in Nigeria. 4G Long term evolution network technology is based on Third Generation Partnership Project (3GPP) standard. The main goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. Major techniques to 4G LTE for higher data rate are as follows; Orthogonal Frequency Division Modulation (OFDM) which used in downlink channel to allow simultaneous access by numerous users (UEs), secondly, Multiple Input Multiple Output (MIMO) technique which improves reception by use of multiple antennas, thirdly, the Single Carrier Frequency Division Multiple Access (SC-FDMA) technique which is used in the uplink to assign radio resources to multiple users.

The objective of this paper is targeted at using the real empirical data obtained and analyzed from SPECTRANET LTD Abuja to model and characterize LTE network elements similar to the case study, MATLAB LTE system tool is used to build a 4G LTE network depicting the network configuration of SPECTRANET LTD, Abuja. The toolbox incorporates components such as modulators, channel models, convolutional and turbo coders, MIMO and OFDM modules into 4G communication kit enabling end to end system-level throughput performance analysis with adaptive modulation schemes based on channel characteristics.

2.0 Related Research Work

The Fourth generation (4G) network provides access to wide range of telecommunication services, including advanced mobile services, high mobility applications, real time service delivery supported by mobile and fixed networks. Enhancing 4th generation network will bring more resilient service to enforce Internet of thing (IoT) and big data technology, however, the introduction of 4G network in Nigeria has facilitated many businesses in enabling technologically driven environment in all sectors of economy including, e-hailing application services (Uber, Bolt etc.), media institutes, banking application and numerous others. Improving the operations of 4G network becomes paramount task in Nigeria as many people and devices delve into its services. Many authors have been working on implementable methods of enhancing deployed LTE networks, the authors examined the root causes of poor performing 4G networks, evaluated the performance of the networks and possible recommendations to curtail the causes of poor quality of services (QoS). Deepak*et al* (2015) carried out research work on techniques of improving 4G LTE networks, the paper reviewed many authors techniques while exploring the open issues, emerging trends and significant research gap, the paper furnishes better comparative analysis of the techniques and highlights their effectiveness in improving the LTE network for the future wireless communication systems, however he didn't discuss any form of application of reviewed techniques or considered scenarios of implementation.

Mohana*et al* (2014) studied and experimented on the performance of LTE system with different spectrum configuration for a Constant Bit Rate (CBR) traffic scenario in the downlink channel. The performance metrics considered for the simulation work were aggregate bytes received, average throughput, average delay and average jitter for different bandwidths of LTE system using QUALNET SIMULATOR, in which the author concluded by stating that 20MHz bandwidth achieved the highest throughput performance across the metrics used over other scales of bandwidths. Nevertheless the author didn't state measures to maximize data throughput or performance over downlink channel. Maria*et al* (2019) studied and tested the level of users mobility performance on 4G LTE network using drive test method and pilot pioneer software for data generation and analysis, she concluded in her research that the use of Reference Signal Received Power (RSRP) values analysis, researchers can narrate vividly the performance of a network and users experience especially in mobility state, however, she didn't mention or discuss ways to improve RSRP performance in 4G LTE network.

Jose*et al* (2015) used method of several multivariate linear regression equations to estimate the value of different service-specific QOS indicators from network performance statistics collected on a cell basis to estimate and evaluate the maximum traffic cell capacity. Jose considered service specific constraints such as delay and throughput in the research, his result showed a strong correlation between QOS performance and the average number of active users in the Physical Downlink Control Channel (PDCCH). However, the author's method of Multi-Service Multiple Linear Regression(MS-MLR) model can only estimate the values of a predefined set of specific QOS indicators, this will limit other variation services offered by 4G network other than Voice over LTE (Voice over LTE). Garcia*et al* (2018) worked on cellular networks, proposed methods of estimating cell ranges in 4G LTE as a key parameter for network planning and optimization using Voronoi tessellation while empirical data are collected. Cell coordinates, antenna azimuths, antenna horizontal and beam widths are considered in his research. The results showed less complex algorithm of estimating nominal cell range over classical approach, however his research didn't address the techniques or process of using result to improve network performance especially in urban populated regions where cell ranges are very small to next serving cell.

3.0 LTE Architecture

LTE network architecture comprises mainly of three main parts,

1. The LTE UE (User Equipment),
2. The LTE E-UTRAN (Evolved Universal Terrestrial Radio Access Network)
3. The LTE EPC (Evolved Packet Core)
4. The Internet Protocol IP networks (Internet) or the cloud or packet Data Network (PDN)

LTE network architecture is presented in figure 1, showing the major functional parts of 4G LTE network, ranging from the UEs, eNodeBs, Core network, and the packet data network

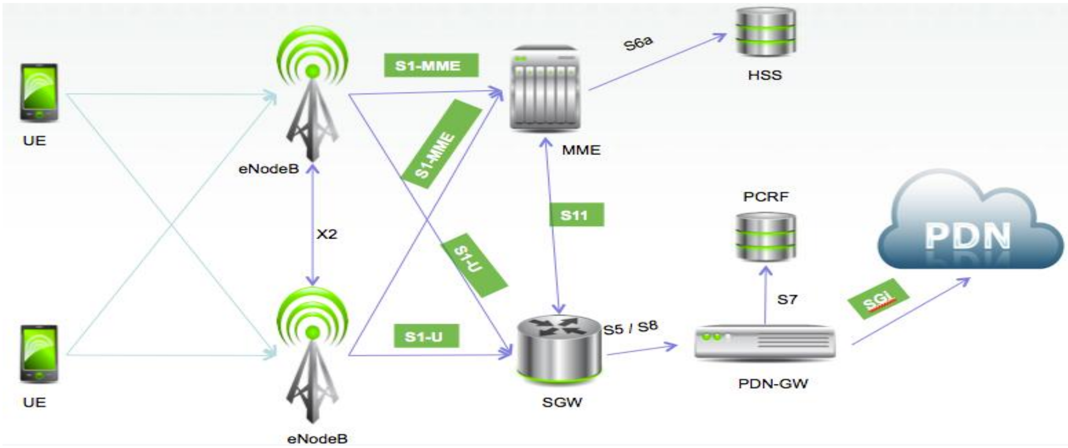

Figure 1: LTE Network architecture (Andy, 2013)

LTE UEs are also known as Mobile stations (MS) or LTE data terminals or devices that are of standard to access the internet via 4G LTE network, such as the mobile phones, smart TVs, WiFi devices, tablets etc. LTE E-UTRAN consists mainly of the eNodeB, providing air interface for data traffic to and fro user equipment, eNodeB does several important functions such as Radio Resource Management (RRM), radio bearer control, radio admission control, mobility connection control, radio resource scheduling , packet compression and ciphering, routing of User Plane Data towards S-GW (Serving Gateway), packet scheduling and transmission of broadcast information and paging messages, measurement, reporting, configuration and reconfiguration of E-UTRAN parameters, load control, admission control etc.

Major components of eNodeB are the LTE Antennas, Remote Radio unit (RRU), Base Band Unit (BBU), LMPT/UMPT (LTE Main Processing and Transmission Unit/ Universal Main Processing and transmission unit), LBBP (LTE Baseband Processing Unit) etc. Evolved Packet Core**:** also known as Enhanced Packet Core is fully packet-switched backbone network in the LTE systems. EPC consists of five major subsystems, namely; Mobility Management Entity (MME), Home Subscriber System (HSS), Serving Gateway (S-GW), Packet Data Gateway (PDN), Policy and Charging Rule Function (PCRF).

4.0 LTE Modulation Scheme

Modulation is the process of encapsulating information bits or data signal before transmission over a channel to avoid distortion, achieve less vulnerability to any form of noise or interference. Modulation could also be defined as a process of converting data into electrical signals for enhanced transmission. Phase Shift Keying and Quadrature Amplitude modulation schemes are widely used for 4G network, QPSK is an example of Phase Shift Keying (PSK) which encapsulates two bits per symbol, making it very spectrally efficient. QPSK can be referred to as 4-PSK because there are four amplitude-phase combinations, by using smaller phase shifts, more bits can be transmitted per symbol, Quadrature Amplitude Modulation (QAM) concept combines amplitude and phase shift to transmit more bits per symbol, for instance, 8QAM uses four carrier phases plus two amplitude levels to transmit 3 bits per symbol, other popular variations of QAM are 16QAM, 64QAM, and 256QAM, which transmit 4, 6, and 8 bits per symbol respectively.

5.0 Frequency Division Multiplex (FDD) and Time Division Multiplex (TDD)

Duplexing technique is one of major techniques employed in communication network to aid optimal use of radio resources and reduce the period of time used for assigned users to get done with a particular radio resource. Duplexing technique is very important in cellular communication system because it has the capacity of transmitting and receiving signal simultaneously over a given channel which gives platform for conversation where one can talk and listen at the same time as required. Duplexing is a technique for isolating uplink and downlink channels. Two most used duplexing technique are Frequency division Duplexing (FDD) and Time division Duplexing (TDD). LTE FDD requires paired spectrum with sufficient frequency separation to allow simultaneous transmission and reception while LTE TDD does not require paired spectrum, both transmit and receive occur on the same channel, there is discontinuous transmission in TDD to allow both uplink and downlink transmission. LTE TDD channel propagation parameters in both transmit and receive system are configured the same but the parameters differs in the case of LTE

FDD as a result of different frequency bands. Nonetheless, spectrum regulators advocate equal allocation of uplink and downlink capacity in TDD system while asymmetric allocation is recommended for FDD system. Finally, neighbouringeNodeBs in LTE TDD needs to be configured with same uplink and downlink transmission time, else interference between cells will occur, however neighbouring cells in LTE FDD can have different transmission times without causing cell interference.

6.0 Relationship between Eb/No and SNR

E_b/N_0 (the energy per bit to noise power spectral density ratio) is an important parameter in digital communication and data transmission for performance analysis. Eb/No can be defined as normalized signal-to-noise ratio (SNR) measurement in (dB) or can described as the "SNR per bit", it is especially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without taking bandwidth into consideration.

$$SNR = \mathrm{NR\,abs} \; = \; \mathrm{Eb/N0\,abs} \; \cdot \; \mathrm{RNR\,abs} \; = \; \mathrm{Eb/N0\,abs} \; \cdot \; \mathrm{R} \qquad (1)$$

Where R represents the modulation and coding rate in use; for instance, if QPSK modulation and coding rate 1/3 is used, R value will be (2 * 1/3) equal to 2/3. The subscript “abs” indicates that the units are in absolute domain, in dB domains or Logarithmic domain.

$$\mathrm{SNR\ (dB)} \; = \; \mathrm{Eb/N0\ dB} \; + \; 10\log10\ (\mathrm{R}) \qquad (2)$$

The energy per bit, Eb, can be determined by dividing the carrier power by the bit rate and is a measure of energy with the dimensions of Joules. No is a power per Hertz and therefore has the dimensions of power (joules per second) divided by seconds), looking at the dimensions of the ratio Eb/No all the dimensions cancel out to give a dimensionless ratio. Energy-per-bit is the total energy of the signal divided by the number of bits contained in the signal. E_b can also expressed as energy-per-bit and average signal power multiplied by the duration of one bit.

$$\mathrm{Eb} \; = \; \frac{1}{(\mathrm{N.Fbit})} \sum_{n=1}^{N} x^2(n) \qquad (3)$$

Where: N is the total number of samples in the signal, and F_{bit} is the bit rate in bits-per-second.
Signal, $\boldsymbol{x}$ (n) is in units of Volts, the units of $E_b$are Joules. The power spectral density of the noise has units of Watts per Hertz.

7.0 Bit Error Rate

Bit error rate, (BER) is a key functional parameter in telecommunication that is used in evaluating systems that transmit digital signal (data) from one transmitting station to one or more receiving stations. BER can be used to assess the performance of radio link as well as Ethernet and fiber optic links for data transmission. The major causes of transmitted data bits to be in error are the channel imperfection, multipath, noise, phase jitter, interference etc. These factors causes degradation on the quality of signal received. (Irfan et al. 2013).

$$BER = \frac{\mathrm{NBerr}}{\mathrm{TBtr}} \qquad (4)$$

Where NB_{err} is the number of bits received in errors, $TB_{tr}$is the total number of bits sent.

8.0 LTE Radio Frame and LTE Resource Grid

In the time domain, different time intervals within LTE are expressed as multiples of a basic time unit *T*s = 1/30720000. The radio frame has a length of 10 ms (*T*frame = 307200 ・ *T*s). Each frame is divided into ten equally sized sub-frames of 1 ms in length (*T*sub-frame = 30720 ・ *T*s). Figure 2 presents an illustrative diagram of LTE radio frame structure.

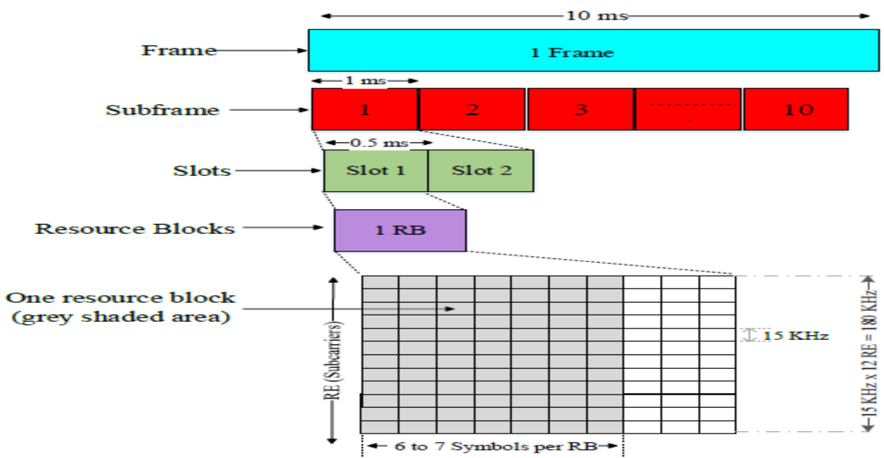

Figure 2: LTE Radio Frame (3GPP TS.36, 2010)

Scheduling is done on a sub-frame basis for both the downlink and uplink. Each sub-frame consists of two equally sized slots of 0.5 ms in length (Tslot = 15360 · Ts). Each slot in turn consists of a number of OFDM symbols which can be either seven (normal cyclic prefix "CP") or six (extended cyclic prefix). Figure 3 depicts typical LTE DL resource radio resource grid with each sub- frame indicating resource elements for control and data purposes.

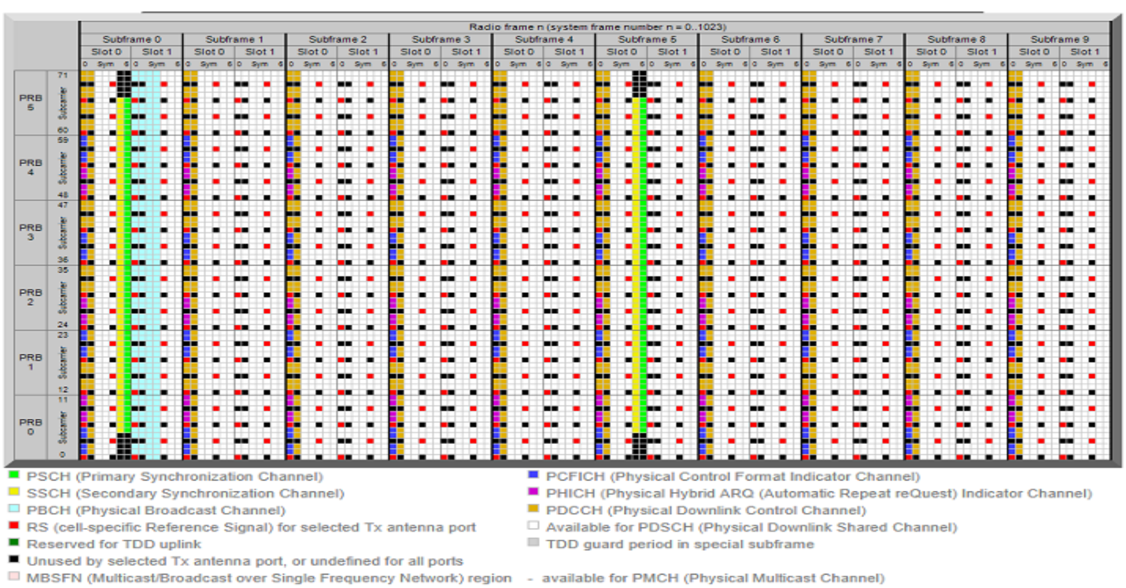

Figure 3: LTE Downlink radio resource grid (NiviUK, 2019)

Observe from the resource grid that the resulting number of sub-carriers and OFDM Symbol index is a function of the applied channel bandwidth, from 3GPP Technical Specification TS.36, 1.4 MHz bandwidth has 6 Physical Resource Blocks (PRB), and each PRB corresponds to 12 OFDM or 14 OFDM (depending on the applied CP) subcarrier, hence total of 72 sub-carriers, same is applicable to the resource grid when 5MHz (300 sub carriers), 10 MHz (600) and 20 MHz (1200 subcarriers) bandwidth is experimented.

9.0 Simulation Approach

MATLAB LTE Toolbox is used to generate standard compliant LTE uplink and downlink waveforms which could be used to examine performance of end user applications. The toolbox provides functions for flexible and easy generation of the full link (end to end), adaptable to subscriber's requirements. Table 1 presents the network parameters of SPECTRANET configuration and values.

Table 1: SPECTRANET LTD, ABUJA Network configuration

S/N	PRAMETER FEATURE	CONFIGURATION
1	NETWORK STRUCTURE	UE, eNodeB, MME/SGW/PDNGW
2	Duplex Mode (Mode of operation)	TDD
3	Radio Frame Structure	10ms
4	Access Technique	DL (OFDMA), UL (SC:FDMA)
5	Channel Bandwidth	20 Mhz
6	Operational Frequency	2.3Ghz
7	TX Diversity (MIMO)	4x4
8	Number of Physical Resource Block	100
9	Modulation Schemes	QPSK 16QAM 64QAM
10	Average number of nodes (eNodeBs):	145
11	Average number of User per cell	50
12	Average Throughput of the network	>2Mbps
13	Poor Performing Cells average throughput	800Kbps
14	Average number of active subscribers	15200

Table 2 presents the parameter configuration of reference measurement channels as described by 3GPP technical speciation on LTE network.

Table 2: Pre-Defined LTE RMCs (3GPP TS 36.101)

Reference channels	Reference channels (continued)
R.0 (Port0, 1 RB, 16QAM, CellRefP=1, R=1/2)	R.31-3A FDD (CDD, 50 RB, 64QAM, CellRefP=2, R=0.85-0.90)
R.1 (Port0, 1 RB, 16QAM, CellRefP=1, R=1/2)	R.31-3A TDD (CDD, 68 RB, 64QAM, CellRefP=2, R=0.87-0.90)
R.2 (Port0, 50 RB, QPSK, CellRefP=1, R=1/3)	R.31-4 (CDD, 100 RB, 64QAM, CellRefP=2, R=0.87-0.90)
R.3 (Port0, 50 RB, 16QAM, CellRefP=1, R=1/2)	R.43 FDD (Port7-14, 50 RB, QPSK, CellRefP=2, R=1/3)
R.4 (Port0, 6 RB, QPSK, CellRefP=1, R=1/3)	R.43 TDD (SpatialMux, 100 RB, 16QAM, CellRefP=4, R=1/2)
R.5 (Port0, 15 RB, 64QAM, CellRefP=1, R=3/4)	R.44 FDD (Port7-14, 50 RB, QPSK, CellRefP=2, R=1/3)
R.6 (Port0, 25 RB, 64QAM, CellRefP=1, R=3/4)	R.44 TDD (Port7-14, 50 RB, 64QAM, CellRefP=2, R=1/2)
R.7 (Port0, 50 RB, 64QAM, CellRefP=1, R=3/4)	R.45 (Port7-14, 50 RB, 16QAM, CellRefP=2, R=1/2)
R.8 (Port0, 75 RB, 64QAM, CellRefP=1, R=3/4)	R.45-1 (Port7-14, 39 RB, 16QAM, CellRefP=2, R=1/2)
R.9 (Port0, 100 RB, 64QAM, CellRefP=1, R=3/4)	R.48 (Port7-14, 50 RB, QPSK, CellRefP=2, R=1/2)
R.10 (TxDiversity|SpatialMux, 50 RB, QPSK, CellRefP=2, R=1/3)	R.50 FDD (Port7-14, 50 RB, 64QAM, CellRefP=2, R=1/2)
R.11 (TxDiversity|SpatialMux|CDD, 50 RB, 16QAM, CellRefP=2, R=1/2)	R.50 TDD (Port7-14, 50 RB, QPSK, CellRefP=2, R=1/3)
R.12 (TxDiversity, 6 RB, QPSK, CellRefP=4, R=1/3)	R.51 (Port7-14, 50 RB, 16QAM, CellRefP=2, R=1/2)
R.13 (SpatialMux, 50 RB, QPSK, CellRefP=4, R=1/3)	R.6-27RB (Port0, 27 RB, 64QAM, CellRefP=1, R=3/4)
R.14 (SpatialMux|CDD, 50 RB, 16QAM, CellRefP=4, R=1/2)	R.12-9RB (TxDiversity, 9 RB, QPSK, CellRefP=4, R=1/3)
R.25 (Port5, 50 RB, QPSK, CellRefP=1, R=1/3)	R.11-45RB (CDD, 45 RB, 16QAM, CellRefP=2, R=1/2)
R.26 (Port5, 50 RB, 16QAM, CellRefP=1, R=1/2)	
R.27 (Port5, 50 RB, 64QAM, CellRefP=1, R=3/4)	
R.28 (Port5, 1 RB, 16QAM, CellRefP=1, R=1/2)	

LTE network operators have different configuration to suit their subscriber's need, the pre-defined parameters are referred as Radio Measurement Channel (RMC) and specified in 3GPP TS 36.101. The table 2 shows some of the characteristics of pre-defined RMC. The marked RMCs [R.6, R.9, R.12, R.13, and R.14], are the ones with parametrization set close to SPECTRANET configuration and serves the best interest of the research upon modification. The basic flow chart of modifying predefined RMCs is presented in figure 4.

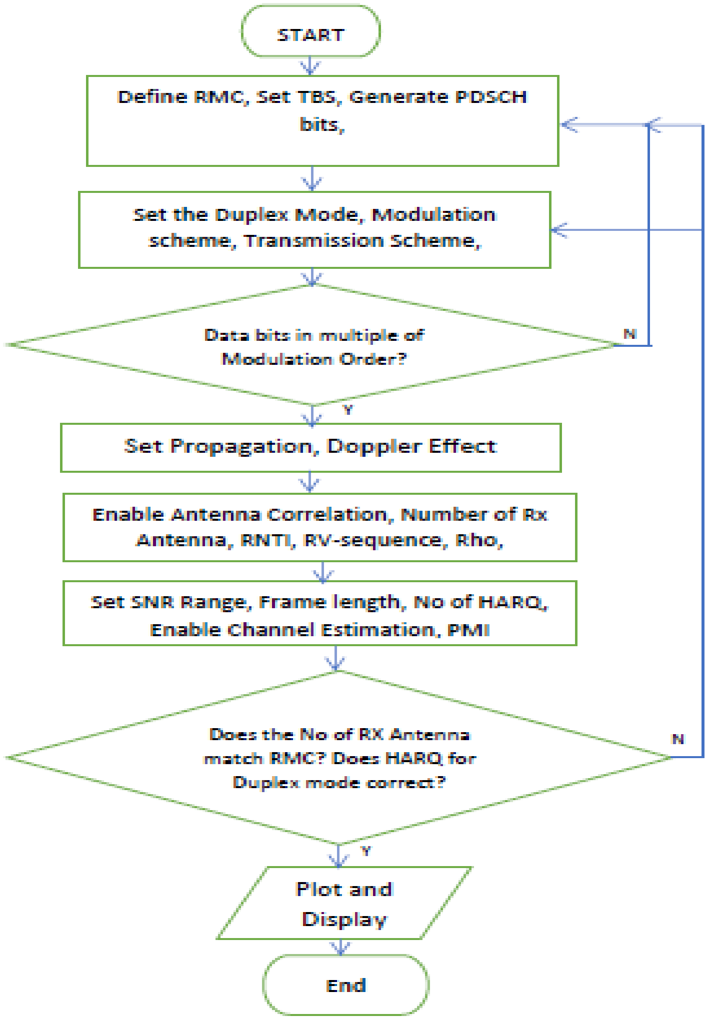

Figure 4: Flow chart algorithm for throughput performance against SNR

The Parameters to configure are as follows; First, the network duplex mode has to be setup and its corresponding uplink and downlink configuration, number of transmit ports; 1, 2, or 4), Modulation scheme: QPSK, 16QAm, 64QAM, transmission layer and total information bits per frame per code-words. Radio network temporary identifier (RNTI) has 16 bits value, usually a scalar integer (0 by default, 1). RNTI helps to recognize and distinguish connected UEs in the cell. RV Sequence [0, 1, 2, 3,] specifies the sequence of Redundancy Version (RV) indicators for each hybrid automatic repeat request (HARQ) process. The number of elements in each row is equal to the number of transmissions in each HARQ process. If RV-Seq is a row vector in a two code-word transmission, then the same RV sequence is applied to both code-words.

Physical Downlink Shared Channel (PDSCH) resource element power allocation (Rho) in dB, it is usual a scalar integer (0 default, 1) and OFDM Channel Noise Generator (ON/OFF). Number of Sub frames: (2/5/10/20), it is a non-negative scalar integer, usually set to determine the number of sub-frames to generate and Number of Code-words (1/2). PMI set (1): Pre-coder matrix indication (PMI) set is an integer vector with element values usually from 0 to 15. If it is a single value, corresponds to single PMI mode, or multiple digits corresponding to multiple or sub-band PMI mode. The number of values depends on transmission layer and transmit scheme.

Number of HARQ (8 for FDD, 7 Max for TDD) provides for the number of HARQ processes per component carrier or subcarrier. Windowing samples (0) is usually set as non-negative scalar integer, it shows number of time-domain samples over which windowing and overlapping of OFDM symbols is applied Transport Block Size - Size of transport block, Available PDSCH Bits - Size of coded transport block after rate matching code-word size), NTurboDecIts - Number of turbo decoder iteration cycles Waveform variables, Resource Grid output variable, RMC configuration output variable etc., can be generated (Mathworks 2015).

10.0 Results and Analysis

Figure 5 is standard-compliant waveform spectrum generated from SPECTRANET configuration; it shows that the 100 resource blocks allocated for R.9 correspond to 20 MHz signal bandwidth as specified in 3GPP TS 36.101

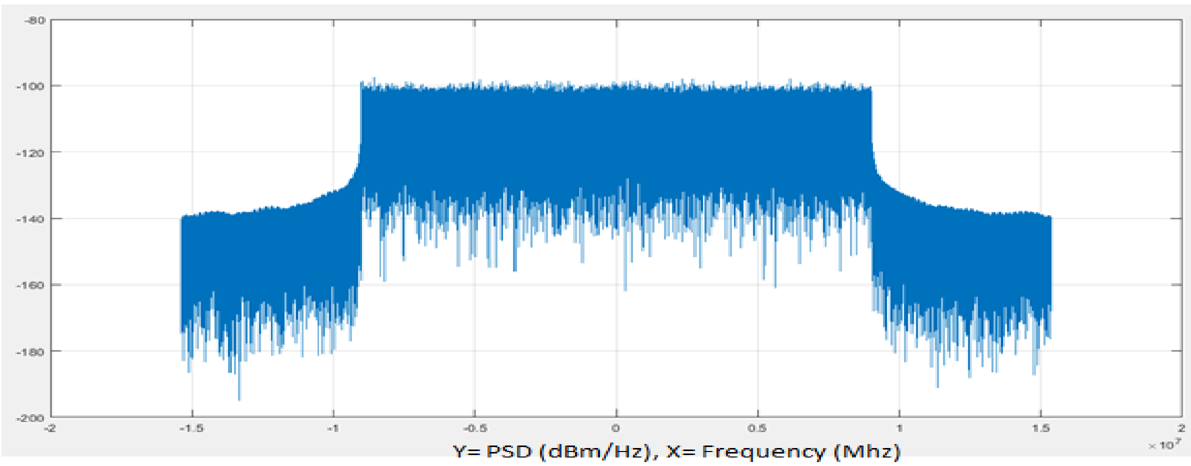

Figure 5: R.9 RMC Spectrum

The carrier frequency in the uplink and downlink is designated by the E-UTRA Absolute Radio Frequency Channel Number (EARFCN) in the range 0 - 65535. The relation between EARFCN values and the carrier frequency in MHz for the downlink and Uplink is given in 3GPP table of E-UTRA channel number of TS-36.141. The figure 6 presents the generated spectrogram of RMC.9.

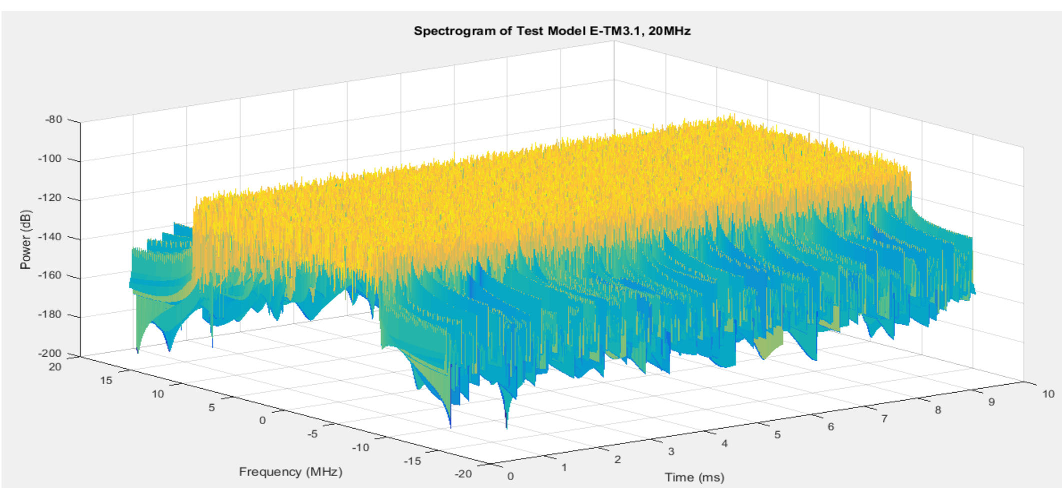

Figure 6: Generated physical downlink SPECTOGRAM for Test Model E-TM 3.1, 20MHz

Spectrogram is advanced representation of spectrum; it is three dimensional by nature, which includes time, frequency and magnitude of spectrum. It is usually displayed by using time (ms) in x-axis, frequency (MHz) in y-axis, and power (dB) in Z-axis. Spectrogram makes use of colours to show the magnitude of spectrum. It describes the distribution form of generated waveform and amplitudes of signal over time. Figure 7 shows the BER performance of different modulation scheme.

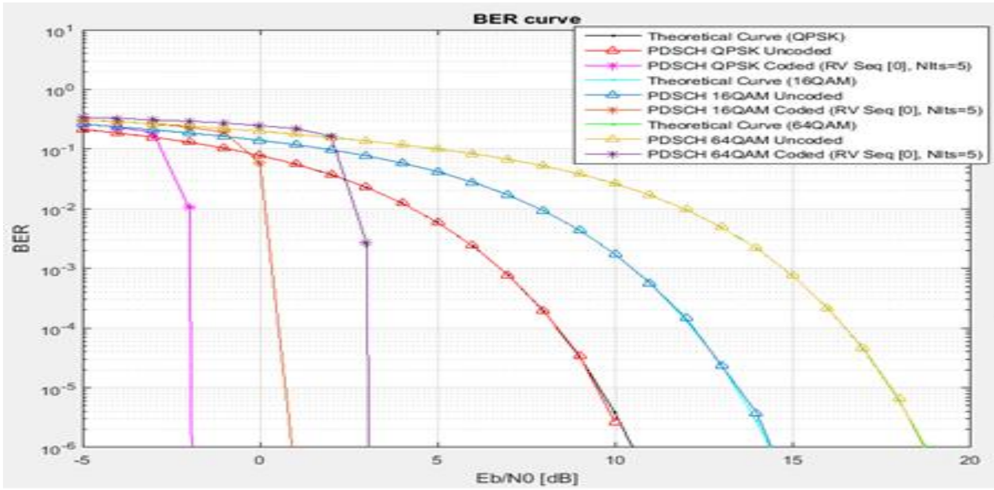

Figure 7: BER Performance for QPSK, 16QAM, and 64QAM

The above plot has the following configuration: Transport block size (6000), available PDSCH bits (12780), Modulation (QPSK, 16QAM, 64QAM), Eb/No Range (-5: 1:20), Redundancy version was set to zero [0], turbo decoder iteration set to (5) five. BER increases in Vertical Y-axis, while Eb/No increase horizontally in x-axis. BER remains one of the best metrics to characterize the performance of a digital communication system. When the bit-error-rate BER is high, many received bits will be received in error. The worst-case bit-error-rate is 50 percent, at this point, the modem is essentially useless, and communications systems require bit-error-rates several orders of magnitude lower than 50 percent, the bit-error-rate curve is plotted as a function of SNR and includes enough points to cover a wide range of bit-error-rates. Bit-error-rate of 10^{-6} means only one bit out of every million bits will be received in error. If test signal contains only 1000 bits, bit-error-rate recorded may be insignificant. In order to be statistically significant, each simulation must generate some number of errors.

If a simulation generates no errors, it does not mean the bit-error-rate is zero, it could mean there was no enough transmitted bits, however, rule of thumb need about 100 (or more) errors in each simulation, in order to have confidence that the bit-error-rate is statistically valid. At high SNRs, this may require a test signal containing millions, or even billions of bits, observe from figure 7, at very low Eb/No, all the modulation order tend to have close BER performance even near to the theoretical and un-coded curve performances. However, with little increase in energy bits, QPSK showed a stronger BER performance as compared to 16QAM and 64QAM. The throughput performance of RMC.12 for TDD model is presented in figure 8.

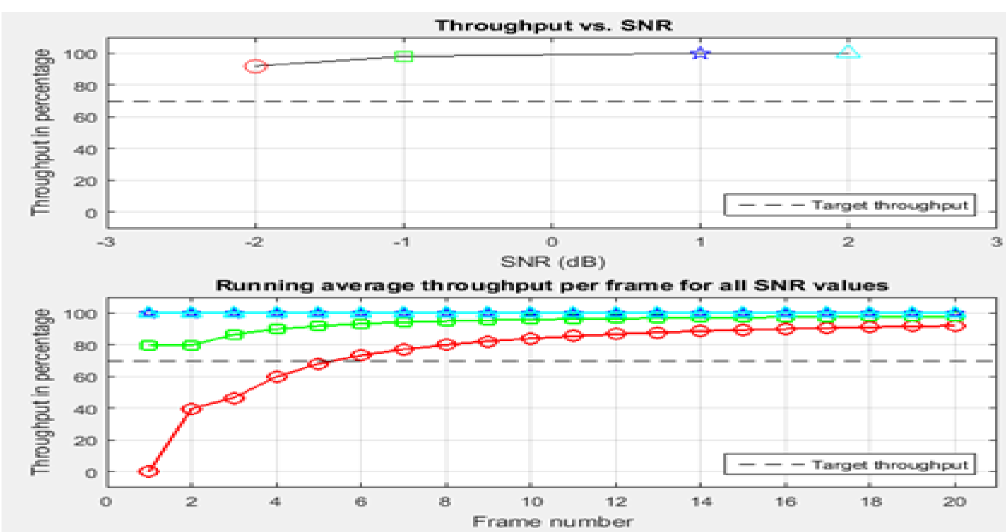

Figure 8: Throughput Vs SNR curve for R.12, TDD, 6PRBs, 4x4 MIMO, QPSK, EPA (20 Frames), Channel Estimator (On)

The network configurations and parameterization above presented the performance of figure 8; below is the plot performance result;
Result for -2 dB SNR; Throughput: 91.99%: Result for -1 dB SNR; Throughput: 97.97%
Result for 1 dB SNR; Throughput: 100.00%: Result for 2 dB SNR; Throughput: 100.00%.

The throughput performance of RMC.12 for FDD model is presented in figure 9.

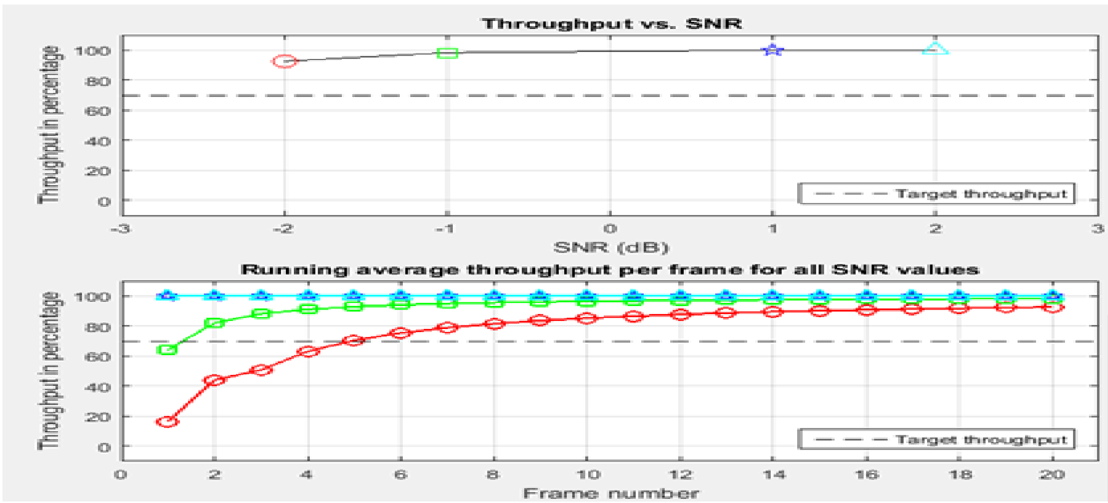

Figure 9: Throughput Vs SNR curve for R.12, FDD, 6PRBs, 4x4 MIMO, QPSK, EPA (20 Frames)

The plot performance result is as follows:
Result for -2 dB SNR; Throughput: 92.61%: Result for -1 dB SNR; Throughput: 98.21%
Result for 1 dB SNR; Throughput: 100.00%: Result for 2 dB SNR; Throughput: 100.00%.

Figure 10 presents throughput performance of 2x2 MIMO as compared with performance in figure 8 which shared same network configuration.

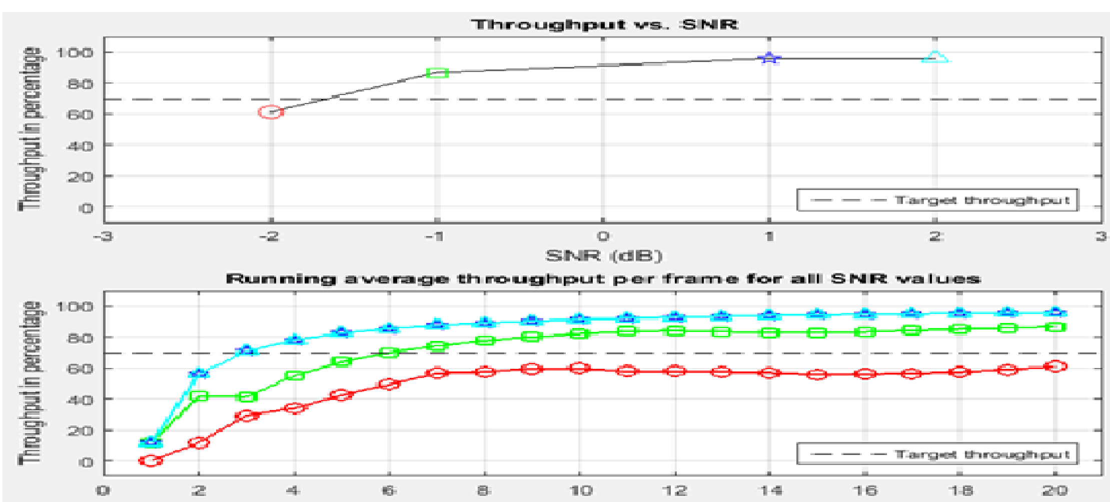

Figure 10: Throughput Vs SNR curve for R.12, TDD, 6PRBs, 2x2 MIMO

The plot performance result is as follows:
Result for -2 dB SNR; Throughput: 60%: Result for -1 dB SNR; Throughput: 82.29%
Result for 1 dB SNR; Throughput: 97.05%: Result for 2 dB SNR; Throughput: 98.01%

11.0 Conclusion

BER and SNR proved to be reliable parameter of analyzing how healthy a 4G network services are to the subscribers, knowledge of the BER also enables other features of the link such as the power and bandwidth utilization etc. BER testing is a powerful methodology for end to end testing of digital transmission systems. Each test provides measurable and useful indication of the performance of the system that can be directly related to its operational performance. However the simulation showed that Quadrature Phase shift Key (QPSK) presented stronger BER performance (10^{-4}) with -3dB energy per bit to noise power spectral density ratio, Eb/No while 16QAM (Quadrature Amplitude Modulation) and 64QAM had same BER performance(10^{-4}) with Eb/No power of 2dB and 4dB respectively. Nonetheless, LTE Physical downlink shared channel (PDSCH) throughput conformance test carried out, proved that signals in Frequency Division Duplex (FDD) demonstrated better SNR performance than received signals in Time Division Duplex (TDD) system by 1.2%, finally SNR performance of 4X4 MIMO system configuration is better than 2X2 MIMO system by 23%.

12.0 Recommendation

The simulation and analysis of measured data presents to 4G network operators an efficient ways of evaluating the network performance using MATLAB for BER and SNR conformance test, therefore, the research makes the following recommendation for better throughput performance; FDD system gives better throughput performance from the experiment carried out as well as can be seen in theory than TDD system operated by SPECTRANET

Secondly, BER at lower modulation gives better performance but against desire high data rate, SPECTRANET should endeavor to integrate a robust Adaptive coding and modulation (AMC) techniques based on true values of attenuation models in temperate regions like Abuja, for instance rain attenuation in Abuja differs hugely from rain attenuation of Lagos, Sokoto or Rivers State, therefore, assumptions on west Africa model won't be efficient for AMC operation.

References

Andy, P., 2013. What is 2G, 3G, and 4G? Pentura Labs, United States.Retrieved from https://penturalabs.wordpress.com/2013/12/07/what-is-2g-3g-4g/ on 27th July, 2019.

Deepak, N.R., Balaji, S., 2015. A Review of Techniques used in EPS and 4G-LTE in Mobility Schemes. Centre for Emerging Technologies. International Journal of computer application, Vol 109, Page No. 9

Freescale, S., (2008).Long Term Evolution Protocol Overview. New York, US, (1st Ed). Freescale Semiconductor Incorporation, 10, 1-21.

Garcıa, A. J.,Buenestado, V., Toril, M., Luna-Ram´ırez, S., Ruiz, J.M., 2018.A Geometric Method for Estimating the Nominal Cell Range in Cellular Networks.Mobile Information Systems Volume 2018, Page No 1.

Irfan, A., Jagan, N., 2013.Bit-Error-Rate (BER) Simulation Using MATLAB. University, India.

Jose, A., Fernandez, S., Salvador, L., Matias, T., Juan, J., Sanchez, S., 2015. Estimating Cell Capacity from Network Measurements in a Multi-Service LTE System. IEEE COMMUNICATIONS LETTERS, VOL. 19, Page NO. 3.

Maria, U., Chairunisa, T. U., 2019. Performance Analysis 4G LTE NetworkOperator X and Y in the District of North Balikpapan.Department of Electronics Enginering, PoliteknikNegeri Balikpapan, Indonesia.

Mathworks., 2015. Long Term Evolution (LTE) documentation. Retrieved from https://www.mathworks.com/help/lte/on 4th June, 2019.

Mohana, H. K., Mohankumar, N. M., Devaraju, J.T., 2014. Effect of Bandwidth Scalability on System Performance in the Downlink LTE Systems.International journal of advanced research and computer science. Vol 5, Page number 7.

NiviUK., 2019. LTE resource grid Resource grid DCI decoder PDSCH allocation calculator. Scripts retrieved from http://niviuk.free.fr/lte_resource_grid.html on 16th July, 2019.

Third (3rd) Generation Partnership Project., 2010. Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception. (Release 10) TS. 36.