ISSN 2714-7533

Effect of Modulation on Throughput of 4G LTE Network Frequency 1800 MHz

Dikky Chandra[a,1,*], Fauzi Aditia Rahmat[a], Siska Aulia[b], Firdaus[a], Andre Febrian Kasmar[c]

[a] Department of Electronics Engineering, Politeknik Negeri Padang, West Sumatera, Indonesia
[b] Department of Information Technology, Politeknik Negeri Padang, West Sumatera, Indonesia
[1] dikky@pnp.ac.id
* corresponding author

ARTICLE INFO

Article history
Received November 17, 2022
Revised January 15, 2023
Accepted February 5, 2023

Keywords
Network
4G LTE technology
drive test
throughput parameters
modulation scheme

ABSTRACT

In the development of 4G LTE technology, network speed (Throughput) in several regions has increased or decreased. Network speed (Throughput) certainly cannot be separated from Modulation. In modulation there are several kinds of modulation schemes, be it QPSK modulation, 16 QAM modulation, and 64 QAM modulation. The modulation scheme is instrumental in increasing throughput. Based on several previous studies, they only check the Throughput parameters without doing a more in-depth analysis of the modulation scheme which also plays a very important role in network speed (Throughput). For this reason, it is necessary to carry out an analysis related to the effect of modulation on the throughput value. To find out the effect of modulation on throughput, it is necessary to take data in the field, the method used is the Drive Test method. Based on the results of the Drive Test, QPSK modulation has a Throughput value of 5.247.4 Kbps, modulation of 16 QAM has a Throughput value of 27.293.9 Kbps and modulation of 64 QAM has a Throughput value of 65.275.1 Kbps. Based on the data in the field and in terms of calculations, the modulation that most affects the throughput value is the modulation of 64 QAM. Modulating 64 QAM having 64 symbols where each symbol consists of 6 bits will make the data rate at throughput higher. This also applies to the use of modulation of 16 QAM (16 symbols with 4 bits) and QPSK (4 symbols with 2 bits).

1. Introduction

Cellular telecommunications in this day and age has experienced very rapid development, this can be seen from the increasing number of subscribers [1]. In terms of growth, mobile phone subscribers have experienced a significant increase from the growth of other industries. Customer development must also be accompanied by good service quality. With such many subscribers and widespread everywhere, many operators have established a number of new BASE Stations to keep up with the increasing number of subscribers. However, the addition of BTS is not a total solution to compensate for the increase in the number of subscribers because there are new problems arise such as the occurrence of Bad Spot Areas caused by Interference or Obstacles. The more BTS that is established, it requires careful planning thus the coverage area can provide maximum results both in terms of service quality and thus there is no overlap with adjacent cells.

To check the problem of bad spots and actual signal quality on the site, a drive test activity was carried out. The drive test is a measurement of signal quality carried out using a vehicle in a relatively large area (outdoor) using an application, namely TEMS Pocket. The drive test is used to collect real data on the quality of a network in the field [2]**.** The cellular telecommunications technology to be studied is 4G LTE. 4G LTE network enthusiasts will certainly continue to increase because the 4G LTE network offers data speeds of up to 100 Mbps for downloads and up to 50 Mbps for uploads [3]. Therefore, telecommunications service providers are expected to be able to provide maximum network services. The parameters measured on the 4G LTE network are RSRP (Reference Signal Received Power), SINR (Signal to Noise Ratio), PCI (Physical Cell Identity), CQI (Channel Quality Indicator), and Throughput [4]. The parameter data collection supports three categories of KPI classification in network evaluation, namely Accessibility, Retainability, and Integrity.

One of the areas in the Padang City area, precisely in Koto Tangah District, which has an area of ±232.55 KM2 with a population of ±197 797 people (Central Statistics Agency of Padang City, 2020), 4G LTE technology still has problems that customers complain about. These problems include unstable signals received, data access that is difficult to connect, and connection failures. Therefore, research will be carried out to determine the value of several parameters on the 4G LTE network. Therefore, researchers tried to examine the performance of the 4G LTE network in the Koto Tangah area, Padang City.

Things that affect network performance in an area decrease due to obstacles and interference. The influence of network performance that is quite bad both caused by obstacles and interference also affects the SINR value, according to Sudiarta et al., (2019), the SINR parameter is one of the qualities that affect the throughput parameter [5], if the value of SINR is bad, it will cause the value of the Throughput parameter to be bad. Throughput is the average number of bits received by user equipment in a network. To minimize the problem, modulation is carried out. Modulation is the change of parameters from a carrier signal to an information signal. One of the functions of the modulation method for areas experiencing poor network performance is that it is resistant to interference. According to Chandra et al., (2021), the throughput value is influenced by the modulation obtained from the measurement results on each route taken. The effect of modulation on the throughput value obtained from each cell served. Based on the results of the data that have been studied by Chandra et al., (2021), the use of QAM modulation has a better throughput value compared to the use of PSK modulation [6].

According to several other researchers in previous studies, several factors influence the causes of the high-low throughput value affected by modulation. The effect of throughput values on modulation is due to the distance between eNode B and user equipment, the greater the distance between eNode B and user equipment, the smaller the throughput value on modulation [7].

Based on the studies that have been carried out, several conclusions can be drawn that the research carried out previously was only based on reading the data obtained in the field. Therefore, the researchers are interested in conducting research on the effect of modulation on throughput not only about the data obtained in the field but also carried out based on theoretical calculations of the maximum data speed (throughput) that can be obtained.

2. Material And Method

The research on the effect of modulation on throughput on the 4G LTE network of the 1800 MHz frequency uses a qualitatively observative non-participatory method, namely by comparing the values of each 4G LTE parameter and knowing the influence and causes that occur in each parameter, especially the effect of modulation on the throughput of the predetermined path or route from the eNode B.

A. Retrieval Methods (Drive Test)

This chapter contains an explanation of the data retrieval methods that will be carried out. In this study, data collection was carried out using the Drive Test method. The drive test method is a method used in sampling real network data in an area [8]. Some of the equipment used in data sampling is in the form of a Samsung Galaxi Note 5 smartphone that has been installed with the TEMS Pocked application, LTE Data Card in this case using a Telkomsel network card. TEMS Pocket is used to measure the performance of cellular networks when conducting drive tests, as well as collecting information on the quality of cellular networks in the area [9]. As for data analysis, it uses a plate like a laptop with the software used, namely TEMS Discovery and MapInfo Pro, TEMS Discovery is used to process and analyze the results of the drive test data.

B. 4G LTE (Long Time Evolution) Network

Long Term Evolution (LTE) is a long-term evolutionary radio access network output from the 3rd Generation Partnership Project (3GPP) [10]. LTE provides all-IP on its network architecture where lies the difference in functions in devices from previous generations. From the interface side, LTE uses OFDMA (Orthogonal Frequency Division Multiple Access) on the downlink side and SC-FDMA (Single Carrier-Frequency Division Multiple Access) on the uplink side. LTE technology theoretically offers downlink speeds of up to 100 Mbps and Uplink of up to 50 Mbps [11]. Flexible operating bandwidth is up to 20 MHz. LTE supports the use of Adaptive Modulation and Coding (AMC) to improve user performance in uplink and downlink directions. The modulations that can be used are QPSK (2 bits per symbol), and 16QAM (4 bits per symbol), 64QAM (6 bits per symbol). In OFDM, there is the term resource Block (RB)[12].

A Resource Block is a transmission block on OFDM composed of time and frequency domains. The number of block resources depends on the bandwidth used. The greater the bandwidth, the greater the available block resources. Therefore, the larger the system has a block resource, the greater the maximum throughput generated [12].

C. Throughput

Throughput is the number of bits received by a particular terminal in a network in a unit of time. Throughput has units of bits per second (bps). The throughput amount is the average number of bits received for all terminals on a network. Throughput is a parameter that can be felt directly by the user, thus this parameter affects the level of user satisfaction [13].

Table 1. Standard Throughput Value

Range	**Throughput**	**Legend**
>=14000	Very Good	Purple
>=7000 x <14000	Good	Blue
>=1000 x <7000	Normal	Green
>=512 x <-1000	Bad	Yellow
<512	Very Bad	Red

To obtain maximum throughput data results, its formulation can be seen in the following [14].

Max Data Rate = Number of Resource Block x 12 *subcarriers* x Modulation x 14/ms (1)

D. Modulation

Modulation is the change of parameters from a carrier signal to an information signal [15]. Digital modulation is the process of sending a digital signal (bit stream) into the carrier signal. Digital modulation is actually the process of changing the characteristics and properties of the carrier wave in such a way that the form of the result (modulated carrier) has the characteristics of the bits (0 or 1) it contains [6].

On uplinks, modulation is performed by the QAM modulator. QAM modulators are actually a long-standing modulation method, but they have developed along with the development of telecommunications technology. The available modulation methods (for user data) are QPSK, 16QAM, and 64QAM. The first two apply to all devices, and for 64QAM, it depends on the UE function, which means that there are devices (smartphones, modems, etc.) that support 64 QAM and that do not support 64 QAM. The following is a diagram of the modulation constellation which can be seen in the following figure [6].

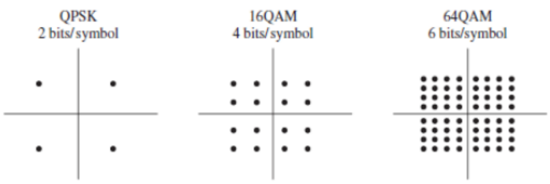

Figure 1. Modulation constellation diagram

The modulation scheme that supports LTE networks is 64 QAM, 16 QAM, and QPSK, where adaptive modulation and coding have 2 important components, namely modulation and coding schemes. The following is an explanation of each modulation scheme [6].

1) Quadrature Phase Shift Keying (QPSK): This modulation scheme belongs to the low-order modulation category because it consists of 4 symbols and each symbol consists of 2 bits. When the condition of the channel between the sender and receiver is in a bad state or the SINR value is low, this QPSK modulation is suitable for use. One of the advantages of this QPSK modulation is that it is resistant to interference [6].

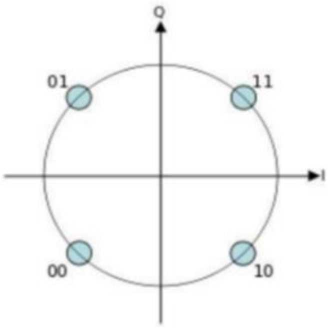

Figure 2. QPSK modulation

2) 16 Quadrature Amplitude Modulation (16 QAM): This modulation consists of 16 symbols and each symbol consists of 4 bits. The following is an illustrative overview of the modulation of 16 QAM [6]:

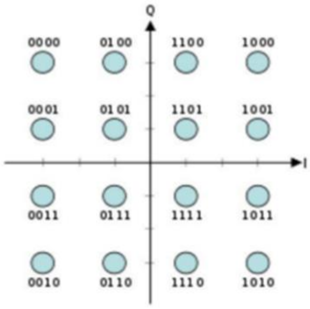

Figure 3. 16 QAM modulation

3) 64 Quadrature Amplitude Modulation (64 QAM): When viewed from the high SINR value, the conditions between the sender and receiver channels are categorized as quite good, then the modulation of 64 QAM is suitable for use. Modulation of 64 QAM consists of 64 symbols and each symbol consists of 6 bits. The advantage of this modulation is that it can provide a high data rate, but the disadvantage is that it is very susceptible to interference, noise, and channel estimation errors [6].

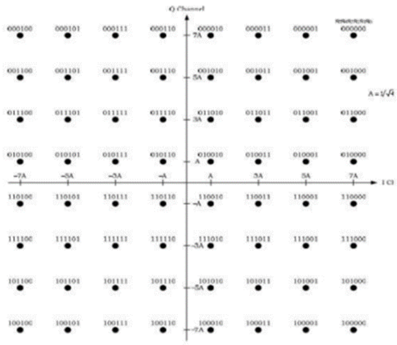

Figure 4. 64 QAM modulation

Thus, the effect of bandwidth usage on the modulation used is obtained as can be seen in the following table.

Table 2. Effect of Bandwidth on Modulation, Resource Blocks, and Subcarriers

Bandwidth	**10 MHz**	**15 MHz**	**20 MHz**
Resource Block	50	75	100
Subcarrier	600	900	1200
Data Rate (QPSK)	13.44	20.16	28.88
Data Rate (16 QAM)	26.88	40.32	53.76
Data Rate (64 QAM)	40.32	60.48	80.64
Data Rate (64 QAM MIMO 2X2)	80.64	120.96	161.28

3. Method

The effect of channel bandwidth on throughput is analyzed based on real test results on active cells using the drive test method. Tests were carried out on cells that have channel bandwidths of 10MHz, 15MHz, and 20MHz which occupy frequency bands that are not adjacent, namely sequentially in the bands 900MHz, 2100MHz, 1800MHz, and 2300MHz. Regional planning and cell/eNodeB determination play an important role in achieving the objectives of this research. Regional planning is related to the existence of cells serving on all bandwidth channels and not using MIMO antennas. Measurements were made on eNodeB/cell with PCI number 328 in the city of Padang. Figures 1 and 2 show the location of the serving cell and the measurement route through the drive test.

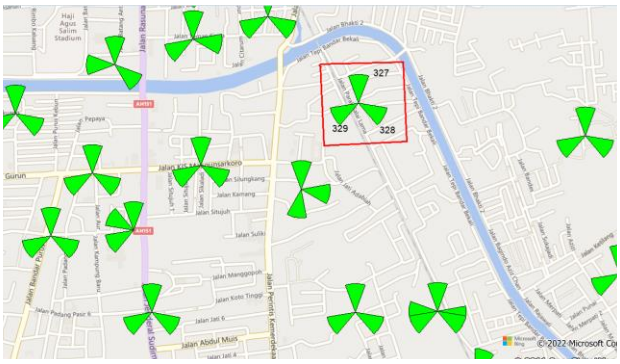

Figure 1. Serving Cell PCI 328

Figure 2. Drive test route

4. Results

4.1. Throughput testing based on channel bandwidth variations.

Tests were carried out on cells that have four channel bandwidth licenses that occupy different frequency bands as shown in Table 1.

Table 1. Cell Parameters (PCI 328)

Channel Bandwidth (MHz)	UL Frequency (MHz)	DL Frequency (MHz)	TxRx	50
10	885 - 895	930 - 940	SISO	75
15	1942.5 - 1957.5	2132.5 - 2147.5	SISO	75
20	1775 - 1795	1870 - 1890	SISO	100
20	2310 - 2330	2310 - 2330	SISO	100

The outcomes of throughput tests in the radio domain with varying channel bandwidth and other factors are displayed in Table 2. According to the test results, the maximum throughput values differ depending on the SINR values, modulation methods, and the number of PRBs on each bandwidth channel. The 20MHz band 2400 bandwidth channel of 64666.80kbps with 91 PDSCH Resource Block (PRB) numbers, modulation scheme 16QAM, and 18.8dB SINR conditions have the highest throughput values. While the throughput with the lowest SINR value and a channel bandwidth of 10MHz band 900 is 22137.20 kbps at 23PRB, QPSK modulation technique. The relationship between variations in channel bandwidth and maximum throughput values is nonlinear.

Table 2. Througput$_{max}$ value on channel bandwidth variations and several radio domain parameters

PCI	Freq Band (MHz)	Channel Bandwidth (MHz)	Max Throughput (kbps)	SINR (dB)	PRB
328	900	10	22137.2	21.4	23
328	1800	20	24958.8	14.7	44
328	2100	15	48120.4	16.1	67
328	2300	20+10	64666.8	18.8	91

The results of monitoring the throughput and coverage characteristics while taking channel bandwidth variations are shown in Table 3. The maximum throughput numbers, as well as the Pathloss and RSRP parameters, varies for each bandwidth channel. Path loss on channel bandwidth fluctuations and changes in throughput with changes in RSRP is not linearly correlated. Changes in frequency bands that are connected to RSRP and throughput can be perceived as linearity.

Table 3. Througput$_{max}$ on variations of channel bandwidth and coverage parameters (RSRP, Pathloss)

PCI	Freq Band (MHz)	Max Throughput (kbps)	Channel Bandwidth (MHz)	Pathloss (dB)	RSRPmax (dBm)
328	900	22137.2	10	76.7	-60.9
328	1800	24958.8	20	85	-69.3
328	2100	48120.4	15	96	-80.7
328	2300	64666.8	20	97.4	-85.7

4.2. Correlation between Channel Bandwidth and Throughput

In the radio domain, theoretically Down Link (DL) data throughput is affected by the number of scheduled RB per subframe which is directly related to the amount of channel bandwidth, the Resort Element as calculated in Table 4.

Table 4. Max Throughput per scheduling block [2]

Parameter	Channel Bandwidth		
	10MHz	15MHz	20MHz
Resource Block (RB)	50	50	100
Resource Element (RE) per RB	84	84	84
RE Per Schedulling Block (2xRB): 1ms	168	168	168
Reference signal (RS) RE (per RB/RS (Per Scheduling)	8/16	8/16	8/16
RE per CRS (OFDM*12-4RS Tx): SISO	8	8	8
Total Number RE per Schedulling Block Available for PDSCH	144	144	144
Bits per Scheduling Block - QPSK (2 bits)	288	288	288
Bits per Scheduling Block - 16QAM (4 bits)	576	576	576
Bits per Scheduling Block - 64QAM (6 bits)	864	864	864
Max Theoretical L1 Througput (MBps)	43.2	64.8	86.4

The channel bandwidth determines the size of RB and RE. The modulation strategy has an impact on the number of bits in each symbol that are transferred to each RE. The maximum throughput increases as the channel bandwidth and bits per symbol increase. The throughput DL that the cell can handle at its maximum is calculated above. This is correlated with the results of the maximum PDSCH throughput test in Table 2.

On the LTE network, the efficiency domain factor also affects the PDSCH throughput, such as the RSRP and SINR parameters. SINR is determined by the UE position (RSRP, and interference between cells according to the following formula [2].

$$SINR = \frac{RSRP_{serv}}{\sum RSRP_{other} + 1 + N} \quad (1)$$

The effect of SINR and RSRP on throughput on different Channel Bandwidths can be seen based on the comparison of the test points on serving cell PCI 328 as shown in Figure 3 and Figure 4. It is taken into consideration that each bandwidth channel occupies a different frequency band and is not contiguous.

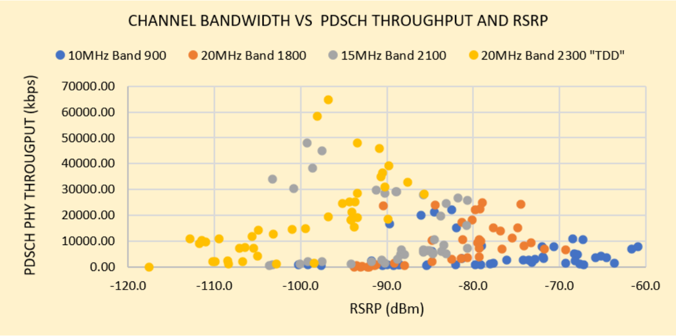

Figure 3. RSRP and throughput correlation on channel bandwidth variations

Figure 3 shows that the dominating throughput value will rise the better the RSRP value on each bandwidth channel. There is no linear change in the RSRP value of throughput when compared to changes in channel bandwidth, however, the frequency band that the channel bandwidth occupies has a greater impact on throughput growth. The maximum RSRP and throughput increase with the frequency band that the channel bandwidth occupies. Conversely, the maximum RSRP and maximum throughput lower the frequency band occupied by the channel bandwidth (figure 4).

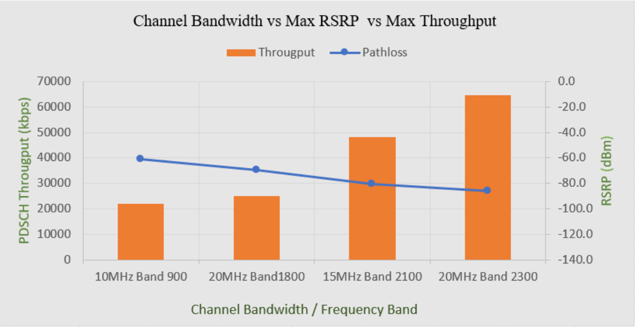

Figure 4. Graph of channel bandwidth to coverage and throughput parameters

Based on SINR parameters, channel bandwidth performance against throughput can also be examined. Shannon states that SINR, bandwidth, and channel capacity all influence channel capacity (C) in bps. The channel capacity can be mathematically stated using the following formula. [10].

$$C = 3.32\, B\, log_{10}\,(1 + \frac{S}{N}) \quad (2)$$

Where C = channel capacity (bps)

B = occupied bandwidth in (Hz)

$\frac{S}{N}$ = Signal to Noise Ratio (dB)

According to formula 2, the channel capacity will be at its highest under favorable SNR circumstances. If this relationship holds for the test findings depicted in Figure 5, then throughput increases when SINR on each channel's bandwidth increases. Changes in SINR and throughput are not linearly affected by changes in channel bandwidth.

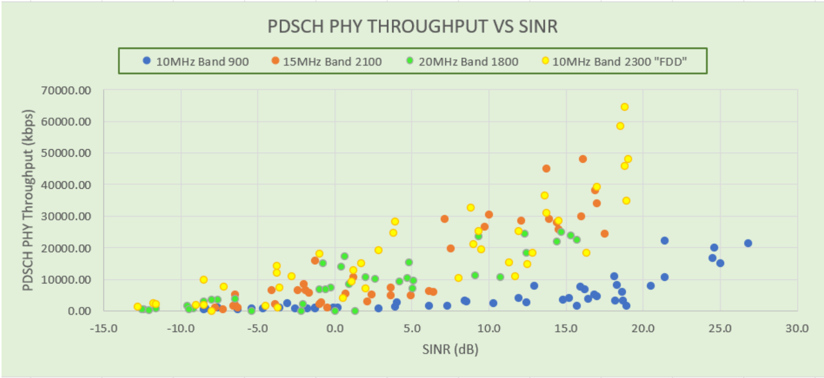

Figure 5. SINR and throughput on channel bandwidth variations

5. Conclusions

The maximum capacity of a cell is affected by channel bandwidth. The maximum user throughput may be affected by the channel bandwidth. The amount of PRBs, bits per scheduling block, has an impact on channel bandwidth performance. The maximum throughput does not increase linearly with increased channel bandwidth. The 20MHz channel bandwidth in the 2300 band, 15MHz in the 2100 band, 20MHz in the 1800 band, and 10MHz in the 900 bands have the best throughput from highest to lowest. The maximum throughput and the frequency band that the channel bandwidth uses have a linear correlation.

References

[1] Dahlman, arkvall, Skold.. “4G, LTE-Advanced Pro and The Road to 5G “Third Edition, Elsivier, 2016

[2] Jar.M., , and Fettweis.G, Throughput Maximization for LTE Uplink via Resource Allocation, 2012, International Symposium on Wireless Communication Systems (ISWCS)

[3] X. Zhang, “LTE Optimization engineering handbook “, first edition, IEEE Pres, Willey, 2018

[4] Republik Indonesia “Peraturan menteri Komunikasi dan Informatika Republik Indonesia no 27 Tahun 2015 Tentang Persyaratan Teknis Alat Dan/Atau Perangkat-Perangkat Telekomunikasi Berbasis Standar Teknologi Long Term Evolution “Kementrian Komunikasi dan Informatika, Jakarta, P.5, 2015

[5] Chandra, D., Yusnita, Bahari, “The Analysis of Service Integrity on Video Streaming Services Using Time Division Duplex and Frequency Division Duplex Technology on LTE Networks”, International Journal of Advanced Science Computing and Engineering ISSN 2714-7533 Vol. 3, No. 2, August 2021

[6] Chandra, D., Bahari, “LTE Network Area Coverage on FDD and TDD Technology”, International Journal of Advanced Science Computing and Engineering ISSN 2714-7533 Vol. 2, No. 1, April 2020, pp. 21-33

[7] Adityo , Usman, Cahyono, “Analisis Penerapan Flexible Bandwidth Untuk Meningkatkan Performansi Jaringan Lte”, Seminar Nasional Inovasi Dan Aplikasi Teknologi Di Industri 2018

[8] Mubarok, Putri, Analisis, “Dampak Inter-Band Carrier Aggregation pada Perencanaan Jaringan LTE-Advanced”, 2019 ELKOMIKA

[9] Hwang, Park, “On the Effects of Resource Usage Ratio on Data Rate in LTE Systems”, ICACT 2017 February 19 ~ 22, 201

[10] Hadi.A.A., Clancy.C., "A utility proportional fairness approach for resource allocation in 4G-LTE," in IEEE International Conference on Computing, Networking and Communications: Computing, Networking and Communications Symposium (ICNC'14 - CNC), 2014

[11] Ghorbanzadeh .M., Abdelhadi.A., Clancy .C., A Utility Proportional Fairness Radio Resourc Block Allocation in Cellular Networks, Hume Center for National Security and Technology Virginia Tech, Arlington, VA, 22203, USA

[12] Al Dulaimi, A.M., Al-Azzawi.E.M., Al-Anssari.A.I., Balancing model of resource blocks allocation in LTE downlink, 2016, International Conference on Electronics and Information Technology (EIT)

[13] Kachroo.A., Ozdemir.M.K., Mogulkoc .H.t., Optimization of LTE radio resource block allocation for maritime channels, 2016 IEEE 37th Sarnoff Symposium

[14] Jar.M., , and Fettweis.G, Throughput Maximization for LTE Uplink via Resource Allocation, 2012, International Symposium on Wireless Communication Systems (ISWCS)

[15] Yu.I. and Yin.C., Block-Level Resource Allocation with Limited Feedback in Multicell Cellular Networks, Journal of Communications and Networks, Vol. 18, No. 3, June 2016

[16] Cox.. “An Introduction To LTE, LTE-Advanced, Sae, Volte And 4G Mobile Communication” Second Edition, Wiley, 2014

[17] Arthur, Forgor, Effah, Analysing the Effect of MIMO Configuration on The Throughput of LTE Network in Multipath Environtments, 2019, International Conference on Communications, Signal Processing and Networks (ICCSPN)

[18] Vijeth J. Kotagi, Rahul Thakur, Sudeepta Mishra, and Chebiyyam Siva Ram MurthyAssigning Downlink Transmit Power and Resource Blocks to LTE Enabled IoT Networks, IEEE Communications Letters (Volume: 20, Issue: 8, August 2016)

[19] Haider.F., Hepsaydir.E., Binucci.N., Performance analysis of LTE-advanced networks in different spectrum bands, 2011, Wireless Advanced

[20] Liu,.J., Shen.G.,, Performance of Multi-Carrier LBT Mechanism for LTE-LA, 2016, IEEE 83rd Vehicular Technology Conference (VTC Spring)