LTE Capacity Estimation with Changing Different Planning Parameters

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***Abstract*—**Capacity improvement is the essential advantages in 4th generation mobile systems which called Long-Term Evolution (LTE). The maximum data transmission rate of LTE cell is 100 Mb/s in downlink direction and 50Mb/s in uplink, and this rate can be enhanced with deploying different techniques like MIMO, carrier aggregation, and many others. Because of that 4G-LTE mobile network is considered pure packet switching, there are many parameters which affect the maximum cell capacity. This study will evaluate the result of changing many parameters on the maximum mobile cell capacity. The aim is to extract the best values of the different parameters to maximize LTE mobile cell capacity.

Index Terms—MAPL, LTE, eNB, OFDMA, EPC, and MIMO

I. INTRODUCTION

LTE is new mobile technology proposed to deliver quite migration to Fourth Generation mobile network. It is designed to improve capacity, coverage, and data rate [1]. LTE was designed to deliver enhanced performance comparing with other 3rd-Generation Partnership Project systems, with a maximum peak throughput of 100Mbit/s in downlink direction (DL) direction and 50Mbit/s in uplink direction (UL), reduced latency, and minimal terminal power consumption. LTE is also frequency flexible with bandwidth allocations starting from minimum 1.4MHz to maximum 20MHz [2].

Along with the bandwidth flexibility considered, a huge mountain range of various spectrums is defined and supported by FDD or TDD to allow an performance in both paired spectrum and unpaired spectrum [3], [4].

The remaining parts of this study is presented as follows. LTE network structure is declared in section II. LTE network operation will be summarized in section III. Section IV declares the results of changing many parameters to shows the relations with these parameters and the mobile cell capacity. Summary of this study will be presented in section V.

II. LTE NETWORK STRUCTURE

LTE adopts Orthogonal Frequency-Division Multiple Access (O-FDMA) as the base technique for resource sharing among Multiple equipment [5]. The Commercially available LTE doesn't satisfy the technicality of 4G wireless services Available in document series of 3GPP rel. 8 and 9 and the requirements set by ITU-R organization [6]. 3GPP further extended the original proposal of LTE, which is known as LTE-Advanced. This release aims to support rate up to 1Gbit/s and 500 Mb/s in DL direction and UL direction, respectively [5]. Note that these rates are the theoretical peak rates because the actual rates depend on many other parameters. OFDMA signal includes of many subcarriers which spaced by 15 kHz, this eliminates Intra Cell or Adjacent Channel Interference. The minimum resource which is assigned to users called Resource-Block (RB) which includes 12 adjacent sub-carriers that together occupy 180 kHz. Form time view this 12 subcarrier lasts for 0.5ms which called slot. The network bandwidth divided to a group of RBs as presented in Table I.

TABLE I: RESOURCE BLOCKS VS. BW

BW- MHz	1.4	3	5	10	15	20
RB	6	15	25	50	75	100

LTE networks involve two main parts, Evolved Node-B (eNBs) which represents the radio network interface part and Evolved Packet Core (EPC) which is the network core, as declared in Fig. 1. eNB is the responsible item for the radio functions like transmission power management, mobility management and resource scheduling [7].

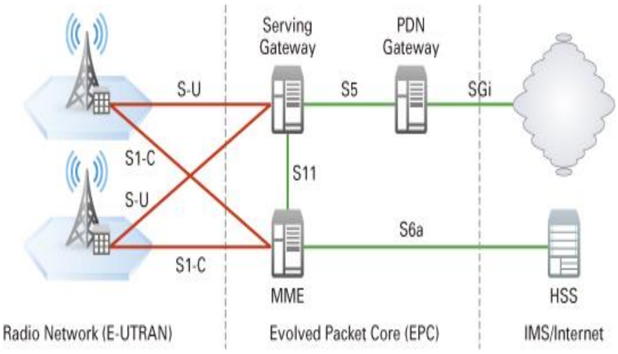

Fig. 1. LTE network architecture

EPC involves two main parts: Service Gateway (S-GW) which makes the User Equipment (UE) to communicate with another users of 4G-LTE network and PDN Gateway which is the responsible element of

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providing the connectivity between subscriber's terminal and another external network like IMS or Internet. MME exists in core also, its functions are controlling the access nodes via signaling messages, mobility management, and other functions related to network management. The Home-Subscribe Server (HSS) exists in the EPC and it stores information related to the subscribers [8].

To accomplish the required data rates in LTE, LTE deployed diverse MIMO modes technologies together like Single user (SU)-MIMO, Transmit diversity, Multiuser (MU)-MIMO and Dedicated beam forming. The LTE SU-MIMO scheme is specified for the configuration with two to four transmits antennas DL direction, which supports the transmission of maximum four layers to a specified UE [9].

The EPC doesn't support Circuit-Switched (CS) services, including voice, which is considered as the essential revenue for Mobile Service Providers (MSPs). LTE only have Packet-Switched (PS) services. This is the basic difference between the previous UTRAN/GERAN networks like UMTS, which provide both services (CS/PS services). The Evolved-Universal Terrestrial Radio Access Network (EUTRAN) is the radio access part for LTE and LTE-A. 3GPP presented the technical specifications of 4G-LTE and LTE-Advanced in Rel. 8 and 10, respectively [10].

To support VoIP calls in LTE two solutions exists. Circuit switching fallback (CSFB), and Voice over-LTE (Vo-LTE). Vo-LTE is deployed by the aid of IP-Multimedia Subsystem (IMS). IMS is a central network that is exists over the 4G-LTE network (from the view of services hierarchy), Because of these characteristics, LTE offer good performances, and particularly for those bandwidth consuming facilities i.e. data downloading or video streaming services [11].

III. LTE NETWORK OPERATION

The eNB executes scheduling function that execute resource allocation function to UEs. The scheduler utilizes indicator named Channel Quality Indicator (CQI) transmitted by UEs. Based on CQI information resource assignment is performed [12].

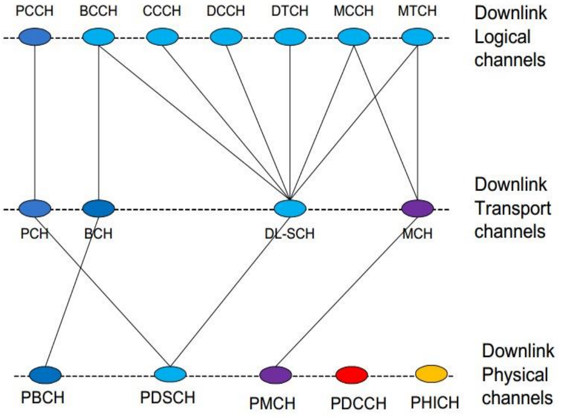

Fig. 2. LTE Channel mapping

As declared in Fig. 2, LTE network assigns a number of RBs to a mobile station for each new Transmission Time Interval (TTI) which occupies a subframe. However, not all OFDMA symbols of an RB are used to transmit user data. It depends on the location of the RB in the overall resource grid to determine the type of data that the symbol carries.

Cell Reference Signals (CRS) is transmitted in a predetermined RBs and used in DL channel condition's estimation by different mobiles [13]. Each antenna has its own CRSs. Resource Elements (REs) allocated to CRS on one antenna are not used on the other antennas (empty RE that called Discontinuous Transmission RTX). CRSs are inserted on every seventh symbol on the time axis and on every sixth subcarrier on the frequency. A total of 504 different reference signal sequences exist.

For initial synchronization, Primary and Secondary Synchronization Signals (PSSs / SSSs) are transmitted in every first and sixth subframe (i.e. transmitted every 5 ms) on the middle 62 subcarriers of the channel [9]. It is assumed that these signals are transmitted from the first antenna while the network apply DTX to the corresponding resource elements in other antennas [14].

Physical Broadcast Channel (PBCH) is used to send system information for all mobiles that contains the bandwidth of the network, System Frame Number (SFN), and length of Hybrid ARQ (HARQ) Indicator Channel (PHICH). PBCH occupies three symbols on 72 middle subcarriers (=6 RBs). PBCH is broadcasted every 40 milliseconds and follows the PSSs and SSSs [9]. PBCH is QPSK modulated and is transmitted on all antennas [15].

PCFICH carries information that determines the PDCCH size and is sent at each of subframe beginning. It contains the Control Format Indicator (CFI) which is 2 bits in length, and it is encoded using a code rate of 1/16 during the first symbol within each subframe [15].

Physical Downlink Control Channel (PDCCH) carries messages that indicate to each UE when, where, and what kind of data is scheduled for them on the downlink direction and which RBs can be used in the uplink direction. PDCCH occupies the first one to four symbols over the whole channel bandwidth in every subframe.

PDCCH carries scheduling information of different types such as downlink resource scheduling, power control instructions. The control information carried by PDCCH called DCI (Downlink Control Information) which is transmitted as an aggregation of Control Channel Elements (CCEs). One CCE contains 9 Resource Element Groups (REGs) and each REG has 4 REs. Each RE carries 2 bits because QPSK is the only available modulation format. A PDCCH can contains 1, 2, 4 or 8 CCEs [16]. The PDCCH data is padded with DUMMY data prior to an interleaving function. The DUMMY data is used to ensure that the combined PDCCH plus DUMMY data occupies an integer number of OFDMA symbols. The subcarriers occupied by the PDCCH depend upon the cell identity.

For error correction capability, some symbols are reserved to acknowledge the proper reception of uplink messages or to signal the mobile device that a block was not received correctly. This is done by HARQ and the corresponding channel is PHICH. Each PHICH group occupies 12 RE. PHICH groups $N_{g,PHICH}$ is calculated from the number of RBs $N_{RB,DL}$ and the PHICH group scaling factor N_g as indicated in eq 1 . The scaling factor take on of the following values the scaling factor 2, 1, 1/2, or 1/6.

$$N_{g,PHICH} = \{N_g * N_{RB,DL}/8 \text{ ;for normal CP, } 2*N_g*N_{RB,DL}/8 \text{ ; for extended CP}\} \quad (1)$$

Physical Downlink Shared Channel (PDSCH) is used for data transmission and allocated the REs which have not been used by the other physical channels and signals. The PDSCH is not able to use RE which belong to the same symbol as the PHICH, PCFICH or PDCCH.

In Uplink direction (UL) there are three physical channels in LTE. Physical Uplink Shared Channel (PUSCH) that supports QPSK and 16 QAM, and optionally 64QAM modulation is used to carry user traffic. PUSCH carries control messages in addition to user data. Some other control messages carried by Physical Uplink Control Channel (PUCCH) and its size is configurable. Physical Random-Access Channel (PRACH) is used to let UEs get access to LTE network [17].

Table II lists the percentage of resources used in signals and control channels.

ITU developed number of channel models which implemented as a tapped-delay-line. ITU recommends the following six channel types (three cases with two distinct delay spreads): vehicular, indoor, pedestrian, with small delay spread (Channel A) and medium delay spread (Channel B). Pedestrian environment is existed in small cell and low power. Base stations (BS) with low antenna altitude are located outdoors while pedestrian UEs are located on the streets and inside buildings. The mobile speed assumption is 3 km/h [18].

TABLE II: LTE DIFFERENT CHANNELS USAGE IN LTE

Signals and Channels	**DL %**	**UL %**
Number of PDCCH Sym. per Subframe	3	-
Number of RBs for PUCCH	-	8
RACH Density per 10 ms	-	1
Reference Signal	9.5	13.14
Primary Sync. Signal (PSS)	0.09	-
Secondary Sync. Signal (SSS)	0.09	-
PBCH / PRACH	0.16	0.6
PDCCH / PUCCH	19	8
- / Sounding	-	N/A
-/PUSCH (UCI)	-	1.2
Total System Overhead	29	23

IV. PLANNING PARAMETERS

The mobile cells capacity depends on the following main parameters:

- Cyclic Prefix (CP): have two options Normal: 7 sym./slot; or Extended: 6 symbols/slot
- PDCCH symbols: 1 to 4 symbols.
- PUSCH RACH resources occupy 6 PRB (1.08MHz) in frequency domain, it can use 1, 2, or 3 sub frames.
- Reference Signal: if one Tx antenna: 4 RSs per RB, if 2 Tx antenna, there are eight RSs per Resource Block, if 4 Tx antenna, there are twelve RSs per RB.
- Channel models: Enhanced Pedestrian A(EPA) channel model with 5Hz frequency shift, Enhanced Typical Urban(ETU) channel with 70Hz Doppler shift valid for high speed mobiles (i.e >30km/h) [19].
- Operating frequency range and system bandwidth.
- Cell load which describe the neighbor cell load.
- Link budget values which use in estimation of MAPL.

Table III lists the main parameters which used in the calculation.

TABLE III: LTE DIMENSIONING PARAMETERS

Operating frequency	2600 MHz
BW	10 MHz
Downlink/Uplink rate	4096/384 Kb/s
eNB power	20 W (43 dBm)
Antenna gain	18 dBi
Noise figure (DL/UL)	7 dB/2.2dB
BLER	10 %
Default load	50 %

V. RESULTS AND DISCUTION

Fig. 3 presents the relation of total eNB cell throughput (maximum capacity) with the neighbor cell load in different clutters. Fig. 3 declare the huge impact appears in urban and dense urban because the cell limit in these clutters is small comparing with other clutters. When the neighbor cell load increases the interference margin increases which affect cell throughput because high index MCS can't be used. The figure lists the reduction from 57 Mb/s in zero load to 30 Mb/s in 100% load.

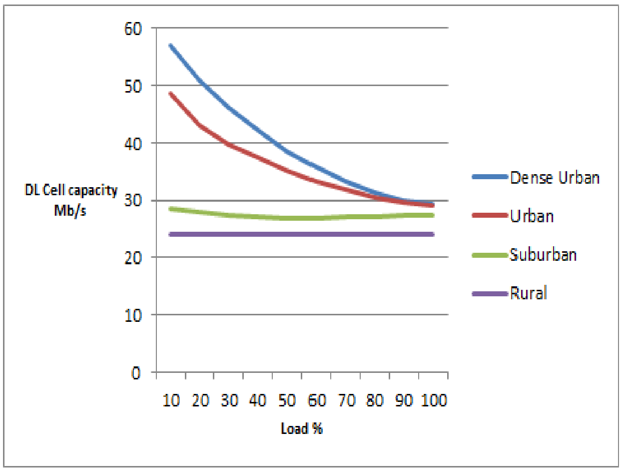

Fig. 3. Downlink cell capacity against neighbor cell load

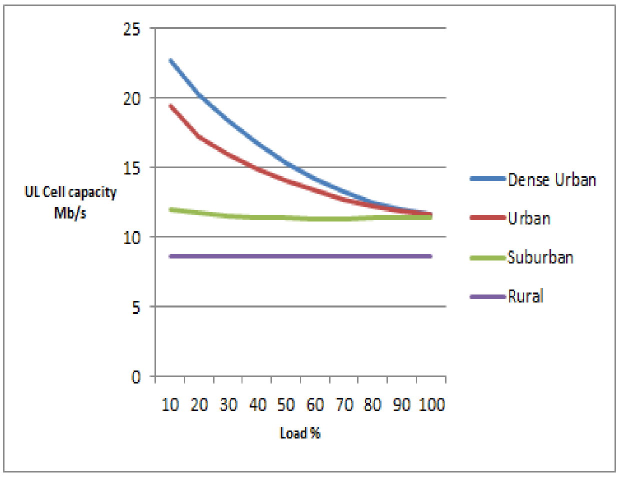

Fig. 4. Uplink cell capacity against neighbor cell load.

Fig. 4 shows uplink cell capacity in Mb/s versus neighbor cell load. The value of Uplink throughput is less that downlink throughput, this effect because the UL direction sends less power value than down link, also the modulation types of uplink cannot use 64-QAM in most UE types.

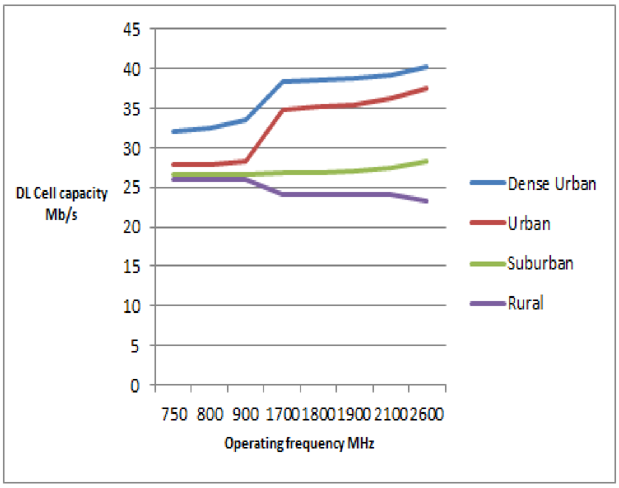

Fig. 5. DL cell capacity against operating frequency

Fig. 5 presents the maximum eNB cell throughput in downlink direction for different clutters using different operating frequency. The figure declares that for Dense-Urban and Urban clutters, the throughput increases with operating frequency increasing, this is result of the operating frequencies increases the cell limit decreases which enables eNB and UE to modulate signals using high MCS index which increase the maximum cell capacity. This isn't the case in rural clutter because at high frequency range the cell size decrease but still large area size uses low MCS and the path loss increases which decreases the amount of throughput.

Fig. 6 declares the maximum eNB cell throughput in uplink direction for different clutters using different operating frequency. The values of uplink cell capacity start to increase with increasing the operation range of operating frequency for Dense-Urban and Urban. The opposite situation appears with rural areas.

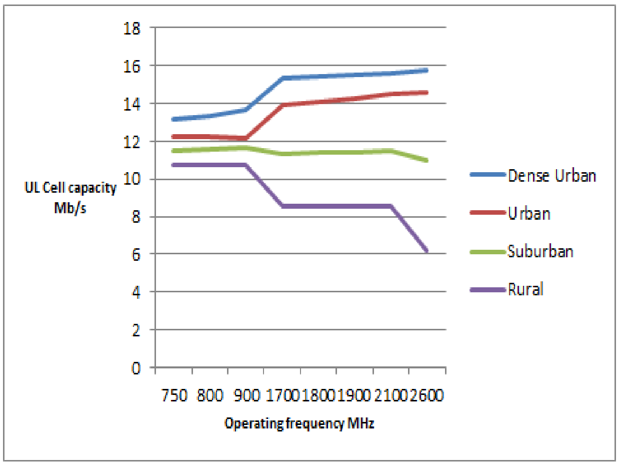

Fig. 6. UL cell capacity against operating frequency

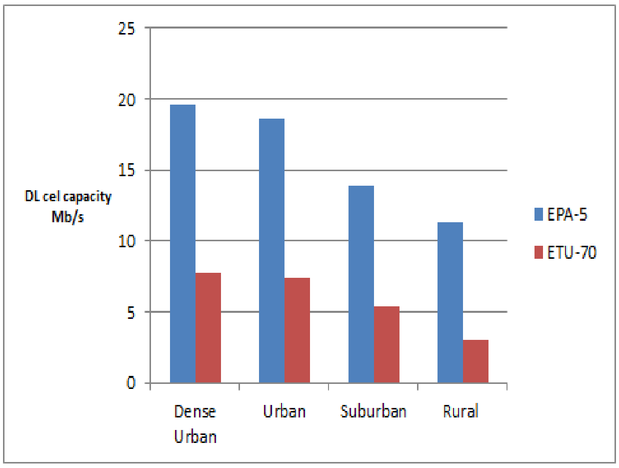

Fig. 7. Downlink cell capacity against channels models

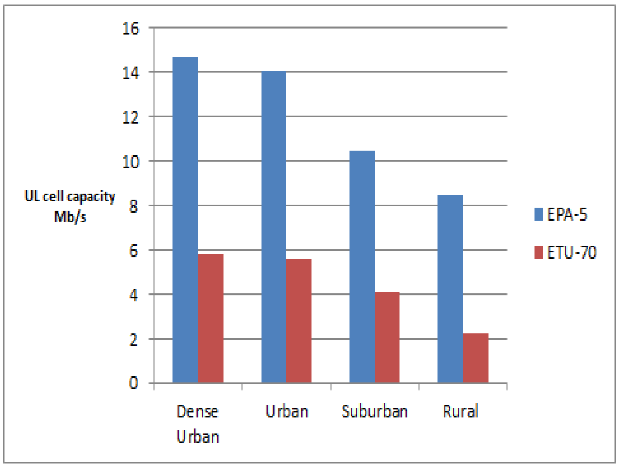

Fig. 8. Uplink cell capacity against channels models

Fig. 7 and Fig. 8 present the effects of channel model on the eNB cell capacity in DL/UL directions. Channel model affects signal-to-noise plus interference (SINR) ratio required at the receiver. When EPA model is used, it means 5Hz Doppler spread and low speed mobiles, this mean low fast fading, if ETU channel model is used, it means that the average Doppler spread about 70 Hz and mobile speed is larger than 30 Km/h. this means high fast fading which decrease SINR. This means low cell capacity.

Fig. 9, and 10 describe the relation among the downlink, and uplink spectral efficiency, network bandwidth, and inert-site distance (ISD). The figures show that the spectrum efficiency increased with increasing the system bandwidth, this effect is result of the scheduling gain which increases with bandwidth.

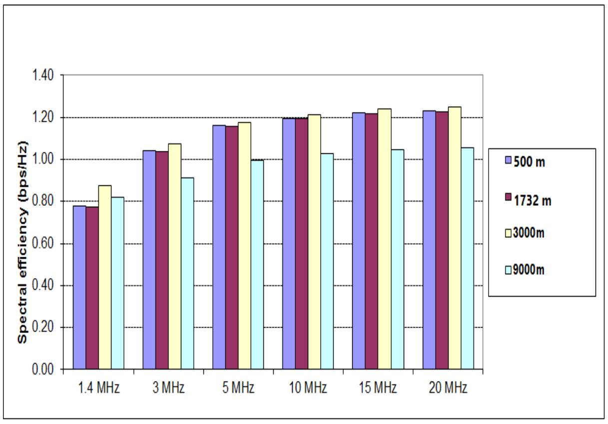

Fig. 9. Downlink spectral efficiency vs. BW and ISD

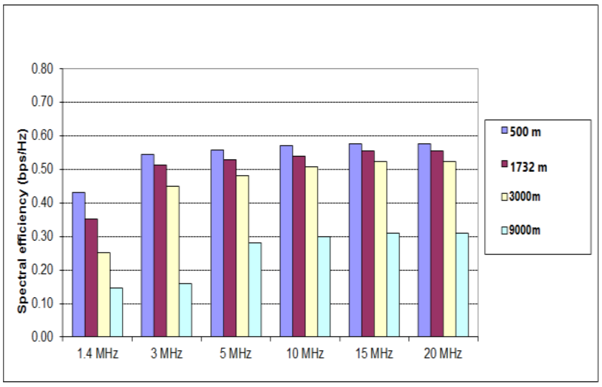

Fig. 10. Uplink spectral efficiency vs. BW and ISD

VI. CONCLUSION

LTE network provides very high rates and capacities comparing with the previous mobile technologies. But actually, the mobile network capacity depends on many parameters in like operating frequency, system bandwidth, neighbor load, clutter types, cell range, control channel overhead, and many others. In the paper we present the relation of changing these parameters with the eNB cell capacity. The study goal is to get the relations and values of the different parameters which give the best capacity. The study declares that with increasing the neighbor load in Dense-Urban and Urban clutter, the cell throughput is decreased. Also operating in large system bandwidth is preferred compared with small bandwidth.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Haider. M. T. ALHILFI conducted the research and wrote the paper; MUTHANNA JAAFAR ABBAS analyzed the data of the paper. Both authors had approved the final version.

REFERENCES

[1] C. C. Lin, K. Sandrasegaran, H. A. M. Ramli, and R. Basukala, "Optimized performance evaluation of lte hard handover algorithm with average rsrp constraint," *International Journal of Wireless & Mobile Networks (IJWMN)*, vol. 3, no. 2, pp. 1-16, April 2011.

[2] R. M. P. D. S. Gameiro, "Performance comparison of voice communications between VoLTE and UMTS/GSM," MSc. thesis, Universidade de Lisboa November 2015.

[3] Y. Zakaria and L. Ivanek, "Performance evaluation of UE location techniques in LTE networks," *American Journal of Applied Sciences*, vol. 14, no. 1, pp. 81-89, 2017.

[4] LTE frequency ranges. [Online]. Available: https://en.wikipedia.org/wiki/LTE_frequency_bands

[5] K. C. Silva, J. P. L. Araújo, and C. R. L. Francês, "A performance evaluation of WLAN-Femtocell-LTE beyond the capacity crunch. Does femtocell have to overcome WLAN or can they coexist in HetNets?" *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, vol. 15, no. 4, pp. 402-417.

[6] K. Riyazuddin and A. K. Sharma, "Performance evaluation of LTE based system parameters using OFDM in indoor and outdoor environment," *Indian Journal of Science and Technology*, vol. 9, no. 48, December 2016.

[7] Y. Barayan and I. Kostanic, "Performance evaluation of proportional fairness scheduling in LTE," in *Proc. World Congress on Engineering and Computer Science*, 2013, pp. 713-717.

[8] A. J. Jameel and M. M. Shafiei, "QoS performance evaluation of voice over LTE network," *Journal of Electrical & Electronic Systems*, vol. 6, no. 1, 2017.

[9] G. C. Eze, L. S. Ezema, H. O. Orah, and E. Onuekwusi, "Performance evaluation of multi-antenna techniques in Long Term Evolution (LTE) networks," *International Journal of Scientific & Engineering Research*, vol. 7, no. 9, pp. 1615-1622, September 2016.

[10] M. R. Tabany and C. G. Guy, "An end-to-end QoS performance evaluation of VoLTE in 4G E-UTRAN-based wireless networks," in *Proc. Tenth International Conference on Wireless and Mobile Communications*, 2014, pp. 90-97.

[11] S. Ansari and R. Gupta, "Evaluate performance of voice over LTE networks using voice codec's," *International Journal of Science, Engineering and Technology Research (IJSETR)*, vol. 5, no. 5, pp. 1500-1507, May 2016.

[12] Y. Labyd, M. Moughit, A. D. Marzouk, and A. D. H. Qiq, "Performance evaluation for voice over LTE by using G.711 as a codec," *International Journal of Engineering Research & Technology (IJERT)*, vol. 3, no. 10, pp. 758-763, October 2014.

[13] M. Meidlinger and Q. Wang, "Performance evaluation of LTE advanced downlink channel estimators," in *Proc. IWSSIP 2012*, Vienna, Austria, April 2012, pp. 252-255.

[14] Long Term Evolution. [Online]. Available: http://www.lte-bullets.com

[15] R. M. Rao, S. Ha, V. Marojevic, and J. H. Reed, "LTE PHY layer vulnerability analysis and testing using open-source SDR tools," in *Proc. IEEE MILCOM 2017*, Oct. 2017.

[16] S. S. A. Abbas, M. B. S. Mary, J. R. Nisha, and S. J. Thiruvengadam, "Implementation of pipelined architecture for physical downlink channels of 3gpplte," *International Journal of Next-Generation Networks (IJNGN)*, vol. 5, no. 1, March 2013.

[17] A. Z. Yonis and M. F. L. Abdullah, "Downlink and uplink physical channels in long term evolution," *I. J. Information Technology and Computer Science*, vol. 11, pp. 1-10, 2012.

[18] R. F. Chisab and C. K. Shukla, "Performance evaluation of 4G-LTE-SCFDMA scheme under SUI and ITU channel models," *International Journal of Engineering & Technology*, vol. 14, no. 1, pp. 58-69.

[19] Channel Models. [Online]. Available: https://www.mathworks.com/help/lte/ug/propagation-channel-models.html

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