Journal of Electronics and Informatics (ISSN: 2582-3825)
www.irojournals.com/iroei/

5G Coverage Planning for Urban Area at Kathmandu City, Nepal

Nirmala Sharma[1], Subarna Shakya[2]

[1,2]Department of Electronics and Computer Engineering, Institute of Engineering, Tribhuvan University, Kathmandu, Nepal

E-mail: [1]076msice010.nirmala@pcampus.edu.np, [2]drss@ioe.edu.np

Abstract

The excitement about the 5G wireless network has passed. Mobile network operators (MNO) have begun rolling out 5G networks alongside 4G cellular networks in lower frequency and mid-frequency bands (i.e., 3-6 GHz) all over the world. The mid-frequency band can greatly improve the performance of the current network (i.e., 50 MHz–100 MHz). All we know that the wider spectrum can be provided by the high frequency bands which is required to fulfill the greatest bitrates (20 Gb/s), lowest latencies, and constantly increasing capacity demands. The free space propagation loss rapidly increases as we move to higher frequency bands, that will reduce the individual cell site radius to 100 m for the high frequency band from various distances in 4G. To offer consistent 5G coverage, the MNOs will have significant challenges in precisely planning and acquiring these enormous numbers of new cell site locations. This paper describes about the signal characteristics at 800MHz, 1800MHz for 4G and at 700MHz, 2300MHz, 2600MHz, 3500MHz for 5G and the upgradation of 4G towards 5G in the test environment. The 5G Coverage Planning with three sector cells and its SINR Mapping in advance antenna array will be performed to provide better coverage in 5G environments.

Keywords: 4G, 5G, massive MIMO, 5G Coverage Planning, antenna array, SINR Mapping, millimeter-wave

1. Introduction

We all know that every year mobile users want faster throughputs and quality of service (QoS) must be high. The launch of 5G opens up opportunities for numerous economic sectors to grow. High speed (for transferring more data), decreased latency (for better responsiveness), and the ability to connect more devices simultaneously are all advantages of

DOI: https://doi.org/10.36548/jei.2022.3.004
Received: 20.07.2022, received in revised form: 16 .08.2022, accepted: 28.08.2022, published: 08.09.2022

5G technology (for sensors and smart devices)[1]. Fifth-generation network technology, in conjunction with artificial intelligence and the Internet of Things, will be employed in many aspects of life. 5G provides high data rates with an integrated network capability along with an expanded converage into all mobilecommunication system equipment.

In 5G wireless networks, the design of network congestion or densification is extensive, with a New Radio (NR) designed for the updated frequency bands like millimeter wave. Coverage of 5G is limited when it is implemented with mm-wave. As a result, network congestion or densification is required. New access technologies offer deployment flexibility with a larger backbone capacity. For an efficient network, a combination of optical backhaul along with a wireless front end is desgined to make a hybrid optical wireless access network. Massive MIMO antennas in 5G ultra-dense cellular networks allow wireless cellular connections to be dispersed. Massive MIMO technology's main purpose is to utilize all of the benefits of classic MIMO technology in a broader context that is energy efficient, resilient, secure, and spectrum efficient[2]

Studies on millimeter wave (mmWave) antennas and propagation are critical for 5G wireless communications to attain the requisite coverage of mobile systems. The ray tracing method has been used to predict wave propagation for wireless communications with great success[3].

Previously, Nepal Telecom has announced to launch the country's first 5G technology trials on June 2022 if everything goes as per planned by the operator. Unfortunately, the 5G trial was not performed as per the plan by the Nepal Telecom and it will be performed very soon if everything goes well. According to Nepalitelecom.com, NT has been granted permission to test services in the 2600MHz band for up to a year. In present conditions calculating the signal behavior for a specific frequency would be useful for frequency-territorial planning at 5G infrastructure. Appropriate modeling of radio wave propagation in metropolitan environments, where the density and of the storeys count are constantly rising, becomes a primary issue in conjunction with the active adoption of new broadcasting and communication systems for diverse reasons[1].

On the one hand, mmWave has a vast spectrum and allows the incorporation of huge number of antennas in a small space for achieving a high antenna gain[4]. On the other hand, mmWave communication has significant disadvantages, including increased Path Loss (PL), weak penetrating properties, high foliage loss in dense vegetation, and strong air absorption at certain mmWave frequencies, among others. Fortunately, atmosphere absorption is almost non-existent at the 26 GHz frequency of operation, whereas atmospheric absorption loss at 60 GHzis roughly 20 dB/km[4].

1.1 Problem Statement

Users of fifth-generation (5G) mobile networks could expect high throughputs and ultra-low latency networks, as well as a large number of devices connected to the network. However, there is high population density in urban areas and it is must to provide coverage in urban areas so that all the people living in the dense area will get access to the internet. To address this problem, one method is to map SINR for a 5G urban macro-cell where user density is very much high and also traffic load is very much high. Also using three-dimensional ray tracing, we can know the optimum coverage of the urban dense area.

2. Related Work

A significant amount of research has been done for urban areas in order to provide betterservices to urban people where there is high traffic load and population density is also very much high. Many of these researches are based on MIMO.

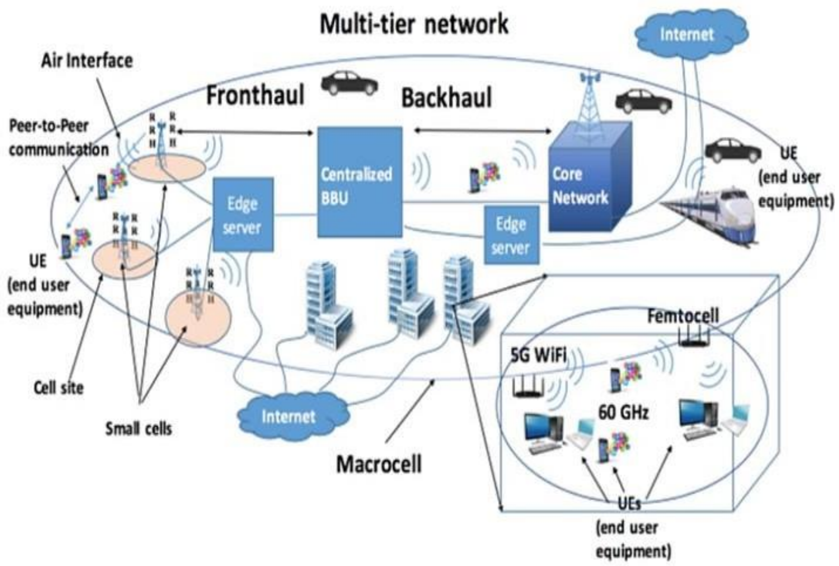

Figure 1. 5G with multi-tier architecture [2]

The architecture of a 5G network is depicted in Figure 1, which includes a macro-cell along with Remote Radio Heads (RRHs), user equipment (UEs), small cells, Base Band Unit (BBU), with its Core Network. Small cells have been acknowledged as a key advancement in 5G networks, but they aren't the only base stations that will deliver 5G connectivity.

In comparison to small cells, high-frequency millimeter wave (mmwave) capabilities, 5G networks will utilize macro cells such as cell towers for connectivity and these larger base stations will enable to lower 5G frequencies. As indicated in Figure 1, fronthaul is connected between the BBU and the RRH on both ways whereas, backhaul is connected in the sameway between the core network and BBU. A digital radio-over-fiber (DRoF) connection transmits the baseband signal digital form from BBU to RRH[5]. The RRH converts the uplink signal received radio frequency (RF) from the UE into a digital baseband signal. The entire macro area network (MAN) is segregatedinto microcells (MCs), then each of the microcell is further segregated into smaller cells (SCs) to achieve full network coverage[5]. Small cells are superimposed on the top of macrocells, resulting in a multi-tiered network structure.

Densification minimizes the burden of individual BSs, whereas dense tiny cells minimizes the communication end to end delay. It also improves the energy efficiency because the BSs use less power over the macrocells.

At mmWave frequencies, propagation properties differ from those below 6 GHz, which has a substantial impact on system design efforts. Where there is dense vegetation, mmwave transmission can suffer severe attenuation along with narrow transmitter and also receiver beams which diminish angular and Doppler spreads. As a result, new air interface designs for wireless systems operating in the mmWave bands will be required to fit the unique propagation characteristics of mmWave channels. While several 3GPP models, such as the WINNER II[6] and 3GPP SCM[7] , are being built based on the architecture of models below 6 GHz, those models were developed under a tight deadline and do not reflect all of the important features ofmmWave channels.

3. Proposed Work

The coverage of the network may be defined as the area surrounding its cell site and base station in which the user allowed to request for any service and it will be forwarded to that cell site for getting the requested service. The radius of the cell is calculated as the maximum distance between the user and cell site from which the user can transmit and receive requests without interruption.

First of all, the real time dataset for 4G networks are taken from one of the Telecommunication Operators of Nepal. Here real time 4G subscriber’s dataset is used from Nepal Telecom. We experiment on the urban dense area of Kathmandu City, Nepal for 4G coverage in the existing network and compared the data with the real time dataset of Nepal Telecom. After the 4G coverage is preformed, we build our test environment for 5G on the same area which was taken for 4G coverage so that to plan the upgradation of existing network 4G towards the Next Generation Network which is 5G in our case.

The UE reports the received power level using the RSRP (Reference Signal Received Power) number. The power of the received reference signal which is from the eNodeB determines the RSRP, which is defined with a 1 dBm step in a range in between -140 dBm to -44 dBm. RSRQ (Reference Signal Received Quality) is a result of the formula(i), where N is the number of used resource blocks (PRBs) and RSSI (Received Signal Strength Indicator) represents the all of the received power by the UE in which interfering signals are also included[8].

$$RSRQ = N\ \frac{RSRP}{RSSI} \quad (1)$$

Table 1. Relationship between RSRP, RSRQ and SINR [11]

RF Conditions	**RSRP [dBm]**	**RSRQ [dB]**	**SINR [dB]**
Excellent	≥ -80	≥ -10	≥ 20
Good	-80 to -90	-10 to -15	13 to 20
Mid Cell	-90 to -100	-15 to -20	0 to 100
Cell Edge	≤ -100	≤ -20	≤ 0

The RF link budget represents the equation which accounts the gain of the power and losses that an RF signal experiences as it travels from a transmitter to its receiver. Hence it is used to figure out how much received signal power is needed to get a good signal-to-noise ratio (SNR) when the signal arrives at the receiver.The following equation (v) represents the RF linkbudget.

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{RX} \quad (2)$$

Here, the received signal power (dBm) is P_{RX}, and the sent signal power (dBm) is P_{TX} (dBm). G_{TX} (dBi) and G_{RX} (dBi) represent the antenna gains of transmitter and receiver respectively. L_{TX} (dB) and L_{RX} (dB) are losses related with transmitters and receivers, respectively (e.g., loss at feeder, loss at cable and loss at connection, etc.). The free space pathloss is given by L_{FS}. Also (dB) is used to represent all remaining miscellaneous losses such as atmospheric loss, body loss, fading margin, polarization mismatch, etc. The pathloss ofthe urban dense area can be calculated as below[9]:

$$PL = PL_b + PL_{tw} + PL_{in} + (0, \sigma^2{}_p) \tag{3}$$

Where,

PL_b refers to the basic outdoor Pathloss

PL_{tw} refers the Outdoor-To-Indoor (O2I) building penetration loss

PL_{in} refers the inside loss dependent on the depth into the building

σ_p refers the standard deviation for the penetration loss

The SINR of the urban dense area can be calculated using the formula of given equation 4 [9]:

$$SINR = \frac{P^R}{1+N} \tag{4}$$

Where,

P^R represent the received power

I represent the sum of interference powers andN represent the noise power

Table 2. 5G NR Frequency Bands for Simulation [10]

Band	Duplex Mode	Frequency (MHz)	Common Name	Frequency Range (MHz)	Channel Bandwidth (MHz)
n12	FDD	700	Lower SMH	UL(699-716) DL(729 – 746)	15
n40	TDD	2300	S-Band	2300-2400	100
n7	FDD	2600	IMT-E	UL(2500 –2570) DL(2620 –2690)	50
n78	TDD	3500	C-Band	3300 – 3800	100

Table 3. Parameters used in simulation for 5G Coverage and SINR

5G Design Parameters	Corresponding Values
Operational Frequencies	700MHz, 2300MHz, 2600MHz, 3500MHz
Bandwidths	15MHz, 100MHz, 50MHz, 100MHz

Antenna Height of BS	25m
Transmit Power of BS	44dBm
Antenna Gain of BS	10dBi
Noise Figure of BS antenna	7dB
Height of Receiver	1.5m
Noise Figure of Receiver	7dB
Gain of Receiver	8dBi
Number of cell sites	19
Inter-Site Distance	200m

The flowchart of the given model is as shown below:

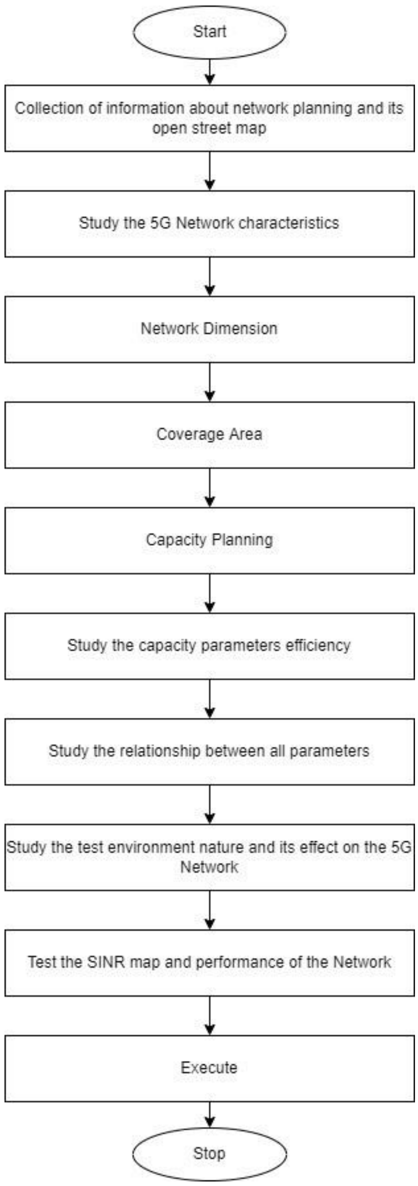

Figure 2. 5G Urban Area Network Planning Diagram

First of all, the collection of information about the network planning for 4G is done using Nepal Telecom dataset and the test environment is taken from the open street map. After that we study the 5G network characteristics on that area along with the network dimension and its coverage area. Now the capacity planning is performed.

We also study the efficiency of the capacity parameters and relationship between all theother parameters. After that we study the test environment nature and its effect on the 5G network. Now we test the SINR map and performance of the network. Finally, we get our resultsin the tested environment.

4. Results and Discussion

ATOLL Version 3.3.2 is used for the simulation of 4G while MATLAB 2021a is used for the simulation of 5G.

4.1 4G Analysis

Using the dataset of Nepal Telecom, the sites and transmitters are plotted in the open street map which is shown as below.

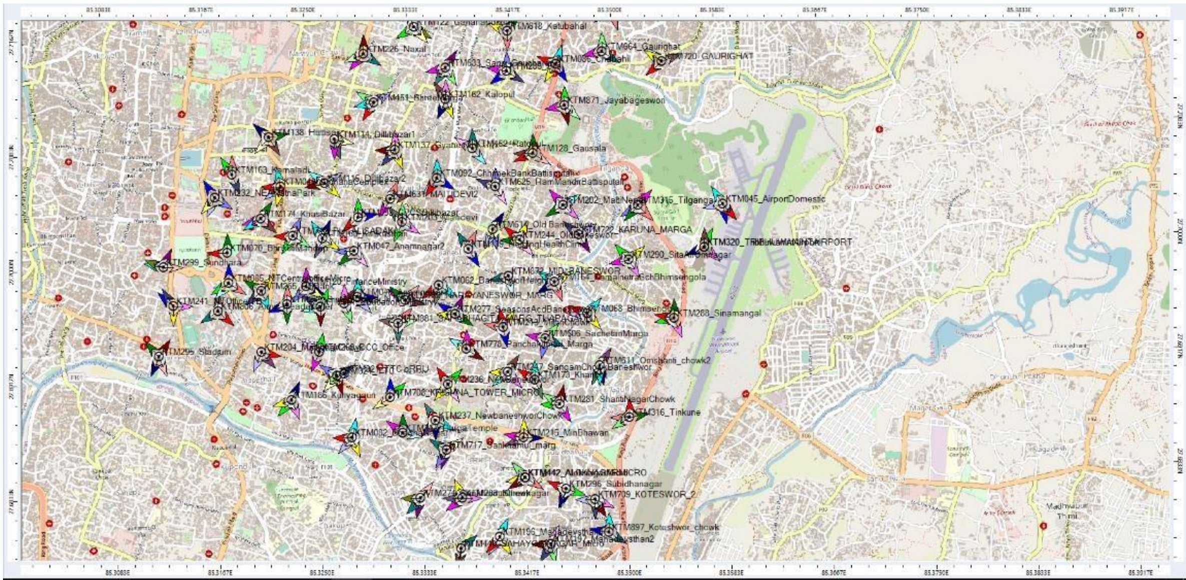

Figure 3. Plotting for 4G Sites and Transmitters

After the sites and transmitters are plotted, now the plotting of the coverage for the 4G on frequency of 800MHz and 1800MHz are done. The area covered by 4G on the frequency of 800MHz and 1800MHz can be illustrated as in Figure 6 and Figure 7 respectively.

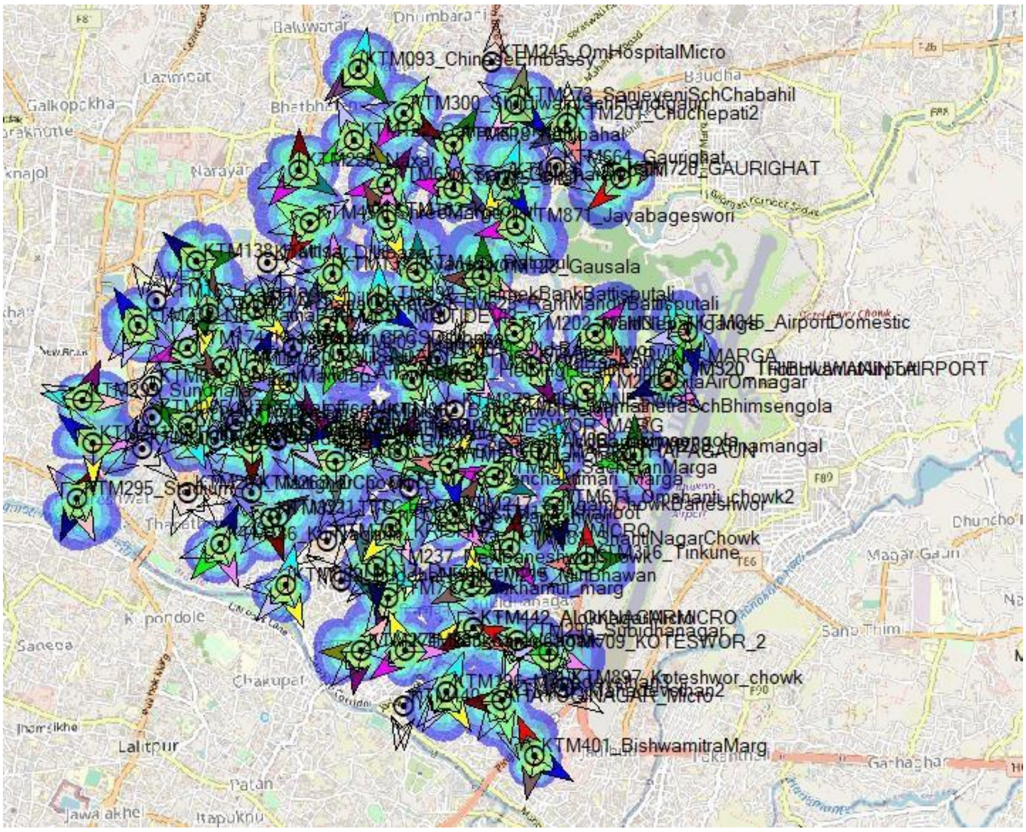

Figure 4. 800MHz 4G Coverage by Downlink

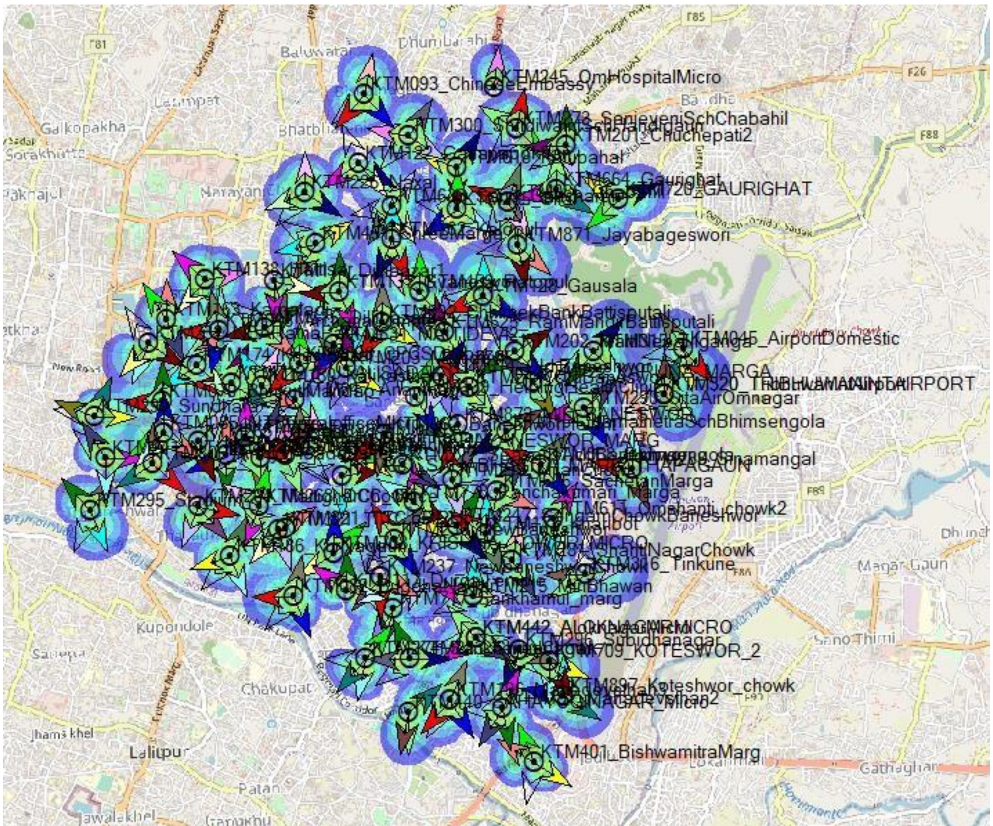

Figure 5. 1800MHz 4G Coverage by Downlink

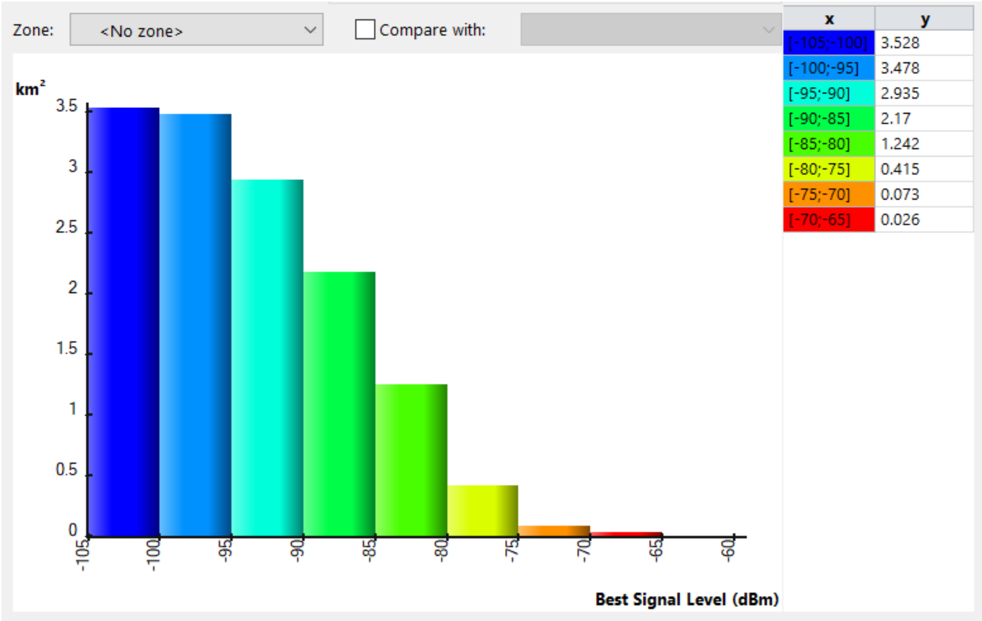

Figure 6. Area Covered by Downlink Signal at 800MHz

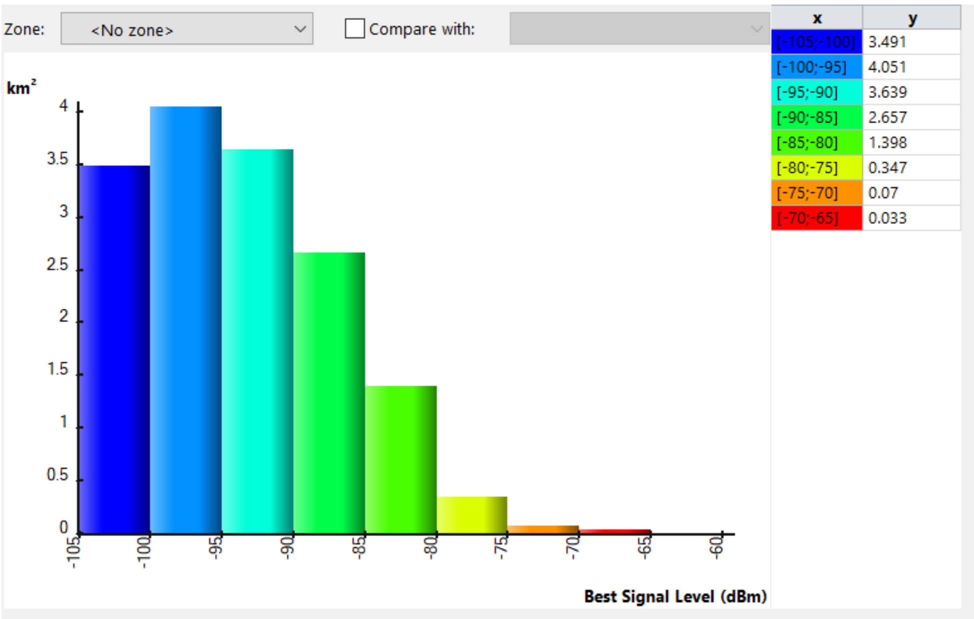

Figure 7. Area Covered by Downlink at 1800MHz

The area of coverage by 800MHZ is 3.5sqKm and by 1800 MHz is 4sqKm with the bestsignal level by 1800MHz than that of 800MHz.

4.2 5G Analysis

SINR mapping on the given test environment is done. Using Table 2 and Table 3 for 5Gcoverage and SINR mapping, firstly 19 cell are created in the given test environment.Here cellsector angles are taken at 30, 150 and 270 degree.

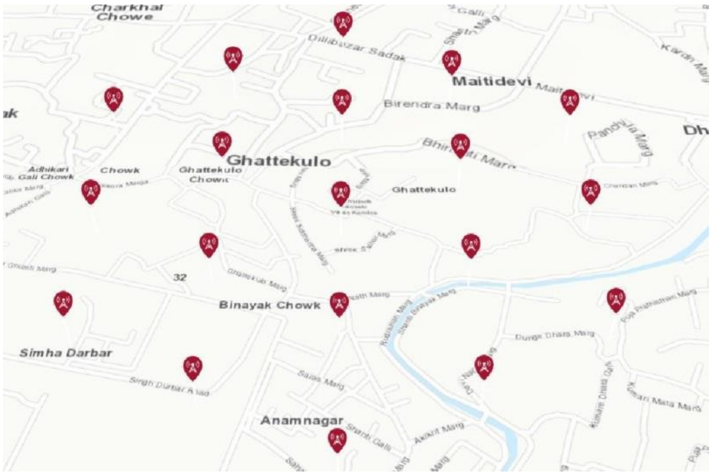

Figure 8. Network Layout with Cell Parameters for Transmitter Sites for 5G

After the 19 transmitters are created, we now create antenna element using phased array system for single antenna element and rectangluar antenna element for 8*8 array and 16*16 array.

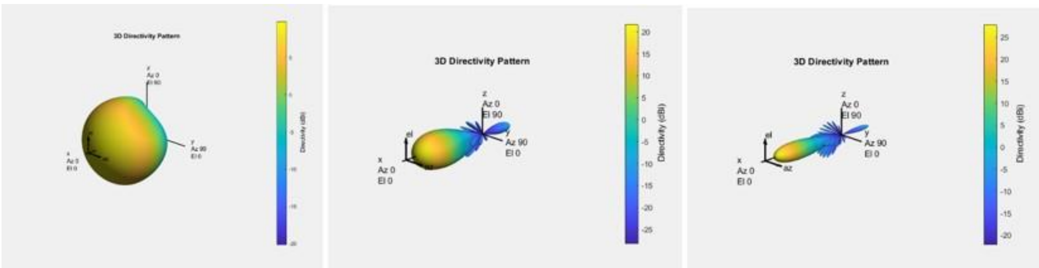

Figure 9. 3D Directivity Pattern for Single Antenna,8*8 and 16*16 Rectangular Antenna

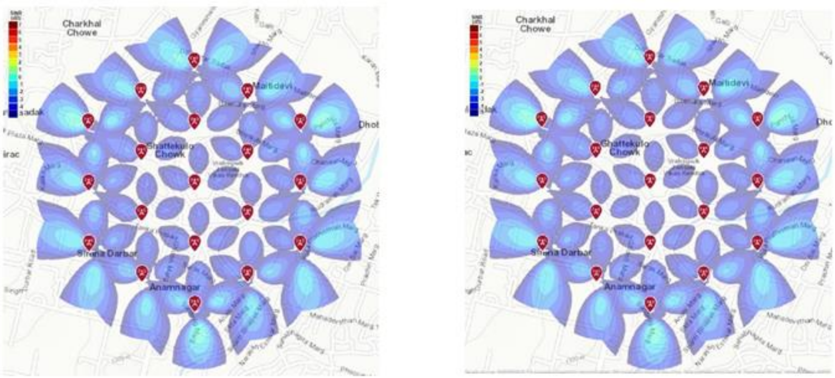

Figure 10. 700MHz left and 2300MHz right side Output 5G Network Coverage and SINR Map for Single Antenna

Now the visualization of SINR mapping for the single antenna element at different frequencies 700MHz, 2300MHz, 2600MHz and 3500MHz are done in the test environment andthe free space propagation model is used.

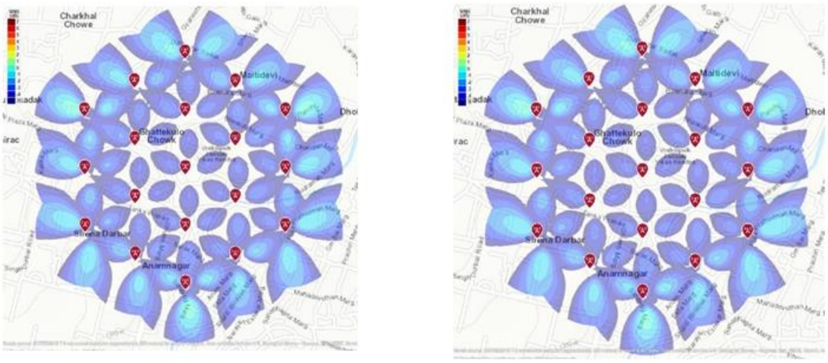

Figure 11. 2600MHz left and 3500MHz right side Output 5G Network Coverage and SINR Map for Single Antenna

Now, we can conclude that the SINR for single antenna is very much less. Thus, the coverage is also be very much less. So, to improve the SINR mapping, we check it by rectangular antenna array of 8*8 and 16*16 and we will be able to know using which rectangular antenna array does the optimum SINR will be obtained.

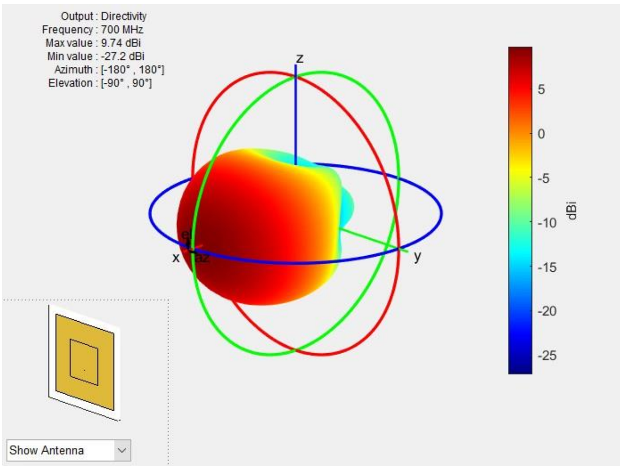

Figure 12. 700MHz 3D Directivity Pattern Rectangular Antenna Array for 8 by 8

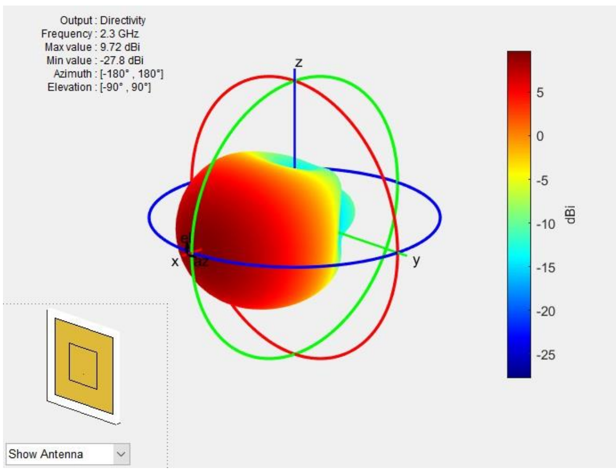

Figure 13. 2300MHz 3D Directivity Pattern Rectangular Antenna Array for 8 by 8

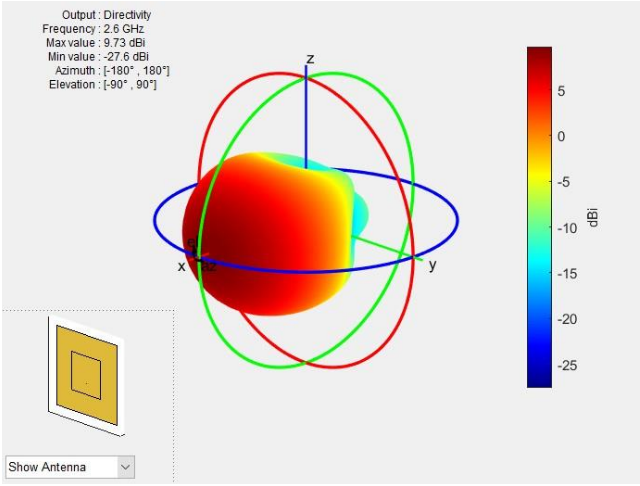

Figure 14. 2600MHz 3D Directivity Pattern Rectangular Antenna Array for 8 by 8

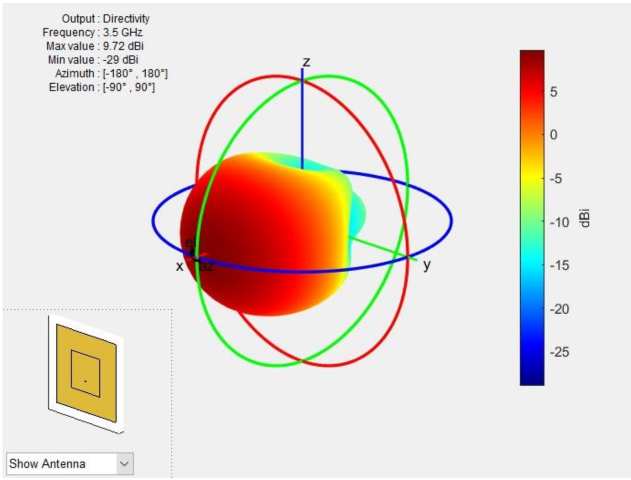

Figure 15. 3500MHz 3D Directivity Pattern Rectangular Antenna Array for 8 by 8

We can have analysis that the power is more when 8 by 8 antenna is used and thus the coverage must also be more than that of single antenna.

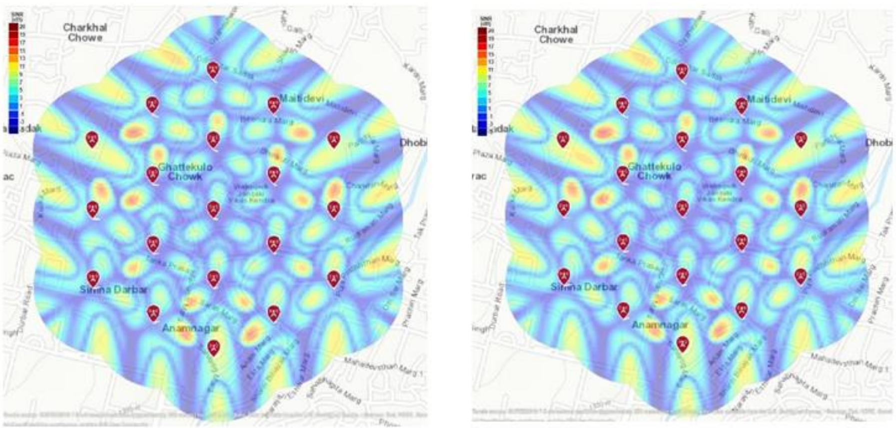

Figure 16. 700MHz left and 2300MHz right side Output 5G Network Coverage and SINR Map for 8 by 8 Antenna Array

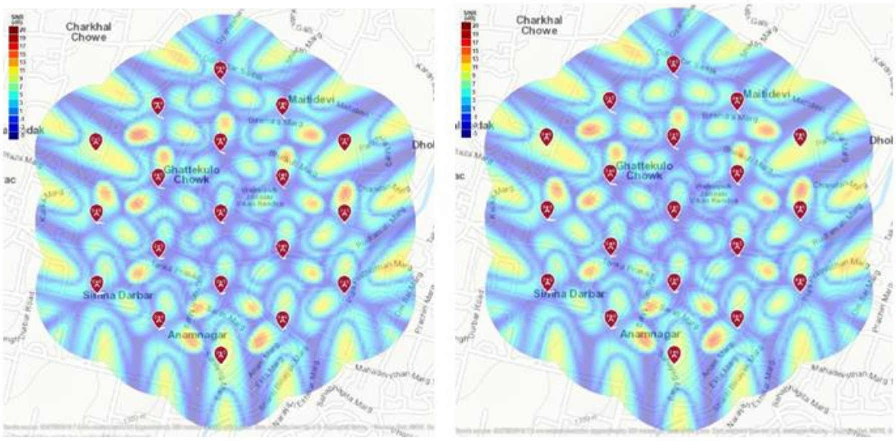

Figure 17. 2600MHz left and 3500MHz right side Output 5G Network Coverage and SINR Map for 8 by 8 Antenna Array

Now, let us look at SINR mapping of 16 by 16 antenna array and its coverage.

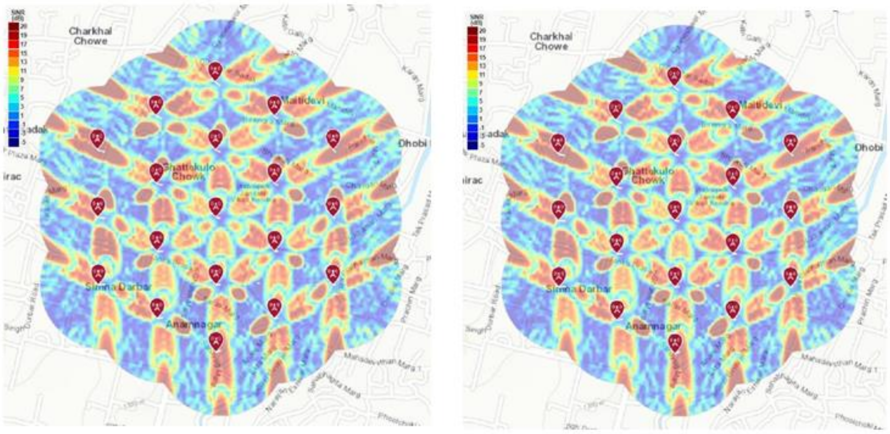

Figure 18. 700MHz left and 2300MHz right side Output 5G Network Coverage and SINR Map for 16 by 16 Antenna Array

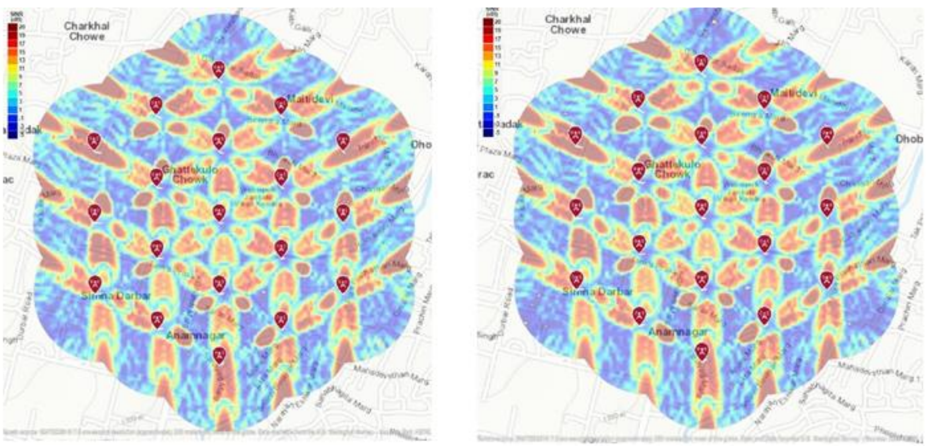

Figure 19. 2600MHz left and 3500MHz right side Output 5G Network Coverage and SINR Map for 16 by 16 Antenna Array

5. Conclusion

We can conclude that using antenna array of 16 by 16 maximum SINR can be obtained thus the coverage will also be very much high in the higher frequency spectrum. Maximum power is delivered at 700MHz frequency. Thus, in context of Nepal, we can use 700MHz frequency for network planning of 5G so that to cover optimum range in the existing 4G environment and the cell should be planned in such a way that there is no interference. Also, we came to conclusion that using 16 by 16 antenna array, the optimum range is covered. This research also discusses the difficulties that must be overcome for a quicker rollout of the 5G network, such as accurate cell site design, acquiring thousands of new cell site locations, backhaul, energy efficiency, etc.

References

[1] Institute of Electrical and Electronics Engineers, 2019 Radiation and Scattering of Electromagnetic Waves, RSEMW : conference proceedings : Divnomorskoe, Krasnodar Region, Russia, June 24-28, 2019.

[2] 2019 First International Conference of Intelligent Computing and Engineering (ICOICE). IEEE.

[3] C. Antennas and Propagation Society. International Symposium 2017 San Diego, Antennas and Propagation Society, Institute of Electrical and Electronics Engineers, Calif. IEEE Antennas and Propagation Society International Symposium 2017.07.09-14 San Diego, Calif. IEEE International Symposium on Antennas and Propagation 2017.07.09-14 San Diego, and Calif. AP-S Symposium 2017.07.09-14 San Diego, 2017 IEEE Antennas and Propagation Society International Symposium proceedings : July 9-14, 2017, Manchester Grand Hyatt, San Diego, California, USA.

[4] Saba, Norshahida, Lauri Mela, Muhammad Usman Sheikh, Kalle Ruttik, Jari Salo, and Riku Jäntti. "Measurements at 5G commercial 26 GHz frequency with above and on rooftop level antenna masts in urban environment." In 2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring), pp. 1-5. IEEE, 2021.

[5] Tahir, Sabeen. "A novel architecture for 5G ultra dense heterogeneous cellular network." International Journal of Advanced Computer Science and Applications 9, no. 11 (2018).

[6] Kyösti, P., J. Meinilä, L. Hentilä, X. Zhao, T. Jämsä, C. Schneider, M. Narandzić et al. "Winner II channel models, part I channel models." *Information Society Technologies, Tech. Rep. IST-4-027756 WINNER II D* 1 (2007).

[7] Mondal, Bishwarup, Timothy A. Thomas, Eugene Visotsky, Frederick W. Vook, Amitava Ghosh, Young-Han Nam, Yang Li et al. "3D channel model in 3GPP." *IEEE Communications Magazine* 53, no. 3 (2015): 16-23.

[8] "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management (3GPP TS 36.133 version 8.9.0 Release 8)," 2010. [Online]. Available: http://portal.etsi.org/chaircor/ETSI_support.asp

[9] "3 rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on channel model for frequencies from 0.5 to 100 GHz (Release 14)," 2017. [Online]. Available: http://www.3gpp.org

[10] "5G NR frequency bands." [Online]. Available: https://en.wikipedia.org/wiki/5G_NR_frequency_bands

[11] Parikh, Jolly, and Anuradha Basu. "Effect of mobility on SINR in long term evolution systems." ICTACT Journal on Communication Technology 7, no. 1 (2016): 1239-1244.

Author's biography

Nirmala Sharma currently pursuing her MSc. Degree in Information and Communication Engineering from Pulchowk Campus, Institute of Engineering, Tribhuvan University.

Subarna Shakya received MSc and PhD degrees in Computer Engineering from the Lviv Polytechnic National University, Ukraine, in 1996 and 2000, respectively. Currently, he is a professor at the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University. His research interest includes e-government system, distributed and cloud computing, and software engineering and information system, Deep Learning, and Data Science.