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Analysis of 5G Capacity in Line-Of-Sight Condition of Urban Macro (UMa) Scenario Using 3.5 GHz Frequency

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Abstract

This study is projected to be the initial design for the implementation of 5G technology, particularly in the Urban Macro (UMa) scenario, with a frequency of 3.5GHz, bandwidth of 100 MHz in various cluster size. We perform capacity calculations for users at random locations accessing the 5G gNB (Base station) at the center of cell. According to the simulation result, this study demonstrates that capacity is dependent on user location arrangement and the cluster size applied. The cluster size, N = 3 yields a capacity of 1,1 Gbps for the user nearest to the gNB and 0,4 Gbps for the user farthest from the gNB. Meanwhile, the cluster size N = 7 yields a capacity of 0.5 Gbps when the user is closest to the gNB and 0.2 Gbps when the user is farthest away from the gNB. In this simulation is also proven that increasing SNR increases capacity. The smallest cluster size increases bandwidth efficiency and yields more optimum capacity. Furthermore, distributing users near the gNB will boost capacity.

Keywords: 5G, Capacity, User location, Cluster size, Urban Macro.

1. Introduction

Globally, telecommunications service companies are pursuing 5G technology. The borders between the physical and digital worlds are blurred by this fifth generation of telecommunication technology. Long-Term Evolution-Advanced (5G) wireless technology serves to increase capacity and speed quicker than the advancement of existing technology (4G standard). Additionally, it offers very high data rates of up to 1 Gbps downstream and 500 Mbps upstream with very low latency[1]

The Working Party 5D (WP 5D) conference was held in San Diego, California, where ITU-R officially announced IMT 2020 as the name of the fifth generation of mobile communications. In terms of quicker data transfers, 5G mobile technology offers an edge over the previous generation. With extraordinary speeds of up to 20 Gbps, this generation is also said to be more energy-efficient than the previous generation. The development of the Internet of Things is also anticipated to be impacted by the presence of 5G. (IoT)[2]. Because the issue provided by the development of cellular technology is the increase in data traffic volume, 5G New Radio (NR), also known as IMT-2020, is anticipated to transport high-capacity data more quickly and generate more mobile data traffic connected to more devices. Because of this, the telecoms sector and mobile carriers anticipate that 5G will fulfill the demands of high traffic volume density, connection density, and mobility. Additionally, the development of 5G technology will have a big impact on what the new spectrum demands.

The three main frequency ranges required by 5G technology are low band, mid band, and high band. Low band, or frequencies below 1GHz, are used for coverage, particularly for mMTC applications. The mid band, which has a frequency range of 1 to 6 GHz and a greater bandwidth, is utilized for eMBB and mission-critical applications. High band utilizes frequencies above 24 GHz, which are used for extremely wideband devices[3]. The tools used by mobile operators, which can

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only operate in a specific frequency range, and the frequency band test are two factors that are taken into account when choosing a frequency band. It presents a fresh challenge for the telecom provider to organize everything in accordance with the strategy in order to get the greatest network to serve the clients all the time.

Urban mobility promotes a trend of universal connectivity, and 5G has the capacity to meet the needs of infrastructure systems [4]. The network must guarantee everyone's efficiency, continuity, and effectiveness due to the increasing number of users [5]. The 5G network distinguishes itself from earlier generations due to its high throughput, low latency, greater mobility, ultra-high precision, and wider coverage. The employment of communication and positioning technology is crucial in urban settings when there are many users congregated in a small space. To assess the 5G network and its capabilities in dealing with the obstacles that the urban environment demands, several test presented in [6], [7], [8] were carried out.

The purpose of this study is to evaluate the 5G NR network's capacity in Macro-dense urban areas (UMa). The technique uses technical analysis techniques with a bandwidth of 100 MHz and a capacity frequency of 3.5 GHz. Based on 3GPP 38.901, the propagation model has been standardized. The data evaluated and provided the signal to noise ratio's (SNR) and capacity's values.

2. 5G Overview

2.1. 5G Technology

The previous generation of cellular technology was revolutionized by the new standard known as 5G in the field of telecommunications. 2020 saw the release of the 5G standard, also known as IMT-2020. The telecommunications sector, industrial automation, and public safety will all benefit from 5G technology [9]. To support mobile applications in the future, 5G will demand more bandwidth and throughput. Future 5G mobile applications are divided into three categories as established by the International Telecommunication Union (ITU) in June 2015, as illustrated in Fig. 1. The three types of 5G services each have different bandwidth, latency, mobility, density, and data rate needs [10]

- The ability of mobile broadband to access multimedia material, which are essential components of cellular communication, can be improved with the help of enhanced mobile broadband (eMBB).
- For all connected communications, including the Internet of Things (IoT) and other vertical industries, Massive Machine Type Communication (mMTC) is used.
- Low latency and extremely reliable communication are features of ultra-reliable and low-latency communication (uRLLC). High dependability and low latency are required by, automated driving, telemedicine, smart grids, and others.

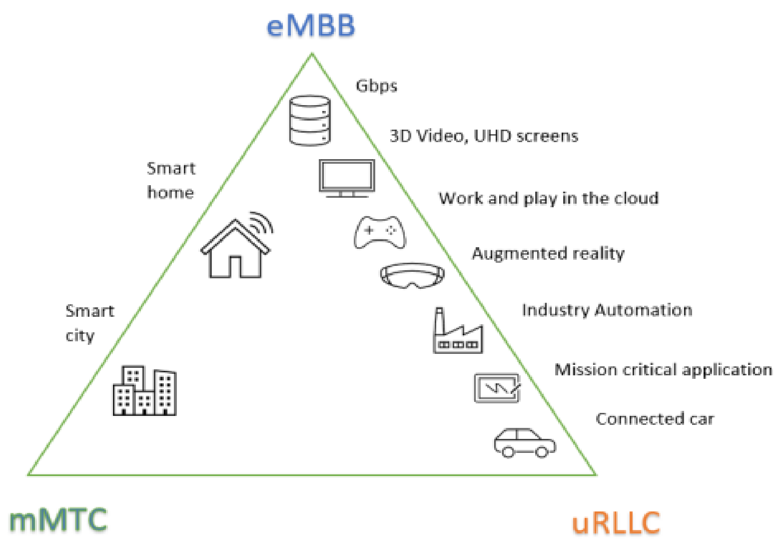

Fig 1. 5G usage scenarios

2.2. 5G Architecture

The significantly more service-oriented 5G NR network architecture, as shown in Fig. 2, includes a detailed system definition from 3GPP. 5NG-RAN is made up of a number of gNB that are connected to 5GC over the NG interface and can operate in FDD, TDD, or dual-modes. The gNB supplies the user NR plane to the user equipment and manages the termination protocol (UE). The ng-eNB gives the UE access to the E-UTRA user plane and manages protocol terminations. Through the Xn interface, the gNB and ng-eNB were connected. The 5GC, specifically the Access and Mobility Management Function (AMF) using the NGC interface and the User Plane Function (UPF) using the NG-U interface, is also connected to the gNB and ng-eNB via the NG interface [11]

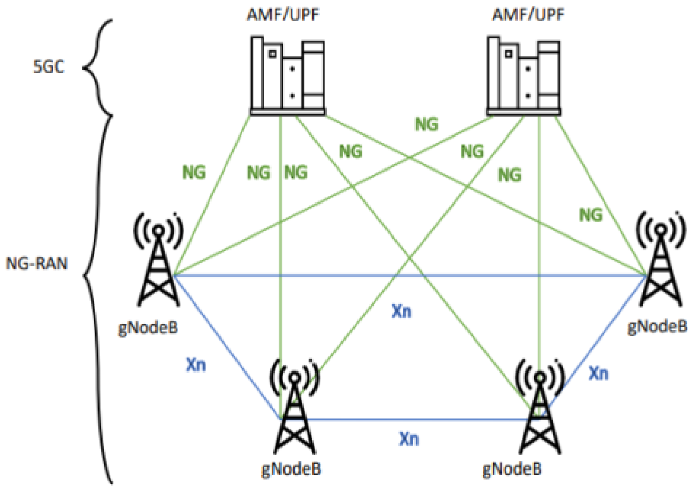

Fig 2. 5G Architecture

2.3 Use case of 5G

2.3.1 Internet of Things

Not only does 5G technology want to link more phones, but it also intends to connect billions of equipment, whether they are in our homes or offices. The most popular machines and devices that can be connected wirelessly and exchange large amounts of data quickly over wireless media are printers, smart watches, and smartphones. Notifications about forthcoming events, pertinent documents, or meeting materials will appear on the user's smartphone.[12]

2.3.2 Massive Machine Type Communications

For machine type communications to provide mobility on demand for only those users who will need it, new cellular network architectures, concepts, and essential network components will be needed. For various IoT services, billions of nodes must be supported by the cellular networks that M2M technologies use. The 5G cellular network is expected to propel a $23 billion surge in the M2M industries by 2023. The rise in popularity of IoT and M2M services is closely related to 5G cellular networks' ability to process large amounts of data, including high-definition photos and machine-operated equipment control systems. Elevating the quantity of linked gadgets contributes to elevating communication to an unprecedented degree [13]

2.3.3 Ultra-Reliable and Low Latency Communication

Future 5G applications will allow for more flexible spectrum usage, including the utilization of frequencies in cellular systems that have never before been used. Robots, virtual reality, self-driving cars, remote surgery, smart cities, and real-time automation are a few examples of uses [14]. The enormous demand for IoT will lead to the creation of several enterprises for 5G networks and large-scale deployments. The industrial Internet of things (IoT) applications and the entire mobile ecosystem will change as a result of technologies like cloud, software-defined networking (SDN), and network function virtualization (NFV), which depend on Ultra-Reliable and Low Latency Communication (URLLC) [15]

3. Research Method

It is essential to take into account a number of important factors while developing a suitable network architecture, such as proper computation capacity planning. In this study, 5G network planning will be done at 3.5 GHz with a 100 MHz bandwidth. link budget estimates utilizing the 3GPP 38.901 UMa propagation model, which is based on the path loss propagation model (Urban Macro). Using the cluster size N = 3 and N = 4, users are distributed at random location from the gNB (gNB) at the center cell.

3.1. Model of Propagation

In comparison to earlier technology, 5G has a distinct propagation mechanism. UMa (Macro dense urban/urban/suburban), RMa (rural macro), and UMi (Micro urban/dense urban) are conditions included in the standard 3GPP propagation model 38.901 used in 5G. The 3GPP 38.901 UMa LOS model's basic equation for propagation is:

$$PL_{UMa-LOS} = 28.0 + 30log(d_{3D}) + 20log_{(fc)} - 9log\,[(d'_{BP})^2 + (h_{BS} - h_{UT})^2] \quad \text{.............................} (1)$$

Were,
$PL_{UMa-LOS}$ = Pathloss (dB)
d_{3D} = Resultant of distance between h_{BS} and h_{UT} (m)
h_{BS} = Antenna Height of gNB (m)
h_{UT} = Transmission user height (m)
f_c = Frequency of carrier (Hz)
d'_{BP} = Breakpoint distance (m)
$d'_{BP} \leq d_{2D} \leq 5000m$
Equation (2) is used to get the value of d_{2D} and (3) to obtain the value of d'_{BP} :

$$d_{2D} = \sqrt{(d_{3D})^2 - (h_{BS} - h_{UT})^2} \quad \text{.....................} (2)$$

$$d'_{BP} = 4 \cdot h'_{BS} \cdot h'_{UT} \cdot \frac{Fc}{c} \quad \text{.....................} (3)$$

Were,
c = Speed of light ($3 \cdot 10^8$) (m/s)
d_{2D} = BS-UT Distance/ Cell Radius (m)
h'_{BS} = Antenna Height of gNB – height of equipment (m)
h'_{UT} = Transmission user height – height of equipment (m)

3.2 Signal to Noise Ratio and Capacity

SNR was described as the ratio of the transmitted signal's strength to the ambient noise. SNR is characterized by.

Signal Noise Ratio (SNR) = $\frac{Pt\,.\,G}{No\,\Delta f}$.. (4)

P_t is the Mobile gNB transmitted power, N_0 is the white noise power spectral density, Δf is the sub carrier spacing. The associated path loss G can be calculated using Equation.

Gain (G) = $10^{-PL/10}$ .... (5)

The path loss PL as mentioned in Equation (1). To measure capacity is calculated by using Shannon equation as follows[16]

C = B $\log_2(1 + SNR)$ .... (6)

4. Results and discussion

In the capacity analysis, the user to gNB distance has a significant impact on the capacity. In addition, the frequency reuse factor applied to the cell also significantly affects the capacity. In this study, users are distributed at random location using cluster size N = 3 and N = 7. In table 1, configuration parameters for the simulation are listed. Experimental parameters based on typical 5G parameters.

Table 1. Simulation Parameters

Parameter	Value
Number of cells	N = 3, N = 7
Cell radius	1000 (m)
gNB Height(hBs)	25 (m)
User terminal height (huT)	2 (m)
Frequency	3.5 GHz
Transmit Power	43 dBm
Bandwidth	100 MHz

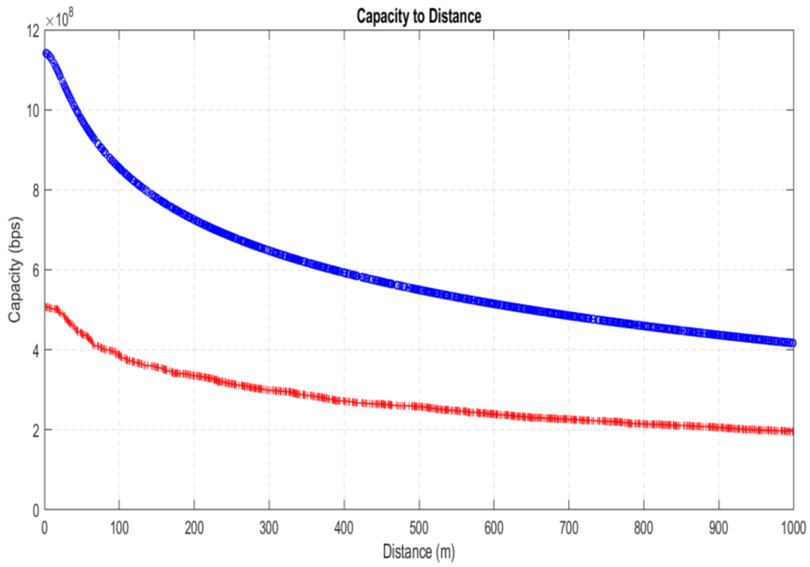

Fig 3. Impact of user location to capacity

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As seen in Fig. 3, system capacity rises as the user gets closer to the gNB. The cluster size N = 3 yields a capacity of 1,1 Gbps for the user nearest to the gNB and 0,4 Gbps for the user farthest from the gNB. Meanwhile, the cluster size N = 7 yields a capacity of 0.5 Gbps when the user is closest to the gNB and 0.2 Gbps when the user is farthest away from the gNB. The closer the user is to the gNB, the lower the pathloss value, which affects the quality of the received signal. According to the simulation results, cluster size N = 3 provides more capacity than cluster size N = 7. This is accomplished because smallest cluster size gives more bandwidth efficiency, resulting in increased system capacity

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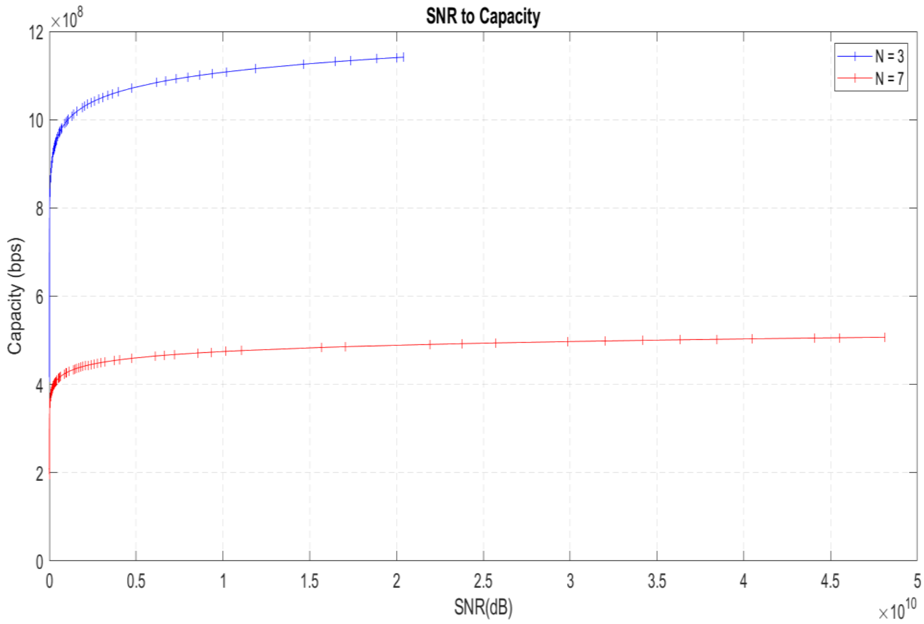

Fig 4. The relation between SNR and Capacity

Fig.4 depicts the relation between SNR and system capacity. In the cluster size N = 3, the greatest SNR value of 2 x 10^{10} dB results system capacity of 1.1 Gbps, while the lowest SNR of 6 x 10^3 dB results capacity of 0.4 Gbps. The capacity of cluster size N = 7 result 0.5 Gbps at the greatest SNR value of 4.8 x 10^{10} dB while lowest SNR 13 x 10^3 result capacity 0.1 Gbps. Based on simulation, increasing SNR has an impact on increasing capacity. Apart from that, the maximum capacity is achieved by smallest cluster size, when the cluster size is N = 3.

5. Conclusion

The continuation of 4th generation (4G) communications technology is the 5th generation (5G), also known as IMT 2020. To prepare for 5G network, a design must be completed while taking numerous criteria into account. The 3.5 GHz frequency spectrum and 100 MHz bandwidth for the 5G Urban Macro (UMa) scenario are computed using a capacity technique in this study. The system capacity is influenced by the user distribution arrangement and the cluster size. According to the simulation result, the smallest cluster size will boost bandwidth efficiency and produce more ideal capacity, as will user distribution close to the gNB.

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