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5G URBAN CELL PLANNING ESTIMATION AND BASE STATION THROUGHPUT DETERMINATION

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ABSTRACT

Operators need to consider several factors that could impact a network's profitability with the increasing demand for 5G wireless telecommunications. These factors include the environment, base station layouts, and frequency scheme patterns. 5G systems promise low-power devices, comparable coverage strategies, high dependability, low latency, and a million-fold increase in scheme capacity over current networks. The first and most crucial step in creating a 5G network and radio network design is to calculate the number of cells in a specific area. To estimate the number of cells, this article utilizes the Radio Link Budget (RLB) computation method to calculate each cell's maximum permitted path losses. Additionally, determining the number of 5G base stations required to cover an area and maximize cell performance adequately necessitates carefully evaluating the center frequency, 3GPP propagation model, maximum permitted route losses, and channel bandwidth. To accomplish this, four different scenarios have been considered, using four different center frequencies, and for each scenario, two 3GPP propagation models (Urban Macro 3D-UMa NLOS and Urban Micro 3D-UMi NLOS) are utilized to find the estimated 5G cell number for an urban area of 4 km2. This article emphasizes the importance of carefully considering several variables, such as the center frequency, 3GPP propagation model, maximum permitted route losses, and channel bandwidth, to ensure reliable signal transmission and reception, high data rates, and efficient utilization of network resources—further the more. The second objective of this article is the 5G new radio throughput calculation, which is essential for determining the sufficient fronthaul link data rate required for planned C-RAN and 5G cell structures.

KEYWORD: *5G cell planning, 3GPP propagation models, Umi, UMa, Radio Link Budget, Pathlosses, 5G throughput.*

INTRODUCTION

The network's throughput and coverage area have significantly improved as a result of the growing demand for 5G wireless telecommunications, which can now support a variety of new applications like mobile phones, multimedia communication, social network connections, internet gaming, video conferencing, e-learning platforms, and e-healthcare systems. In addition to a million times more scheme capacity than present networks, 5G systems offer a wide range of low-power devices, similar coverage strategies, high dependability, and low latency [1]. Operators must consider various variables that may affect the profitability of a wireless cellular network while designing one, including the environment, the anticipated number of users, base station designs, route loss, and frequency scheme patterns. More Radio

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Frequency (RF) bands, including more mm-Wave bands, are anticipated for 5G than for previous mobile generations. Additionally, Massive Multiple-In Multiple-Out (MIMO) antenna technology and hybrid beamforming are essential methods for delivering the highest data rates intended for many users in congested areas [2]. 5G networks' radio access technology does not need to function with previous generations; however, it should be compatible with the device's basic settings, much like prior cellular generations[3]. Therefore, to adopt 5G, the 3G and 4G systems must be integrated as portions of macro-cells rather than being shut down. The 5G access component should be created concurrently employing micro-cell, pico-cell, and femtocells that operate in GHz bands up to 60 GHz. Channel widths up to 1 GHz and access speeds that may theoretically exceed 10 Gbps under superlative conditions should be unitized by the 5G access component [4]. Consequently, a new 5G air interface called 5G NR (New Radio) was developed by 3GPP in release 15 as a wireless industry standard[3].

To fulfill client expectations within a predetermined region and keep internal infrastructure affordable, 5G radio access networks must be planned effectively. Moreover, to shape the design of cells for 5G and future mobile generations, Radio Network Planning (RNP) is crucial [5]. Furthermore, RNP is essential for telecom companies aiming to build wireless cellular networks cheaply. The primary outcomes of RNP involve determining the optimal locations and configurations of base stations to ensure comprehensive network coverage while minimizing costs. This results in mobile devices connecting to a cell at the farthest possible distance while keeping expenses low. Additionally, calculating coverage areas relies on the offered data rates and their corresponding attainable coverage ranges. The maximum data speeds are possible close to the base station. In contrast, the lowest data rates are still reachable at the outer reaches of cell coverage since smaller coverage areas equate to more excellent data rates [6].

Numerous academics have authored informative research papers addressing the intricate aspects of 5G network planning. In the citation[7], the central focus revolves around the future requirements that 5G cellular networks will encounter over the next decade. These demands stem from the increasing need for swifter data transmission, extended network coverage, and an expected surge in wireless access capacity. The authors highlight the substantial advantages that 5G technology is poised to bring to both end-users and various industries. It envisions establishing a "hyper-connected society," characterized by the seamless interconnectivity of individuals and interconnected devices. The article also probes into diverse applications and utilization scenarios of 5G technology, exploring advanced features such as network densification and antenna beamforming, which amplify system mobility and capacity within fifth-generation mobile systems. In addition, the authors cited in [8] want to look into how B5G/6G New Radio (NR) technology is used in a new administrative capital's Knowledge City. This study focuses on the potential and difficulties associated with using this cutting-edge technology in a densely populated metropolitan environment where high data rates are essential for applications related to smart cities. The growth of smart cities is greatly aided by B5G/6G technology, which offers vital connectivity for sensors, data processing, and other key resources. The authors' study emphasizes how technology has the power to alter urban landscapes into entities that are resilient, sustainable, and highly effective. The paper outlines a thorough network planning procedure that considers Knowledge City coverage zones at 2.6 GHz, 3.5 GHz, and 28 GHz. Standardized propagation models, such as Urban Macro (UMa) and Urban Micro (UMi), are used to estimate the link budget for a variety of scenarios, including

Outdoor-To-Outdoor (O2O) scenarios with Line-of-Sight (LOS) circumstances. Additionally, the academics referenced in reference [9] go in-depth on the difficulties associated with 5G network cell design. They offer a useful illustration for calculating the necessary number of cells or base stations in a specific region while considering factors like user counts and the allotted bandwidth per user. This information is very beneficial for pre-sales activity and determining whether additional investments are required. The article presents four situations, each with different network parameters, to show how the required number of base stations varies depending on these circumstances. These hypothetical situations serve as examples of a single 5G network inside a fictitious geographic region, taking user bandwidth allotment into account. It is important to highlight that this study's assumption of a constant cell radius for all situations is one of its limitations. The primary and most vital step in the development of planning of 5G and radio network involves the estimation of the number of cells inside a certain place, which is the first step in the creation of a radio network planning of the 5G network, and our research is centered on this task. The important tool for determining this projected cell count is the Radio Link Budget (RLB) computation, which evaluates the Maximum Allowed Pathlosses (MAPL) for each cell to guarantee a satisfactory level of received power at the R_x about the sensitivity of the receiver. Determining the necessary signal intensity that the receiver must possess, a criterion known as Receiver Sensitivity (S_{RX}), is crucial for the efficient execution of an RLB. S_{RX} is the incoming transmitted signal at which a receiver may be relied upon to perceive and process it [10]. When the signal intensity received at the R_x reaches or surpasses the bar established by the S_{Rx}, the link is said to be successful. Or, to put it another way, the connection is considered to be operating well if the received signal intensity exceeds the minimal threshold demanded by the receiver sensitivity. This shows that the receiver can precisely identify and interpret its received signal, enabling dependable communication and data transmission. The computation of 5G new radio throughput, a crucial component in estimating the required data rate for the anticipated Cloud Radio Access Network (C-RAN) and 5G cell architectures, is the second goal of this study. The contribution of this article lies in highlighting the significance of carefully considering channel bandwidth, maximum allowable path losses, the center frequency, and the 3GPP propagation model. These elements are crucial in accurately predicting the 5G base stations required for optimum coverage in an urban area. Furthermore, the article emphasizes the critical role of channel bandwidth in determining cell throughput. Finally, one specific contribution of this work is the suggested algorithm that automatically determines the gNodeB cell radius based on the 3GPP and IEEE suggested parameters, providing a practical tool for network planners and designers for determining the expected cell radius within the given network information.

1. SENSITIVITY OF THE RECEIVER

The receiver's sensitivity can be affected by various factors, including the desired Bit Error Ratio (BER), the modulation method used, the system's bandwidth, and the acceptable level of noise power (known as the noise floor) produced within the receiver. This sensitivity is typically quantified by indicating how well the receiver can detect weak signals, commonly characterized by the level of the received signal.

Using the following equation, the Sensitivity of the Receiver (S_{RX}) in dBm can be computed [10]:

$$S_{RX} = TN + NF + SINR \quad (1)$$

Wherein:

$S_{RX} = Sensitivity\ of\ the\ Receiver\ \ (dBm)$
$TN = Thermal\ Noise\ (dB)$

$$TN = -174 + 10\ log(\mathrm{BW}) \tag{2}$$

BW=The Signal Bandwidth $in\ Hz$
$NF = Noise\ figure(dB)$
$SINR\ is\ signal - to - noise\ and\ interference\ ratio\ (mesured\ in\ dB)$

2. RADIO LINK BUDGET OF THE FIFTH GENERATION

The RLB plays a pivotal role in establishing the maximum effective range for communication between a transmitter and receiver. It involves intricate calculations considering factors like antenna characteristics, transmitter properties, transmission lines, and the surrounding propagation conditions. Essentially, the link budget assesses the efficiency of communication links, meticulously analyzing all losses and gains occurring throughout the transmission system [10]. In the initial phase of radio network planning of 5G, the primary goal is to estimate the coverage and capacity within the designated area roughly. It turns out that a radio link budget is an effective instrument for reaching this goal. It provides a simple method to assess possible signal losses for uplink (UL) and downlink (DL) broadcasts in various settings. This tool may determine how many base stations will be required to service the intended area. However, a more precise estimate may be generated by adding more precise models and digital maps into a radio network design tool. Adjusting base station locations, power outputs, antenna heights, and other practical aspects can greatly impact deployment costs and ROI. To guarantee a successful deployment, careful radio network planning is necessary, both in the nominal and detailed phases. When using radio network planning tools for complete designs, propagation models and assumptions are frequently enhanced based on actual field testing, leading to specific adjustments for each cluster. To increase 5G coverage and capacity while minimizing deployment costs, effective radio network architecture is crucial [6]. When designing 5G radio networks, the Radio Link Budget (RLB), which accounts for route losses, is of utmost relevance. Adopting a suitable 5G 3D propagation model, as specified in standard 36.873 by the 3rd Generation Partnership Project (3GPP), is required for accurate route loss assessment. These models consider various elements, such as topographical features, building density, and climatic variables. Three different types of 3GPP propagation models are identified: Urban Micro Cell (UMi), Rural Macro Cell (RMa), and Urban Macro Cell (UMa). These models enable the accurate estimation of route losses by thoroughly understanding radio waves' behavior in various situations.

Fig (3) and Fig. 1 explain the connection between the location of the unit terminal and the base station.

$$d_{3D} = \sqrt{(h_{BS} - h_{UT})^2 + {d_{2D}}^2} \tag{3}$$

$Where$:
d_{3D} $represents\ the\ vertical\ separation\ between\ the\ highest\ point\ of\ the\ UT\ and\ the\ base\ station.$
d_{2D} $represent\ radius\ of\ the\ cell\ .$
h_{BS} $represent\ the\ base\ sation\ height$
h_{UT} $represent\ the\ UT\ height.$

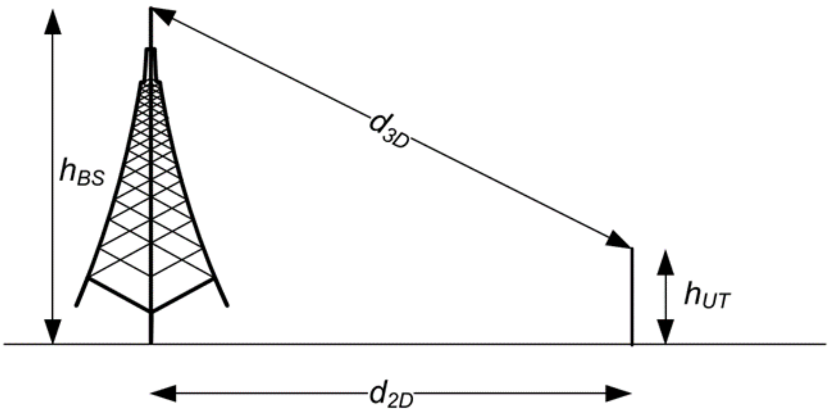

Fig.(1):- The definitions of d2D and d3D about the outdoor unit equipment.

The calculation of PL for two different types of areas under investigation is as follows: (Please note that this study exclusively focuses on urban areas).

3.1 The Urban Macro Cell (UMa) Path Losses:

The path loss of the UMa model takes into account various factors such as distance, frequency, and environmental characteristics, all of which influence signal transmission under these conditions. Path losses (P_L) can be determined through the following equation [11]:

$$P_L = 32.4 + 30log_{10}(d_{3D}) + 20log_{10}(f_c) \quad (4)$$

$Where\ in$:
f_c $represent\ the\ centeral\ frequency\ mesured\ in\ GHz$

In this case , the shadow fading σ_{SF} measured in (dB) equal to $7.8\ dB$ [11]:

3.2 The Urban Micro Cell (UMi)- Street Canyon path losses:

Similar to the PL calculation for UMa, the PL for UMi takes into account the identical variable quantity and can be computed as follows: [4]:

$$P_L = 32.4 + 20log_{10}(f_c) + 31.9log_{10}(d_{3D}) \quad (5)$$

In this case, The shadow fading σ_{SF} measured in (dB) equal to $8.2\ dB$ [11]:

Afterwards, the PL that have been computed are utilized to determine the receiver's Received Signal Levels (RSL). Subsequently, these RSL values are compared to the predefined receiver sensitivity threshold. Links are deemed valid if the received RSL surpasses the receiver sensitivity threshold. Otherwise, they are classified as failed links. This evaluation occurs at a distance denoted as 'd_2D,' corresponding to the point where the link extends beyond the 5G cell radius (R). The RSL at the receiver is then calculated using the provided equation [9]:

$$RSL = P_{Tx} + G_{Tx} + G_{UE} - T_{CL} - R_{CL} - RI_M - I_A - PL - SF_M - PE_L - F_L - BB_L - I_M - PE_{LI} \quad (6)$$

Where in:
RSL represents the Level of the Received Signal Power at the receiving end (measured in dBm)
PL idenotes the Path Losses as per the propagation model (expressed in dB)
Additional details can be found in Table 3 for further clarification.

3.
The Fifth Generation Base Stations Required Number

The required number of fifth-generation base stations depends on various factors like the RLB, receiver sensitivity, and area size. Unlike previous generations, 5G networks usually work on higher frequencies with shorter wavelengths. This allows for faster data transfer but also means that each base station covers a smaller area. To ensure seamless coverage, multiple base stations are often necessary. In densely populated urban areas with many users, buildings, and obstacles, even more base stations might be required to maintain a reliable network capacity and coverage. This is because physical barriers can limit the higher frequency signal bands.

To determine the essential 5G base stations, you first need to calculate the area to be covered (C_a) with a single base station. The following equation, where R stands for the 5G cell radius, can be used to do this:
$C_a$should be calculated as per the formula: [9]:

$$C_a = R^2\pi \quad (7)$$

Eventually, the following equation is utilized to compute the necessary 5G gNodeB stations (N_{5Gs}).[9]:

$$N_{5Gs} = \frac{S_q}{C_a} \quad (8)$$

Where is:
S_q: *The overall cluster surface area*
C_a: *A single gNodeB coverage area*

3. The Fifth Generation Throughput Calculations for New Radio

Compared to the 4G network, the 5G network offers much higher throughput. According to the source, it has a maximum data speed of 20 Gbps and typical transfer rates of more than 100 Mbps [12]. The maximum throughput possible inside the 5G NR network may be determined using the 5G New Radio Throughput equation described in *5G NR(data rate in Mbps)* 3GPP TS 38.306 by users and individual cells. Additionally, throughput estimates are essential for determining the maximum data rate that can be dependably transferred across the fronthaul connection, which helps with C-RAN deployment planning and performance evaluation. To get the data transmission rate for 5G NR, use formula (9) below [13]:

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$$= 10^{-6}.\sum_{j=1}^{J}(v_{Layers}^{(j)}.Q_m^{(j)}.f^{(j)}.R_{max}.\frac{N_{PRB}^{BW(j),\mu}.12}{T_s^{\mu}}.(1-OH^{(j)})) \quad (9)$$

Where:

J : The system decides how many Combination Carriers (CC) are present in a group of bands or a band. The maximum CC that may be used in 5G NR is limited to 16. This restriction exists because adding more CC can increase the bandwidth, enhancing the 5G system's throughput and overall performance.

R_{max}: The value is subject to change depending on the type of coding. In case of LDPC code the highest achievable value is 0.92578125.

$v_{Layers}^{(j)}$: The maximum number of MIMO layers possible is constrained by several factors, including the number of antennas and the specific transmission direction (Downlink or Uplink).

$Q_m^{(j)}$: The quantity of symbols that can be transmitted through a digital communication system is contingent on the modulation order employed.

$f^{(j)}$: The scaling factor is established by the carriers and is employed for scenarios involving high and medium mobility. Its values could be [0.4, 0.75, 0.8, or 1].

$N_{PRB}^{BW(j),\mu}$: Represents the highest Resource Block (RB) within a bandwidth denoted as $BW^{(j)}$ using a specific numerology μ. This information can be found in 5.3 TS 38.101-2 and 5.3 TS 38.101-1.

μ: Represents the numerology mentioned in TS 38.211.

T_s^{μ}: Determined via equation (10), it represents the mean duration of an OFDM symbol within a subframe given the μ value corresponding to a standard cyclic prefix.

$$T_s^{\mu} = \frac{10^{-3}}{14 * 2^{\mu}} \quad (10)$$

$OH^{(j)}$: Adopts the following values for overhead representation.

When it comes to Downlink (DL) in FR1, it stands at 0.14.

When it comes to Downlink (DL) in FR2, it amounts to 0.18.

Regarding Uplink (UL) in FR1, it registers 0.08.

Concerning Uplink (UL) in FR2, it records 0.10.

4. Proposed Parameters of the System:

Establishing specific parameters plays a pivotal role in the 5G network planning procedure, including those parameters utilized for computing RLS (Radio Link Success), path losses, and receiver sensitivity. The ability to precisely define these characteristics enables network planners to choose the best location and configuration for 5G base stations. These parameters are listed below:

6.1 parameters of the Pathlosses, link budget and receiver sensitivity.

To conduct RLB calculations, specific factors are required, including those for determining receiver sensitivity, radio channel characteristics, and path loss computation based on 3GPP propagation models. In this particular case, we employ the Urban Micro 3D-UMi Non-Line of Sight (NLOS) and Urban Macro 3D-UMa NLOS propagation models to accommodate NLOS conditions within an urban region. Tables 1 to 3 include the values of these numerous factors that affect link budget computations. These values were chosen by the relevant 3GPP specifications and IEEE guidelines listed in the cited source [6, 9].

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Table(1): -List of parameters indicating receiver sensitivity.

Parameters	Values
$SINR(dB)$	-10
$Bandwidth\ mesured\ in\ Hz$	10^6
$Noise\ Figur$	7

Table (2):- Parameters related to 3GPP path loss

Parameter	Value
f_c (central frequency)	3.5 GHz
h_{BS} (in UMi Model)	10 m
h_{UT} (in UMi Model)	1.5 m
h_{BS} (in UMa Model)	25 m
h_{UT} (in UMa Model)	1.5 m

Table (3):- List of Parameters for the Link Budget

Parameter	Value
$Tx\ Power\ of\ \ gNB(P_{Tx})\ \ in\ (dBm)$	46
$Gain\ of\ Antenna\ \ (G_{Tx})\ in\ (dB)$	11
$Cable\ Losses\ of\ Rx\ \ (R_{CL})\ in\ (dB)$	0
$Penetration\ Losses\ (PE_L)in\ (dB)$	22
$Interference\ margin\ (I_M)\ in\ (dB)$	3
$Indoor\ Penetration\ Loss\ \ (PE_{LI})in\ (dB)$	0 (Outdoor)
$Slow\ Fading\ Margin(SF_M)\ in\ (dB)$(in UMa Model)	7.8
$Slow\ Fading\ Margin\ \ (SF_M)\ in\ (dB)$(in UMi Model)	8.2
$Ice\ or\ Rain\ Margin\ (RI_M)in\ (dB)$	0
$Indoor\ Attinuation\ (I_A)in\ (dB)$	0
$Cable\ Losses\ of\ gNodeB\ (T_{CL})\ in\ (dB)$	2
$Gain\ of\ Antenna\ \ (G_{UE})in\ (dB)$	0
$Foliage\ Losses\ (F_L)\ in\ (dB)$	7.5
$Body\ Block\ Loss\ (BB_L)\ in\ (dB)$	3

6.2 The parameters for 5G NR Throughput calculations.

The method uses configuration values of carriers within particular bands of frequencies, specifically, 1-30 kHz, 0-15 kHz, and 2-60 kHz, to calculate the magnitude of the subcarriers (µ parameter). According to 3GPP 38.211, a subcarrier size of 30 kHz is used in this specific

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instance. Additionally, reference is used to determine the amount of resource blocks [14]. Control channels (OH) in the downlink have header values of 0.18 in the F2 band and 0.14 in the F1 band, compared to 0.10 in the F2 band and 0.08 in the F1 band in the uplink. The corresponding frequency ranges for F1 and F2 are 450 MHz to 6 GHz and 6 GHz to 52.6 GHz. Time Division Duplex (TDD), which enables using a single frequency for uplink and downlink broadcasts but at various intervals, is the system's chosen spectrum utilization technique. This strategy is thought to be more practical than employing Frequency Division Duplex (FDD) paired spectrum, particularly in situations when paired spectrum is not available [15]. Table 4 provides an overview of the parameters utilized in the throughput calculation of 5G NR.

Table (4):-Parameters for 5G New Radio Throughput

Parameter	Value		
J	1		
$v_{Layers}^{(j)}$	4 in case of DL		
$f^{(j)}$	1 scaling factor (1)		
$Q_m^{(j)}$	8 for 256QAM		
R_{max}	948/1024		
$BW^{(j)}$	0 MHz (FR1)	80 MHz (FR1)	100 MHz (FR1)
$N_{PRB}^{BW(j),\mu}$	133	217	273
μ	1 in case of 30 KHz (subcarrier spacing)		
$OH^{(j)}$	0.14 in case of F1 for DL		

5. Required 5G gNodeB Stations Determination Method

The process for determining the necessary urban 5G gNode stations is visually depicted in the flowchart found in Appendix A. This flowchart outlines a series of critical steps involved in this process, including calculating receiver sensitivity, assessing propagation path losses, computation of the link budget, conducting link testing, determining the single cell coverage area, and estimating the required 5G gNode stations. These phases are essential for evaluating the signal's strength, considering optimizing the deployment of base stations and propagation characteristics. The flowchart serves as a user-friendly guide, commencing with the calculation of receiver sensitivity using equations (1) and (2), as well as PL computation through equations (3-5), considering both propagation models UMi and UMa. Subsequently, it proceeds to the computation of the RLB, testing for the MAPL, and calculating the coverage area using equation (7). Finally, it concludes by approximating the necessary 5G gNodeB using equation (8).

This flowchart supports applying the calculation method methodically, facilitating scholars and practitioners in accurately estimating the throughput of 5G NR and determining the most efficient positioning of gNodeB in urban areas. For a more precise understanding, the calculation method can be summarized in the following steps:

Step 1:	**Initially, the S_{RX} calculation is carried out using (1 and 2) along with the parameters in Table 1.**
Step 2:	Then, the determination of propagation path losses for UMa and Umi models is accomplished using (3 to 5) in conjunction with the parameters listed in Table 2.
Step 3:	Using (6) and the values listed in Table 3, the link budget for each propagation path loss of the UMa and Umi models is computed.
Step 4:	The link is then evaluated by calculating the MAPL and determining the longest cell radius before the connection fails.
Step 5:	Utilizing this information, the single highest coverage area is then calculated using (7).
Step 6:	Finally, the estimated 5G gNodeBs needed in a desired area or city is calculated using (8).

6. RESULT AND DISCUSSION

This study aims to estimate the required number of 5G gNodeBs for a specific urban area and examine how the choice of the central frequency affects how many of these base stations are needed to provide adequate coverage. To do this, we looked at two deployment scenarios for each of our selected four main frequencies. We used the widely used 3GPP Urban Macro (UMa) and Urban Micro (UMi) propagation models, considered industry standards. Table 5 lists the precise central frequencies applied in this study.

Table(5):- The various central frequencies in diverse situations.

n34(Fc=2010Mhz)		**n40(Fc=2300MHz)**		**n77(Fc=3300MHz)**		**n79(Fc=4400MHz)**	
Scenario(1) UMa	Scenario (1) UMi	Scenario (2) UMa	Scenario (2) UMi	Scenario (3) UMa	Scenario (3) UMi	Scenario (4) UMa	Scenario (4) UMi

The 3GPP has developed standardized route loss models for predicting path attenuation in various propagation scenarios. Urban Macro cellular (UMa), Urban Microcellular (UMi), and Rural Macro cellular (RMa) models are included in this group. These three models create a common framework for evaluating signal propagation characteristics and designing 5G networks that can operate well in various settings. By using these models, network strategists and operators may decide where to install wireless 5G equipment in the best possible way while considering antenna placement, frequency allocation, and power levels.

The UMi model is used to handle urban microcellular settings, which are marked by considerable signal attenuation due to the presence of structures and other obstructions. The UMa model, on the other hand, is designed for urban macro cellular environments where barriers are sparser and signal propagation is affected by the landscape and vegetation. The RMa model also focuses on rural locations where the topography and vegetation mainly determine propagation losses. Because this study focuses on a metropolis, both UMa and UMi non-line-of-sight (NLOS) situations are considered.

Figure 2 shows that the UMi model predicts more route losses than the UMa model. The UMi model includes impediments like buildings, which can considerably attenuate the signal and increase the overall route loss, so there is a disparity. The UMi model provides a more accurate representation of signal propagation characteristics in highly populated urban environments typified by closely spaced buildings that block the direct line of sight between transmitter and receiver. As opposed to the UMi model, which tends to predict higher route losses, the UMa model assumes that the propagation environment will be more favorable with fewer obstructions and better line of sight conditions.

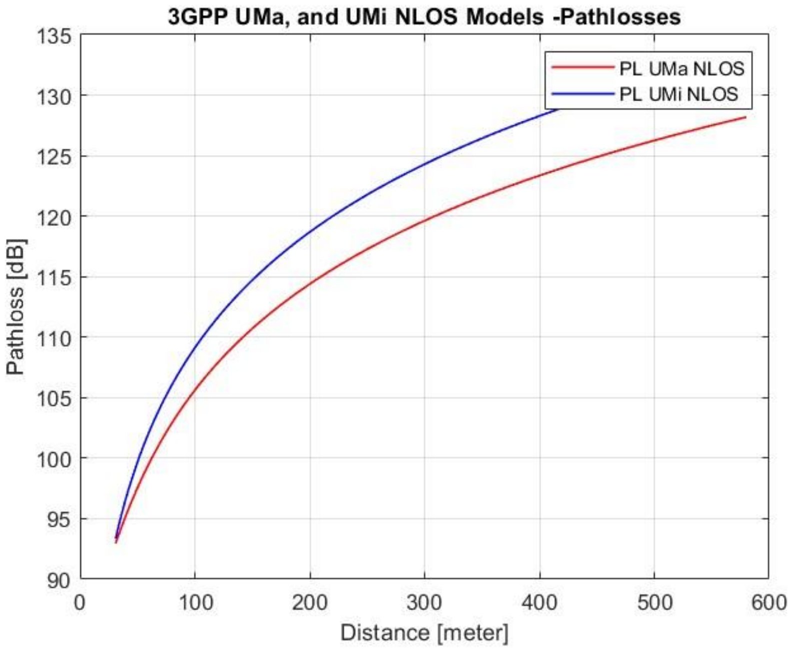

Fig.(2):- Pathloss for NLOS situations at a frequency of 3.5 GHz in the context of 3GPP UMa and UMi.

The amount of base stations required to cover a given region depends critically on the central frequency of a 5G base station. The maximum permissible route losses, the radius of a single base station (also known as d2D), the coverage offered by a single base station, and the total number of 5G stations required for a particular region are all heavily impacted by this core frequency. The average maximum permissible route losses in the UMa and UMi situations, which were around 118.6 dB and 118.2 dB, respectively, are shown in Figure 3. The maximum permitted route losses, the designated central frequency, and the 3GPP propagation model all impact the maximum radius of the 5G NR cell. Figure 4 shows that shorter d2D distances before the link breaks are caused by greater center frequencies. Additionally, while adopting the same central frequency, the UMa model broadens the cell radius. As shown in Figure 5, this radius determines the coverage area of a single cell, which impacts the projected number of 5G gNodeB base stations needed in a given region.

According to the study's findings, additional base stations must be deployed to provide the needed coverage when using a higher central frequency, as shown in Figure 6. This need results from the fact that high-frequency transmissions, which have shorter wavelengths, are more prone to obstruction by natural barriers like trees and buildings. As a result, a more dense base station network is required to guarantee dependable signal transmission and reception throughout the service region. Lower frequency transmissions, which have longer wavelengths, can, on the other hand, penetrate barriers more successfully, requiring fewer base stations to cover the same area. Therefore, choosing the central frequency is a crucial factor in determining how many 5G base stations are needed for a specific deployment scenario.

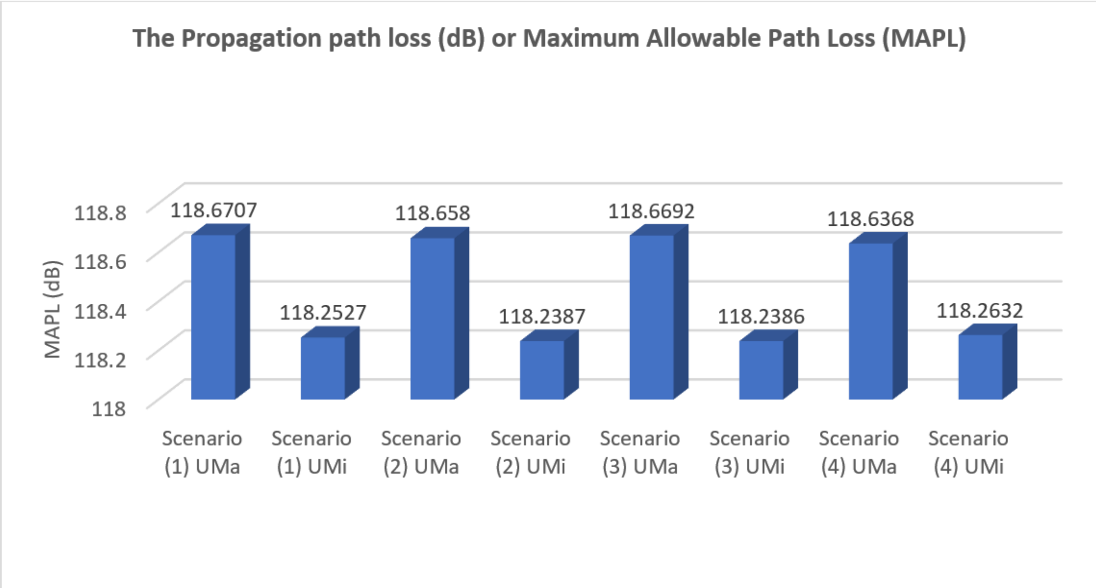

Fig.(3):- MAPL for each Scenario

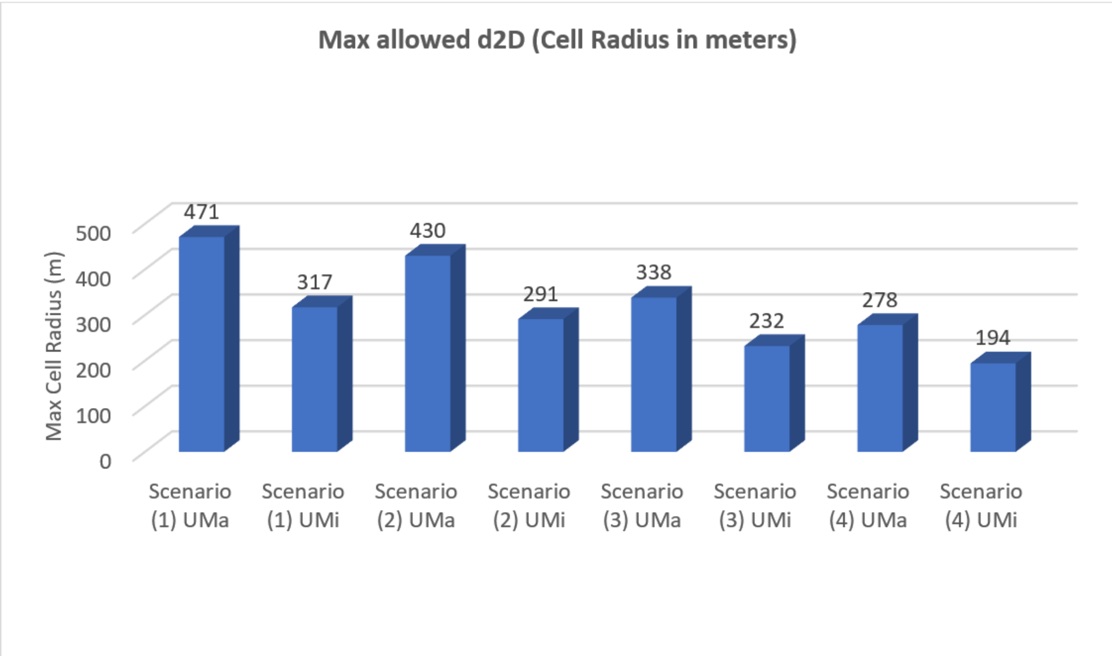

Fig.(4):- 5G Cell Radius Calculated

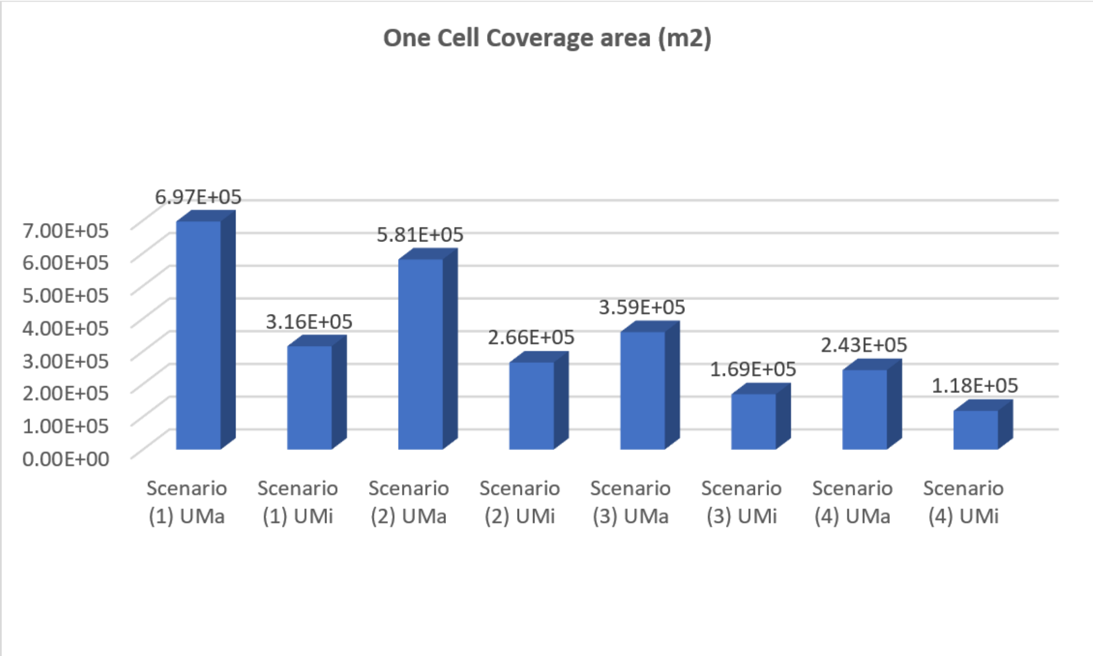

Fig.(5):- One Cell Coverage Area Estimated

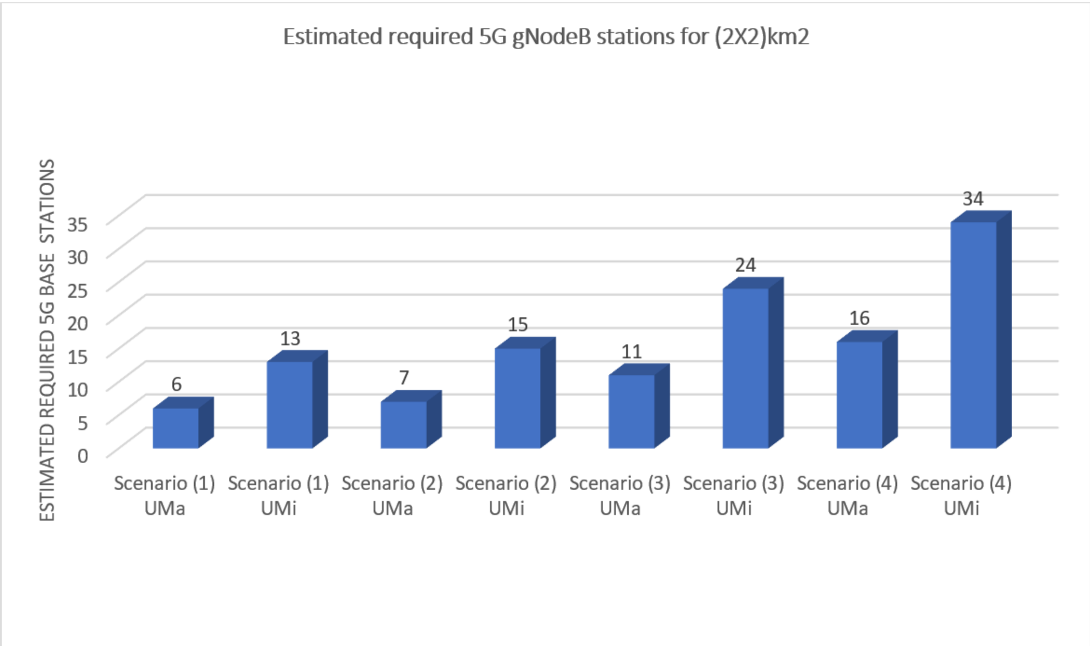

Fig.(6):- Approximated 5G gNodeB stations needed for a (2X2) square kilometer area.

The information shown in Figure 7 shows that the channel bandwidth significantly impacts the 5G NR throughput that can be attained. More specifically, more excellent throughput rates are produced via broader channel bandwidths. For example, using a 100MHz channel bandwidth results in a throughput of 2.34Gbps, which is a twofold improvement over the throughput of 1.1385Gbps obtained with a 50MHz channel bandwidth at the exact center frequency (FR1). It's important to note that the estimated throughput of the 5G gNodeB stations suggests that the suggested low-cost fronthaul link architecture, which offers a data rate of 25Gbps, provides a sufficient connection between the central and distribution units. It is essential to take into account a second fronthaul link design with a capacity of 120Gbps in the event that it becomes necessary to boost the number of combination carriers (CC) in order to improve the throughput of the 5G gNodeB beyond 25Gbps.

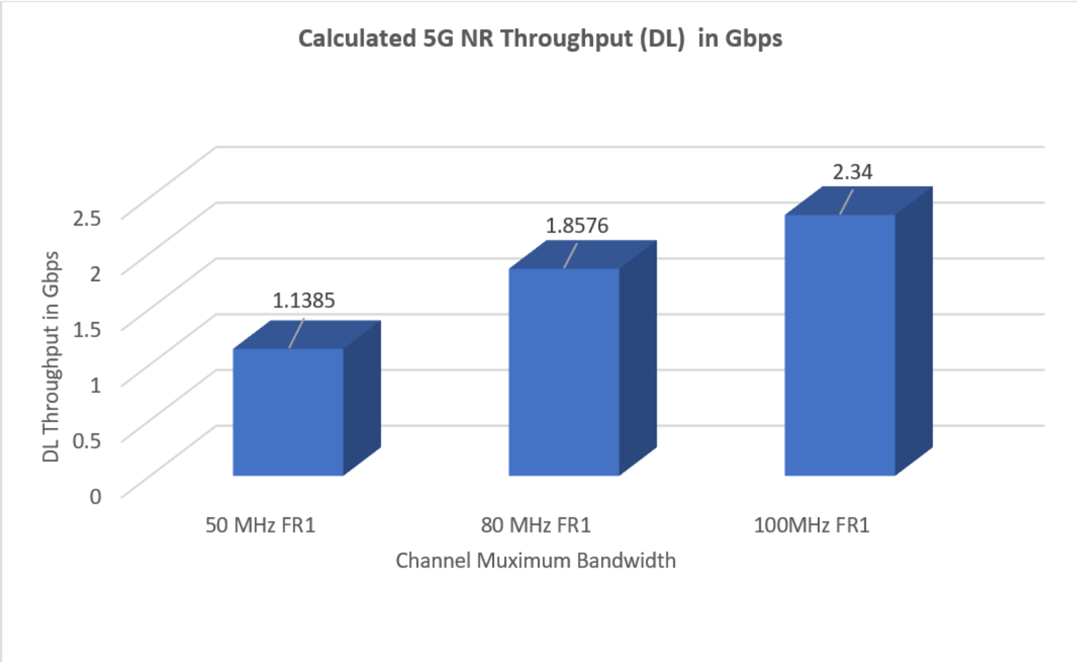

Fig.(7):- Throughput Calculation of 5G NR in the Downlink Side

7. CONCLUSION

In conclusion, the centre frequency, the selected 3GPP propagation model, and the maximum permitted pathlosses all substantially impact the predicted number of 5G base stations needed to serve a particular region. Compared to the UMi model, the UMa model offers a larger radius for each cell while maintaining the same core frequency, leading to a larger coverage area. To provide dependable signal transmission and reception, a higher center frequency also causes a shorter maximum radius, necessitating a denser network of base stations. Additionally, as it directly impacts the highest data rate that can be obtained, the channel bandwidth also plays a crucial part in determining the cell throughput. Better data rates are possible with larger bandwidths, which results in higher cell throughputs. However, expanding the bandwidth may also result in more interference and a smaller coverage area, which may require additional base stations. In summary, the centre frequency, 3GPP propagation model, maximum allowable route losses, and channel bandwidth must all be carefully considered and optimized to accurately predict the number of 5G base stations necessary to cover a region and maximize cell throughput properly. Any 5G deployment scenario should pay close attention to these elements to guarantee top performance and effective utilization of network resources.

Future Work

Future work for this article could involve the following. Firstly, conduct a comprehensive performance evaluation of different 3GPP propagation models, center frequencies, maximum allowable path losses, and channel bandwidths, explicitly focusing on the FR2 frequency range (millimeter wave frequencies).

Secondly, investigate advanced interference management techniques to mitigate interference caused by larger bandwidths. This could involve exploring methods like beamforming, advanced antenna systems, and dynamic spectrum allocation.

Appendix A

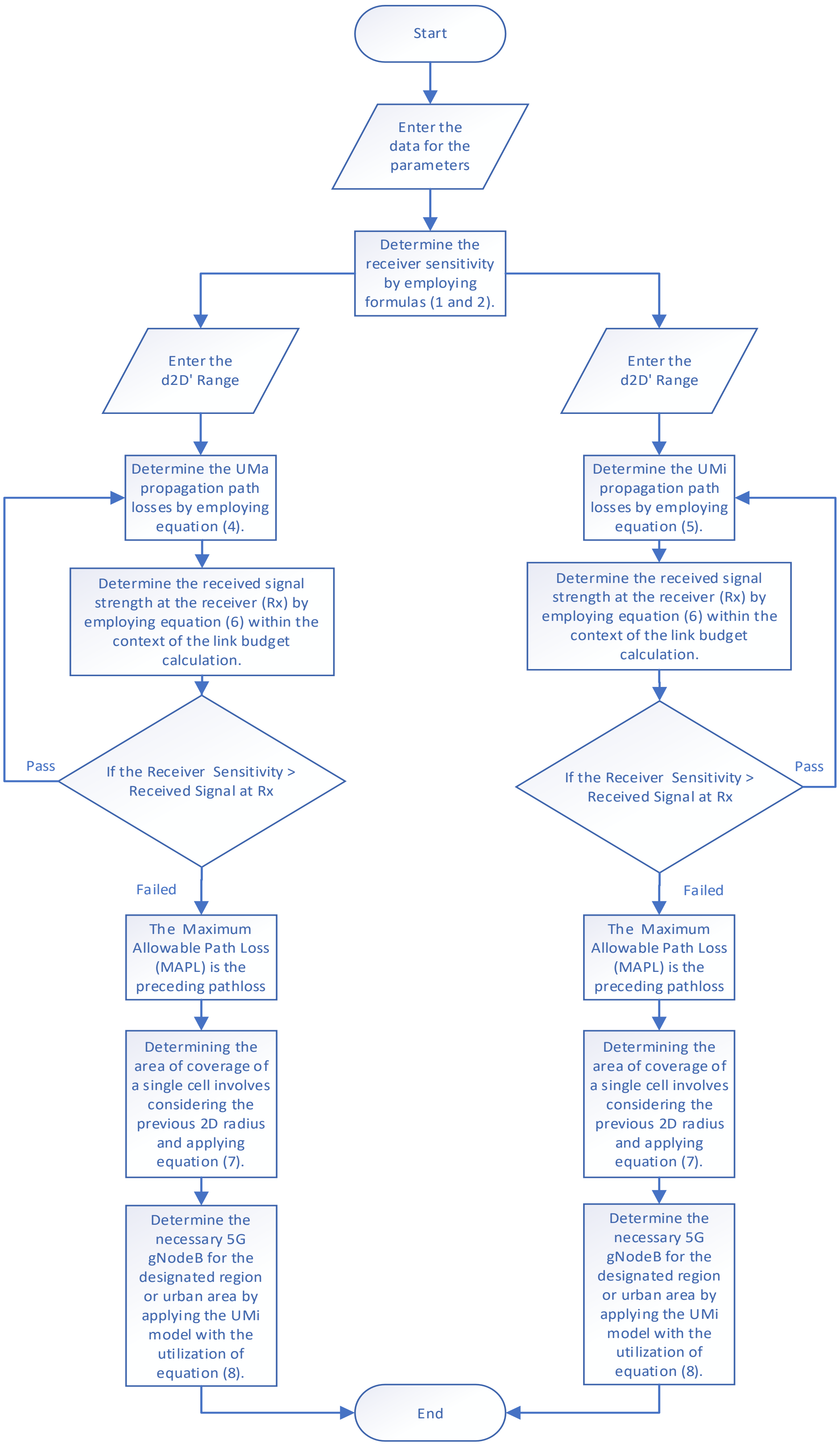

Fig.(8):- Flow chart of estimating the number of 5G NR cells using UMa and UMi models

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