International Journal on Advanced Science Engineering Information Technology

Vol.13 (2023) No. 6
ISSN: 2088-5334

Deployment of 5G NR Outdoor-to-Indoor at Midband and mmWave Frequency Implementation in Indonesia's Industrial Area

Alfin Hikmaturokhman [a*], Ghina Fahira [b], Rai Nur Esa [c], Asri Wulandari [d], Goh Khang Wen [e]

[a] *Faculty of Telecommunication & Electrical Engineering, Institut Teknologi Telkom Purwokerto, 53147, Indonesia*
[b] *PT Cahaya Arif Abadi, Jakarta, 12810, Indonesia*
[c] *PT Biznet, Balikpapan, 76128, Indonesia*
[d] *Electrical Engineering, Politeknik Negeri Jakarta, Depok, 16425, Indonesia*
[e] *Faculty of Data Science and Information Technology, INTI International University, Nilai 71800, Malaysia*

*Corresponding author: *alfin@ittelkom-pwt.ac.id*

Abstract—**In the world of telecommunications, there have been significant advancements in broadband access, especially with the introduction of fifth-generation cellular technology, or 5G NR. The presence of 5G may have an impact on performance. This research compares 5G NR network deployment in mid-band at the 3.5 GHz frequency and high-band at 28 GHz frequency in a 5 km^2 Pulogadung industrial area. To provide reliable service, link budget calculations were conducted using the downlink outdoor-to-indoor (O2I) and uplink outdoor-to-indoor (O2I) scenarios based online of sight (LOS). The Urban Micro (UMa) propagation model was used for the 3.5 GHz frequency, while the Urban Micro (UMi) model was used for the 28 GHz frequency, both standardized by 3GPP TR 38.901. The calculation results were simulated using the Automatic Site Placement (ASP) feature in Mentum Planet Tools version 7.2.1, which provided recommendations for the new site locations. The simulations showed that the Downlink O2I-LOS scenario, which requires more sites, resulted in stronger signal strength than the Uplink O2I-LOS scenario. The highest signal strength was achieved by the downlink O2I-LOS scenario at the 3.5 GHz frequency, as indicated by an average SS-RSRP value of -91.88 dBm. On the other hand, the lowest signal strength was obtained by the uplink O2I-LOS scenario at the 28 GHz frequency, with an average SS-RSRP value of -98.11 dBm. The difference in predicted 5G SS-RSRP values is influenced by the variation in standard parameter values in the link budget for each frequency.**

Keywords— **5G NR Deployment; broadband access; outdoor-to-indoor (O2I); mmWave frequency; 5G link budget; mentum planet.**

Manuscript received 18 Aug. 2023; revised 31 Oct. 2023; accepted 5 Nov. 2023. Date of publication 31 Dec. 2023.

I. INTRODUCTION

Countries worldwide strive to acquire 5G New Radio (NR) technology services that offer high speed, extensive coverage, and reliability. In 2020, the operating system for this fifth-generation technology is expected to be formally disclosed, and certain industrialized nations, including the US, Japan, Europe, and China, will then begin to market it. A few sophisticated nations have started preparing and conducting tests to use the technology. Indonesia is one of the top internet-using emerging nations, making it crucial to debate this development technological roadmap at both national and international gatherings. The newly launched 5G technology is categorized into three usage scenarios, shown in Fig. 1. enhanced Mobile Broad Band (eMBB): The human user case for accessing information, services, and multi-media data is handled by mobile broadband. The demand for cellular broadband will continue to rise, resulting in improved mobile broadband. This usage scenario encompasses a variety of situations with various requirements, such as hotspots and vast coverage areas. Ultra-Reliable Low Latency Communications (URLLC): The characteristics needed for this use case, such as high availability, low latency, and good throughput, must meet tight criteria. For instance, wireless manufacturing or industrial process control, remote medical assistance, smart grid distribution automation, transportation security, etc. Massive Machine Type Communications (mMTC): This use case is distinguished by a high density of connected devices that regularly transfer sensitive data instantaneously at a low volume [1].

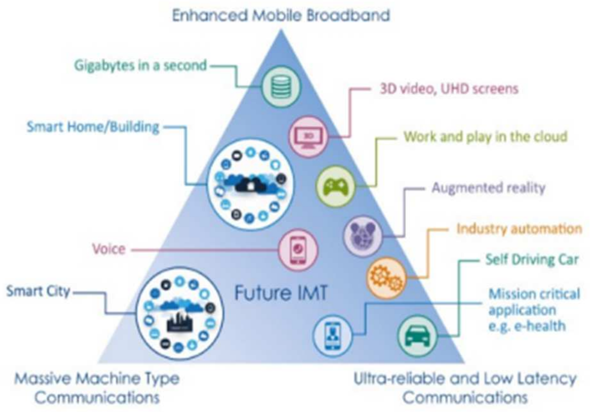

Fig. 1 Vision of 5G technology[1]

Fifth-generation cellular technology, also known as 5G NR, has significantly improved the telecoms sector. A new generation of radio technology and network architecture known as 5G New Radio (NR) will offer extremely strong connections for humans and the Internet of Things [2], broadband access, and ultra-reliable and low-latency communication. With over 50% annual subscriber growth, cellular network data traffic demonstrates how essential telecommunications services have become to addressing modern human requirements. These services offer quick access to information to support daily activities and enhance quality of life. The development roadmap of this technology is an important topic in national and international meetings due to the requirement to define 5G NR technology standards.

Different network solutions, including the development of current networks and the potential for new network infrastructures, are needed for the 5G NR service, which demands speed, coverage, and dependability. This can include access to several frequency spectrums and wireless communication. By utilizing millimeter wave (mmWave) frequencies as an additional spectrum form, the 5G NR standard for cellular technology can provide users with data speeds of up to several gigabits per second (Gbps). This technology is expected to operate at frequencies between 1 GHz and 100 GHz. The Telecommunications Regulation of Indonesia covers the selection of radio frequency bands for testing the use of IMT-2020 technology, and it defines the following frequency bands, shown in Table I.

TABLE I
FREQUENCY BAND IN INDONESIA [2], [3]

Frequency Center	Range
Frequency band of 700 MHz	694 – 790 MHz
Frequency band of 3.5 GHz	3.3 – 4.2 GHz
Frequency band of 15 GHz	14.5 – 15.35 GHz
Frequency band of 26 GHz	24.25 – 27.5 GHz
Frequency band of 28 GHz	26.5 – 29.5 GHz

The key factors in the selection of frequency bands are the worldwide ecosystem for testing frequency bands and the accessibility of the testing equipment used by mobile carriers, which can only work within specific frequency ranges. Mobile operators advise using these bands as a result [2]. These high-frequency bands challenge all Indonesian telecom service providers to create precise planning while offering the best network and catering to their clients nationwide.

The parameter values in Table II are unrepresentative of the true values for the maximum values in a typical 5G system. The key issue with massive Machine Type Communications (mMTC) is connection density, although peak data rate and spectrum are not strictly essential. Latency and mobility are two of the primary objectives of Ultra-Reliable and Low Latency Communications (URLLC). In eMBB (enhanced Mobile Broadband), peak data rate, user experience data rate, latency, mobility, and connection density are all important considerations [4].

TABLE II
RECOMMENDATIONS FOR DEVELOPING 5G NR CAPABILITIES FROM ITU-R [4]

Parameter	IMT Advanced	IMT-2020
Peak Data Rate (Gbps)	1	20
User Experienced Data Rate (Mbps)	10	100
Spectrum Efficiency (bps/Hz)	10	30
Mobility (km/h)	350	500
Latency (ms)	10	1
Area Traffic Capacity ($Mbps/m^2$)	0.1	10
Connection Density (dev/km^2)	10^5	10^6

Two different architecture models are available for applying 5G technology: standalone and non-stand-alone. A 5G network that is independent or standalone is referred to as a standalone network. The Standalone network architecture will be equipped with a 5G Core (5GC) and a new 5G air interface known as New Radio (NR). End-to-end 5G addressing is offered via a standalone 5G network, which will continue to operate in tandem with the 4G LTE network in order to provide continuous services between the two network generations. 5G network can function independently while also interacting with the LTE network to link 5G and non-5G users and cover places where 5G is not yet available. Standalone has the benefits of being simpler and more efficient, less expensive hardware, greater data throughput performance up to network limits, support for wireless use cases, and reliable low-latency communication (URRLC) [5], [6].

In contrast, in the non-stand-alone 5G network (non-independent network), the NR (New Radio) radio cells are connected to the LTE radio cells utilizing a dual link, and the core network can either be the Evolved Packet Core (EPC) or 5GC depending on the operator's preference. In this case, operators may combine existing 4G installations with LTE and New Radio (NR) radio resources in the EPC or the new 5GC to supply 5G cellular services. This solution and the LTE Radio Access Network (RAN) are anticipated to function closely together. Dual connectivity is present in the Non-Stand-Alone architecture. It supports 5G New Radio (NR) with Evolved Packet Core (EPC) and has a feature known as E-UTRAN New Radio (NR) Dual Connectivity (EN-DC). In order to link the User Equipment (UE), the eNodeB acts as the master node (MN), and the en-gNB acts as the secondary node (SN) [5], [6].

The paper addresses the 5G NR network deployment issue, particularly comparing deployments at two different frequency bands, 3.5 GHz and 28 GHz. The problem revolves around the challenge of optimizing network coverage, signal strength, and site planning for these frequencies, given their unique propagation characteristics. The calculated data will be tested using a planning tool called Mentum Planet ver. 7.2.1, which will provide the SS-RSRP value.

The research objective is to evaluate the deployment of 5G NR networks in the Pulogadung industrial area, focusing on two frequency bands (3.5 GHz and 28 GHz). The Pulogadung Area, one of East Jakarta's industrial zones, will serve as the site for coverage planning for the 5G NR network. The study aims to determine the number of required sites, signal strength, and cell radius for both frequency bands and assess how well these frequencies meet the needs of various use cases.

Before performing network planning, assumption data collection for the recommended link budget is conducted for the 5G NR network. The coverage calculation will involve obtaining values for MAPL, propagation values, and cell radius values, ultimately determining the number of required sites in the Pulogadung industrial area.

The paper contributes to understanding 5G NR network deployment by providing a detailed analysis of coverage planning and site placement for the 3.5 GHz and 28 GHz frequencies. It evaluates the signal strength (SS-RSRP) in different scenarios and highlights the differences in path losses between these frequency bands. This research informs network planners and policymakers about the challenges and opportunities associated with 5G NR deployment in industrial areas and emphasizes the need to consider factors like frequency, propagation models, and site planning.

II. MATERIALS AND METHOD

The method used in this research involves data collection, calculations, and testing using planning tools. Fig. 2 illustrates the process carried out to conduct this study.

A. Research Method

The activities flow in this research is shown in Fig. 2. The stages involved are planning the 5G NR network at frequencies of 3.5 GHz and 28 GHz in terms of area coverage for a site. The number of sites needed to cover the targeted region completely will be determined as the final result of this research. The East Jakarta of Pulogadung as an industrial area was chosen for the 5G NR network planning in the first stage. This area was chosen as the case study due to the main objective of 5G technology, which aims to provide wireless connectivity in the economic and industrial sectors. The required data for classification includes the area's size, geographical position, and a description of the area. The classification of service areas is based on the user density in the region [7]–[12].

The cell radius value can be calculated as the greatest possible distance between a gNodeB and a User Terminal (UT), using the path loss values for the uplink and downlink using the Uma (Urban Macro) propagation model for the 3.5 GHz frequency and Umi (Urban Micro) model for the 28 GHz frequency, as recommended in 3GPP 38.901. The known cell radius value will be used to compute a site coverage area, and as a final result of the coverage planning calculation, it will be determined how many sites are needed for the Pulogadung industrial area [13]–[16].

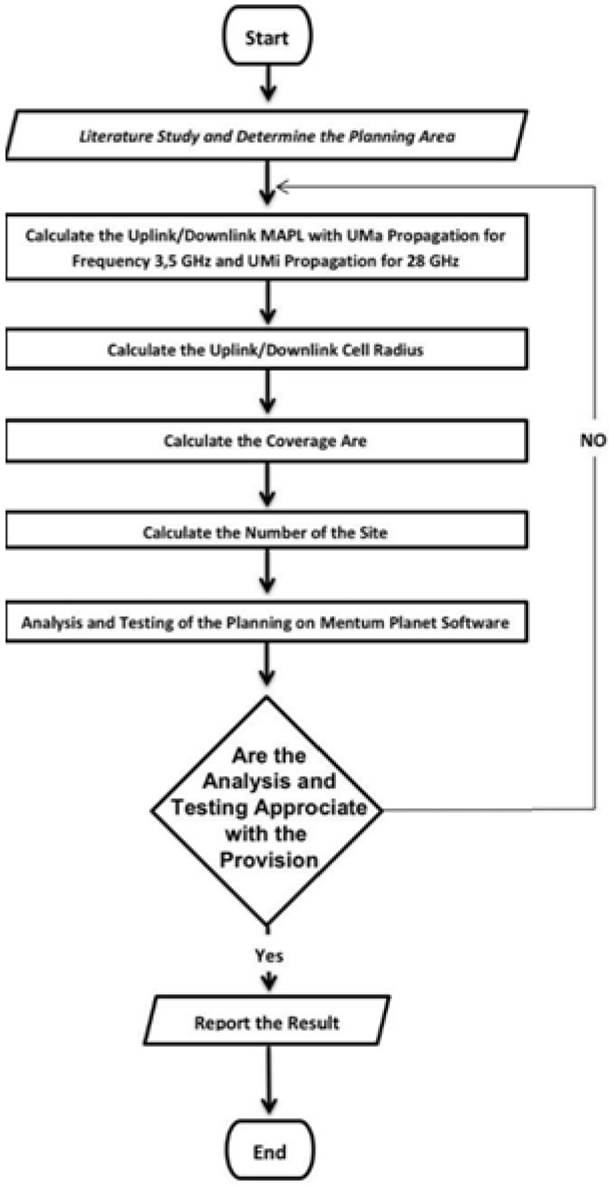

Fig. 2 Flowchart of the research

The Mentum Planet program version 7.2.1 is then used to run simulations for analysis and planning. This phase is essential and plays a vital role in the study. The simulation will show the coverage area and compare the parameters to the outcomes of the computation of the link budget coverage. This process thoroughly assesses the intended network's coverage performance and guarantees compliance with the estimated link budget. The propagation models used are based on the link budget for 5G networks that is shown in Fig. 3.

B. Link Budget

The link budget computation that is shown in Table III is applied to calculate the maximum signal attenuation or total path loss between the gNodeB antenna and the cellular antenna on the uplink and downlink sides [18], [19].

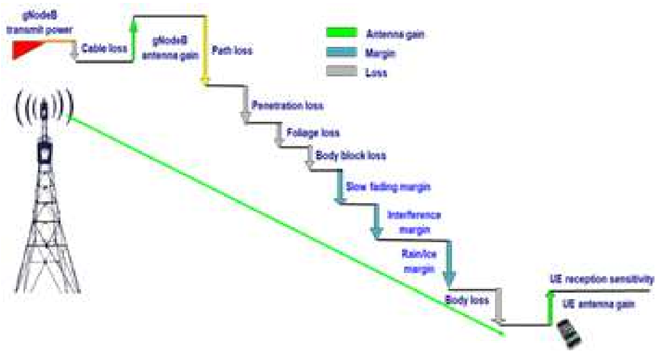

Fig. 3 Factors affecting link budget on 5G NR technology [17]

TABLE III
5G NR LINK BUDGET [17], [20]–[22]

Comment Parameter	3.5 GHz		28 GHz	
	DL	UL	DL	UL
gNodeB Transmiter Power (dBm)	49		35	
Resource block	273		132	
Subcarrier quantity	3276		1584	
gNodeB antenna gain (dBi)	2		2	
gNodeB cable loss (dBi)	0		0	
Penetration loss (dB)	26.85		12,23	
Foliage loss (dB)	19,59		5	
Body block loss (dB)	3		15	
Interference margin (dB)	6	2	1	0.5
Rain/Ice margin (dB)	0		3	
Slow fading margin (dB)	8		8	
UT antenna gain (dB)	0		0	
Bandwidth (MHz)	100		100	
Konstanta boltzman (mWs/K)	1.38×10^{-20}		1.38×10^{-20}	
Temperature (Kelvin)	293°		293°	
Thermal noise power (dBm)	-156.16		-153.93	
UT noise figure (dB)	7		7	
Demodulation threshold SINR (dB)	-1.1		-1.1	
Planning Area	5 km²		5 km²	

III. RESULTS AND DISCUSSION

The obtained data is then input into the calculation process and simulation process using Mentum Planet planning tools.

A. Urban Macro (UMa) and Urban Micro (UMi) Propagation model

Planning for cellular networks typically takes into account two perspectives: capacity planning and coverage planning. Designing the network based on the area it will cover is known as coverage planning. Specific factors like transmit power, receive power, path loss, device sensitivity, radio link budget calculation, and cell radius calculation might have an impact on planning inside the coverage. The radio link budget is used to determine the maximum permissible path loss between the UE antenna and the gNodeB antenna. On the other hand, propagation modeling is used to compute the cell radius [23]–[26].

The number of sites in the Pulogadung industrial area is determined using propagation modeling. The propagation models used are based on the link budget for 5G networks that is shown in Fig. 3, according to 3GPP 38.901. In this study, the Urban Macro (UMa) model is used for the 3.5 GHz frequency, while the Urban Micro (Umi) model is used for the 28 GHz frequency.

In the UMa model with Outdoor-to-Outdoor (O2O) and Outdoor-to-Indoor (O2I), the gNodeB is installed on the rooftop level of surrounding buildings, with a Tx (transmit) roughly a height of 25 meters and an Rx (receive) height of around 1.5-2.5 meters. The Inter-Site Distance (ISD) is approximately 500 meters. On the other hand, in the UMi model with gNodeB O2O and O2I, the gNodeB is installed below the rooftop level of the buildings in the vicinity. The open area is used to record real-world situations such as cities or terminals. The coverage area typically ranges from 50-100 meters, with a Tx height of 10 meters and an Rx height of around 1.5-2.5 meters. The ISD is around 200 meters.

First, fill out the link budget table and calculate the Thermal Noise and Subcarrier Quantity values.

$$Thermal\ Noise = 10\ Log\ (k.T.\ \mathrm{B}) \tag{1}$$

$$= 10\ Log\ (1.38 \text{ x } 10\text{-}20 \text{ x } 293 \text{ x } 100)$$

$$= -153.93 \text{ dBm}$$

K = Boltzmann constant ($1.38 \times 10\text{-}20$ mWs/K)
T = Temperature (293° K)
B = Bandwidth (100 MHz)

$$\mathrm{SCQ} = \mathrm{RB} \times Subcarrier\ Per\ \mathrm{RB\ (OFDM)} \tag{2}$$

SCQ 3.5 GHz = 273 x 12 = 3276
SCQ 28 GHz = 132 x 12 = 1584

For the penetration loss value in dB, calculations are performed using different formulas for each frequency[22] :
Low-loss model (dB) for 28 GHz =

$$5 - 10\log_{10}(0.3 \times 10^{\frac{-Lglass}{10}} + 0.7 \times 10^{\frac{-Lconcrete}{10}} \tag{3}$$

High-loss model (dB) for 3.5 GHz =

$$5 - 10\log_{10}(0.7 \times 10^{\frac{-LIRRglass}{10}} + 0.3 \times 10^{\frac{-Lconcrete}{10}}) \tag{4}$$

Standard multi-pane glass (L_{glass}) = $2 + 0.2f$
IRR glass ($L_{IRRglass}$) = $23 + 0.3f$
Concrete ($L_{concrete}$) = $5 + 4f$

Penetration Loss $_{3.5\ GHz}$ = 26.85 dB
Penetration Loss $_{28\ GHz}$ = 12.23 dB

Then, calculate the pathloss value of link budget that is shown in Table 3 and Fig. 3, using the equation [17]:

Pathloss (dB) = gNodeB transmit power (dBm)–10 $\log_{10}$ (subcarrier quantity)+gNodeB antenna gain (dBi) – gNodeB cable loss (dB) – penetration loss (dB) – foliage loss (dB) – body block loss (dB) – interference margin (dB) – rain/ice margin (dB)– slow fading margin (dB) + UT antenna gain (dB)– thermal noise figure (dBm) – UT noise figure (dB) – demodulation threshold SINR (dB) (5)

1) Pathloss DL-O2I $_{3.5\ GHz}$ = 100.66 dB
2) Pathloss UL-O2I $_{3.5\ GHz}$ = 104.66 dB
3) Pathloss DL-O2I $_{28\ GHz}$ = 108.80 dB
4) Pathloss UL-O2I $_{28\ GHz}$ = 109.30 dB

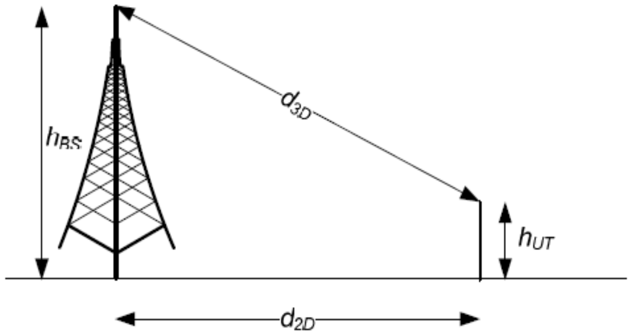

Fig. 4 Picture of pythagoras between d_{3D}; d_{2D}; and (h_{BS}-h_{UT}) [22]

The Pythagoras triangle between d3D, d2D, and (hBS-hUT) is shown in Fig. 4. Before getting the d_3D value from the PL formula, it is necessary to find the h'_{BS} value; the h'_{UT} value and the d'_{BP} value first [22]:

$$h'BS = hBS - hE \tag{6}$$

$$h'UT = hUT - hE \tag{7}$$

$$d'BP = 4 \text{ x } h'BS \text{ x } h'UT \text{ x } fc/c \tag{8}$$

d'_{BP} = break point distance (m)
fc = frequency (GHz)
h_{BS} = height of gNB (25 m for 3.5 Ghz; 10 m for 28 GHz)
h_{UT} = height of UT (1,5 m)
c = speed of light ($3 \text{x} 10^8$ m/s)
hE = height of equipment (1 m)

In the UMa model for the Line of Sight (LOS) case, it has the formula [17]:

$$PL1 = 28 + 40 \log10 (d3D) + 20 \log10 (fc) - 9 \log10 ((d'BP)2 + (h'BS - h'UT)2) \tag{9}$$

In the UMi model for the Line of Sight (LOS) case, it has the formula [17]:

$$PL1 = 32.4 + 21 \log10 (d3D) + 20 \log10 (fc) \tag{10}$$

PL_1 = value of pathloss (dBm)
d_{3D} = resultant of the distance between h_{BS} dan h_{UT} (m)
d'_{BP} = break point distance (m)
fc = frequency (GHz)
h_{BS} = height of gNB (m)
h_{UT} = height of UT (m)

The area covered by one site can be determined using the coverage formula, which is as follows, by knowing the cell radius:

$$\text{Radius cell (d2D) or 'd'} = \sqrt{(\text{d3D})^2 - (h_{BS} - h_{UT})^2} \tag{11}$$

$$\text{Coverage area} = 2.6 \text{ x d2} \tag{12}$$

The needed number of sites in the designated coverage area will be calculated using the following formula:

$$\text{Number of site} = \frac{\text{total surface area } (km^2)}{\text{coverage area of 1 site } (km^2)} \tag{13}$$

The results of each calculation flow in this research, predicting site requirements, are shown in Table 4 for the 3.5 GHz frequency and Table 5 for the 28 GHz frequency.

TABLE IV
RESULT OF THE CALCULATION FOR FREQUENCY 3.5 GHZ

Comment Parameter	3.5 GHz	
	DL-O2I	UP-O2I
Thermal Noise	-156.16	-156.16
Subcarrier Quantity	3276	3276
Pathloss	100.66 dB	104.66 dB
h'_{BS}	24 m	24 m
h'_{UT}	0.5 m	0.5 m
d'_{BP}	560 m	560 m
d_{3D}	708.27 m	891.66 m
d_{2D} / Cell Radius	707.80 m	891.35 m
Coverage Area	1,302,856.48 m^2	2,065,728.18 m^2
Number of gNodeB	4 sites	3 sites

TABLE V
RESULT OF THE CALCULATION FOR FREQUENCY 28 GHZ

Comment Parameter	28 GHz	
	DL-O2I	UP-O2I
Thermal Noise	-153.93	-153.93
Subcarrier Quantity	1584	1584
Pathloss	108.80 dB	109.30 dB
h'_{BS}	9 m	9 m
h'_{UT}	0.5 m	0.5 m
d'_{BP}	1056 m	1056 m
d_{3D}	182.00 m	192.26 m
d_{2D} / Cell Radius	181.80 m	192.07 m
Coverage Area	85,940.56 m^2	95,921.46 m^2
Number of gNodeB	59 sites	53 sites

B. Simulation Result

RSRP represents the power level of the reference signal. In 5G networks, the signal intensity received by each surrounding cell transmitter's Secondary Synchronization Signal (SSS) is measured by the User Equipment (UE). The average power (in Watts) during the entire measured time on the User Equipment (UE) from the secondary synchronization (SS) signals delivered by the cell transmitters is referred to as Secondary Synchronization - Reference Signal Received Power (SS-RSRP) [27]. The primary system parameters used in this simulation are given in Table VI and are presumptive based on past research.

TABLE VI
MAIN SYSTEM PARAMETERS [28], [29]

Key Parameter	System	
	3.5 GHz	28 GHz
Technology template	NR	NR
Carrier frequency	3500 MHz	28.000 MHz
Start frequency	3450 MHz	26.500 MHz
End frequency	3550 MHz	29.500 MHz
Bandwidth	100 MHz	100 MHz
Duplex	TDD	TDD
Antenna file	Kathrein (omnidirectional)	Kathrein (omnidirectional)

1) Scenario 1 (Outdoor-to- Indoor (O2I) Downlink): This design does not utilize existing site locations. Instead, based on coverage concerns, new site options will be suggested. The Mentum Planet software's ASP tool will automatically customize the site placement. In contrast to the calculated result of 3 sites, Scenario 1 at 3.5 GHz suggests 4 sites for the planning region. The recommendation, which deviates from the predicted result by 1 site for a frequency of 28 GHz, calls for the use of 60 sites. These discrepancies result from restrictions in the Automatic Site Placement (ASP) feature's setup of the number of gNodeB and their radius distance.

The parameter being analyzed is SS-RSRP from a coverage perspective. The service provided in the simulation is Video Streaming. Please refer to Fig. 5 and Fig. 6 for the estimated results of SS-RSRP at 3.5 Ghz and 28 GHz.

Fig. 5 ASP for gNodeB mapping at frequency 3.5 GHz

TABLE VII
SIMULATION RESULT FOR SS-RSRP AT FREQUENCY 3.5 GHZ

SS-RSRP Value (dBm)	Percentage	Area (km^2)	Color
< -116.98	0.20%	0.010	
-116.98 s/d -109.96	0.05%	0.002	
-109.96 s/d -102.94	0.23%	0.011	
-102.94 s/d -95.92	18.02%	0.892	
-95.92 s/d -88.9	60.91%	3.014	
-88.9 s/d -81.8	16.00%	0.791	
-81.8 s/d -74.86	3.17%	0.157	
-74.86 s/d -67.84	0.62%	0.030	

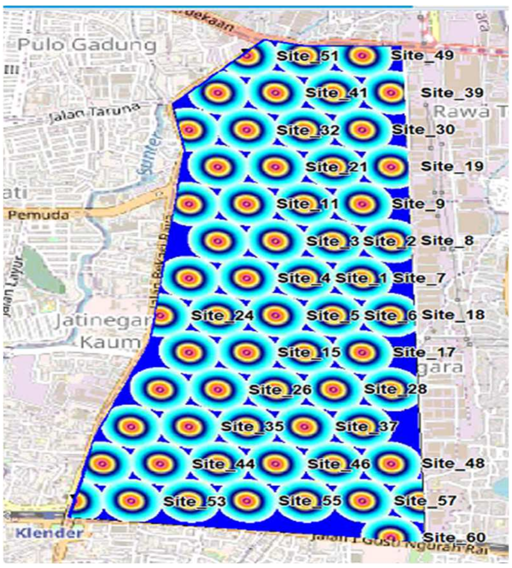

Fig. 6 ASP for gNodeB mapping at frequency 28 GHz

TABLE VIII
SIMULATION RESULT FOR SS-RSRP AT FREQUENCY 28 GHZ

SS-RSRP Value (dBm)	Percentage	Area (km^2)	Color
< -110.96	1.41 %	0.070	
-110.96 s/d -104.92	9.10 %	0.450	
-104.92 s/d -98.87	42.28 %	2.089	
-98.87 s/d -92.83	23.40 %	1.156	
-92.83 s/d -86.79	12.22 %	0.604	
-86.79 s/d -80.74	6.47 %	0.320	
-80.74 s/d -74.70	2.99 %	0.148	
-74.70 s/d -68.65	2.00 %	0.099	

From the simulation results in the planning with a frequency of 3.5 GHz, Fig. 7 and Table 7 showed that a 0.20% portion of the total area does not receive service from the gNodeB due to signal strength. In the planning with a frequency of 28 GHz, Fig. 8 and Table 8 showed that a 1.41% area falls outside the range. These areas outside the range are indicated in blue color on the map and table. Table 9 shows the SS-RSRP statistic calculation for 3.5 GHz and 28 GHz.

TABLE IX
STATISTIC CALCULATION

Raster Statistic	Value (dBm)	
	3.5 GHz (4 sites)	28 GHz (59 sites)
Minimum	-116.89	-110.97
Maximum	-67.51	-68.66
Mean	-91.88	-97.07

The prediction average SS-RSRP, as determined by 4 gNodeB at a frequency of 3.5 GHz is -91.88 dBm, while using 60 gNodeB at a frequency of 28 GHz is -97.07 dBm. Both frequencies result in signal strengths that are considered very good according to LTE technology standards [30].

2) *Scenario 2 (Outdoor-to-Indoor (O2I) Uplink):* This design does not utilize existing site locations. Instead, new site options will be suggested based on concerns for coverage. The Mentum Planet software's ASP tool will automatically customize the site placement. In contrast to the calculated result of 3 sites, Scenario 1 at 3.5 GHz suggests 4 sites for the planning region. The recommendation, which deviates from the predicted result by 1 site for a frequency of 28 GHz, calls for the use of 60 sites. These discrepancies result from restrictions in the Automatic Site Placement (ASP) feature's setup of the number of gNodeB and their radius distance. The parameter being analyzed is SS-RSRP from a coverage perspective. The service provided in the simulation is Video Streaming.

Fig. 7 ASP for gNodeB mapping at frequency 3.5 GHz

TABLE X
SIMULATION RESULT FOR SS-RSRP AT FREQUENCY 3.5 GHZ

SS-RSRP Value (dBm)	Percentage	Area (km^2)	Color
< -116.98	2.22%	0.110	
-116.98 s/d -109.96	1.61%	0.080	
-109.96 s/d -102.94	2.92%	0.145	
-102.94 s/d -95.92	38.37%	1.903	
-95.92 s/d -88.9	41.47%	2.056	
-88.9 s/d -81.8	10.90%	0.540	
-81.8 s/d -74.86	2.13%	0.105	
-74.86 s/d -67.84	0.37%	0.018	

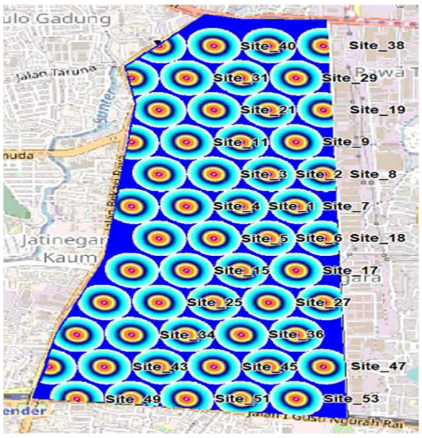

Fig. 8 ASP for gNodeB mapping at frequency 28 GHz

TABLE XI
SIMULATION RESULT FOR SS-RSRP AT FREQUENCY 28 GHZ

SS-RSRP Value (dBm)	Percentage	Area (km^2)	Color
< -110.96	1.82 %	0.090	
-110.96 s/d -104.92	17.22 %	0.851	
-104.92 s/d -98.87	39.53 %	1.953	
-98.87 s/d -92.82	20.58 %	1.017	
-92.82 s/d -86.77	10.66 %	0.527	
-86.77 s/d -80.73	5.68 %	0.281	
-80.73 s/d -74.68	2.61 %	0.129	
-74.68 s/d -68.63	1.80 %	0.089	

The simulation results in the planning with a frequency of 3.5 GHz. Table 10 shows that a 2.22% portion of the total area does not receive service from the gNodeB due to signal strength in the planning with a frequency of 28 GHz. Table 11 shows that a 1.82% area falls outside the range. The map and table indicate these areas outside the range in blue.

TABLE XII
STATISTIC CALCULATION

Raster Statistic	Value (dBm)	
	3.5 GHz (3 sites)	28 GHz (53 sites)
Minimum	-116.99	-110.97
Maximum	-67.82	-68.64
Mean	-94.87	-98.12

Table 12 shows the prediction average SS-RSRP, as determined by 3 gNodeB at a frequency of 3.5 GHz is -94.87 dBm, while using 53 gNodeB at a frequency of 28 GHz is -98.12 dBm. Both frequencies result in signal strengths that are considered very good according to LTE technology standards [30].

IV. CONCLUSION

In this research, the authors thoroughly evaluated 5G NR network coverage planning within the Pulogadung industrial area in East Jakarta. Our research focused on using specific frequency bands, including 3.5 GHz and 28 GHz, aligning with Indonesia's recommended spectrum allocation. Importantly, our investigation revealed that the 28 GHz frequency band exhibited more significant path losses when compared to the 3.5 GHz frequency band.

At the 3.5 GHz frequency, the permissible path loss between gNodeB and User Terminals (UT) was measured at 100.66 dB for the downlink-O2I scenario and 104.66 dB for the uplink-O2I scenario. Conversely, at 28 GHz, significantly higher path losses of 108.80 dB for the downlink-O2I scenario and 109.30 dB for the uplink-O2I scenario were observed.

To efficiently address the network traffic requirements in the Pulogadung industrial area, the 3.5 GHz frequency necessitates the deployment of four sites for scenario 1, while scenario 2 requires only two sites. In contrast, the 28 GHz frequency demands a denser site deployment, with 60 sites needed for scenario 1 and 53 sites for scenario 2. This discrepancy emphasizes that the 28 GHz scheme requires a higher site density than the 3.5 GHz scheme.

Furthermore, when assessing the Serving Cell Reference Signal Received Power (SS-RSRP) parameters, we found that scenario 1 (downlink-O2I-LOS) at 3.5 GHz yielded the most favorable average SS-RSRP value at -91.88 dBm. Conversely, scenario 2 (uplink-O2I-LOS) at 28 GHz exhibited the lowest average SS-RSRP value. It is worth noting that variations in the standard values of several parameters in the link budget for each frequency contribute to the observed differences in predicted SS-RSRP results.

ACKNOWLEDGMENT

The authors would like to thank Institut Teknologi Telkom Purwokerto for the funds and facilities provided during the research, as well as the PT Cahaya Arif Abadi (CAA) team, which contributed to the provision of Mentum Planet software, Politeknik Negeri Jakarta, and INTI International University, for their assistance, support, and recommendations in completing this research.

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