ANALYSIS OF 5G NETWORK PERFORMANCE IN LINE-OF-SIGHT CONDITIONS USING 3.3 GHZ FREQUENCY AT SAWAHAN, SURABAYA

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***Abstract*--This research is expected to be the beginning of the initial design for the implementation of 5G technology in Indonesia especially in the area of Sawahan, Surabaya based on the coverage area with the frequency of 3.3 GHz. Performance analysis with line-of-sight (LOS) conditions using propagation model urban macro (uMa) according to the recommendation of 3GPP (3rd Generation Partnership Project) TR 38.901. This research based on four scenarios, outdoor-to-outdoor (O2O) for downlink and uplink, and outdoor-to-indoor (O2I) scenario for uplink and downlink. Performance of 5G network simulated using Atoll 3.4 and shown the pathloss values of 105.405 dB for uplink and 101.405 dB for downlink. The performance results in the O2O scenario for the uplink direction require 5 gNodeB and 8 gNodeB in the downlink direction. In the O2I scenario, the uplink direction requires as many as 6 gNodeB and the downlink direction as much as 9 gNodeB. The simulation parameters analyzed in this research are based on the signal strength received by the user (SS-RSRP) and signal quality (SS-SINR). The best result of SS-RSRP in the O2I uplink scenario is -89 dBm and the SS-SINR parameter in the O2O scenario is 0.93 dBm. These results show that in the Sawahan District can be applied 5G networks.**

***Keywords*: Atoll 3.4, Coverage area, gNodeB Line-of-sight, SS-RSRP, SS-SINR.**

I. INTRODUCTION

The technology implementation of International Mobile Telecommunication Year of 2020 (IMT-2020) has made 5G as the technology that developed fast. The 5G technology requires a better speed, coverage and reliability compared to the previous technology. The service concept can be divided into 3 characteristics called enhanced Mobile Broadband (eMBB), ultra-Reliable and Low Latency Communications (uRLLC), and massive Machine Type Communications (mMTC). eMBB is used with the aim to meet the user's need of digital lifestyle while its service focusing on the higher bandwidth such as High Definition (HD) video, Virtual Reality (VR), and Augmented Reality (AR) [1]. uRLLC aims to be used in various frequencies with different characteristics. The low spectrum range of mMTC with low frequency spectrum has enabled the 5G coverage to be used in a wider area, while the high spectrum is used for uRLLC. The high frequency range with the bigger bandwidth can provide the capacity of user in bigger number with high speed [2],[3]. The purpose of mMTC is to meet the digital era challenge by focusing on the service, for example in the implementation of smart city and smart agriculture, in the 5G technology, there are two types of architecture, they are stand-alone (SA) dan non-stand-alone (NSA). The 5G stand-alone technology is the 5G network supported by the 5G infrastructures in providing service which operating independently and being operated in the same time to cover an area. On the other hand, the non-stand-alone 5G network is the 5G network which is still supported by LTE infrastructures [4].

The 5G technology needs the spectrum with three ranges of main frequencies, they are low band, mid band, and high band. Low band is the frequency under 1GHz which used for the coverage especially fo mMTC application. Mid band is the frequency ranging from 1 – 6 GHz with a wider bandwidth which used for the eMBB and mission-critical. High band uses the frequency above 24 GHz which used for the something with huge bandwidth [5].

The frequency band is chosen based on many considerations, one of which is the frequency band test and the tools used by mobile operator which can only operate in a certain frequency range. It raises a new challenge for the telecommunication service provider in Indonesia to make arrangement according to the plan in order to obtain the best network to serve the customers throughout Indonesia. The study [6] explains the 5G network coverage planning based on the path loss propagation and shadowing on the working frequency of 869 MHz utilizing the rooftop towers with different heights. The 5G network performance using the non-standalone scheme with the frequency of 28 GHz operating in FR-1 and FR-2 is conducted in the study[7]. The results of study [7] generate latency of 0.473 ms, throughput 1052,26 Mbps, and packet loss of 0,0003%.

Ref. [8] and [9] designed a 5G network at frequency of 3.5 GHz with a wider area than this research. This research used a smaller frequency of 3.3 GHz with implementation in a smaller coverage area so that it affected the number of gNodeB needed. The characteristic of the area and the frequency used also affect the performance value in design. This research about 5G NR network planning was done in Sawahan District, one of the districts in Surabaya City with an area of 7.64 km2 and the total populations are 27979 people/km2 from the year 2020-2026. Based on Table 1, the population density of the region, the propagation model used for the Sawahan, Surabaya is urban category.

TABLE 1
Regional classification based on population density

Classification	Minimum Population Density (people/km2)	Maximum Population Density (people/km2)
Dense Urban	20000	500000
Urban	4500	19999
Sub-Urban	250	4 499
Rural	0	249

This research used the 3,3 GHz frequency based on the frequency band in Indonesia as written in Table 2. The standardization of propagation model based on 3GPP 38.901 [10]. Before the planning done, the link budget of power assumption which recommended for 5G NR network was required. The calculation based on the coverage would give the value of MAPL, propagation and cell radius which in the end would create the number of site needed in the location. The data tested used Atoll 3.4 simulation tool and gave the value of signal to noise and interference ratio (SS-SINR) and secondary synchronization reference signal received power (SS-RSRP).

TABLE 2
The range of frequency 5G

Frequency Center	Range
Band frekuensi 3.5 GHz	3.3 – 4.2 GHz
Band frekuensi 15 GHz	14.5 – 15.35 GHz
Band Frekuensi 26 GHz	24.25 – 27.5 GHz
Band Frekuensi 28 GHz	26.5 GHz – 29.5 GHz

II. METHOD

A. *Flowchart of Research*

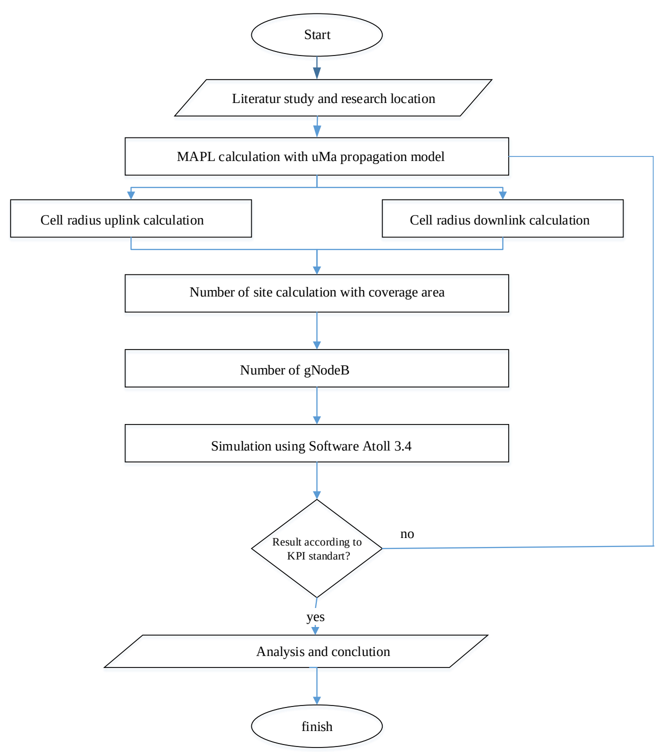

Fig. 1. Flowchart of research.

Fig. 1 shows the flow of research design 5G NR network planning based on area coverage. The final result of this research is the number of sites needed in the Surabaya area based on the results of the area prediction. The initial stage of this planning was to determine the area where the 5G NR network would be implemented later. The location chosen was the City of Surabaya with a sample in a district namely Sawahan. The district has an area of 7.64 km with a total population density of 27,979 people/km2. The data needed to carry out the design included the area, the geographical location, and the description of the area. After that the research parameters were used to calculate the path loss value for both uplink and downlink using the Urban Macro (uMa) propagation model recommended by 3GPP 38.901. There were four scenarios used, namely outdoor-to-outdoor (O2O) downlink, outdoor-to-indoor (O2I) downlink, outdoor-to-outdoor (O2O) uplink, and outdoor-to-indoor (O2I) uplink for line-of-sight (LOS) conditions installed on the rooftop of a building. The open area will describe the real conditions in the field. The width of the coverage area is usually around 50 – 100 meters with a transmitter height of 10 m and a receiver 1.5 – 2 meters [5][4].

Analysis and simulation were done using Atoll 3.4 software in which it was the most important stage in the research because the simulation would display the coverage area and parameters that would be compared with the link budget calculation results.

B. Coverage Area Planning

Coverage area planning was a network planning by performing calculations based on the area to be covered by the network. Parameters affected this planning were the transmit power, pathloss, device sensitivity, radio link budget calculation and cell radius. To determine the best pathloss value that can be accepted by gNodeB and user equipment (UE) were done by using the link budget calculation, while the uMa propagation model was used to determine the cell radius.

C. Link Budget Parameters

To calculate the link budget, the Maximum Allowable Pathloss (MAPL) value was required as shown in Table 3. Path loss was a method used to measure the loss of an area by considering the weather, land contours, and area conditions showing the measurement of signal levels between the transmitter and receiver. The equation to calculate the path loss value shown as in (1).

Pathloss (dBm) = gNodeB transmit power (dBm) – 10 log10 (subcarrier quantity) + gNodeB antenna gain (dBi) – gNodeB cable loss (dB) – penetration loss (dB) – folliage loss (dB) – body block loss (dB) – interference margin (dB) – rain margin (dB) – slow fading margin (dB) + UT antenna gain (dB) – thermal noise figure (dBm) – UT noise figure (dB) – demodulation threshold SINR (dB) (1)

TABLE 3
Maximum Allowable Path Loss (MAPL) [11]

Maximum Allowable Path Loss (MAPL)		
Parameters	Downlink	Uplink
gNodeB Transmitter Power (dBm)	49	49
Resource block	217	217
Subcarrier quantity	2604	2604
gNodeB antenna gain (dBi)	2	2
gNodeB cable loss (dBi)	0	0
Penetration loss (dB)	26.85	26.85
Foliage loss (dB)	19.59	19.59
Body block loss (dB)	3	3
Interference margin (dB)	6	2
Rain/ice margin (dB)	0	0
Slow fading margin (dB)	7|8	7|8
UE antenna gain (dB)	0	0
Bandwidth (MHz)	80	80
Konstanta boltzman (K) (mWs/K)	1,38 x 10-23 J/K	1,38 x 10-23 J/K
Temperature (kelvin)	293	293
Thermal noise power (dBm)	-124.901	-124.901
UT Noise Figure (dB)	9	9
Demodulation threshold SINR (dB)	-1.1	-1.1

To calculate the thermal noise and subcarrier quantity (SCQ) in Table 2 used the equation (2) and (3):

$$\text{Thermal Noise} = 10 \log (K\ T\ B) \quad (2)$$

where, K is konstanta boltzman (1,38 x 10-23 J/K), bandwidth (B) and (T) is temperature (293^o K).

$$SCQ = RB \times \text{subcarrier per resource block} \quad (3)$$

With the sum of RB is 132 and the sum of subcarrier per resource block of 12. To find the resultant value of distance (d3D), the parameter of d'_{BP}, value of h'_{BS}, h'_{UT} were needed, which can be written as:

$$h'_{BS} = h_{BS} - hE \tag{4}$$

$$h'_{UT} = h_{UT} - hE \tag{5}$$

$$d'_{BP} = 4 \times h'_{BS} \times h'_{UT} \times \frac{fc}{c} \tag{6}$$

where,

d'_{BP} = distance of break point (meters)
fc = frequency (GHz)
h_{BS} = height of gNodeB antenna (meters)
h_{UT} = height of user terminal antenna (meters)
c = speed of light 3×10^8 m/s

Model of UMa propagation for LOS condition was calculated using the equation of:

$$PL_1 = 28 + 40\log_{10}(d3D) + 20\log_{10}(fc) - 9\log_{10}((d'_{BP})^2 + (h'_{BS} - h'_{UT})^2) \tag{7}$$

where PL_1 is path loss value (dBm) and $d3D$ is resultant distance between h_{BS} and h_{UT}.

After obtaining the value of based on the path loss calculation, the next step was to calculate the value of d2D which the cell radius by using the equation:

$$d2D = \sqrt{((d3D)^2 - (h_{BS} - h_{UT})^2)} \tag{8}$$

After getting the value $d2D$, thus the coverage area (CA) covered in one gNodeB can be obtained using the equation of:

$$C_A = 1{,}9 \times 52{,}6 \times d^2 \tag{9}$$

From the calculated area, the next step was to determine the number of sites needed in an area with the simulated area. The number of sites was calculated using the equation of:

$$N\ gNodeB = \frac{luas\ area}{C_A} \tag{10}$$

D. Secondary Synchronization Reference Signal Received Power (SS-RSRP)

SS-RSRP was the average power carried the reference signal in the frequency range used which indicated the level of signal strength in a cell. On a 5G network, user equipment measured the strength of the received signal on a secondary synchronization signal (SSS) for each nearby transmitter cell. SS-RSRP was defined as the average power (watts) measured on the UE of the secondary synchronization signal (SSS) coupled with the cell transmitter. The indicator for SS-RSRP as shown in Table 4.

TABLE 4
Indicator for SS-RSRP

Range	Indicator
Very Good	> - 85 dBm
Good	- 85 dBm to -95 dBm
Normal	- 94 dBm to -105 dBm
Bad	<= 105 dBm

E. Signal to Noise and Interference Ratio (SS-SINR)

SS-SINR was defined as the ratio of the strength of the transmitted signal compared to the background noise arose. SS-SINR was also said to be the ratio between the average receiving power with the average interference and noise. The indicator for SS-RSRP as shown in Table 5.

TABLE 5
Indicator for SS-RSRP

Range	Indicator
Good	16 to >30 dB
Normal	1 -15 dB
Bad	<-10 to 0

III. RESULT AND DISCUSSION

Determining the coverage planning including the calculation of pathloss and link budget would create the final results of the number of sites needed in one region. To obtain the number of sites in Sawahan District was done by determining the propagation model. The propagation model used in this research was suitable with 3GPP 38.901 called the Urban Macro (uMa) propagation model. Based on the calculation results from several scenarios, different values were obtained. They were affected by the value of the interference margin and slow fading margin for uplink and downlink.

The scenarios used in this study were outdoor-to-outdoor (O2O) and outdoor-to-indoor for uplink and downlink in line-of-sight (LOS) conditions. From the four scenarios, the number of gNodeB for the uplink O2O scenario was 5 sites, the downlink O2O scenario was 8 sites, the uplink O2I scenario was 6 sites, and the downlink O2I scenario was 9 sites, as shown in Table 6.

TABLE 6
The result of link budget calculation

Parameters	Scenario 1 O2O LOS uplink	Scenario 2 O2O LOS downlink	Scenario 3 O2I LOS uplink	Scenario 4 O2I LOS downlink
Thermal Noise	-154.901 dB	-154.901 dB	-154.901 dB	-154.901 dB
Subcarrier Quantity	2604	2604	2604	2604
Pathloss	105.405 dB	101.405 dB	104.405 dB	100.405 dB
h'_{BS}	24 meter	24 meter	24 meter	24 meter
h'_{UT}	0.5 meter	0.5 meter	0.5 meter	0.5 meter
d'_{BP}	416 meter	416 meter	416 meter	416 meter
$d3D$	796.621 meter	632.779 meter	752.059 meter	597.382 meter
$d2D$	796.275 meter	632.342 meter	751.692 meter	596.919 meter
Coverage Area	1648541 m^2	1039629 m^2	1469107 m^2	926414 m^2
Number of gNode B	5	8	6	9

The simulation results obtained were based on the data on the main parameters in Table 3 and the calculation results can be explained as follows:

A. *Scenario 1: Outdoor-to-outdoor (O2O) uplink*

The outdoor-to-outdoor uplink scenario was a condition where the base station and the user situated outside the room with the signal emitted from the user's direction to the base station. In this scenario, based on the results of the link budget calculation, 4 sites were required to cover all regions.

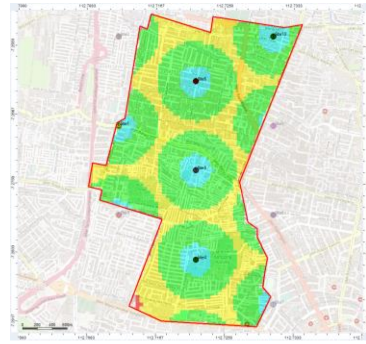

Fig. 2. Simulation result of SS-RSRP value in scenario 1

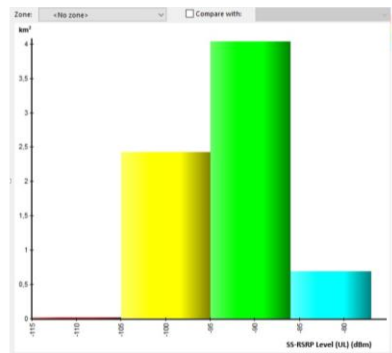

Fig. 3. Histogram of SS-RSRP value in scenario 1

The SS-RSRP obtained in scenario 1 is -92.65 dBm with the result simulation has 5 site, as shown in Fig.2 and details data in Table 7. It shown in Fig. 3 that the signal was in normal condition with a minimum value range of -106 dBm and a maximum of -55 dBm. Based on the results of the area distribution, 96.6% of the area in the paddy fields had good RSRP value and only 0.5% of the area had poor SS-RSRP value.

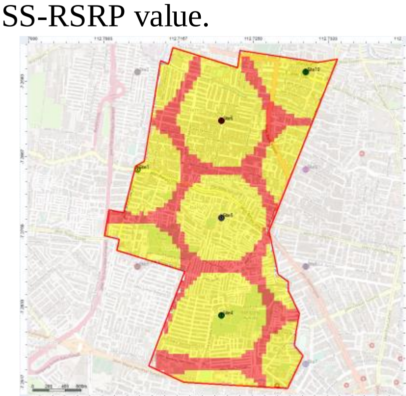

Fig. 4. Simulation result of SS-SINR value in scenario 1

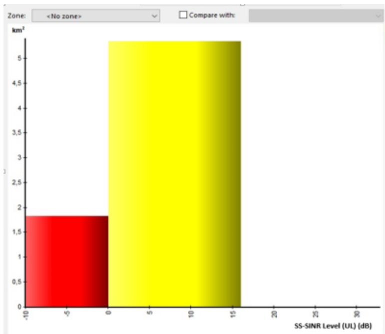

Fig. 5. Histogram of SS-SINR value in scenario 1

B. Scenario 2: Outdoor-to-outdoor(O2O) downlink

This design did not use the location of the existing site, but used the location of the new site which will be recommended based on the calculation of the coverage area. Site placement was set automatically in the Atoll software 3.4 version. From the scenario 2 which was designed based on MAPL calculations, it was obtained that the number of required sites was 8 sites, but the sites obtained automatically from the simulation results of the Sawahan Area can be served by 8 sites. For the site placement can be seen in Fig. 6 and Fig. 8.

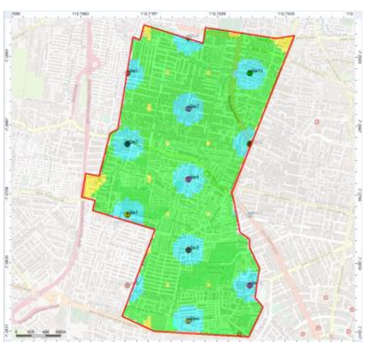
Fig. 6. Simulation result of SS-RSRP value in scenario 2

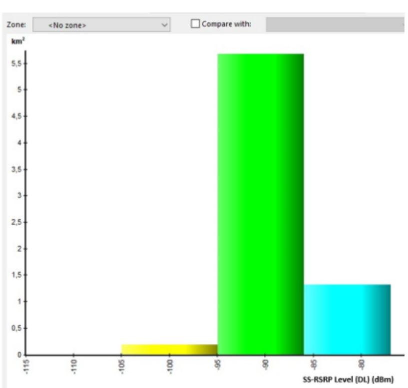

Fig. 7. Histogram of SS-RSRP value in scenario 2

The average SS-RSRP that can be served in the scenario 1 is -89.45 dBm, it means that the signal strength was very good, with only 0.98% of the total area having a less than optimal SS-RSRP value. Meanwhile, this study presented the results of the maximum SS-RSRP value of -55 dBm and the minimum SS-SRSP of -106 dBm.

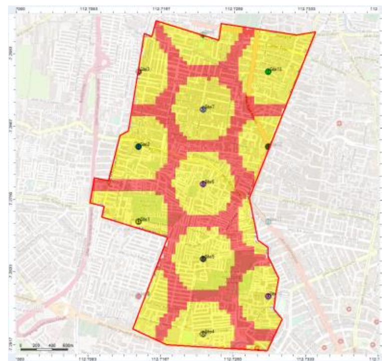
Fig. 8. Simulation result of SS-SINR value in scenario 2

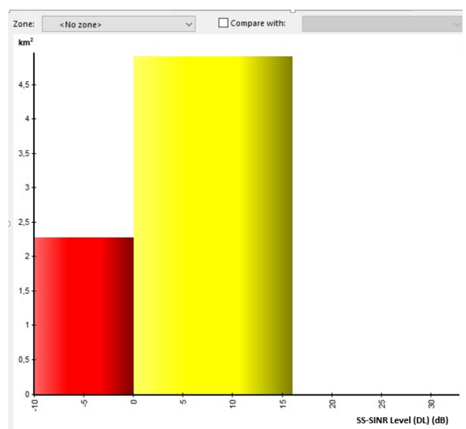

Fig. 9. Histogram of SS-SINR value in scenario 2

The average SS-SINR that can be served in the scenario 2 is 0.93 dB, it means that the signal strength was very good as shown in Fig. 9. The range of values and percentages of simulation results for scenario 1 and 2 can be seen in Table 7 and 8. Table 7 shows that scenario 2 has a stronger signal received by users are greater than scenario 1. Table 8 shows the percentage value of the received strong signal in accordance with the range of values for KPI standard.

TABLE 7
The calculation SS-RSRP in scenario 1 and 2

Statistic	Skenario 1 (dBm)	Skenario 2 (dBm)
Minimum	-106	-106
Maximum	-55	-55
Mean	-92.65	-89.45

TABLE 8
The simulation result of SS-RSRP in scenario 1 and 2

Range of value	Percentage Skenario 1	Percentage Skenario 2
-106 until -80	93.34	96.60
-80 until -79	0.94	0.60
-79 until -76	2.06	0.90
-76 until -68	2.55	1.40
-68 until -67	0.14	0.10
-67 until -55	0.98	0.50

The ratio of the transmitted signal strength to the average interference and noise in this study obtained a mean value of 0.78 dBm, with a maximum value of 5 dBm and a maximum of 5 dBm. The standard SS-SINR value obtained was still categorized as good with a percentage of 68.4% of the total designed area.

SS-SINR in this research obtained a mean value of 0.93 dBm, with a maximum value of 5 dBm and a maximum of 5 dBm as shown in Table 9. The standard SS-SINR values presented in accordance with Table 10 were still categorized as good with a percentage of 74.64% having SS-SINR values ranging from 0 to 5 dBm, and 24.69% SS-SINR values ranging from 0 to -3 dBm.

TABLE 9
The calculation SS-SINR in scenario 1 and 2

Statistic	Skenario 1 (dBm)	Skenario 2 (dBm)
Minimum	-5	-5
Maximum	5	5
Mean	0.78	0.93

TABLE 10
The simulation result of SS-SINR in scenario 1 and 2

Range of value	Percentage Skenario 1	Percentage Skenario 2
0 until 5	68,40	74,64
-3 until 0	30,90	24,69
-5 until -3	0.7	0.66

C. Scenario 3: Outdoor-to-indoor (O2I) uplink

In the scenario 3, the simulation was carried out by designing an outdoor-to-indoor where gNodeB situated outside the room, but the user was indoors. The O2I scheme was designed in LOS conditions, in which between the transmitter and the receiver had no obstacle.

Fig. 10. Simulation result of SS-RSRP value in scenario 3

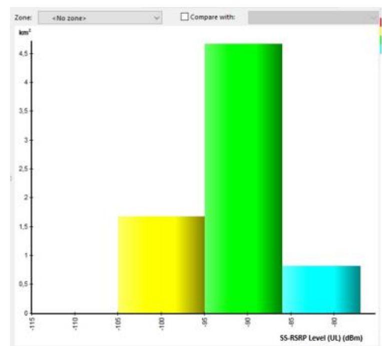

Fig. 11. Histogram of SS-RSRP value in scenario 3

Based on the results of calculations for the scenario 3, the number of sites required was 6 sites. After designing using Atoll, the SS-RSRP value was still good and normal with an average value of -92.65 dBm with a sub-area distribution of 96%.

Result of this scenario as described in Tables 11 and 12. Based on the simulation results, the SS-RSRP value assessed with a range of -67 to -65 dBm was in a very small percentage, only 0.5% of the total area. Thus, for the scenario 3, the SS-RSRP results were good and normal.

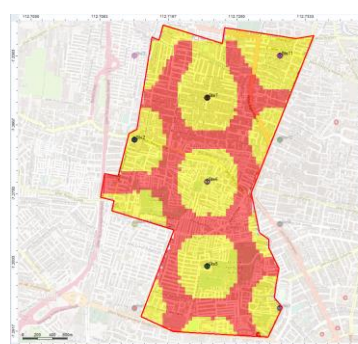

Fig. 12. Simulation result of SS-SINR value in scenario 3

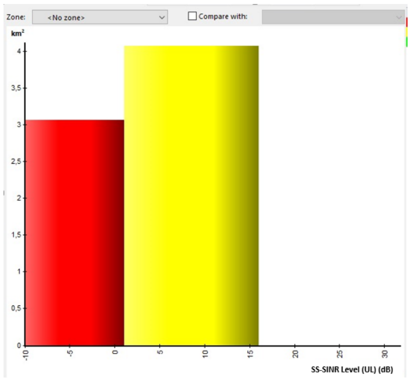

Fig. 13. Histogram of SS-SINR value in scenario 3

The average SS-SINR that can be served in the scenario 3 is 0.8 dB, it means that the SS-SINR was very good as shown in Fig. 13.

D. Scenario 4: Outdoor-to-indoor (O2I) downlink

Scenario 4 was done by doing O2I design on the downlink side. The O2I scenario was a scenario where the base station was situated outside the room and the user was indoors. From the calculation of the link budget for scenario 4, the number of sites needed was 9 sites. The simulation results showed that the SS RSRP value was still in good condition with an average value of -89 dBm. The parameters SS-SINR is normal category with 0.8 dBm.

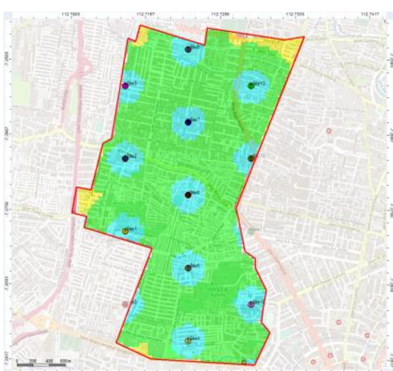

Fig. 14. Simulation result of SS-RSRP value in scenario 4

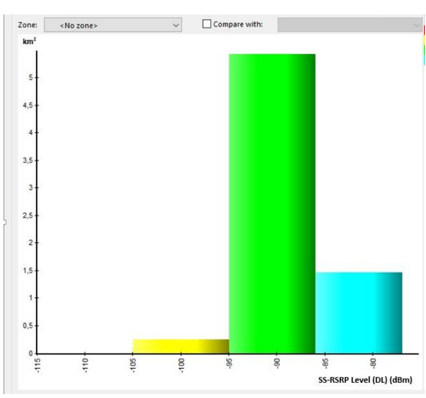

Fig. 15. Histogram of SS-RSRP value in scenario 4

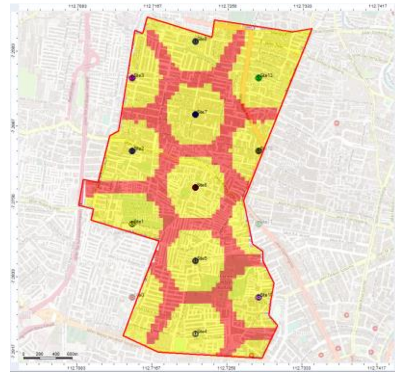

Fig. 16. Simulation result of SS-SINR value in scenario 4

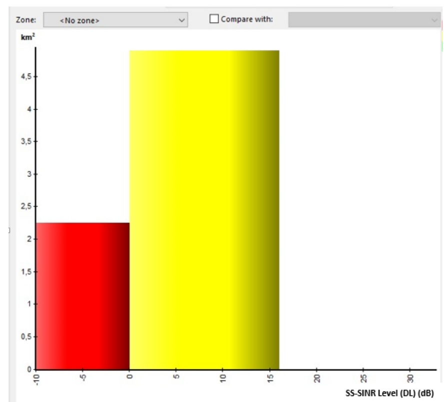

Fig. 17. Histogram of SS-SINR value in scenario 4

TABLE 11
The calculation SS-RSRP in scenario 3 and 4

Statistic	Skenario 3 (dBm)	Skenario 4 (dBm)
Minimum	-106	-106
Maximum	-55	-55
Mean	-89	-91

TABLE 12
The simulation result of SS-RSRP in scenario 3 and 4

Range of value	Percentage Skenario 3	Percentage Skenario 4
-106 until -80	92.40	96.10
-80 until -79	0.91	0.60
-79 until -76	2.63	1.10
-76 until -68	2.93	1.60
-68 until -67	0.25	0.10
-67 until -55	0.88	0.50

Table 11 and 12 show the distribution of the maximum, minimum, and average SS-RSRP values using the Atoll simulation. The largest SS-RSRP value was in the range of -106 to -80 dBm with a distribution percentage of 92.40% of the total coverage area. The average value of SS-RSRP obtained was -89 dBm. The lowest SS-RSRP value obtained was in the range of -76 to -55 dBm with a percentage of 0.8% of the sub-area covered. From the simulation results for scenario 4, O2I downlink had good SS-RSRP value and was in normal condition.

In addition to the SS-RSRP values in scenarios 3 and 4, it also obtained the results for the comparison of signal values to noise interference (SS-SINR). The simulation results of SS-SINR values for scenarios 3 and 4 can be seen in Table 13 and 14. The average SS-SINR obtained for scenario 3 was 0.8 dBm and for scenario 4 was 0.92%. With each distribution of SS-SINR values that had a range from 0 to 5 was only 68.56% and 74.35% of the total sub-area.

TABLE 13
The calculation SS-SINR in scenario 3 and 4

Statistic	Skenario 3 (dBm)	Skenario 4 (dBm)
Minimum	-5	-5
Maximum	5	5
Mean	0.8	0.92

TABLE 14
The simulation result of SS-SINR in scenario 3 and 4

Range of value	Percentage Skenario 3	Percentage Skenario 4
0 until 5	74.35	68.56
-3 until 0	24.98	30.29
-5 until -3	0.66	1.16

IV. CONCLUSIONS

Based on the discussions regarding the design of the 5G network at a frequency of 3.3 GHz in the Sawahan District, the following conclusions can be written as follows:

1. The number of sites needed in the Sawahan District based on the coverage area under LOS conditions using the uMa propagation model were in the uplink O2O scenario 5 sites were needed while in the downlink O2O scenario 8 sites were needed. For the O2I uplink scenario, 6 sites were needed and the O2I downlink scenario required 9 sites. The required number of sites can be used to accommodate the distribution of traffic in the area.
2. From the parameters (SS-RSRP) for the four executed scenarios, it shown that the downlink O2O scenario got the SS-RSRP value of -89.45 dBm, the uplink O2O scenario got the SS-RSRP value of -92.65 dBm, and the O2I scenario downlink obtained the SS-RSRP value of -89 dBm and the uplink O2I scenario obtained the SS-RSRP value of -91.6 dBm. From the SS-SINR parameters, it shown that the downlink O2O scenario had the lowest average SINR of 0.77 dBm and the uplink O2I scenario had the highest average SINR of 0.92 dBm. It was due to the difference in the number of sites obtained to cover the planning area.

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