Comparison of 5G NR Planning in Mid-Band and High-Band in Jababeka Industrial Estate

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Abstract— **New Radio (NR) is the fifth generation of wireless access technology that is able to provide extreme mobile broadband, massive connectivity and low-latency communications. This study aimed to compare network planning in mid-band at 2.6 GHz and in high-band at 26 GHz which enables very large bandwidth for multi-Gigabit-per-second (Gbps) data rate transmission. The network planning used Mentum Planet 7.3 based on coverage area in the form of a case study in Jababeka Industrial Estate with an area of 22.67 km^2. Link budget was calculated using Downlink Outdoor-to-Outdoor (O2O) with Line of Sight (LOS) and Non-Line of Sight (NLOS) scenarios based on the Urban Micro (UMi) and Urban Macro (UMa) propagation models with 3GPP TR 38.901 standardization. The simulation results showed that scenario 1 (downlink-O2O-LOS) produced a better network than scenario 2 (downlink-O2O-NLOS). The NLOS scenario required a higher number of gNodeB than the LOS scenario because in the NLOS scenario, there was a trouble between the gNodeB and the user terminal. The maximum data rate at 2.6 GHz was 436.31 Mbps with an average SS-RSRP value of -96.01 dBm and an average SS-SINR value of 4.21 dB, while the maximum data rate for 26 GHz was 1.83 Gbps with an average SS-RSRP value of -78.14 dBm and an average SS-SINR value of 0.46 dB.**

Keywords—5G NR Planning, Mid-Band, High-Band, Mentum Planet, Data Rate

I. Introduction

The term 5th Generation (5G) refers to the fifth generation of cellular communication system. This generation is included in the next major phase of mobile telecommunications standard apart from the current network that will meet the upcoming requirements for the International Mobile Telecommunications (IMT)-2020 from the International Telecommunication Union-Radio (ITU-R). 5G offers significantly faster data rates with very low-latency compared to the current systems including LTE. Therefore, this generation allows for the adaptation of highly sophisticated services in wireless environments [1].

International Telecommunication Union (ITU) at Rec. ITU-R M 2083-0 discusses an upgrade in IMT-2020, where there are eight key features in the 5G network, various features that support different usage scenarios. The eight parameters of the capabilities of IMT-2020 are: peak data rate (Gbit/s), user experienced data rate (Mbit/s), latency (ms), mobility (km/h), traffic capacity (Mbit/s/m2), network energy efficiency, connection density (device/km2), and spectrum efficiency [2]. It is expected that in 2020 and beyond, IMT expands and supports various usage scenarios and applications that will continue following the current IMT. The usage scenarios of IMT for 2020 and beyond include Enhanced Mobile Broadband (eMBB), Ultra-reliable and Low Latency Communications (uRLLC) and Massive Machine Type Communications (mMTC). All capabilities may be important to some extent for most usage scenarios; the relevance of particular key capabilities may differ significantly depending on the usage scenarios. The importance of each key capability for Enhanced Mobile Broadband, Ultra-reliable and Low Latency Communications and Massive Machine Type Communications is illustrated in Figure 1. This is done using indicative grade in three categories, i.e. "high", "medium" and "low".

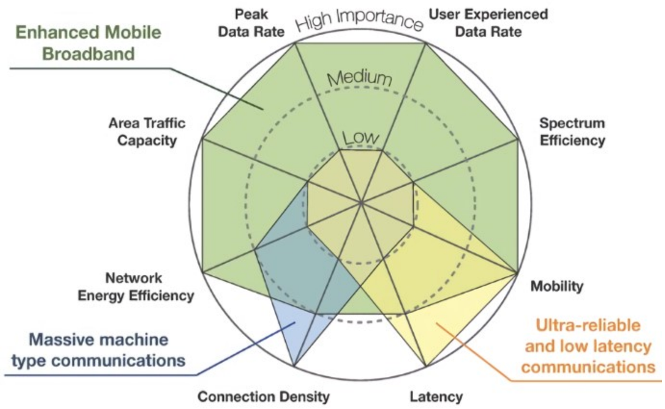

Fig. 1. Key capabilities in different usage scenario [3]

Limited frequency spectrum is very important for the telecommunications industry, especially along with data-intensive service deployment. The usage scenarios for eMBB, uRLLC and mMTC require various frequency spectrums with different characteristics. The spectrum bands allocated to 5G deployment can be divided into three macro categories, namely low bands, medium bands, and high bands as seen in Table I.

TABLE I. 5G FREQUENCY LAYERS AND SCHENARIO [4][5]

Category	Frequency and Bandwidth	Usage Scenario
Low Frequency Bands Coverage Layer	Below 1 GHz Bandwidth up to 20 MHz	mMTC
Medium Frequency Bands Coverage and Capacity Layer	1 – 6 GHz Bandwidth up to 100 MHz	mMTC eMBB
High Frequency Band Super Data Layer	Above 6 GHz Bandwidth up to 800 MHz	eMBB uRLLC

The reason for using low-band for mobile broadband and the Internet of Things (IoT) is because wireless signals can penetrate barriers such as buildings, have extreme coverage and minimum data rates. Mid-band is the ideal frequency for 5G NR because it can provide a good network based on coverage and capacity. MillimeterWave (mmWave) is a very high frequency that offers large amounts of spectrum that can provide Gbps data rates, high capacity and minimum latency (1ms). Unfortunately, due to its wavelength, mmWave generally requires a line of sight because the mmWave signal can be interfered by rain / ice and it is easily blocked not only by building materials, but also by leaves and human bodies.

5G NR network planning in mid-band and high-band in Jababeka Industrial Estate based on coverage area was discussed in this research. Frequency selection for implementing 5G has become a challenge for operators. This study used frequencies of 2.6 GHz and 26 GHz because these frequency bands are recommended for Indonesia and it is expected that these bands become a reference in implementing 5G networks in Indonesia [5]. Link budget and propagation model calculations were conducted to determine the path loss values and cell radius to determine the number of sites required in Jababeka Industrial Estate.

The structure of this paper is as follows. Section II discusses the methodology, planning concepts and parameters to be used. Section III presents the results of the link budget and the results of each parameter from the simulation.

II. METHOD

A. *Research Method*

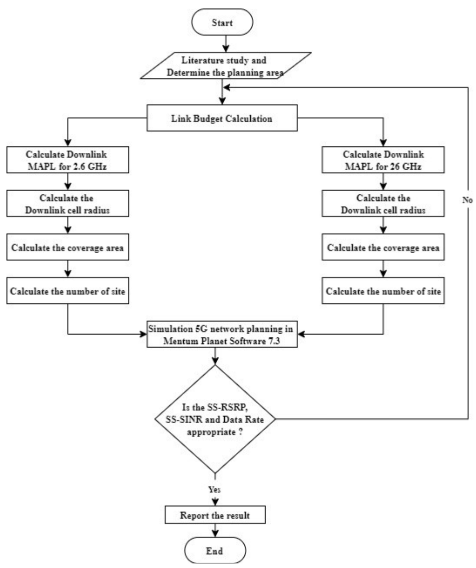

Fig. 2. Proposed design and calculation models

The research on 5G NR planning in mid-band at 2.6 GHz and high-band at 26 GHz was based on coverage planning. The research started by determining the areas where the 5G NR network planning was to be conducted. Jababeka Industrial Estate was a good location for the initial planning of 5G NR technology. This location has an industrial density; with an area of 22.67 km^2, there are more than two thousand companies from thirty countries which are expected to support the deployment of 5G [6]. Geographical data were required for the classification of area and types of area. Coverage planning required link budget calculations based on propagation model to obtain the Maximum Allowable Path Loss (MAPL) value. After the pathloss value was determined, the Urban Macro (UMa) and Urban Micro (UMi) propagation models were used to determine the cell radius as the maximum distance between gNodeB and User Terminal (UT). The cell radius was needed to determine the coverage area that gNodeB can serve and to finally determine the required number of sites.

The results of the simulation, data planning and calculations were processed using Mentum Planet 7.3 software. The simulation showed the coverage area with the parameters of SS-RSRP, SS-SINR and Data Rate. After that, the results of the mid-band simulation at 2.6 GHz and those of the high-band simulation at 26 GHz were compared.

B. *Coverage Planning*

Cellular network planning generally involves two points of view, i.e. coverage planning and capacity planning. Coverage planning is network planning in terms of the area to be covered by the network. This planning is influenced by a number of parameters, namely transmitting power, receiving power, path loss, device sensitivity, radio link budget calculations, and cell radius calculations. Radio link budget calculations are used to determine the maximum allowable path loss between gNodeB antennas and User Equipment (UE) antennas, while propagation model is used to determine cell radius [7].

C. *5G NR Reference Signal Parameters*

Synchronization-Signal Reference Signal Received Power (SS-RSRP) is defined as the linear average over the power contribution (in Watt) of the resource elements that carry secondary synchronization signals (SS) [8]. Signal strength is used as input for cell resection and handover decisions. In addition, gNodeB has a processing circuit that is configured to encode a number of Synchronization Signal Blocks (SSB). Each of the antennas on NR has SSB to transmit a reference signal; SSB consists of a Primary Synchronization Signal (PSS), Secondary Synchronization Signal (SSS), and Physical Broadcast Channel (PBCH), all of which contain system information.

Synchronization-Signal Signal-to-Noise and Interference Ratio (SS-SINR), is defined as the linear average over the power contribution (in Watt) of the resource elements that carry secondary synchronization signals divided by the linear average of the noise and interference power contribution (in Watt) over the resource elements that carry secondary synchronization signals within the same frequency bandwidth. The measurement time resources for SS-SINR are limited within SS/PBCH Block Measurement Time Configuration window (SMTC).

D. *Data Rate*

The maximum downlink and uplink data rates that are supported are calculated by band or band combination supported by user equipment. In 5G, the approximate data rate for a given number of aggregated carriers in a band or band combination is calculated as follows [9].

$$\text{Data Rate (Mbps)} = 10^{-6} \cdot \sum_{j=1}^{J} \left(v_{Layers}^{(j)} \cdot Q_m^{(j)} \cdot f^{(j)} \cdot R_{max} \cdot \frac{N_{PRB}^{BW(j),\mu} \cdot 12}{T_s^{\mu}} \cdot \left(1 - OH^{(j)}\right) \right) \quad (1)$$

Where:
- J = Number of aggregated component carriers
- R_{max} = 948/1024
- $v_{Layers}^{(j)}$ = Maximum number of supported layers
- $Q_m^{(j)}$ = Maximum supported modulation order
- $f^{(j)}$ = Scaling factor (1, 0.8, 0.75, 0.4)
- μ = Numerology
- T_s^{μ} = The average Orthogonal Frequency Division Multiplexing (OFDM) symbol duration
- $BW(j)$ = Bandwidth
- $OH^{(j)}$ = Overhead
- N_{PRB}^{BW} = Maximum resource block allocation

The affected of data rate in NR in given above. The approximate maximum data rate can be computed as the maximum of the approximate data rates computed using the above formula for each of the supported band or band combinations.

III. RESULT AND ANALYSIS

A. *Link budget*

Link budget calculation is intended to estimate the Maximum Allowable Path Loss (MAPL) or the maximum attenuation of signal received between the mobile antenna and the mobile station antenna on the downlink and uplink of the UMa and UMi propagation models. Each scenario has a different link budget value that is in accordance with the scenario conditions.

TABLE II. LINK BUDGET 5G NEW RADIO [10][11][12][13]

Comment parameter	**2.6 GHz**		**26 GHz**	
	DL O2O LOS	***DL O2O NLOS***	***DL O2O LOS***	***DL O2O NLOS***
gNodeB Transmiter Power (dBm)	49	49	35	35
Resource block	273	273	264	264
Subcarrier quantity	3276	3276	3168	3168
gNodeB antenna gain (dBi)	2	2	0	0
gNodeB cable loss (dBi)	0	0	0	0
Penetration loss (dB)	24.36	24.36	12.23	12.23
Folliage loss (dB)	19.59	19.59	5	5
Body block loss (dB)	3	3	15	25
Interference margin (dB)	2	6	1	1
Rain/Ice margin (dB)	0	0	3	3
Slow fading margin (dB)	7	7	7	7
UT antenna gain (dB)	0	0	0	0
Bandwidth (MHz)	100	100	100	100
Kontanta boltzman (K)	1.38×10^{-20}	1.38×10^{-20}	1.38×10^{-20}	1.38×10^{-20}
Temperature (Kelvin)	293	293	293	293
Thermal noise power (dBm)	-156.16	-156.16	-153.93	-153.93
UT noise figure (dB)	9	9	7	7
Demodulation threshold SINR (dB)	-1.1	-1.1	-1.1	-1.1

B. *Propagation Model*

The number of sites in Jababeka Industrial Estate was determined by determining the propagation model. The propagation model used was based on the link budget to the 5G network in accordance with 3GPP 38.901. The propagation model for the mid-band at 2.6 GHz used Urban Macro (UMa), while that for the high-band at 26 GHz used Urban Micro (UMi). The first thing was to determine the path loss which required several other parameter calculations of which the values were not immediately obtained, i.e. thermal noise and subcarrier parameters. Thermal noise is noise caused by the thermal agitation of a device [14].

To get value of thermal noise and subcarrier quantity can be searched using the following equation:

Thermal Noise = 10 log (K.T.B) (2)
SCQ =RB x Subcarrier Per Resource Block (3)

With:
K = Boltzmann constant (1.38×10^{-20} mWs/K)
T = Temperature (293° K)
Bw = Bandwidth (MHz)
RB = Resource Block
Subscarrier per Resource Block = 12

To calculate value of pathloss use propagation model UMa and UMi based on standardization of 3GPP 38.901 with the equation [10]:

Pathloss (dBm) = gNodeB transmit power (dBm)–10 log10 (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) (4)

Based on 3GPP TR 38.901 the propagation model for LOS use formula [10]:

$$PL_1 = 28.0 + 40\log(d_{3D}) + 20\log(fc) - 9\log((d'_{BP})^2 + (h'_{BS} - h'_{UT})^2 \quad (5)$$

$$PL_2 = 32.4 + 21\log(d_{3D}) + 20\log(fc) \quad (6)$$

And the propagation model for NLOS use formula [10]:

$$PL_1 = 13.54 + 39.08\log(d_{3D}) + 20\log(fc) - 0.6(h_{UT} - 1.5) \quad (7)$$

$$PL_2 = 35.3\log(d_{3D}) + 22.4 + 21.3\log(fc) - 0.3(h_{UT} - 1.5) \quad (8)$$

With:
PL_1 = Pathloss value of UMa (dB)
PL_2 = Pathloss value of UMi (dB)
d_{3D} = Resultant of distance between h_{BS} and h_{UT} (m)
fc = Frequency (GHz)
d'_{BP} = Breakpoint distance (m)

d'_{BP} = 4 x h'_{BS} x h'_{UT} x (fc/c)
c = Speed of light ($3x10^8$m/s)
h'_{BS} = $h_{BS} - h_E$
h'_{UT} = $h_{UT} - h_E$
h_{BS} = Height of gNodeB (m)
h_{UT} = Transmission user height (m)
h_E = Height of equipment (m)

The value of d_{3D} will be obtained from the formula of propagation models. The cell radius can be found by the d_{2D} value that shown in Fig 3.

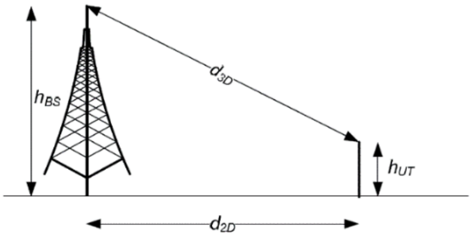

Fig. 3. Pythagoras between d3D, d2D and ($h_{BS} - h_{UT}$) [10]

By knowing the value of d3D, to find the cell radius (d2D) and coverage area that can be covered by gNodeB use the coverage formula [10]:

Cell Radius (d_{2D}) = $\sqrt{(d_{3D})^2 - (h_{BS} - h_{UT})^2}$ (9)

Coverage area = 2.6 x d_{2D}^2 (10)

Finally to determine the number of sites are needed to provide good network service for East Jakarta Industrial Park based on the area that will be simulation use formula:

Number of Sites = Large of Area / Coverage Area (11)

From the calculation the result of each propagation model can be show from table III.

TABLE III. RESULT OF CALCULATION

Comment parameter	**Propagation Model**			
	UMa – 2.6 GHz		***UMi – 26 GHz***	
	DL O2O LOS	***DL O2O NLOS***	***DL O2O LOS***	***DL O2O NLOS***
Thermal noise (dBm)	-153.93	-153.93	-147.91	-147.91
Subcarrier quantity	273	273	264	264
Pathloss (dB)	101.92	101.92	102.57	100.57
h'_{BS} (m)	24	24	9	9
h'_{UT} (m)	0.5	0.5	0.5	0.5
d'_{BP} (m)	416	416	1680	1680
d3D (m)	660.15	112.04	91.91	21.94
d2D / cell radius (m)	659.73	109.54	91.51	20.23
Coverage Area (km^2)	1.13	0.03	0.02	0.002
Large of Area (km^2)	22.67	22.67	22.67	22.67
Number of GnodeB	20	727	1041	10922

C. *NR Data Rate Calculation*

Based on the data rate formula released by 3GPP on 3GPP TS 38.306, the data rate in NR can be calculated. Network specifications and the results of the data rate calculation are shown in Table IV.

TABLE IV. DEFINTION OF FREQUENCY RANGEA [15]

Parameters	**Symbol**	**2.6 GHz**	**26 GHz**
Bandwidth	-	100 MHz	400 MHz
Subcarrier Spacing	-	30 KHz	120 KHz
Component Carier	J	1	1
Modulation Order	$Q_m^{(j)}$	2	2
Number of Layer	$v_{Layers}^{(j)}$	4	4
Scaling Factor	$f^{(j)}$	0.75	0.8
Numerology	μ	1	3
Number of RB	N_{PRB}	273	264
Overhead	$OH^{(j)}$	0.14	0.18
Data Rate (in Mbps)	NR_{Thr}	438.18	1723.87

D. *Simulation Result*

1. gNodeB Allocation on Mentum Software

The planning in this study did not use the existing site location. Instead, the Automatic Site Placement (SP) feature on the Mentum Planet software was used, i.e. a new site that is allocated based on coverage area. There were a higher number of gNodeB in the non-line of sight (NLOS) scenario than in the line of sight (LOS) scenario because there were some troubles in the NLOS scenario between the gNodeB and UE, causing greater losses so there were more gNodeB to serve in that area. Figure 4 shows the number of gNodeB based on the simulation results.

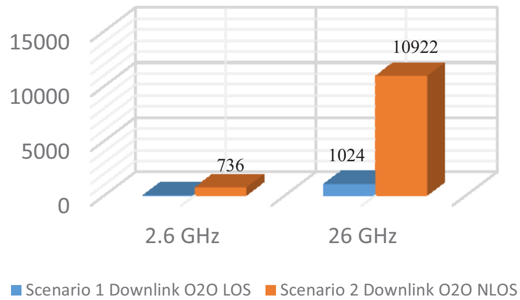

Fig. 4. Number of gNodeB for Each Scenario

The number of gNodeB was different from the number resulted from the calculation. This is due to the limited number of gNodeB and gNodeB cell radius in the Automatic Site Placement (ASP) feature used. The number of gNodeB was based on coverage area. A simulation of gNodeB coverage is shown in Figure 5.

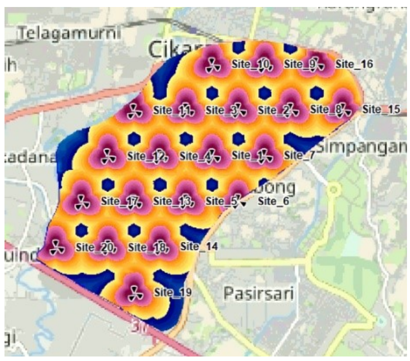

Fig. 5. gNodeB Coverage in Mentum Planet

2. SS-RSRP and SS-SINR Parameters

The SS-RSRP value was displayed as a simulated coverage area. Scenario 1 was a downlink outdoor-to-outdoor (O2O) with line of sight (LOS) which was compared between the two frequencies. Figure 6 shows the comparison of SS-RSRP values. Although the maximum value at a frequency of 2.6 GHz was -43 dBm, which is better than that at 26 GHz, the average SS-RSRP value at a frequency of 26 GHz was -78.14 dBm, which is better than that at 2.6 GHz, i.e. -96.01 dBm. In scenario 1, the average SS-RSRP value at a frequency of 26 GHz was 17.87 dBm, that is higher than that at a frequency of 2.6 GHz.

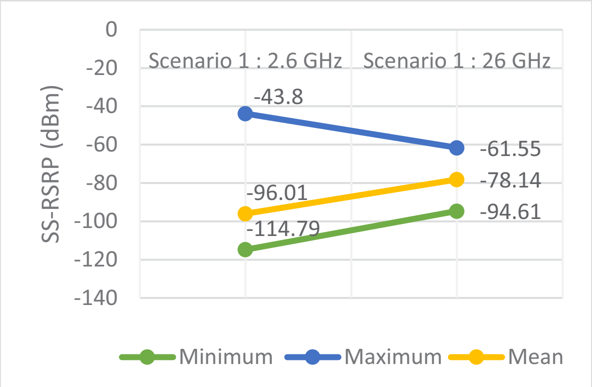

Fig. 6. SS-RSRP of Scenario 1 : Downlink O2O LOS

Figure 7 presents the SS-RSRP value for scenario 2, namely downlink outdoor-to-outdoor (O2O) with non-line of sight (NLOS). The maximum value at 2.6 GHz was -40.84 dBm, that is better than that at 26 GHz. The average value at 2.6 GHz was -68.1 dBm, while that at 26 GHz was -71.11 dBm. Based on the simulated scenario 2, the average SS-RSRP value at 2.6 GHz was 3.01 dBm, which is better than that at 26 GHz.

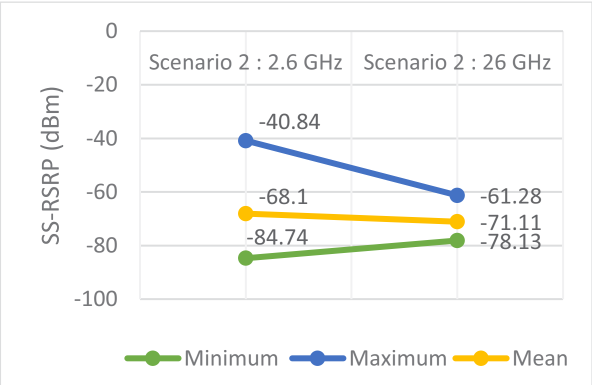

Fig. 7. SS-RSRP of Scenario 2 : Downlink O2O NLOS

The SS-SINR value in scenario 1 (downlink O2O LOS) is shown in Figure 8. In scenario 1, the average and maximum SS-SINR values at a frequency of 2.6 GH were better than those at 26 GHz. The average value at a frequency of 2.6 GHz was 4.21 dB and the maximum value at this frequency was 17.18 dB. In fact, there was a higher number of gNodeB in the area at a frequency of 26 GHz which can increase interference and decrease the SS-SINR value.

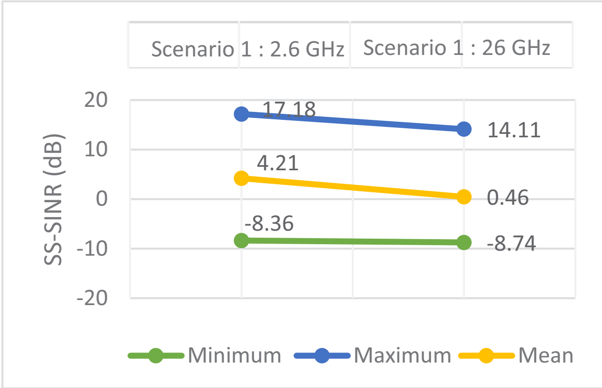

Fig 8. SS-SINR of Scenario 1 : Downlink O2O LOS

The comparison of the two frequencies in terms of the SS-SINR parameter in scenario 2 (downlink O2O NLOS) is clearly presented in Figure 9 below. At a frequency of 2.6 GHz, the SS-SINR value was better than that at 26 GHz. The average value at 2.6 GHz was 2.64 dB, while that at 26 GHz was -7.09 dB with a difference of 4.45 dB.

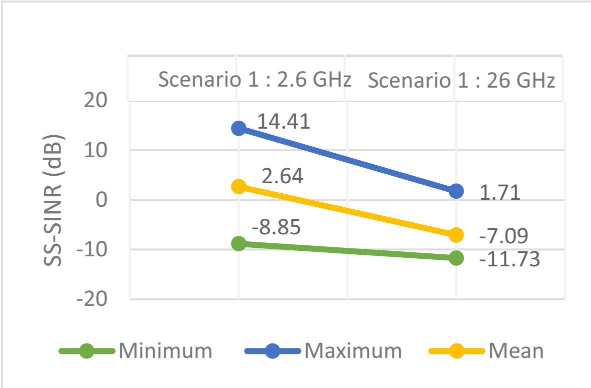

Fig. 9. SS-SINR of Scenario 2 : Downlink O2O NLOS

Based on the results of the above parameters, the SS-RSRP value at a frequency of 26 GHz was better than that at 6 GHz. Although the average value of -71.11 dBm was lower than the value at 2.6 GHz in scenario 2, this value was still categorized as good signal in the standardization for LTE technology. Nonetheless, based on the SS-SINR parameter at a frequency of 2.6 GHz, the result was better. The comparison for each scenario is shown in Figure 8 and Figure 9 above.

3. Data Rate Parameter

The key to this simulation result is data rate. The maximum data rate in this statistic can be considered as the peak data rate. In scenario 1 (downlink O2O LOS), the data rate at a frequency of 26 GHz was 1828.9 Mbps while the data rate at a frequency of 2.6 GHz was 436.31 Mbps. The highest average in scenario 1 at a frequency of 26 GHz was 342.19 Mbps and that at 2.6 GHz was 171.15 Mbps. In fact, there was a trouble between the gNodeB and user terminal in scenario 2 (downlink O2O NLOS), causing this scenario to experience more losses, preventing it from reaching the maximum data rate. Figure 10 presents the comparison of data rates between scenario 1 and scenario 2. The simulation results showed that scenario 1 provided a better network than scenario 2. The maximum data rates for each frequency were achieved by scenario 1. The highest data rate was at a frequency of 26 GHz in scenario 1, followed by a frequency of 2.6 GHz in scenario 1.

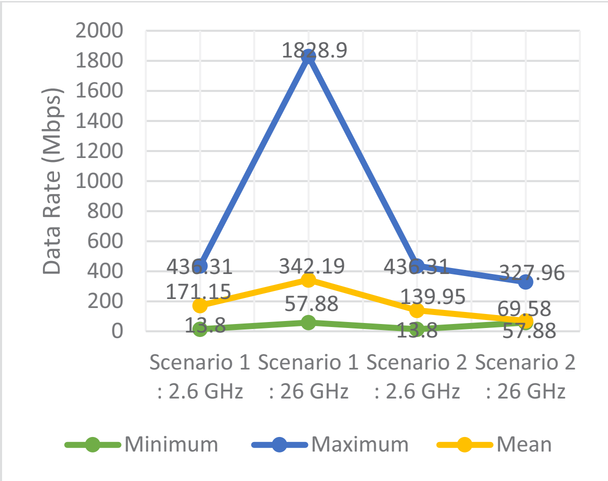

Fig. 10. Data Rate in Scenario 1 and Scenario 2

IV. CONCLUSIONS

1. To accommodate the traffic in Jababeka Industrial Estate, scenario 1 (downlink O2O LOS) requires 20 sites at a frequency of 2.6 GHz and 736 sites at a frequency of 26 GHz, while scenario 2 (downlink O2O NLOS) requires 1024 sites at a frequency of 2.6 GHz and 10922 sites at a frequency of 26 GHz.
2. At a frequency of 26 GHz, the SS-RSRP value is 17.87 dBm, that is higher than that at a frequency of 2.6 GHz. On the other hand, the SS-SINR value at a frequency of 2.6 GHz is 4.21 dB, that is better than that at 26 GHz. Both are in scenario 1 (O2O LOS).
3. The maximum data rate produced at 2.6 GHz is 436.31 Mbps with an average SS-RSRP value of -96.01 dBm and an average SS-SINR value of 4.21 dB. Meanwhile, the maximum data rate at 26 GHz is 1.83 Gbps with an average SS-RSRP value of -78.14 dBm and an average SS-SINR value of 0.46 dB.
4. Based on the parameters of SS-RSRP, SS-SINR and data rate, scenario 1 (downlink O2O LOS) has a better network than scenario 2 (downlink O2O NLOS). This is because scenario 2 has a trouble between the gNodeB and user terminals and has a higher number of sites which increase interference.

V. ACKNOWLEDGMENT

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