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5G Network Planning Using Macrocell and Piccocell Technology

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ABSTRACT — The city of Pontianak is projected to experience substantial growth in network demand, driven by the expansion of commercial hubs, educational institutions, tourism destinations, and essential public services. Under the current status quo, Pontianak lacks 5G network coverage, underscoring the necessity of implementing a comprehensive 5G network plan to support its urban development. This research conducted a detailed analysis of 5G network coverage and capacity planning, utilizing macrocell and picocell technologies to address the connectivity demands of an urban environment. Operating within the 3.5 GHz frequency band with a 100 MHz bandwidth, this research examined network requirements in the medium band spectrum. The results revealed that macrocell technology required 18 uplink and 23 downlink sites to cover an area of 107.8 km², while picocell technology demanded a denser infrastructure, comprising 351 uplink and 364 downlink sites across 90.72 km². Based on a five-year capacity projection for a population of 673,400, the macrocell technology will require 10 uplink and 22 downlink sites. On the contrary, picocell technology, which is more suitable for densely populated areas, will require 261 uplink and 263 downlink sites to serve a population of 423,881. Simulation results indicated that synchronization signal reference signal received power (SS-RSRP) and secondary synchronization signal received power (SS-SINR) values met or surpassed the established key performance indicators (KPI) for both technologies. This 5G network plan aligns with Pontianak's smart city vision by enhancing connectivity, optimizing coverage, and delivering seamless user experiences, highlighting the adaptability of macrocell and picocell solutions in varied urban settings.

KEYWORDS — Macrocell, Picocell, 5G New Radio, SS-RSRP, SS-SINR, Atoll.

I. INTRODUCTION

The development of cellular network technology has reached a significant stage with the emergence of 5G networks. The 5G networks are networks that have high speed, low latency, and large capacity compared to previous 4G long term evolution (4G LTE) networks. The 5G networks present significant opportunities across multiple sectors, such as government services, commerce, education, healthcare, and tourism. Thus, strategic planning of 5G networks is crucial for the development of a smart city. In this research, 5G network planning was conducted in the city of Pontianak, which is characterized by low-lying geographical conditions, its location along the equator, and its extensive network of rivers and swamps. These unique geographical features facilitate the planning and implementation of 5G networks in Pontianak [1].

There are several options in determining the research of frequency planning in Pontianak City: low frequency (below 1 GHz), medium frequency (1–6 GHz), and high frequency (above 24 GHz). Low frequency excels in wide coverage and good signal penetration, but is limited in capacity and data speed, making it suitable for rural areas. Meanwhile, high frequency offers very high capacity and data speed, but its range is very limited, and has poor signal penetration, making it ideal for dense urban areas. Therefore, the medium frequency of 3.5 GHz with a bandwidth of 100 MHz was chosen because it offers an ideal combination of capacity and coverage. This combination includes high capacity, adequate coverage, optimal balance, sufficient spectrum availability, and wide bandwidth. The selection of 3.5 GHz frequency is considered the most optimal for 5G network planning in Pontianak City, considering the balance between capacity and coverage needed [2].

Various technologies can be utilized for 5G networks designation, such as macrocell, microcell, picocell, and femtocell, each designed for varied functions. This research focused on macrocell and picocell due to their superior benefits compared to microcell and femtocell in terms of cost, energy consumption, and scalability [3]. Macrocells require higher installation costs and energy consumption but offer extensive coverage and maximum area, justifying the desired outcomes. On the other hand, picocells are preferred due to their cost-effective installation and energy efficiency, making them well-suited for increasing network capacity in densely populated areas, despite their limited coverage range. Macrocell scalability is constrained in high-density areas, while picocells offer better scalability. Therefore, determining the appropriate technological implementation demands a careful consideration of financial constraints, power consumption efficiency, and responsiveness to shifting network requirements. In practical scenarios, integrating both technologies frequently creates the most favorable outcome, creating harmony between coverage radius, data handling capability, and operational performance [4].

This research implemented both urban macro (UMa) and urban micro (UMi) propagation frameworks; the main assumptions focus on urban environments with dense buildings and varying heights. UMa assumes the base transceiver station (BTS) antennas are high on rooftops, with dominant non-line-of-sight (NLOS) conditions and long propagation distances, making it suitable for wide coverage. In contrast, UMi assumes BTS antennas are low at street level, considering both line-of-sight (LOS) and NLOS conditions, with short propagation distances, making it ideal for dense areas. Both models assume specific frequencies and propagation conditions that simplify calculations, although they limit accuracy in certain situations [5].

Planning and analyzing 5G networks are not a novel task. The 5G planning has been successfully carried out in several experiments utilizing various frequencies, propagation types, sites, and modeling tools. Among these studies is a 5G planning study in Semarang, using the Forsk Atoll 5G software and 3rd Generation Partnership Project (3GPP) UMa propagation type with outdoor to outdoor (O2O) LOS scheme to effectively plan at a frequency of 2.3 GHz. The findings include suggestions and an analysis of Semarang's 5G network planning [6].

Subsequent study conducted in the Golden Triangle of Jakarta successfully implemented 5G planning with the Mentum Planet simulation software version 7.3 and a frequency of 2.6 GHz using the UMa propagation model. The findings include recommendations and an analysis of the 5G network design for Golden Triangle of Jakarta [7].

An additional study employed a 26 GHz frequency UMi propagation model in the Jakarta industrial sector, which was planned to use Mentum Planet simulation software. The findings include recommendations and an evaluation of 5G network design in Jakarta's industrial region [8].

Research on 5G planning in the Yogyakarta region in 2022 used a 24 GHz Umi propagation model, which was modeled using simulation software from Forsk Atoll. The outcomes include recommendations and a study of 5G network planning in the Yogyakarta region [9].

Upon examination of existing literature, no previous research has been identified to employs both UMa and UMi propagation models in conjunction with combined macrocell and picocell technologies. Hence, this research aims to develop comprehensive 5G network planning for Pontianak City through the implementation of UMa and UMi propagation models, incorporating both macrocell and picocell technologies operating at a frequency of 3.5 GHz with a bandwidth allocation of 100 MHz.

II. METHODOLOGY

The planning of the 5G new radio network in Pontianak City can be completed by collecting the necessary information, such as regulations, research scenarios, and target markets, through various references including books, previous research papers, and journals that support 5G design. The 5G network planning uses a coverage planning and capacity planning approach. Coverage planning includes calculating path loss and link budget to determine signal attenuation between user equipment (UE) and gNodeB. Capacity planning requires current population data and population projections for the next five years to calculate the minimum number of sites required. From the 5G network planning, the maximum distance between gNodeBs, site area, and number of sites required can be determined.

The Simulation was conducted using the Forsk Atoll software to obtain 5G network parameter values, specifically synchronization signal reference signal received power (SS-RSRP) and secondary synchronization signal received power (SS-SINR). Regulatory analysis was performed to ensure compliance with applicable regulations and to provide recommendations if harmonization was required. The results of the planning process were summarized, and recommendations were provided for the implementation of 5G in Pontianak City. Technology options, such as macrocells and picocells, were suggested to ensure optimal deployment.

Data collection for this research encompassed target markets, research scenarios, and regulatory frameworks, utilizing a variety of sources such as books containing prior research findings and journals addressing 5G network designs. Capacity planning and coverage planning techniques were used in 5G network design. Coverage planning involved calculating path loss and link budget to estimate the signal attenuation that took place between the UE and the gNodeB.

Data on the existing and projected populations over the next five years are required for capacity planning. Based on this information, the minimum number of sites needed is determined. The outputs of the coverage and capacity approach for 5G network planning can be used to calculate the site area, the number of sites required, and the maximum distance between gNodeBs. The purpose of this simulation is to determine the values of the 5G network parameters, SS-RSRP and SS-SINR [10].

In this study, the 5G new radio design complied with the 3GPP Release-15 guidelines, which define the maximum mask bandwidth in the frequency band. The maximum frequency range 1 (FR1) bandwidth, which operates at a frequency of 3.5 GHz and a bandwidth of 100 MHz, utilizes a 3-sector antenna type.

Publication data on Pontianak City's population in 2024 and technological information were collected as part of the project's initial data collection phase to obtain the necessary data for the object of research in the deployment of 5G cellular networks. After gathering the required data, it was processed using several strategies, including capacity planning and coverage planning, to facilitate the launch of 5G.

A. CAPACITY PLANNING

One of the critical factors to be considered in the planning of a 5G network is the prioritization of meeting user traffic demands. This entails assessing the network's quality and capacity to determine the number of gNodeB sites necessary for the deployment of 5G new radio networks, based on user capacity requirements [11].

Pontianak in West Kalimantan Province is the location for implementing the 5G network planning process. It holds a market share of 48% and is projected to have a 5G new radio subscriber percentage of 52%. As a major metropolitan area on the island of Kalimantan, Pontianak's population was 673,400 in 2024, with a population growth rate of 0.05%, a productive age group comprising 70% of the population, and an area of 107.8 km^2 [7]. Macrocell technology planning covers all areas of Pontianak, while picocell technology planning focuses on the three most populated subdistricts and areas with high population density within the city: Pontianak City, North Pontianak, and West Pontianak. These areas cover 90.72 km^2 and have a combined population of 423,881 people.

In this planning, macrocell and picocell technologies were utilized. Macrocell technology was chosen for its ability to provide extensive coverage, spanning over 5 km, making it suitable for serving large cities as well as rural areas. On the other hand, picocell technology requires minimal power as it is designed to cover very small areas [2]. Picocells were used to enhance the capacity available to subscribers in areas with high network density, while consuming less power to reduce operational costs [12]. The number of users for microcell and picocell was forecasted using (1):

$$U_n = U_0(1 + G_F)^n \quad (1)$$

where U_n denotes the estimated number of users in the nth year, U_0 is the current population, G_F is the growth factor, and n is the number of estimated years.

$$U_p = U_n \times p \quad (2)$$

where p represents the percentage of the productive age group in the area.

$$O_{MS} = U_p \times m \quad (3)$$

where O_{MS} represents the operator market share and m represents the percentage of productive age groups in the area [4].

$$P_u = O_{MS} \times P_n \quad (4)$$

Pu represents the 5G new radio provider user, O_{MS} is the operator market share, and P_n is the assumed 5G new radio penetration value.

After completing the calculations, the number of 5G new radio subscribers was determined to be 117,952 users for planning using macrocell technology and 74,247 for the picocell technology. Prioritizing the fulfillment of user traffic demands by evaluating a network's quality and capacity to estimate the number of GNodeB sites required for installing 5G new radio networks based on user capacity is one of the many factors that must be considered when planning a 5G network [5]. The results of the total site calculation for planning using Macrocell technology are as follows.

1) SERVICE MODEL

After obtaining the total number of 5G new radio subscribers, the next stage involved calculating the traffic and service model using (5).

$$T_S = \frac{(B_R \times S_T \times S_{DR})}{(1 - B_E)}. \quad (5)$$

T_S denotes the throughput per session, B_R is the bearer rate, S_T is the session time, S_{DR} is the session duty ratio value, and B_E is the block error rate value [4].

2) SINGLE USER THROUGHPUT

After obtaining the service and traffic model values per session, the next step was to calculate the single user throughput. The parameters used in the single user throughput calculation process included the throughput value per session, the traffic model, and the peak-to-average power ratio, as defined by (6).

$$U_T = \frac{T_S \times B_{HSA} \times P_R \times (1 + P_{AR})}{3600} \quad (6)$$

where U_T represents the single user throughput, B_{HSA} is the busy hour service attempt, P_R is the penetration rate, and P_{AR} is the peak-to-average ratio or the percentage of traffic spike.

3) NETWORK THROUGHPUT

After obtaining the single user throughput value, the next step involved calculating the network throughput using (7).

$$N_{IP} = P_u \times U_T. \quad (7)$$

N_{IP} represents the network throughput at the IP layer, P_u is the number of 5G new radio provider users, and U_T is the single user throughput.

$$N_{MAC} = \frac{N_{IP}}{0{,}98}. \quad (8)$$

N_{MAC} denotes the network throughput at the media access control (MAC) layer and N_{IP} is the network throughput at the Internet protocol (IP) layer.

The results of the network throughput calculation for planning using macrocell technology for the uplink obtained a value of 41,546,840.11 kbps or 41,546.8401 Mbps, while on the downlink side, it obtained a value of 191,188,734.6 kbps or 191,188.7346 Mbps. Meanwhile, the results of the network throughput calculation for planning using picocell technology for uplink obtained a value of 1,834,029,647 kbps or 1,834,029.647 Mbps, while on the downlink side, it obtained a value of 3,445,577,370 kbps or 3,445,577.37 mbps.

4) TOTAL SITE CALCULATION

The number of gNodeB sites obtained from the capacity planning calculation was determined using (9).

$$S_c = C_c \times 3 \quad (9)$$

S_C represents the site capacity and C is the cell average throughput.

$$S_i = \frac{N_{MAC}}{S_c} \quad (10)$$

S_i represents the total site, S_C is the site capacity, and N_{MAC} is the network throughput at the MAC layer.

Thus, the implementation of macrocell technology resulted in a total of 22 sites, each providing coverage of 4.9 km^2. In contrast, the deployment of picocell technology resulted in a total of 261 sites, with each providing coverage of 0.347586207 km^2.

B. COVERAGE PLANNING

Factors such as antenna gain and sensitivity values are considered in the analysis for the 5G network planning, specifically in coverage planning. In the coverage planning approach for 5G new radio network design, the maximum allowable path loss (MAPL) value must be carefully considered. MAPL calculations must incorporate the use of a propagation model to determine the cell radius, and the number of sites required [5].

The maximum estimate of signal attenuation that the transmitting and receiving antennas can accommodate is calculated using the link budget [13]. The 5G new radio link budget calculation is similar to the 4G long term evolution (LTE) link budget calculation, with the addition of factors such as body block loss, vegetation loss, and attenuation due to rain and snow. The MAPL value, which represents the upper limit of signal attenuation, is determined through link budget computation [14].

The computation for the thermal noise value and subcarrier quantity for the new 5G radio is as follows: the resource block is 273, the subcarrier is 35.15, the subcarrier quantity is 3,278, the temperature is 318 K, the Boltzmann constant is 1.38×10^{-20} mWs/K, the thermal is 153, and the subcarrier resource block is 12. Analysis for the capacity planning of the 5G network considers variables such as antenna gain, sensitivity settings, and other relevant factors. In the coverage planning approach

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for 5G new radio network planning, the MAPL value must be taken into consideration. MAPL calculations must incorporate the use of a propagation model to calculate the cell radius and the number of required sites [15]. The results of the MAPL calculation for planning using macrocell technology are presented in Table I and Table II. Meanwhile, the MAPL calculation for planning using picocell technology is presented in Table III and Table IV.

As this planning incorporated microcell and picocell technologies, the propagation models utilized in this research consists of two types: UMa and UMi. In the calculation of the propagation model, it is essential to consider several parameters, including frequency and antenna height [4]. Equation (11) was used to determine the path loss for the UMa LOS method:

$$P_{L1} = 22\ log\ log\ (d_{3D}) + 28 + 20\ log\ log\ (fc) \quad (11)$$

$$P_{L2} = 40\ log\ log\ (d_{3D}) + 28 + 20\ log\ log\ (fc) - 9\ log\ log\ [(d'_{BP})^2 + (h_{BS} - h_{UT})^2] \quad (12)$$

with conditions of use $P_{L1} = 10m < d_{2D} < d'_{BP}$ and terms of use $P_{L2} = d'_{BP} < d_{2D} < 5000m$. The path loss for the 3D-UMa NLOS model was calculated using (13).

$$P_L = 10\ log\ log\ (d_{3D}) + 13.54 + 20\ log\ log\ (fc) - 0.6(h_{UT} - 1.5) \quad (13)$$

where N represents the path loss exponent, P_L is the path loss (dBm), h_{BS} is the height base station, h_{UT} is the height receiver (m), d_{2D} is the cell radius (m), d_{3D} is the resultant of the distance between h_{BS} and h_{UT} (m), and d'_{BP} is the distance break point (m) [16]. While for the UMi LOS schemes, the pathloss was obtained using (14) and (15):

$$P_{L1} = 22 + 28 + 20(Fc) \quad (14)$$

$$P_{L2} = 40 + 28 + 20(Fc) - 9(d'_{BP})^2 + (h_{BS} + h_{UT})^2) \quad (15)$$

with conditions of use $P_{L1} = 10m < d_{2D} < d'_{BP}$ and terms of use $P_{L2} = d'_{BP} < d_{2D} < 5000m$. For hexagonal cell layout UMi NLOS scheme, the pathloss was obtained using (16) and (17).

$$P_{L1} = Max\ (\mathrm{PL}_{3D.UMi.NLOS,} \mathrm{PL}_{3D.UMi.LOS,}) \quad (16)$$

$$(PL_{1\ 3D.UMi.NLOS,} = 36.7 + 22.7 + 26(Fc) - +(h_{UT} - 1.5) \quad (17)$$

with conditions of use $P_{L1} = 10m < d_{2D} < 2{,}000m$ and terms of use $P_{L2} = 1.5 < h_{UT} < 22.5m$. N is the path loss exponent, P_L is the pathloss (dBm), h_{BS} is the height base station, h_{UT} is the height receiver (m), d_{2D} is the cell radius (m), d_{3D} is the outcome of the separation between h_{BS} and h_{UT} (m), and d'_{BP} is the distance break point (m) [17].

In the macrocell technology, the cell radius calculation results were determined using a non-line of sight scheme of 1.0944 km for the uplink and 0.9625 km for the downlink. This scheme was chosen because the design area is an urban area where the line-of-sight propagation rarely occurs due to tall buildings.

In the picocell technology, the cell radius calculation results were determined using a non-line of sight scheme of 0.22592 km for the uplink and 0.22196 km for the downlink. This scheme was chosen because the design area is an urban area where the line-of-sight propagation rarely occurs due to tall buildings.

Planning a 5G network in an area can be done by identifying the comparison between the surface area of the research and the GNodeB coverage area. In this study, the utilization of three sectoral antenna types in one site aimed to increase the capacity and coverage of the area [18].

TABLE I
MAPL UPLINK CALCULATION FOR THE MACROCELL TECHNOLOGY FOR THE LINK BUDGET (UPLINK) OF > 3500 MHZ

Transmitter	Value	Calculation
UE TX power (dBm)	49	*A*
UE gain (dBi)	0	*B*
Body loss (dB)	2.10	*C*
EIRP (dBm)	11.746561 0	*D = A+B-C*-Total *SC*
Total SC (50 MHz BW)	3276	Total *RB* × *SC* per *RB*
Receiver	**Value**	**Calculation**
gNB noise figure (dB)	5.4	*E*
Thermal noise (dBm)	-93.576	*F = k×T×BW*
SINR demod TH (dB)	1.3	*G*
Receiver sensitivity (dBm)	-86.876	*H = E+F+G*
Interference margin (dB)	0.5	*I*
Slow fading margin (dB)	4.32	*J*
Penetration loss (dB)	10.00	*K*
Feeder loss (dB)	0	*L* (ignored)
gNB gain (dBi)	2	*M*
MAPL (dB)	85.8034	*O = D-H-I-J-K+M*

TABLE II
MAPL DOWNLINK CALCULATION TABLE FOR MACROCELL TECHNOLOGY FOR THE LINK BUDGET (DOWNLINK) OF > 3500 MHZ

Transmitter	Value	Calculation
gNB TX power (dBm)	49	*A*
gNB gain (dBi)	0	*B*
Feeder loss (dB)	2.10	*C*
EIRP (dBm)	11.7465610	*D = A+B+C-* Total *SC*
Total SC (50 MHz BW)	3276	Total *RB* × *SC* per *RB*
Receiver	**Value**	**Calculation**
UE noise figure (dB)	5.4	*E*
Thermal noise (dBm)	-93.576	*F = k×T×BW*
SINR demod TH (dB)	1.3	*G*
Receiver sensitivity (dBm)	-86.876	*H = E+F+G*
Interference margin (dB)	9.5	*I*
Slow fading margin (dB)	9	*J*
Penetration loss (dB)	11	*K*
Body loss (dB)	3	*L*
UE gain (dBi)	7.5	*M*
Beamforming gain (dB)	10	*P*
Vegetation loss (dB)	0	*Q* (N/A in MidBand)
Rain loss (dB)	0	*R* (N/A in MidBand)
MAPL (dB)	83.6234	*O = D-H-I-J-K-L+M+P-Q-R*

TABLE III
UPLINK MAPL CALCULATION TABLE FOR THE PICOCELL TECHNOLOGY FOR THE LINK BUDGET (UPLINK) OF > 3500 MHZ

Transmitter	Value	Calculation
UE TX power (dBm)	2	*A*
UE gain (dBi)	5	*B*
Body loss (dB)	3	*C*
EIRP (dBm)	-31.15343	*D* = *A*+*B*-*C*-Total *SC*
Total SC (50 MHz BW)	3276	Total *RB* × *SC* per *RB*
Receiver	**Value**	**Calculation**
gNB noise figure (dB)	3.5	*E*
Thermal noise (dBm)	-93.576	*F* = *k*×*T*×*BW*
SINR demod TH (dB)	-1.1	*G*
Receiver sensitivity (dBm)	-91.176	*H* = *E*+*F*+*G*
Interference margin (dB)	2	*I*
Slow fading margin (dB)	6	*J*
Penetration loss (dB)	9	*K*
Feeder loss (dB)	0	*L* (ignored)
gNB gain (dBi)	16	*M*
MAPL (dB)	59.0234	*O* = *D*-*H*-*I*-*J*-*K*+*M*

TABLE IV
DOWNLINK MAPL CALCULATION TABLE FOR PICOCELL TECHNOLOGY FOR THE LINK BUDGET (DOWNLINK) OF > 3500 MHZ

Transmitter	Value	Calculation
gNB TX power (dBm)	2	*A*
gNB gain (dBi)	5	*B*
Feeder loss (dB)	3	*C*
EIRP (dBm)	-31.15343	*D* = *A*+*B*+*C*-Total *SC*
Total SC (50 MHz BW)	3276	Total *RB* × *SC* per *RB*
Receiver	**Value**	**Calculation**
UE noise figure (dB)	7	*E*
Thermal noise (dBm)	-93.576	*F* = *k*×*T*×*BW*
SINR demod TH (dB)	-1.2	*G*
Receiver sensitivity (dBm)	-87.776	$H = E + F + G$
Interference margin (dB)	5	*I*
Slow fading margin (dB)	8	*J*
Penetration loss (dB)	9	*K*
Body loss (dB)	5	*L*
UE gain (dBi)	5	*M*
Beamforming gain (dB)	10.1	*P*
Vegetation loss (dB)	0	*Q* (N/A in MidBand)
Rain loss (dB)	0	*R* (N/A in MidBand)
MAPL (dB)	58.723	*O* = *D*-*H*-*I*-*J*-*K*-*L*+*M*+*P*-*Q*-*R*

$$d = \sqrt{((d_{3D})^2 - (h_{BS} - h_{UT})^2)} \quad (18)$$

where h_{BS} denotes heigh base station (m), h_{UT} denotes heigh receiver (m), d_{2D} denotes cell radius (m), and d_{3D} denotes resultant of the distance between h_{BS} and h_{UT} (m). Equation (19) can be used to obtain the cell area.

$$C_A = 1.95 \times 2.6 \times d^2 \quad (19)$$

where C_A denotes the coverage area (km^2) and d denotes the cell radius (km^2). Equation (20) can be used to determine the number of sites.

$$S_i = \frac{L}{C_A} \quad (20)$$

S_i is the coverage area (km^2) and L is the area (km^2).

The coverage area for the 5G network planning can be determined by comparing the surface area of the research area to the gNodeB coverage area [19]. Table V and Table VI show the results of the computation of the cell area and the number of sites required for planning using the macrocell technology.

For the uplink, 18 sites were required; meanwhile, 23 sites were required for the downlink. Tables VII and Table VIII display the cell area, and the number of sites calculated for planning using picocell technology. A total of 351 stations were required for the uplink, while downlink required 364 sites.

The SS-RSRP parameter is determined by considering resource elements that provide reference signal data within the utilized bandwidth [20]. A resource block contains multiple subcarriers, and the reference signal is located within specific resource elements. Any modifications must be limited to the resource elements that carry the cell-specific reference signal. SS-RSRP measures the power level of the reference signal in a 5G network, while reference signal received power (RSRP) is the equivalent metric in 4G networks. In 3G networks, the metric is called the received signal code power (RSCP), while in 2G networks, it is referred to as the received signal level (Rx level). The SS-RSRP value categories are as follows: if x < -115 dBm, the signal is considered unusable; if -100 > x ≥ -115 dBm, the signal is rated as fair to poor; if -80 > x ≥ -100 dBm, the signal is rated good; and if X ≥ -80 dBm, the signal is rated as excellent.

Secondary synchronization parameter, namely the signal-to-noise and interference ratio (SINR), measures the ratio of the main signal's power to the combined power of noise and interference. This range can be referred to as the signal quality level. For example, in 5G networks, it is referred to as synchronisation signal (SS)-SINR; in 4G networks, as SINR; in 3G networks, as EcNo; and in 2G networks, as RxQual, each with specific conditions [21]. The SS-SINR value categories are as follows: if x ≤ 0 dB, the signal is considered unusable; if 0 < x ≤ 10 dB, the signal is rated as fair to poor; if 10 < x ≤ 20 dB, the signal is rated as good; and if x > 20 dB, the signal is rated as excellent.

III. RESULTS AND DISCUSSION

A. PLANNING USING THE MACROCELL TECHNOLOGY

Total of GNodeB required in planning using the macrocell technology was 23 sites, the antenna model configuration was three sectoral. In addition, it was also determined that the antenna height was 25 m high, and the maximum transmitting power of the sender was 49 dBm in each antenna. The results of the 5G new radio network planning in Pontianak City utilizing microcell technology were chosen with the greatest number of GNodeBs to serve consumers as efficiently as possible. Specifically, the coverage planning scenario, which calls for up to 23 GNodeB.

1) PARAMETER SECONDARY SYNCHRONIZATION - REFERENCE SIGNAL RECEIVED POWER (SS-RSRP)

The purpose of SS-RSRP analysis is to ascertain the cell beam's signal intensity as perceived by local users. The closer

TABLE V
CALCULATION OF CELL AREA AND NUMBER OF SITES FOR THE MACROCELL TECHNOLOGY (UPLINK)

Parameter	Value	Calculation
Area (km^2)	107.8	L
Coverage per site (3-sectoral) (km^2)	6.0731	$C = 1.95 \times 2.6 \times d^2$
Total site (3- sectoral)	18	$S_i = L/C$

TABLE VI
CALCULATION OF CELL AREA AND NUMBER OF SITES FOR THE MACROCELL TECHNOLOGY (DOWNLINK)

Parameter	Value	Calculation
Area (km^2)	107.8	L
Coverage per site (3-sectoral) (km^2)	4.6973	$C = 1.95 \times 2.6 \times d^2$
Total site (3- sectoral)	23	$S_i = L/C$

TABLE VII
CALCULATION OF CELL AREA AND NUMBER OF SITES FOR THE PICOCELL TECHNOLOGY (UPLINK)

Parameter	Value	Calculation
Area (km^2)	90.72	L
Coverage per site (3-sectoral) (km^2)	0.25877	$C = 1.95 \times 2.6 \times d^2$
Total site (3- sectoral)	351	$S_i = L/C$

TABLE VIII
CALCULATION OF CELL AREA AND NUMBER OF SITES FOR THE PICOCELL TECHNOLOGY (DOWNLINK)

Parameter	Value	Calculation
Area (km^2)	90.72	L
Coverage per site (3-sectoral) (km^2)	0.24979	$C = 1.95 \times 2.6 \times d^2$
Total site (3- sectoral)	364	$S_i = L/C$

the Rx (user terminal) is to the Tx transmitter, the better the signal level obtained. According to the simulation results produced by SS-RSRP utilizing the macrocell approach, the Pontianak City region was covered by the 5G network in this simulation and was categorized as good with a value of -74.94 dBm (Figure 1). All areas of Pontianak City are served by SS-RSRP 5G new radio network, as shown in Figure 2.

The results of the Atol simulation's SS-RSRP parameter histogram indicated that the 5G network in Pontianak City generated SS-RSRP with an average value of -74.94 dBm, with minimum values falling between 93 dBm and -130 dBm and maximum values falling between -70 dBm and -40 dBm. As a result, the value generated by the simulation fell into the good category. Low SS-RSRP values were found in places that were distant from the GNodeB of the site transmitter antenna.

With a value of 67.2% and an area of 72 km^2, the largest percentage of SS-RSRP parameters within the range of -80 to -70 dBm was classified under the good category, while the smallest percentage, with a value of 0.01% and an area of 0.01 km^2, was classified as poor. These are the percentages of SS-RSRP values from the simulation of the 5G new radio deployment using Atoll software. Therefore, the obtained value was classified as an SS-RSRP value in the good category.

2) PARAMETER: SIGNAL-TO-NOISE AND INTERFERENCE RATIO (SS-SINR) OF THE SECONDARY SYNCHRONIZATION SIGNAL RECEIVED POWER).

An analysis to determine a cell's signal quality level is referred to as SS-SINR. Factors that can affect the SS-SINR value are interference and noise. They are disturbances that often occur in transmission systems. Even if the distance between the site and the user is short, the SS-SINR value may not be optimal, as it depends on the presence or absence of the interference and noise.

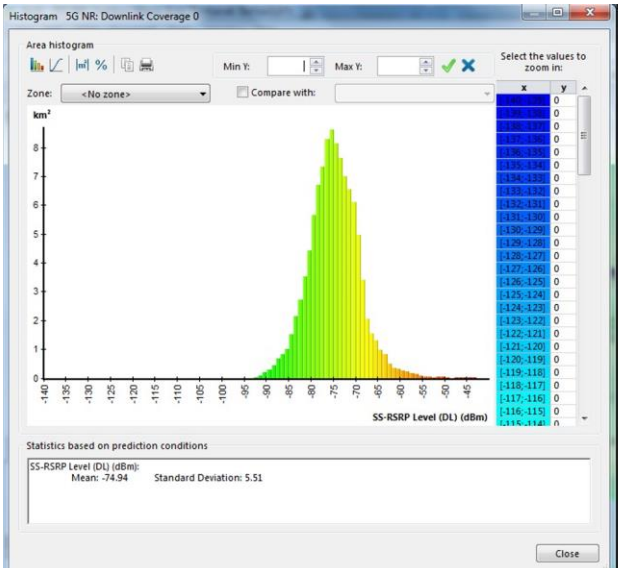

Figure 1. SS-RSRP results in the macrocell technology histogram.

Figure 2. SS-RSRP results of the Pontianak City macrocell technology.

Based on the simulation findings, the Pontianak City region was covered by the 5G network in this simulation and was included in the good category with a value of 19.65 dB (Figure 3). This is according to SS-SINR measurements using the macrocell approach. All areas of Pontianak City are covered by SS-SINR 5G new radio network as shown in Figure 4.

The percentage of SS-SINR values derived from the simulation of 5G new radio deployment using Atoll software indicated that the highest proportion of SS-SINR characteristics fell within the 20–25 dB range, with a value of 42.36% and covering an area of 45.39 km². This range was classified as a good category, confirming that the obtained SS-SINR value meets the criteria for the good category.

B. PLANNING USING PICOCELL TECHNOLOGY

The number of GNodeBs required for planning using microcell technology was 364 sites. Planning simulations were conducted in Pontianak City using Forsk Atoll software. Three sectoral antenna models were utilized, all of which can broadcast signals farther than an omnidirectional antenna type. The maximum transmission power for each antenna was 2 dBm, and the antenna height was 10 m.

1) REFERENCE SIGNAL RECEIVED POWER - PARAMETER SECONDARY SYNCHRONIZATION (SS-RSRP)

The results of the Atoll simulation's SS-RSRP parameter histogram indicated that the 5G network in Pontianak City

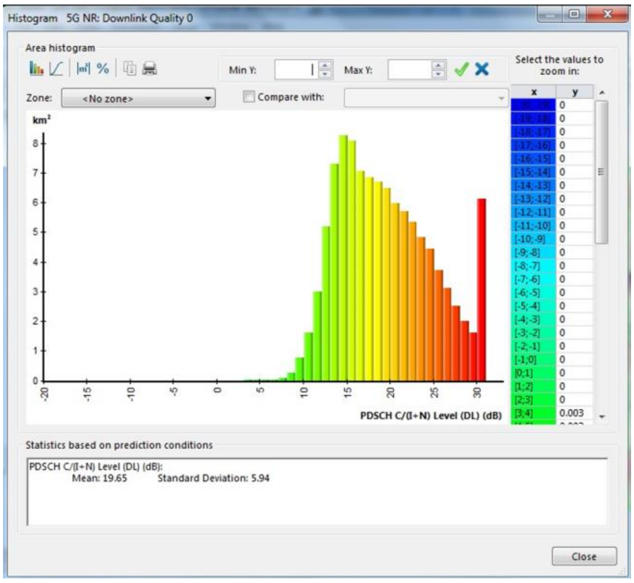

Figure 3. SS-SINR results of the macrocell technology histogram.

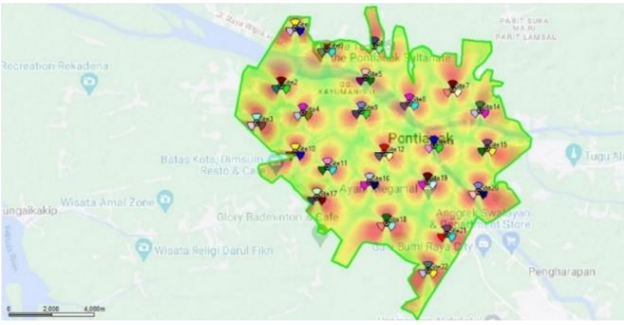

Figure 4. SS-SINR Results of the Pontianak City macrocell technology.

generated SS-RSRP with an average value of -73.2 dBm, with a minimum value ranging from 92.5 dBm and -130 dBm and a maximum value ranging from -70 dBm and -40 dBm. As a result, the value produced by the Atoll simulation was classified as good (Figure 5).

The largest proportion of SS-RSRP values fell within the range of -80 to -70 dBm, with 60.6% of the values from the 5G NR deployment simulation using Atoll software covering an area of 45.4 km². This range was classified as good. In contrast, the lowest proportion, 0.01%, covering an area of 0.01 km², fell into the poor category. For the obtained value to be considered within the good category, it must meet the specified criteria.

2) RECEIVED POWER SIGNAL-TO-NOISE AND INTERFERENCE RATIO OF THE PARAMETER SECONDARY SYNCHRONIZATION SIGNAL (SS-SINR)

Based on SS-SINR simulation results using the macrocell approach, Figure 6 shows that the Pontianak City region is covered by the 5G network and classified as good with a value of 26.03 dB. The findings highlight the distribution of SS-SINR parameters within the Pontianak City area, providing insights into signal quality and performance across the region. Based on the SS-SINR analysis conducted using Atoll software, the average SINR value obtained was 26.84 dB. The simulation results for Pontianak City indicate that the SS-SINR parameters fall within the good range, indicating that interference and noise levels are relatively low and do not significantly disrupt transmission quality.

As shown in Figure 7, the simulation results indicate that the average SS-SINR parameter value is 26.84 dBm, with a

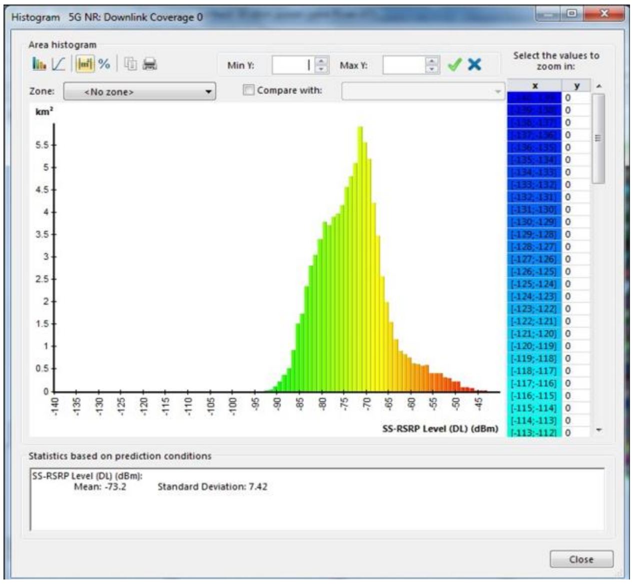

Figure 5. SS-RSRP results in the picocell technology histogram.

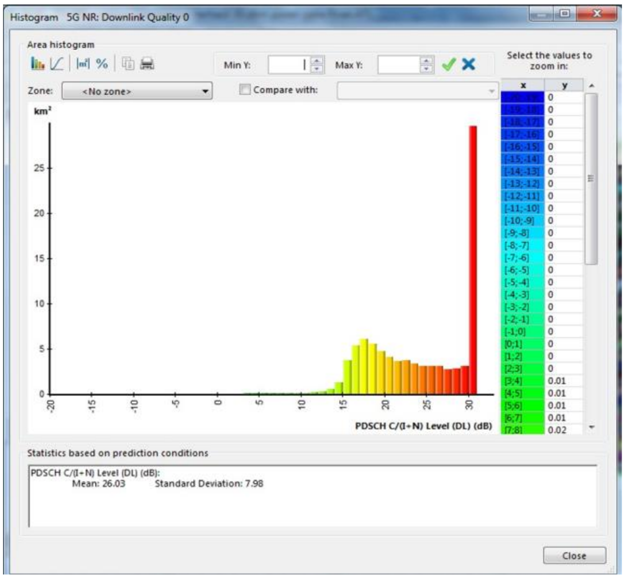

Figure 6. SS-SINR generated histogram use picocell technology.

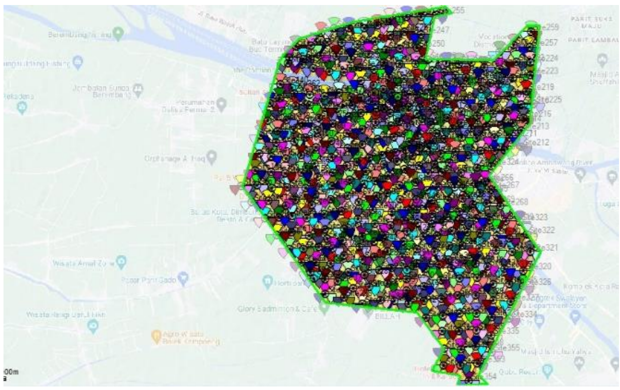

Figure 7. SS-SINR results of the Pontianak City picocell technology.

range spanning from a minimum of -1 dB to a maximum of 31 dB. This distribution provides a comprehensive overview of signal strength variations within the analyzed area.

The highest proportion of SS-SINR parameters was within the range of 20 to 25 dB, with a value of 69.34% covering an area of 62.14 km². According to SS-SINR results from the 5G NR deployment simulations using Atoll software, this range is classified as good. As shown in Figure 7, the obtained value is categorized as an SS-SINR value in the good range.

IV. CONCLUSION

The 5G network planning in Pontianak City can be implemented using the macrocell and picocell technology. The installation of the macrocell technology requires 23 sites with a coverage area of 107.8 km² and requires 364 sites with a coverage area of 90.72 km² for the picocell technology. From the results of the site coverage, the SS-RSRP value parameter was obtained at -74.94 dBm (macrocell) and -73.2 (picocell), while the SS-SINR value was at 26.84 dB (macrocell) and 26.02 dB (picocell). Both parameters met the KPI standard and are categorized as very good.

The 5G network planning in Pontianak City can be developed in further research using low-band and high-band frequencies in dense urban environments, suburban areas, and indoor building complexes, so that its application can be planned in various topographic and structural contexts. Additionally, operator readiness is crucial, including adequate optical fiber infrastructure, 4G network coverage, and compliance with 4G standardization, so that the 5G network planning methodology can be implemented effectively and efficiently.

CONFLICTS OF INTEREST

The author declares that the article entitled “5G Network Planning Using Macrocell and Picocell Technology” is written free from conflicts of interest.

AUTHORS’ CONTRIBUTIONS

Conceptualization, Rivan Achmad Nugroho and Redy Ratiandi Yacoub; methodology, Eva Faja Ripanti and Dedy Suryadi; calculation of link budget and MAPL, Rivan Achmad Nugroho and Dedy Suryadi; simulation using Atoll, Rivan Achmad Nugroho and Herry Sujaini; writing—original draft, Rivan Achmad Nugroho; writing—review and editing, Herry Sujaini, Redy Ratiandi Yacoub, Rivan Achmad Nugroho, Eva Faja Ripanti and Dedy Suryadi; validation, Dedy Suryadi and Redy Ratiandi Yacoub; supervision, Redy Ratiandi Yacoub.

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