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# Range expansion method on heterogeneous network to increase picocell coverage

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**ABSTRACT**

In this study, picocell planning was carried out on heterogeneous networks by applying the range expansion method. The case study was conducted in Coblong Subdistrict-Bandung on the 1800 MHz frequency. Heterogeneous network (HetNet) is a system that combines microcell networks and small cell networks (picocell and femtocell). The application of the range expansion method in picocell was aimed to broaden the scope of picocell. For the simulation, Atoll 3.3.0 software with observational parameters was implemented, including RSRP, SINR, throughput, and user connected. The planning results showed that the application of expansion method increased the coverage and quality of network, where the RSRP value ≥ -90 dBm was 97.72%, SINR ≥ 5 dB was 70.99%, uplink throughput was 17.80 Mbps, downlink throughput was 21.37 Mbps, and user connected was 99.2%.



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## 1. INTRODUCTION

Based on the traffic data in Coblong subdistrict [1, 2], the number of users accessing LTE networks on several sites reached more than 2,000 users per day because in the area there were several tourist attractions, college campuses and shopping centers resulting in the overload capacity. Besides, the drive test results showed several points experienced poor coverage with an average RSRP value of <-90 dBm due to a large number of tall buildings and large trees that caused the decrease of signal quality. In the condition of urban areas, one of the solutions to overcome the problem is by planning heterogeneous networks in the form of picocell.

The research [3-5] explained the picocell planning in Central Cimahi subdistrict was conducted by selecting sites having high traffics. The results of study based on the reference signal received power (RSRP) parameters, signal to noise ratio (SINR), throughput, and user connected showed that the picocell could be the solution to overcome the offload traffic on capacity and also improved the LTE network performance on coverage. Therefore, the planning of heterogeneous networks using small cells is very appropriate to be applied in dense urban areas that allow a surge of capacity.

Heterogeneous network is a scheme introduced by the third generation partnership project (3 GPP), which can combine macrocell networks with small cells (picocells and femtocells) [6-8]. Heterogeneous network (HetNet) is a network consisting of macrocell networks and small cell networks, macrocell networks have high power levels; meanwhile, small cell networks have low transmission power or commonly referred to as low power node (LPN) networks [9, 10]. The LPN network can be in the form of picocells, femtocells, remote radio heads (RRH), and relay nodes. On heterogeneous networks, macrocells are responsible for providing overall coverage of long-term evolution (LTE) network. Macrocells in heterogeneous networks are eNodeB that transmit high power up to 46 dBm [11, 12]. Small cells are implemented under the scope of macrocells to maximize the coverage and to increase the capacity of LTE-A network systems [13]. Small cells provide services at several points that experience offload traffic, especially on the edge of cell [14]. Thus, the small cells can serve users who cannot be served by macrocells. With low power around 23-30 dBm, small cells only have a small coverage (up to 300 m); therefore, in the heterogeneous networks, small cells will provide maximum coverage [15]. With a good collaboration between macrocells and small cells, heterogeneous networks will provide flexible, inexpensive and efficient solutions to increase the coverage and capacity of LTE-Advanced systems [16, 17]. The main problem in heterogeneous network planning is the necessity to ensure that the picocells can serve the users on the cell edge area properly. One of ways to overcome this problem is by increasing areas served by the picocells, which is called as range expansion [18, 19].

In the range expansion system, an offset bias is added to the RSRP picocells to increase the coverage. Before using the range expansion method, the users at the edge of cell would choose to be served by macrocells because of the high RSRP value [20, 21]. In the non-range expansion method, the selection of serving cells was based on the highest RSRP value or commonly called the maximum RSRP. Whereas, after using the range expansion method, the serving cell was chosen based on the RSRP value plus the offset bias of the picocell. When the offset bias value = 0 dB, then the user would be served by a macrocell, whereas if the offset bias value = 1-6 dB, the user would be served by a picocell [22].

Inter-cell interference coordination (ICIC) was introduced in LTE release 8 as a method that can overcome the problem of interference with users at the edge of cell, where inter eNodeB can communicate through the X2 interface to reduce inter-cell interference. In heterogeneous networks, to make the users can get services from picocells with signal strength from stronger microcells, picocells need to do the coordination of control channel and data channel interference with more dominant macrocell interference. In LTE release 10, it was introduced enhanced inter-cell interference coordination (eICIC), which is the development of ICIC method that support heterogeneous networks [23, 24]. The difference is in the addition of the ICIC domain time, where this method uses almost blank subframe (ABS). When a macrocell configures and sends information to a picocell about the ABS pattern, the user can connect to picocell and receive downlink information, both control and user data.

The present study optimized the coverage of LTE networks that experienced offload capacity, by planning heterogeneous networks in the form of picocells at 1,800 MHz frequency and applying range expansion to expand the coverage of picocells. Range expansion can maximize the performance of HetNet because it can improve the coverage of downlinks on picocells [25]. In picocell planning, it was performed the calculation of link budget and capacity dimensioning [26, 27]. Then, it was compared to the results of planning heterogeneous networks and networks without heterogeneous (homogeneous). This article is one of the recommendations for cellular network providers in optimizing the coverage of heterogeneous networks and is a reference for researchers in heterogeneous network research.

## 2. RESEARCH METHOD

In this section, it is explained the stages of picocell planning on the HetNet network by applying the range expansion method. The stages in this plan are in accordance with the cellular provider standard operating procedure (SOP). The planning was started by evaluating geographical conditions, evaluating existing sites, evaluating initial drive test, coverage and capacity dimensioning, modeling the HetNet network with range expansion, and configuring microcells and picocells.

### 2.1. The evaluation of geographical conditions

Geographical conditions in the Coblong subdistrict area indicate that several points become the center of the crowd, which can cause overload capacity. Also, the geographical situation where there are many large trees and uneven earth contours can cause poor coverage, where users do not get maximum service at that point. The observation was carried out in 4 (four) locations including Jalan Ir. H. Juanda (Dago), Gasibu Field, Bandung Zoo, and Cihampelas. Figure 1 shows the survey results of the geographical conditions of the observation area.

Ir. H. Juanda Street has uneven contours and tends to uphill, also there are many trees found there. As one of points for the Sunday car-free day event in the city of Bandung, this street is also the center of crowd. Meanwhile, in Gasibu, there is a market on Sundays. Gasibu is frequently used as a venue for music events visited by many people. Also, the Gasibu field has always been one of the center of crowd during the New Year's Eve and Takbeer night event. Therefore, the service provider must maximize its network to meet the needs of users there. According to CNN Indonesia (5/6), the number of visitors to the Bandung Zoo during the Eid holiday was 28 thousand people, which caused the overload capacity. Besides, in the Bandung Zoo, there are shady trees that can cause poor coverage. Thus, the addition of picocells is needed to optimize the network in terms of coverage and capacity. On Cihampelas street, many shopping centers are frequently visited by visitors from various regions. There is also a skywalk or a pedestrian bridge built on the 450-meter bridge, which can reduce the quality of signal for users below it.

Figure 1. The survey result of observation areas

## 2.2. The evaluation of initial drive test

Based on the measurement of signal by the drive test method using TEMS Pocket software in Coblong Subdistrict, the results shown in Figures 2 and 3. From Figure 2, it can be seen that the result of RSRP parameter reporting of the LTE network condition in Coblong Subdistrict – Bandung. Several points had poor network conditions with yellow and red indicators, which was an RSRP value <90 dBm with a percentage of 53.7%, which means that the portion of Coblong subdistrict had a non-optimal network in terms of coverage. Figure 3 shows the reporting results for the SINR < 5 dB parameter with a red indicator having a percentage of 45.91%. The size of the SINR value will affect the value of throughput obtained by the user. From the reporting above, it can be concluded that the condition of LTE network in the Coblong subdistrict was not optimal because it did not achieve the standard operator of RSRP parameters, which must have a percentage of 90% 90 - 90 dBm and SINR 90% ≥ 5 dB. This problem can be resulted from several factors, such as the influence of geographical conditions, the number of tall buildings, and the number of shade trees or offload traffic. Moreover, the Coblong District has several places that function as the center of crowd, such as shopping centers, tourist attractions, and college campuses. The problem in the Coblong subdistrict occured because only the macrocells provided the coverage. Therefore, it is necessary to conduct the optimization to maximize the existing network services, one of them is by conducting the picocell planning at points that might occur offloading traffic and poor coverage, where the picocells will help the microcells to serve the users who are at the center of crowd or poor coverage.

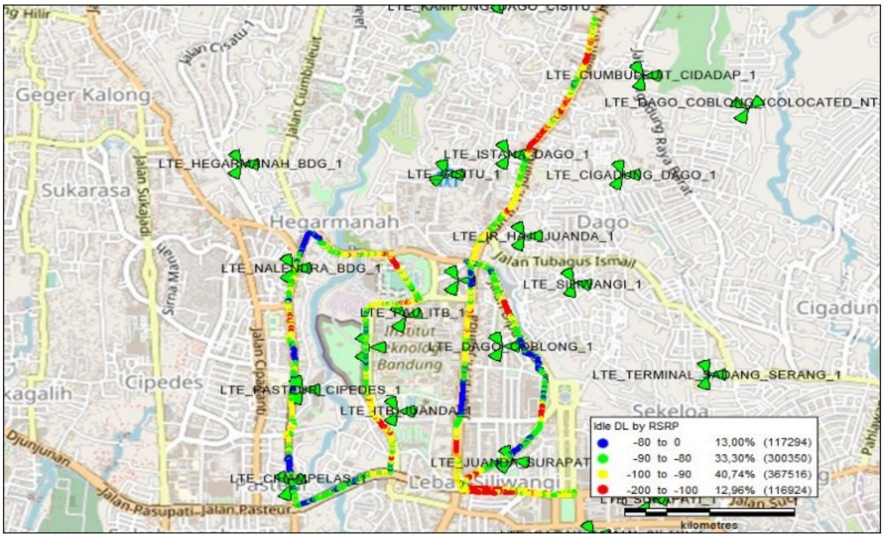


Figure 2. Reporting RSRP

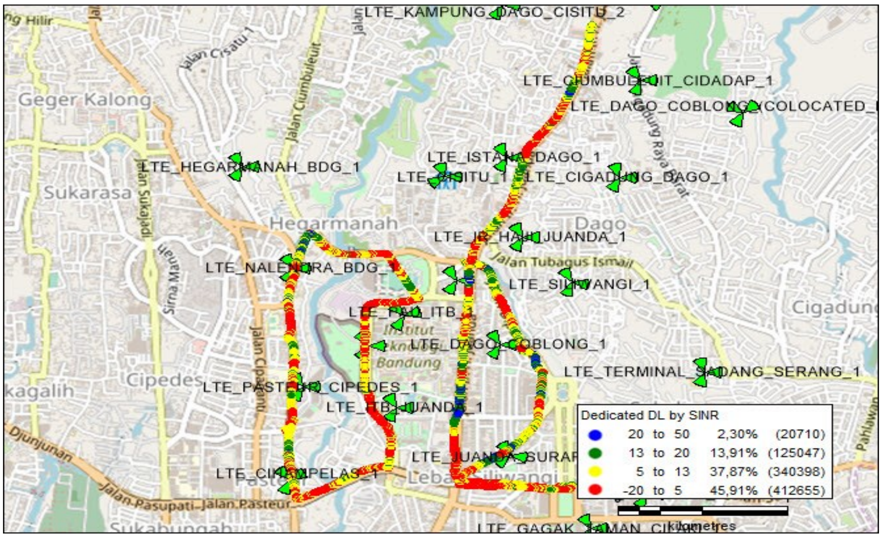


Figure 3. Reporting SINR

### 2.3. The evaluation of existing sites

In the Coblong subdistrict, an analysis of the capacity of existing sites was carried out by observing several sites that had high traffics. Therefore, the heterogeneous network planning could be conducted, by adding picocells in several sites having overload capacity. Based on the traffic data obtained from the operator, there were 5 sites in the Coblong subdistrict having high traffics. Table 1 shows the total users from the five sites in Coblong District taken 3 days in a row. The five sites had a total of users in a day reaching more than 2,000 users. It showed that the number of users accessing the LTE network was high. Thus, heterogeneous network planning was needed to make the traffic surge in macrocells can be handled by small cells, which then lessen the burden on macrocells that have high traffics.

Table 1.Traffic data of sites

| Site_Name | Date | Total User Number 24 Hour |
|---|---|---|
| LTE_ISTANA_DAGO | 26/01/2019 | 2196 |
| | 27/01/2019 | 2500 |
| | 28/01/2019 | 3395 |
| LTE_IR_HAJI_JUANDA | 26/01/2019 | 2764 |
| | 27/01/2019 | 2161 |
| | 28/01/2019 | 2022 |
| LTE_SUMURBANDUNG | 26/01/2019 | 2460 |
| | 27/01/2019 | 2365 |
| | 28/01/2019 | 2211 |
| LTE_TAMANSARI ITB AX | 26/01/2019 | 2891 |
| | 27/01/2019 | 3572 |
| | 28/01/2019 | 2640 |
| LTE_PASTEUR_CIPEDES | 26/01/2019 | 2489 |
| | 27/01/2019 | 2462 |
| | 28/01/2019 | 2786 |

### 2.4. The modelling of heterogeneous network

The solution which is efficient to handle the increasing traffic demand by using small cells instead add more BTS macros. The heterogeneous network planning was carried out by applying small cells within the coverage area of macrocells. Figure 4 shows the heterogeneous network modeling with the application of range expansion method. In this heterogeneous network planning, the small cell used was a picocell that works at a frequency of 1,800 MHz or equal to the working frequency at a macrocell and a bandwidth of 10 MHz. Picocells were placed at the edge of the macrocells coverage to maximize coverage and to increase the network capacity. The range of picocells is very limited influenced by power and interference from stronger macrocells, especially at the edge of cell. The range expansion method will add offset bias to the received signal strength (RSS) of small cells to increase down link (DL) coverage. The offset bias value that can be used for picocells is between 0 - 6 dB. When the offset value is 0 dB, then the picocell does not use the range expansion method.

Thus, the serving cell will be possibly conducted by macrocells, especially for the users who are on the edge of cell. However, when picocells have an offset bias, the users who are within the picocells scopes are not served by macrocells. Table 2 shows the planning scenarios including (1) the simulation of existing sites and (2) the simulation with picocell planning by placement based on the point of overload capacity and poor coverage.

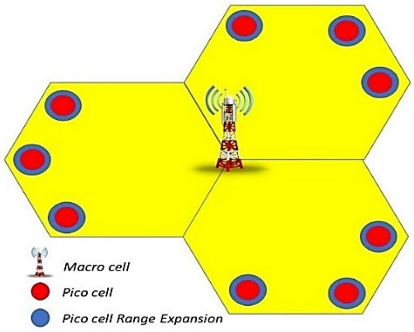


Figure 4. HetNet modelling

Table 2. The planning of scenario

| System Parameter | Scenario 1 | | Scenario 2 | |
|---|---|---|---|---|
| | Macro | Pico | Macro | Pico |
| Frequency (MHz) | 1,800 | - | 1,800 | 1,800 |
| Site Number | 16 | 0 | 16 | 15 |

## 2.5. Coverage planning

To conduct the coverage planning calculation requires the specifications of device used. Table 3 shows the specification of Huawei devices used in this coverage planning. Next is calculating the power link budget to get the value of Maximum Allowed Path Loss (MAPL). Table 4 shows the result of calculation of Picocell Link Budget. After obtaining the value of MAPL picocell, the lowest value was taken as a downlink MAPL for picocells with a value of 125.427 dBm. The MAPL value was used to calculate the cell radius. The calculation of cell radius was performed using in (1) and (2).

$$a(hm) = (1.1 \log(fc) - 0.7)hm - (1.56 \log(fc) - 0.8) \quad (1)$$
$$a(hm) = (1.1 \log(1{,}800) - 0.7)1.5 - (1.56 \log(1{,}800) - 0.8)$$
$$a(hm) = 4.320 - 4.278$$
$$a(hm) = 0.042$$

$$MAPL = 46.3 + 33.9 (\mathrm{Log}\ fc) - 13.82\ \mathrm{Log}\ hb - a(hm) + (44.9 - 6.55\ \mathrm{Log}\ hb) \log d \quad (2)$$
$$125{,}427 = 46.3 + 33.9 (\log 1{,}800) - 13.82 \log (7) - 0.042 + (44.9 - 6.55 \log (7)) \log d$$
$$125{,}427 = 46.3 + 33.9 (3.255) - 13.82 (0.845) - 0.042 + (44.9 - 6.55 (0.845)) \log d$$
$$125{,}427 = 46.3 + 110{,}344 - 11{,}677 - 0.042 + (44.9 - 5{,}534) \log d$$
$$125{,}427 = 46.3 + 110{,}344 - 11{,}677 - 0.042 + 39{,}366 \log d$$
$$125{,}427 = 144{,}925 + 39.366 \log d$$
$$-19.498 = 39.366 \log d$$
$$\frac{-19.498}{39.366} = \log d$$
$$-0.495 = \log d$$
$$10\text{-}0.495 = d$$
$$d = 0.319 \text{ km}$$

After obtaining the value of cell radius, the next step was performing the cell area calculation to cover the entire area. The cell area can be calculated using in (3).

$$Lcell = 2.6 \times d^2 \quad (3)$$
$$Lcell = 2.6 \times (0.319)^2$$
$$Lcell = 0.264 \text{ km}^2$$

Table 3. The specifications of device

| Uplink | | Downlink | |
|---|---|---|---|
| Parameter of Transmitter (UE) | | Parameter of Transmitter (eNodeB) | |
| Parameter | Value | Parameter | Value |
| Max Tx Power | 23 dBm | Max Tx Power | 30 dBm |
| Antenna Height | 1.5 m | Gain Tx | 17 dBi |
| Gain Tx | 0 dBi | Antenna Height | 7 m |
| Parameter of Receiver (eNode B) | | Cabel Loss | 0.5 dB |
| Gain Rx | 17 dBi | Thermal Noise | -132.2 dBm |
| Noise Figure | 2.3 dB | Noise Figure | 2.3 dB |
| Thermal Noise | -132.2 dBm | Parameter of Receiver (UE) | |
| Cabel Loss | 0.5 dB | Antenna Height | 1.5 m |
| Antenna Height | 7 | Body Loss | 3 dB |

Table 4. The calculation of MAPL

| Tx | Formula | UL | DL |
|---|---|---|---|
| Max. Total Tx Power (dBm) | A | 23 | 30 |
| RB to Distribute | C | 3 | 50 |
| Subcarriers to Distribute Power | D = 12*C | 36 | 600 |
| Subcarrier Power (dBm) | E = A-10*Log(D) | 7,436 | 2,218 |
| Tx Antenna Gain (dBi) | G | 18 | 18 |
| Tx Cable Loss (dB) | H | 0.5 | 0 |
| EIRP per Subcarrier (dBm) | J = E + G - H | 23,936 | 20,218 |
| Rx | Formula | UL | DL |
| SINR (dB) | K | -6.19 | -6.19 |
| Rx Noise Figure (dB) | L | 2.3 | 7 |
| Receiver Sensitivity (dBm) | M = K + L – 174 + 10*Log10(15000) | -136,129 | -131,429 |
| Rx Body Loss (dB) | P | 0 | 0 |
| Interference Margin (dB) | Q | 2.72 | 2.72 |
| Min. Signal Reception Strength (dBm) | R = M + P +Q | -133.409 | -128.209 |
| Path Loss | Formula | UL | DL |
| Penetration Loss (dB) | S | 15 | 15 |
| Shadow Fading Margin (dB) | T | 8 | 8 |
| MAPL | T = J - R - S - T | 134,345 | 125,427 |

### 2.6. Capacity planning

To determine the picocells capacity depends on the allocated bandwidth. In the planning process includes the calculation of forecasting number of users, service model parameters, traffic model, site capacity, and number of sites. Forecasting number of user calculation includes the number of residents in the observation area, population growth factors, productive age population (aged 15-65 years), cell phone users, market share operators, and LTE service penetration. To calculate the forecasting number of users uses in (4):

$$P_t=P_o\ (1 + r)\ n \tag{4}$$

where $P_t$ is residents in year t, $P_o$ is residents in the base year, r is population growth, and n is base year. Based on the calculation in Table 5, it is known that LTE users for the next 5 years are 19,064 peoples.

Table 5. Forecasting number

| Residents Number | Productive Age (15-65) | Population Growth Factor | Market Share Operator | LTE Users for the Next 5 years |
|---|---|---|---|---|
| 132,002 | 75% | 1.7% | 17.7% | 19,064 |

The service model was used to find out the minimum amount of throughput so that the customers can access available services on the LTE network. Table 6 shows the parameters of service model and obtained throughput value per session for each types of LTE services from the uplink or downlink direction. On each side requires data: bearer rate (kbps), session time, and session duty ratio. The next step is calculating the cell average throughput using in (5) and shown in Table 7:

$$\text{Cell Average Throughput} = \sum [\text{ SINR Probability } (P_n) \times \text{Cell Capacity}] \tag{5}$$

Table 6. The parameter of service model

| Traffic Behavior | UPLINK Bearer Rate (kbps) | Session Time (s) | Session Duty Ratio | Bler | DOWNLINK Bearer Rate (kbps) | Session Time (s) | Session Duty Ratio | Bler | UL Throughput/ Session (kbps) | DL Throughput/ Session (kbps) |
|---|---|---|---|---|---|---|---|---|---|---|
| VOIP | 26.9 | 80 | 0.4 | 0.01 | 26.9 | 80 | 0.4 | 0.01 | 869.495 | 869.495 |
| Video Phone | 62.53 | 70 | 1 | 0.01 | 62.53 | 70 | 1 | 0.01 | 4,421.313 | 4,421.313 |
| Video Conference | 62.53 | 1800 | 1 | 0.01 | 62.53 | 1800 | 1 | 0.01 | 113,690.9 | 113,690.9 |
| Real Time Gaming | 31.26 | 1800 | 0.2 | 0.01 | 125.06 | 1800 | 0.4 | 0.01 | 11,367.27 | 9,095.,73 |
| Streaming Media | 31.26 | 3600 | 0.05 | 0.01 | 250.11 | 3600 | 0.95 | 0.01 | 5,683.636 | 864,016.4 |
| IMS Signalling | 15.63 | 7 | 0.2 | 0.01 | 15.63 | 7 | 0.2 | 0.01 | 22.103 | 22.103 |
| Web Browsing | 62.53 | 1800 | 0.05 | 0.01 | 250.11 | 1800 | 0.05 | 0.01 | 5,684.545 | 22,737.27 |
| File Transfer | 140.69 | 600 | 1 | 0.01 | 750.34 | 600 | 1 | 0.01 | 85,266.67 | 454,751.5 |
| Email | 140.69 | 50 | 1 | 0.01 | 750.34 | 15 | 1 | 0.01 | 7,105.556 | 11,368.79 |
| P2P File Sharing | 250.11 | 1200 | 1 | 0.01 | 750.34 | 1200 | 1 | 0.01 | 30,3163.6 | 909,503.03 |

Table 7. Cell average throughput

| Direction | Macrocell (Mbps) | Picocell (Mbps) |
|---|---|---|
| UL | 14.70813024 | 29.41629024 |
| DL | 12.25677024 | 24.51357024 |

After obtaining the value of single-user throughput and cell throughput, the next step is determining the number of required picocells. The calculation of cells number was based on the estimated maximum number of users that could served by one picocell site. Because the planning area is an urban area, the peak of the average ratio used was 20% with a DL cell load of 100%. Figures 5 and 6 are the calculation of maximum user for existing sites and pico sites. From the calculation result obtained the maximum of user number served by the existing sites was 840 users per site. There are 16 existing sites in Coblong Subdistrict area. The existing sites enable to serve as many as 13,440 users (840 users x 16 sites).

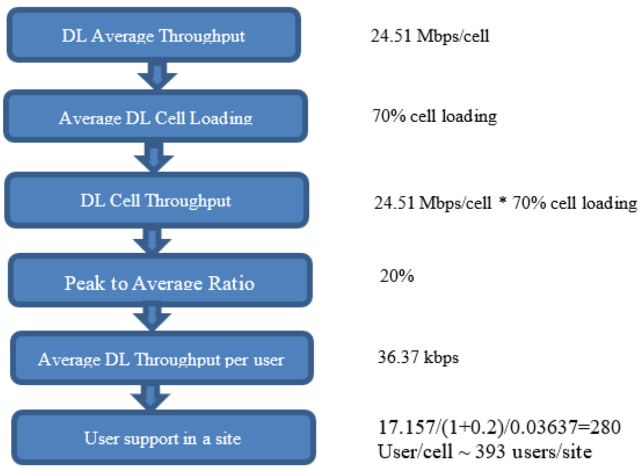


Figure 5. The maximum of existing site user

The maximum number of users that could be served by one picocell site was 393 users with 70% cell loading to anticipate excessive user surges. In this planning, Picocell was used to overcome the overload capacity experienced by existing sites. The calculation result of forecasting number of users in Coblong subdistrict for the next 5 years as many as 19,064 users. The existing sites were not able to serve all users in the region because the maximum number of users that could be served by existing sites was 13,440 users, which means a total of 5,624 users did not get services from existing sites. Based on the maximum number of users in Picocell, it took 15 Picocell sites to serve all users who experienced offload capacity. In heterogeneous network planning, it is necessary to configure picocells; for example, by adding handover margins and individual cell offsets that function as range expansion, and adding configuration of Almost Blank Subframe (ABS) patterns on macro sites that can reduce the impact of interference between macrocells and picocells. Following is the configuration of the ABS pattern used by the macro site:

ABS pattern 1: 1000000010000000100000001000000010000000
ABS pattern 2: 0100000001000000010000000100000001000000
ABS pattern 3: 0010000000100000001000000010000000100000
ABS pattern 4: 0001000000010000000100000001000000010000
ABS pattern 5: 0000100000001000000010000000100000001000
ABS pattern 6: 0000010000000100000001000000010000000100
ABS pattern 7: 0000001000000010000000100000001000000010
ABS pattern 8: 0000000100000001000000010000000100000001
1 = Almost Blank Subframe
0 = Active Subframe

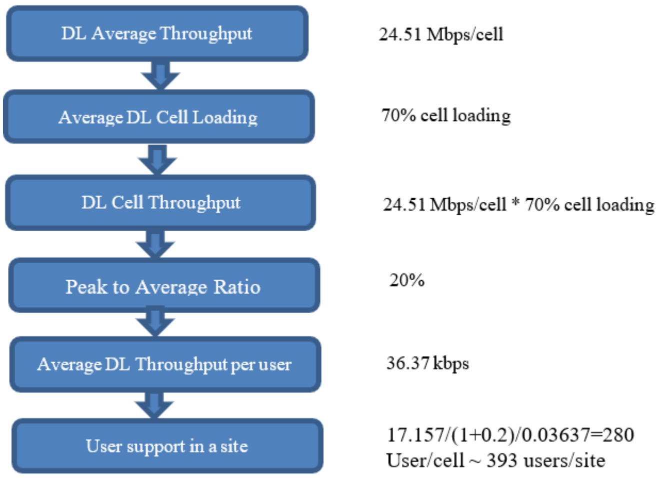


Figure 6. The maximum of picocells users

## 3. SIMULATION AND RESULTS

Scenario 1 simulated the existing sites to find out the performance before heterogeneous network planning was conducted, which then the results were compared to between before and after picocell planning. In the Coblong subdistrict area, there were 16 existing sites. Meanwhile, scenario 2 simulated the existing sites by adding picocells site from the planning results. The picocell placement used in this simulation was based on the poor condition of RSRP and SINR and several points of overload capacity. In this simulation, there were 16 macrocells and 15 picocells. Figures 7 and 8 are the distribution of picocell sites in the Coblong area.

Figure 9 shows the comparison result of two scenarios, namely the RSRP and SINR parameters. RSRP values obtained from the two simulations indicated that the RSRP area coverage met the standard of KPI operator that was with RSRP coverage ≥ -90 dBm, above 90%. After picocells planning, the RSRP value increased by 5%, which it showed that picocells planning increased the RSRP value in terms of coverage. While based on the SINR parameters, both scenarios did not yet meet the standard of KPI operator because the SINR coverage value ≥ 5 dB was still below 90%. The value of SINR ≥ 5 dB in simulation 1 was 59.55% and in simulation 2 was 70.99%. It can be resulted from the number of obstacles, such as large trees, tall buildings, and uneven earth contours so that the quality of the signal power obtained was disturbed.

Based on the standard of KPI operator, the downlink of throughput value was 12 Mbps and the uplink was 6 Mbps. Figure 10 shows that both scenarios met the standard of KPI operator. The most significant increase in downlink throughput occurred in simulation 2. It resulted from the good SINR value that affected the type of modulation used, where the SINR value will be directly proportional to the throughput value because the SINR value will represent the quality of the signal received by the user. Figure 11 shows the comparison of users connected and rejected. In simulation 1, it showed that the KPI standard was not achieved because the value of rejected user was still above 1%. It resulted from the LTE networks that were not able to cope with offload capacity due to the user surges. Meanwhile, in simulation 2 after heterogeneous network planning with picocells, it showed that the scenario was able to serve and overcome the user surges. Because picocells were able to ease the traffic burden on macro sites, where when macro sites will experience a user surge, then the traffic load will immediately be handled by picocells.

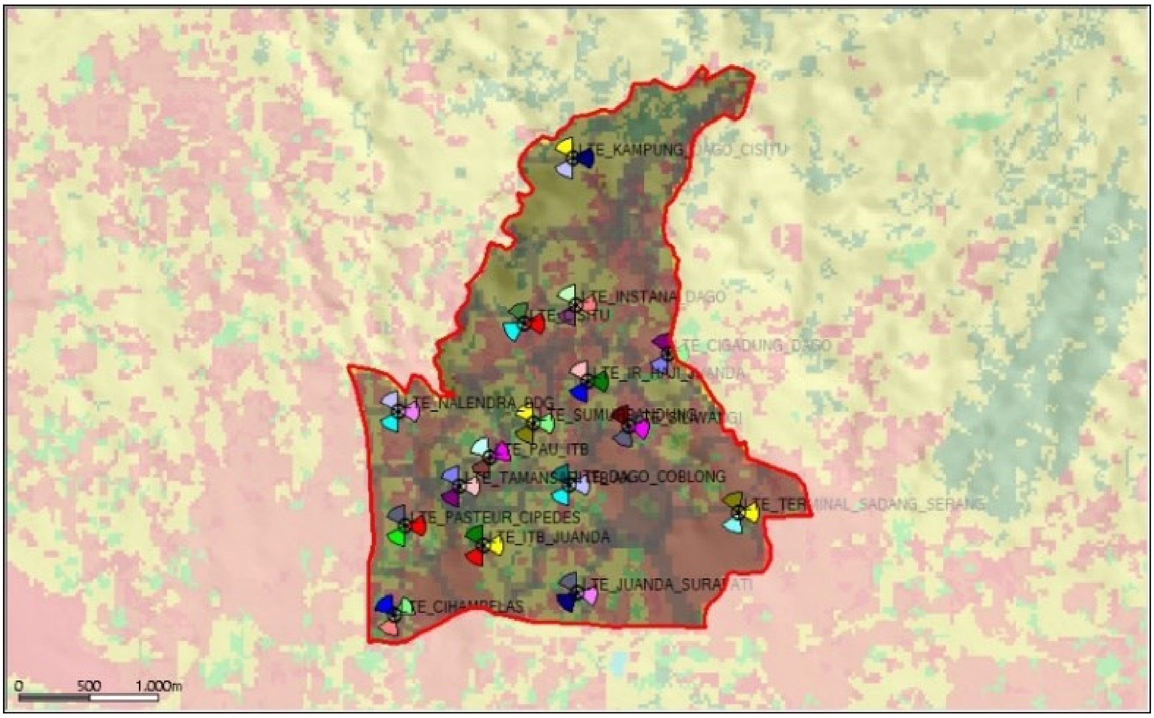


Figure 7. The distribution of existing sites (Scenario 1)

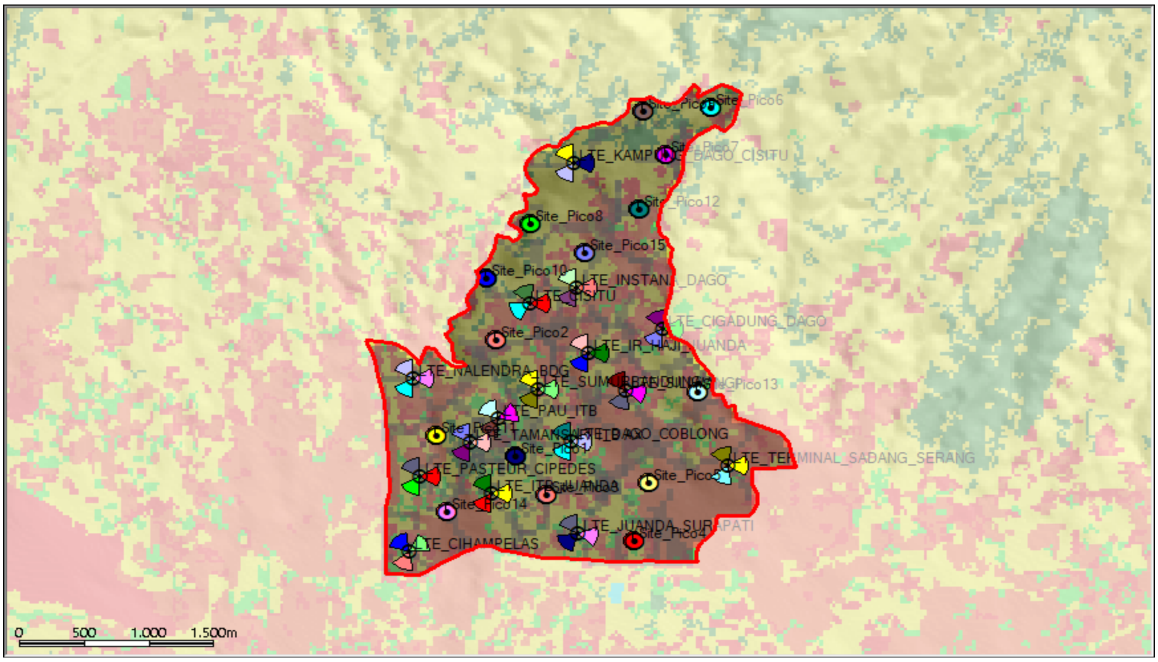


Figure 8. The distribution of picocells (scenario 2)

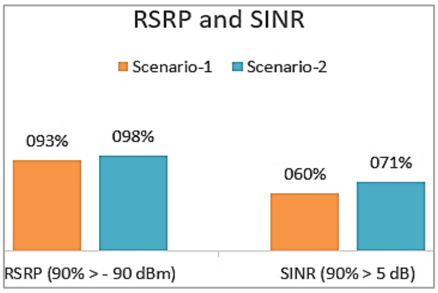


Figure 9. The comparison of RSRP and SINR

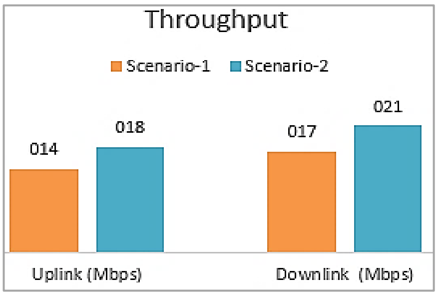


Figure 10. The comparison of throughput value

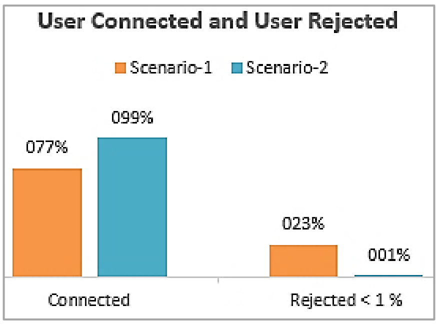


Figure11. The Comparison of user connected and user rejected

## 4. CONCLUSION

Based on RSRP parameters, in simulation 1, the average RSRP value was -69.23 dBm, while the RSRP coverage ≥ -90 dBm was 93.35%. Whereas in simulation 2, the RSRP average value was -64.96 dBm, while the RSRP coverage was ≥ -90 dBm was 97.72%. Based on the SINR parameters, in simulation 1, an average SINR value of 7.57 dB was obtained, while the SINR ≥ 5 dB coverage was 59.55%. Whereas in simulation 2, an average SINR of 10.77 dB was obtained, while the SINR ≥ 5 dB coverage was 70.99%. An increase in the average value of SINR in simulation 2, this will affect the value of throughput. Based on the parameters of throughput, in simulation 1, the average value of downlink throughput is 17.04 Mbps and the average value of uplink throughput is 14.07 Mbps. In simulation 2, the average value of downlink throughput is 21.37 Mbps and the average value of uplink throughput is 17.80 Mbps. Based on user connected parameters, simulation results 1, the number of connected users is 19,238 (77.2%) users and user rejected is 4,391 (22.8%). While the results of simulation 2, the number of connected users increased significantly to as many as 19,078 users (99.2%) and rejected users as many as 163 users (0.8%).

Both planning scenarios showed that heterogeneous network planning was highly effective in overcoming coverage and capacity issues. In terms of coverage, it can provide a very good RSRP and SINR value. Meanwhile, in terms of heterogeneous network capacity, it can increase the throughput and overcome the user surges. Therefore, heterogeneous networks suits to be applied in dense urban areas that have many users and in areas that have many obstacles. This article is one of the recommendations for cellular network providers in optimizing the coverage of heterogeneous networks and a reference for researchers in heterogeneous network research.

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