Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13168
e-ISSN : 2541-2019
p-ISSN : 2541-044X

Microcell Planning Analysis Using Cell Splitting Method In 4G LTE Network

Afrizal Yuhanef [1)*], Zurnawita [2)], Gerin Berliana Syafira [3)], Uzma Septima[4)], Herry Setiawan[5)]
[1,2,3,4,5)] Study Program of Telecommunication Engineering, Department of Electrical Engineering, Padang State Polytechnic, Indonesia
[1)]afrizal@pnp.ac.id, [2)]zurnawita@gmail.com, [3)]gerinberliana@gmail.com, [4)]uzmaseptima@gmail.com, [5)]herysetiawan88@gmail.com

Submitted: Nov 10, 2023 | **Accepted** : Nov 10, 2023 | **Published** : Jan 1, 2024

Abstract: As the growth of technology and telecommunication network, demands of mobile technology is also raised. The quality of the network will decrease by the insufficient number of network and cell to support the growth of user, and the scope of e-Node B is not optimal. The method of cell splitting can be used to solve the problem, this method splitting macro cell network become smaller size of cell with scoping area of each without interruption. The planning of new site as microcell implemented in area of Flamboyan Baru using XL operator. As the count gained, 1 site microcell and 2 cell with the antenna of 18,5 meters and power of 38 dBm, cell splitting method could increase network quality and improve the average number of parameter RSRP, SINR, and throughput, also proving that the implementation of cell splitting in microcell could escalate the quality of LTE network, the improvement of network quality in SINR parameter with average number of 24,23 dB with category of very good, RSRP parameter with average number of -94,28 dBm with category good, and the average number of throughput reach 63.094,91 kbps with category very good.

Keywords: Cell splitting;Microcell;Throughput;SINR;RSRP

INTRODUCTION

As the growth of 4G LTE technology, amount users in mobile technology increased, the channel provided in a cell is not sufficient anymore to support users. Nowadays problems happen caused by the insufficient number of eNodB which use macrocell on its antenna as the interference caused by 2 things, those are coverage and capacity (Arumsidi et al., 2019). By the growth of the fourth generation technology – the Long Term Evolution (4G LTE), numbers of technology users who can access information/data with higher speed.

4G LTE Technology is the improvement of 2G GSM and UMTS (3G)/HSPA (3.5G). 4G LTE technology offers better spectrum speed than before, less latency, and more flexible bandwidth channel selection. 4G LTE technology itself supported by AMC (Adaptive Modulation System and Coding) and MIMO (Multiple-Input-Multiple-Output) (Alfian, 2021). LTE performance compared to the previous technology exist in tranmission speed up to 100 Mbps in downlink and 50 Mbps in uplink. The growth of internet technology communication become the origin of the mold of 4G LTE technology, as the ability to ease internet user to use data (Yufiansa et al., 2019). On a research (Anugerah & Putri, 2020) used cell splitting method to increase LTE network performance, gained improvement of LTE network capacity as the average RSRP 8,28 dBm, number of SINR 3,6 dB, and throughput 1.475 kbps. Another research (Putri et al., 2020) conducted by designing cell splitting shows the improvement of RSRP network 13,32%, SINR improved as 52,75%, and throughput improved as 23,6%.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024 e-ISSN : 2541-2019
DOI : https://doi.org/10.33395/sinkron.v9i1.13168 p-ISSN : 2541-044X

LITERATURE REVIEW

In a book of An Introduction to LTE written by Cristopher Cox stated that there are 3 major ways to improve capacity in a moving communication system. The first way is by minimizing the size of the cell, with channel capacity as the maximum speed which can handled to a cell, by minimizing the size of each cell could lead to the improvement of network capacity. The second way is by improving the bandwith, this technique found quite difficult as the limitation of spectrum frequency by a few operator. The third technology is the improvement or modernization communication technology used, for this technique upgrade technology will need a lot of fund and and time consuming. Based on the condition stated before, then the most appropriate technique is by implementing cell splitting by develop microcell (Christopher Cox, 2014).

Cell splitting method is splitting macrocell become several microcell which leads to the addition amount capacity system, so the network quality which was previously poor because of the numbers of the user could run better as the standard of network quality of LTE. Therefore, designing microcell using cell splitting method is the precise way to improve mobile communication network capacity and solve the problem of low throughput cell (Putri et al., 2020).Cell splitting method can be used to problem where this method could improve parameters such as SINR, RSRP, and throughput. Cell splitting is a method which split macrocell network into several smaller size of cell with scoping area without interruption (Putri et al., 2020).

METHOD

Long term evolution is a project by The Third Generation Partnership Project (3GPP), LTE use the technology of OFDMA(Orthogonal Frequency Division Multiple Access) into downlink then use the technology of SC-FDMA (Single Carrier Frequency Division Multiple Access) into uplink, to reach the faster transfer speed of data, using the bandwidth maximally and efficiently (Christopher Cox, 2014). As the requirement ask, the phone have to change from standby mode into active mode which need time less than 100 milliseconds after the action of the user. LTE being maximized for cell in size up to 5 kilometers, operating in the scale that are less than 30 km and covering cell around 100 km. LTE can work with different bandwidth from 1,4 MHz up to maximum 20 MHz (Alfian, 2021). By LTE, user and customer can enjoy multimedia such as video, browsing, and game in 1 connedted device (Yuhanef et al., 2023).

Hence, provider have to maximize today's performance to ensure the expedite of operational and customer's satisfaction (Jaringan et al., 2020). Analizing 4G LTE network is needed to monitor the quality of existed network (Gedung et al., 2019). Drive test conducted outdoor as been done as people driving vehicle to a walk test for indoor use as it walk. Drive test is use more often than walk test (Yuliana et al., 2019). Drive test is measuring signal made to test the performance of a cell in a location or certain site, the level of sending and receiving power, the level of incorrect access, and failed observing call. This drivetest is used to optimalize the network (Rahmat, 2022). The quality of the LTE provider could be verified by measurement using drive test method. Several research conducted to measure the quality of the network by using drive test method, such as networking quality analysis (Sudiarta et al., 2019). The measurement of drive test generally use adequate software (Track et al., 2022).

Cell splitting is a way of dividing macrocell with populous communication into smaller size of cells and placing them between previous cells. Each microcell has its own base station (BS) with transmission power and antenna height that is no higher than the large cell/macrocell. By using this method, the capacity of the cell system increase the number of channels per unit area, so that this method creates new cells with the same repeating pattern as the original pattern (Putri et al., 2020). If each cell is reduced to a radius, equal to half the radius of the original cell, then to cover the area of the original cell, by splitting this cell, four times the number of cells is needed, which can be described by the following equation (Putri et al., 2020). This method is mostly used to solve network problems and improve network

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024 e-ISSN : 2541-2019
DOI : https://doi.org/10.33395/sinkron.v9i1.13168 p-ISSN : 2541-044X

quality (Layanan et al., 2020). The cell splitting technique can increase channel capacity up to four times than the previous channel capacity (Kamal et al., 2023).

$$\text{New cell radius} = \frac{Old\ cell\ radius}{2}, \quad (1)$$

$$\text{New cell area} = \frac{Old\ cell\ area}{4}, \quad (2)$$

$$\text{(New Traffic Load) / area} = 4 \times \text{Old traffic load / area} \quad (3)$$

The most important aspect in implementing splitting cells is physical configuration in a contiguous location to avoid bigger trouble caused by the form of new small cells between macrocell. Physical tunning is the substitution or configuration physical device in the field into existing network (Yuliana et al., 2019).

Microcell is a smaller cell than macrocell with the scope 500 m up to 2 km. The transmission power is lower than the macrocell, around 38 dBm or 5 watt. Determining factors the value of the radio is the height of microcell antenna itself, the maximum is 20 meters (Putri et al., 2020).

Physical tunning is an optimizing method where optimation is conducted locally by changing or adapting to network physical devices. Physical adjustment could be done by tilting the antenna, adjusting or revoking the height, adjusting azimuth antenna, etc (Yuliana et al., 2019). Optimation of physical tunning conducted to improve the quality of LTE networking (Purnama et al., 2020).

Link budget is measuring the corroboration of all transmitter and receiver after atenuation on the different media transmission until finally accepted by the telecommunications system receiver. The calculation link counted amount signal loss, including various propagation losses that occur during the propagation process (Rezkika et al., 2019). Link budget calculations could improve good quality in mobile network system (Setyo & Sari, 2019). The link budget calculation is to obtain the maximum value of signal attenuation tolerated by the UE with the eNodeB (Rahmania, 2020).

Coverage planning is a mobile network planning method that determines the number of site based on coverage area, coverage calculations to determine the number of antennas needed in network design (Bastianto & Laksana, 2019), considering signal atenuation happens when the signal propagates in both uplink and downlink directions. The propagation wave from the transmitter to the receiver can not be separated from the wave path due to the influence of various attenuation. Atenuating and strengthening signals are shown in the link budget (Mubarok & Putri, 2019). Coverage planning is also explained as the coverage area that can be covered by the network (Niama et al., 2021).

Capacity planning is a network developing plan in an area, intend to include the user covered in a certain area (Arumsidi et al., 2019) , this plan will determine the number of eNodeB needed which will adjust by the user (Safira et al., 2022). Capacity planning is also aim to determine the number of site based on the number of the user. Furthermore, the area will be divided into rural, sub urban, urban, and dense urban (Edwinanto et al., 2020). Network capacity is one of planning criteria, so the operator could predict the size of the network to give different services to the user (Wulan & Budiyanto, 2022).

RESULT

This research aims to analize and comparing in a planning area of microcell with cell splitting method, and parameters observed are RSRP, SINR, and throughput.

Identification of Major Site Specification

Determining planning area which has problem of networking is the main thing have to be done. The existance of *badspots* while doing the drive test identified as related to the existance of reduction networking quality in that area. Based on the result of the analysis, Flamboyan Baru area is categorized as urban area which has quaite dense population of 4829 and there are buildings owned by individuals or the government, Flamboyan Baru has an area of about 511,026.61 m². The density of the population can also affect signal quality. The number of users can cause *user overload* so that signal quality received

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13168
e-ISSN : 2541-2019
p-ISSN : 2541-044X

by users is not maximized, so the number of users must be balanced with the availability of traffic channels in carrying out data services.

The first thing to do is conducting a *drive test* to measure the beginning of network quality of 4G LTE, the drive test was conducted in the previous planning area, the operator used to conduct the drive test in this study is XL, after the drive test is conducted, the measurement results can be analyzed on *MapInfo Pro*, in Figure 1 the measurement result obtain in the *drive test*. Before conducting simulation in the to the *existing site*, a separation of the planning area is conducted, in Figure 2 there is an area which limiting itself in implementing the drivetest and soon will be implement cell splitting method, the red line in the figure is the *computation zone*, which is the area that will be calculated in the simulation with Atoll software. After that, analyze information about site specifications in the form of *longitude*, *latitude*, antenna height, power and others. The location of *existing sites serving* in *badspot* areas can be seen in Table 1.

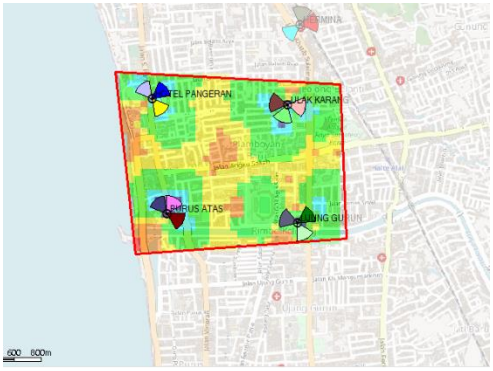

Fig 1. Position of existing RSRP site by Atoll

Table 1 Position of existing site

Site ID	Site Name	Longitude	Latitude
MC425CC02E21	Ulak Karang	100.35989	-0.922777778
4253302E	Ujung Gurun	100.36054	-0.93058
MC4251907E	Purus Atas	100.35206	-0.929916667
4251307E	Pangeran Hotel	100.35108	-0.922391667

Based on on the simulation results on the RSRP parameters in Figure 1, the *computation zone* gained 2,06% range by the number of > -85 dBm, 8,37% range by the number of -90 s.d. -5 dBm, 48,84% range by the number of > -100 s.d. -90 dBm, 31,05% with the range number > -105 s.d. -100 dBm, dan 9,40% exist in range number > -115 s.d. -105 dBm, and 0,25% range exist in number of < -115. The average number by the number of simulation produce is -97,93 dBm. As the result of parameter simulation SINR in Figure 2, can be seen in computation zone gained 62,06% in the range number of > 20 dB, 32,77% with the range number > 10 s.d. 20 dB, 4,38% with the range number > 3 s.d. 10 dB, 0,77% with the range number > 0 s.d. 3 dB. The average number by the number of simulation produce is around 22,14 dB. As the result of parameter *throughput* in Figure 3 can be seen in computation zone gained 92,91% in the range number of > 30.000 s.d. 100.000 kbps, 6,31% in the range number of > 10.000 s.d. 30.000 kbps, 0,77% in the range number of > 5.000 s.d. 10.000 kbps, 0,38% in the range number of > 3.000 s.d 5.000. The average number by the number of simulation produce is around 61.844,09 kbps.

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13168
e-ISSN : 2541-2019
p-ISSN : 2541-044X

After obtaining the result of simulation RSRP, SINR, and *throughput* parameters, also knowing the field condition by conducting *drive test* which can be seen in Figure 4 below, the result of drive test are the measurement of signal quality of the original condition in the fields.

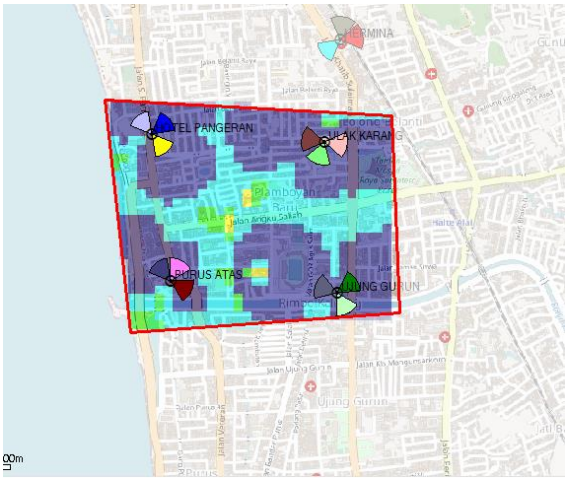

Fig. 1 Result of simulation of existing site parameter SINR

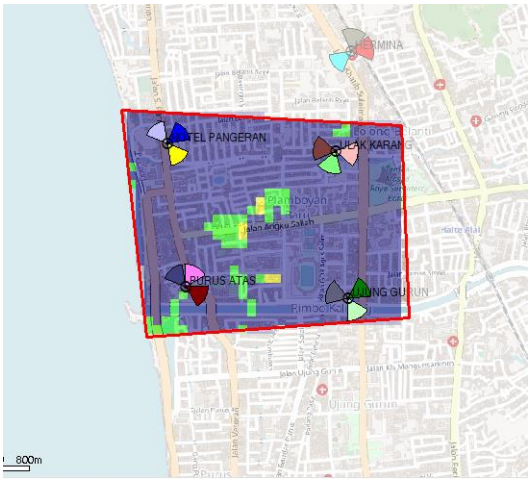

Fig. 3 Result of simulation of existing site parameter throughput

In conducting cell splitting method, it is necessary to have an existing site that own the issue of user overload and low throughput numbers to provide services to users, so the next step is to determine the site to be split. In Figure 5, the graph explaining the user overload of the existing site, and in Figure 6, the graph is the average throughput parameters of each existing site. In both graphs it can be seen that the Ujung Gurun site experiences a higher average user than other existing sites of 142.55, as well as the lowest throughput reception of around 7432.20 kbps. So microcell planning can be done with the cell splitting method at the Ujung Gurun site,

Based on the badspot analysis, it is found that Ujung Gurun site can perform cell splitting since the site is experiencing user overload. The badspot area is a highway close to a residential area. This area is also a busy area because it is close to the Padang beach tourism area. For the placement of new sites by estimating the badspot area, which is towards a fairly dense residential area, the placement of this new site must be considered so that the placement is optimal and effective, therefore the placement must be able to cover the user area so that the placement can be used by the user. New sites in the form of microcells are usually placed on top of buildings to save development costs, this is what distinguishes microcells from macrocells, because the construction of microcells itself does not require a large area. Therefore, the coverage area by microcells is relatively less than macrocells.

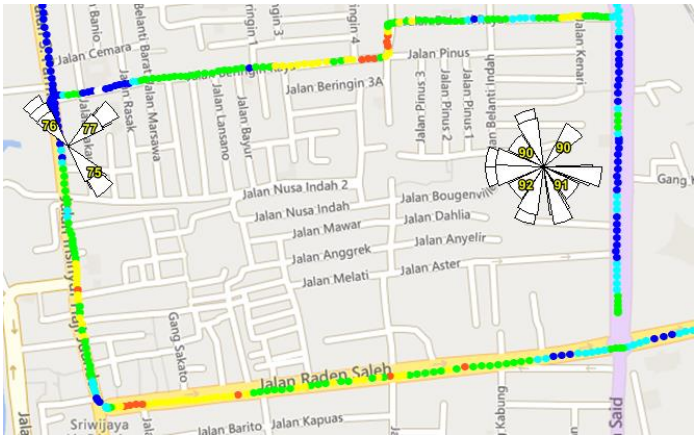

Fig 2 Result of Drive test

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024
DOI : https://doi.org/10.33395/sinkron.v9i1.13168
e-ISSN : 2541-2019
p-ISSN : 2541-044X

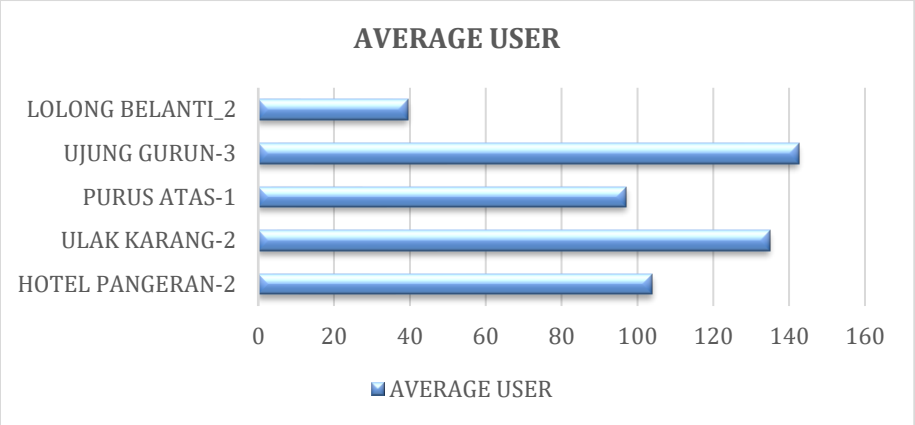

Fig 3 Average user

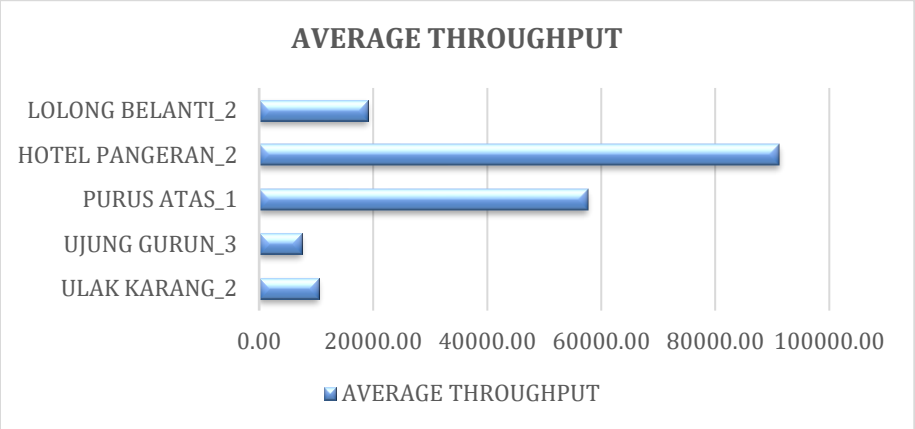

Fig 4 Average throughput

Measurement of Coverage and Capacity Planning

In splitting the site and gaine the number of the sites, the use of coverage and capacity planning by the site of macrocell that experience network problems. Based on the counting link budget in gaining Maximum Allowble Path Loss (MAPL) number by downlink reach 139.037 dB. In table 2 can be seen as the specifications of the Ujung Gurun site. In theory, the power calculation must be reduced by 12 dB from the old cell to cover the microcell area, but field conditions must also be considered because it will greatly impact the quality of the field if there is a traffic spike, then the amount of power is adjusted to the conventional BS standard for microcell which is 38 dBm.

Table 2 Major *Site* Spesification

SPECIFICATION OF UJUNG GURUN SITE	
PARAMTER	SPECIFICATION
Longitude	100.36054
Latitude	-0.93058
Frequency	1800 Mhz
Antenna Height	47 M
Bandwidth	10 Mhz
Radius Cell	1.5 Km
Power	38 dBm
Total Graph (Gb)	145.99

*name of corresponding author

Sinkron : Jurnal dan Penelitian Teknik Informatika
Volume 8, Number 1, January 2024 e-ISSN : 2541-2019
DOI : https://doi.org/10.33395/sinkron.v9i1.13168 p-ISSN : 2541-044X

In this planning, it uses band 3 with a frequency of 1800 MHz and a bandwidth of 10 MHz, so this is the basic for using the cost-231 propagation model. This microcell planning uses 3 antenna sectors, although the calculation uses 2 sectors, but to optimize the placement of new sites and to adapt to field conditions, so it is adjusted to BS standards to 3 sectors. The height of this planning antenna is 18.5 meters. The calculation for coverage planning can be seen in Table 3.

Table 3 Measurement of *coverage* and *capacity planning*

The Calculation of *Coverage & capacity Planning*	
Parameter	Value
Power (dBm)	38 dBm
Radius Cell	0,75 Km
Area Cell	2,85 Km²
Antenna Height	18.5 M
MS Height	1,5 M
MAPL	139,03 dB
Frequency	1800 Mhz
Total site	1 site

Based on the result of planning microcell simulation on Atoll software, parameter observed on this research is RSRP, SINR, and throughput. Based on simulation, the average number of parameter RSRP raise to 0,3%, SINR raise up to 2%, and lastly throughput also raise up to 2%. It proves that microcell planning with cell splitting method has succesfully improved network quality with a lower radius in the Flamboyan Baru area. Table 4 shows a comparison of the following planning results.

Table 4 Comparison of the Planning Result

Comparison of Planning Result			
Site	RSRP (dBm)	SINR (dB)	Throughput (Kbps)
Existing Site	-97,93	22,14	61.844,09
Cell Splitting	-94,28	24,23	63.094,91
Percentage	0,3%	2%	2%

Based on physical tunning, it is proven that the effect of cell splitting with the pyhsical tunning setting whether or not impacting the network quality. This physical tunnig is also minimize the scope of site neighbour so as to avoid interference from microcell planning on the network.

CONCLUSION

The new planning site is microcell which decide the major site who will conduct the cell splitting by considering user and througput from the major site which will be splitted. Based on the simulation result using physical tunning it is gain that the implementation of cell splitting by doing physical tunning to the microcell is effective in improving the performance of LTE network by the raise of average RSRP as -94,28 dBm, average SINR as 24,23 dB, and throughput as 63.094,91kbps and reducing interference which has an impact on improving the coverage of RSRP, with reduced interference on SINR and improved quality of data transfer rate on throughput. This proves that microcell planning using cell splitting method can reduce interference on overlapping signals and cell splitting method can improve network quality and increase the average value of RSRP, SINR, and throughput parameters, and prove that the application of cell splitting on microcell can improve the quality of LTE network.

*name of corresponding author

DISCUSSIONS

This research use cell splitting simulation by splitting macrocell into several microcell which leads to addition of amount capacity in total system. In this case, network quality which previously poor because of amount user could run better as the standard of network quality of LTE. By cell splitting technique, problems such as density or the raise of peak traffic phenomena could be solved by splitting macrocell into microcell without any interference by the previous macrocell, so the problems appear could be solved by the coverage area in a transmitter will be smaller and the less number of the user.

REFERENCES

Alfian, Q. (2021). *Perbaikan Performansi Terhadap Daerah Cakupan Jaringan Lte Di Sepanjang Jalur Kereta Railink Dari Stasiun Ka Bandara Soekarno-Hatta Sampai Stasiun Batuceper*. *20 TELKATIKA, VOL. 1, NO. 1, DESEMBER 2021*, *1*(1), 20–29.

ANUGERAH, F., & PUTRI, H. (2020). Metode Cell Splitting pada Perencanaan Microcell untuk Meningkatkan Performansi Jaringan LTE. *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, *8*(2), 262. https://doi.org/10.26760/elkomika.v8i2.262

Arumsidi, S. F., Isnawati, A. F., & Wahyudin, A. (2019). *Analisis Unjuk kerja Jaringan Microcell LTE Berdasarkan Variasi Level Modulasi*. *16*(2), 99–114.

Bastianto, E., & Laksana, E. P. (2019). Perencanaan Jaringan Indoor Long Term Evolution (Lte) Menggunakan Physical Cell Identity (Pci) Di Lippo Plaza Mampang. *Jurnal Maestro*, *2*(1), 2655–3430.

Christopher Cox. (2014). *An Introduction To LTE*.

Edwinanto, Koncoro, D., & Krisdianto, H. Y. (2020). *Analisis Perencanaan Jaringan Long Term Evolution (LTE) di Pita Frekuensi 3500 MHz Dengan Mode TDD dan FDD Sebagai Frekuensi Alternatif*. 56–80.

Gedung, D. I., Ft, I. T. L., Kampus, U. N. P., & Tawar, A. I. R. (2019). *Analisis Performansi Jaringan 4g Lte Di Gedung Itl Ft Unp Kampus Air Tawar Barat Yerry Rahmaddian 1* , Yasdinul Huda 2 1*. *7*(4).

Jaringan, P., Sukarame, K., Caya, V., Lampung, B., Halim, W. A. Y., Kedamaian, D. A. N., & Kota, D. I. (2020). *Perancangan jaringan lte di kecamatan sukarame, sukabumi, way halim dan kedamaian di kota bandar lampung*. 110–117.

Kamal, M., Suhan, H., Zainuddin, Z., & Duyo, R. A. (2023). *Analisis Penerapan Downtilt Pada Antena Terhadap Luas Cakupan Dari BTS Yang Mengalami Over Coverage Terhadap BTS yang lain*. *15*, 98–109.

Layanan, P., Jalan, D. I., Kopo, T., Akbar, A. F., Cahyono, S. T., & Nurmantris, D. A. (2020). *Perencanaan Lte Cell Splitting Untuk Meningkatkan Bandung Lte Cell Splitting Planning To Improve 4g Service Performance In Jalan Taman Kopo Indah 2 Bandung*. *7*(2), 903–912.

Mubarok, A., & Putri, H. (2019). *Analisis Dampak Inter-Band Carrier Aggregation pada Perencanaan Jaringan LTE-Advanced*. *7*(2), 363–376.

Niama, M. D. S., Linawati, & Gumantara, N. (2021). *Perencanaan Coverage Jaringan 5g Berdasarkan Propagasi Rugi Coverage Planning On The 5g Network Based On Path Loss*. *8*(2), 283–292. https://doi.org/10.25126/jtiik.202184485

Purnama, A., Nugraha, E. K. A. S., & Amanaf, M. A. (2020). *Penerapan Metode ACP untuk Optimasi Physical Tuning Antena Sektoral pada Jaringan 4G LTE di Kota Purwokerto*. *8*(1), 138–149.

Putri, H., Wulan, F. N., Anugerah, F., Aulia, A. R., & Sari, D. A. (2020). *Evaluasi Penerapan Metode Cell Splitting Terhadap Peningkatan Kapasitas dan Kualitas Jaringan LTE*. *Jurnal Rekayasa Elektrika*, *15*(3). https://doi.org/10.17529/jre.v15i3.14741

Rahmania. (2020). *analisis cakupan area jaringan long term evolution*. *12*(01), 26–36.

Rahmat, F. A. (2022). *Analisis Kinerja Kualitas Jaringan 4G LTE Di Kawasan Perumahan Singgalang, Koto Tangah, Kota Padang*. *Telekontran : Jurnal Ilmiah Telekomunikasi, Kendali Dan Elektronika Terapan*, *10*(2), 106–115. https://doi.org/10.34010/telekontran.v10i2.7904

*name of corresponding author

Rezkika, I., Novalianda, S., & Ramadhan, A. (2019). *Analisis Kebutuhan Parameter Jaringan Lte Dengan Sistem Refarming Frekuensi Pada Daerah Urban Metropolitan Centre*. *Semnastek Uisu*, *4*(2), 31–36.

Safira, B., Kurnia, V., Elektro, F. T., Usman, U. K., Elektro, F. T., Satrya, G. B., & Terapan, F. I. (2022). *Perancangan Jaringan Long Term Evolution (Lte) Dikecamatan Pemenang Dan Tanjung Kabupaten Lombok Utara Pada Frekuensi 1800*. *8*(6), 3665–3670.

Setyo, P., & Sari, L. O. (2019). *Optimalisasi Perancangan Jaringan 4G LTE Pada Frekuensi 900 MHz Berbasis FDD Di Kabupaten Rokan Hulu*. *6*, 1–9.

Sudiarta, P. K., Studi, P., Elektro, T., Teknik, F., & Udayana, U. (2019). *Analisa Throughput Jaringan 4g Lte Dan Hasil Drive Test Pada Cluster Renon*. *6*(1), 74–80.

Track, G., Farida, F., & Nurhaliza, S. (2022). *Analisis Layanan Kualitas Jaringan 4G di Kota Pekanbaru dengan G-Net Track*. *1*(1).

Wulan, F. N., & Budiyanto, S. (2022). *Analisis Kinerja Jaringan LTE-Advanced Menggunakan Metode Inter-Band Carrier Aggregation di Wilayah Rancaekek*. *13*(01), 19–24. https://doi.org/10.22441/jte.2022.v13i1.004

Yufiansa, O., Maria, P., & Yusnita, S. (2019). Peningkatan Performansi Jaringan 4G LTE Berdasarkan Pengecekan Sinyal Di Kecamatan Bukit Sundi Kabupaten Solok. *Elektron : Jurnal Ilmiah*, *11*(2), 49–55. https://doi.org/10.30630/eji.11.2.129

Yuhanef, A., Yusnita, S., & Riandaisan, G. (2023). *Analisis Kualitas Throughput Jaringan 4G LTE Indosat pada Site 01JKS504 Di Kebayoran Lama , Jakarta Barat*. *4*(1), 276–282.

Yuliana, H., Basuki, S., & Iskandar, H. R. (2019). *Peningkatan Kualitas Sinyal Pada Jaringan 4G LTE Dengan Menggunakan Metode Antenna Physical Tuning*. 1–10.

*name of corresponding author