

The Evaluation of the Throughput Performance of an LTE-Advanced Urban Area Network with the Inter-Band Non-Contiguous Carrier Aggregation Method

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Abstract: Data obtained from the drive-test in the urban area (a case study of Siliwangi Stadium, Bandung) revealed that the low throughput occurred on the downlink, which was 3.56 Mbps. On the uplink, it was 20.7 Mbps. Additionally, based on the Operating Support System (OSS) data, the site had high resource block usage (80% of PRB usage). It revealed the high traffic volume in the area, which resulted in poor throughput values received by users. The area is one of the potential market areas in the city of Bandung, which is indicated by housing, military area command education and training regiment, schools, hotels, markets, and stadiums. Based on the Site Database (SDB), it was known that the site has not yet implemented the carrier aggregation method. This study evaluated throughput using the Inter-Band Non-Contiguous Carrier Aggregation method by comparing three scenarios: Non-CA, CA Non-Repeater, and CA Repeater. Based on the results of the non-CA simulation, the downlink throughput increased by 23,582 Mbps, and the uplink throughput by 20.098 Mbps. Meanwhile, in the non-repeater CA simulation, the downlink throughput increased by 44.56% to 34.091 Mbps, and the uplink throughput increased by 39.22% to 27.980 Mbps. Furthermore, the CA Repeater simulation increased downlink throughput by 63.70% to 38.603 Mbps and uplink throughput by 45.06% to 29.154 Mbps.

Keywords: Carrier Aggregation, LTE Advanced, throughput, urban area.

带间非连续载波聚合方法的高级 LTE 城域网吞吐量性能评估

摘要: 从市区路测获得的数据 (以万隆西里旺吉体育场为例) 显示, 低吞吐量发生在下行链路上, 为 3.56 Mbps。在上行链路上, 它是 20.7 Mbps。此外, 根据运营支持系统(开源软件)数据, 该站点的资源块使用率很高 (占 PRB 使用率的 80%)。它揭示了该地区的高流量, 这导致用户收到的吞吐量值很差。该地区是万隆市的潜在市场区域之一, 以住房、军区指挥教育训练团、学校、酒店、市场和体育场为标志。根据站点数据库 (深发展) 可知, 该站点尚未实施载波聚合方法。本研究通过比较三种场景: 非加州、加州非中继器和加州中继器, 使用带间非连续载波聚合方法评估吞吐量。根据非加州仿真的结果, 下行吞吐量增加了 23,582 Mbps, 上行吞吐量增加了 20.098 Mbps。同时, 在无中继加州模拟中, 下行吞吐量增长 44.56% 至 34.091 Mbps, 上行吞吐量增长 39.22% 至 27.980 Mbps。此外, 加州中继器模拟将下行链路吞吐量提高了 63.70% 至 38.603 Mbps, 将上行链路吞吐量提高了 45.06% 至 29.154 Mbps。

关键词: 载波聚合、高级 LTE、吞吐量、市区。

1. Introduction

The development of cellular technology continues to proliferate today because more and more users have many demands related to the quality and coverage of cellular networks. The users measure the cellular

operator's network service based on the speed of data access on the internet or data download. Therefore, cellular technology must continuously improve service quality with high data rates, wide bandwidth, and broad coverage areas so that users do not have problems

communicating both voice and data [1]. LTE technology has limited use of wide bandwidth, as it can merely use 20 MHz bandwidth for LTE release 8, which then becomes a problem for all cellular operators [2].

In 2010 the 3rd Generation Partnership Project (3GPP) launched LTE-Advanced (Release 10), which became the first cellular communications standard officially proposed as the candidate for 4G systems to ITU-T. The significant advancement from the 3GPP Long-Term Evolution (LTE-Release 8) was sufficient to meet market demand [3]. This LTE-Advanced (Release 10) has become the solution for cellular communication users who frequently get poor internet access speeds due to the limited bandwidth. Therefore, it is excellent news for the cellular communication users to obtain the additional bandwidth from each operator [4]. From the IMT-2000 requirements, the 4G cellular communication system must assure a peak data rate of 100 Mbps and manage the coverage of 40 MHz per access node [5]. The LTE-Advanced technology launched several features, including Carrier Aggregation, which the operators use [3]. Generally, the operators have bandwidth on several frequency bands and are found in some spectrums that have not been optimally used. Using CA will assist in combining some bandwidths on the frequency bands that have not yet been maximized for CA purposes on LTE [6].

The urban area of Bandung City (a case study of Siliwangi Stadium) is one of the potential market areas in Bandung City, indicated by housing, military area command education and training regiment, schools, hotels, markets, and stadiums. From SDB (Site DataBase) data, one site had not yet implemented the carrier aggregation method. Based on the initial drive test results, the low throughput was supported by the speed test data indicating 3.56 Mbps on the downlink and 20.7 Mbps on the uplink. In OSS Operator X data, the site had high resource block usage (80% of PRB), similar to the high traffic volume in the area, resulting in the poor throughput values received by users. Therefore, it is necessary to optimize the capacity planning [7]. In addition to the data showed the imbalance between cell capacity and user traffic that can affect the quality of the network received by users [8].

In this study, the comparison simulation of Inter-Band Non-Contiguous Carrier Aggregation was conducted in the Siliwangi Stadium area by comparing the planning scenarios of Carrier Aggregation Non-Repeater and Carrier Aggregation Repeater using frequencies of 1.8 GHz and 2.1 GHz [9]. The reason for choosing the two methods is that the two scenarios are the best suited and most efficient to be applied according to the problem [10], compared to other deployment scenarios. In the comparison simulation of LTE-Advanced networks with the Inter-Band Non-

Contiguous Carrier Aggregation method, the analysis includes RSRP, throughput, and SINR [11]. As for selecting the three RF parameters, they are commonly used by the operator, and all the existing parameters are related to the current study.

2. Research Methods

2.1. LTE-Advanced

Long-Term Evolution is a technology standardized by the 3rd Generation Partnership Project (3GPP) and is considered sufficient. Since 2009, LTE technology has experienced rapid development from GSM and UMTS, which is the basis for its development. The International Telecommunication Union (ITU) coined the term LTE-A for the communication systems that exceed the capabilities of LTE [12].

2.2. Carrier Aggregation (CA)

Carrier Aggregation is a technique of simultaneously using two or more carrier frequencies on the same or different frequency bands to increase bandwidth usage. By increasing the use of bandwidth, an increase in network capacity occurs. Each aggregated carrier is referred to as a component carrier [12]. Carrier Aggregation has several types, including CA Intra-band Contiguous, CA Intra-band Non-Contiguous, CA Inter-band Non-Contiguous.

2.3. Carrier Aggregation Deployment Scenario (CADS)

In carrier aggregation, several scenarios can be applied. Carrier Aggregation can elect a new band to enhance the coverage and mobility of the carrier implemented. Deployment Scenario is how to manage the connection from Component Carrier 1 (CC1) and then configure the Component Carrier 2 (CC2) [13]. Several Carrier Aggregation scenarios are considered to be implemented, including:

2.3.1. Carrier Aggregation Deployment Scenario 1 (CADS1)

In CADS1, Component Carrier 1 (CC1) and Component Carrier 2 (CC2) are collocated and overlaid with almost the same coverage. Both layers provide sufficient coverage and can support mobility. This occurs when CC1 and CC2 are located in the same frequency band [13].

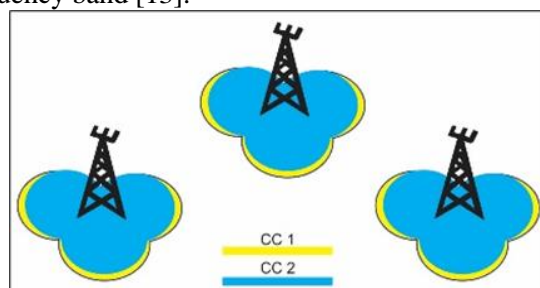


Fig. 1 CADS 1

2.3.2. Carrier Aggregation Deployment Scenario 2 (CADS 2)

CADS 2 is commonly referred to as CA Non-repeater due to no repeater installation on CC 1 or CC2. In CADS2, the cells on Component Carrier 1 (CC1) and Component Carrier 2 (CC2) are collocated and overlaid to each other; however, in CC2, they have smaller coverage due to the immense path loss. Merely, the CC1 has sufficient coverage, while CC2 is applied to increase throughput in areas that are overlaid by both. The mobility is based on coverage from CC1. This scenario occurs when CC1 and CC2 are in different frequency bands [13].

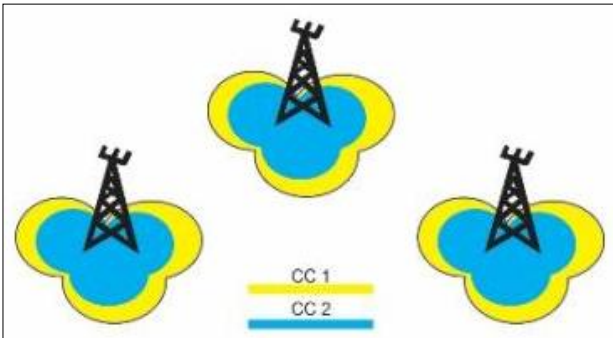


Fig. 2 CADS 2

2.3.3. Carrier Aggregation Deployment Scenario 3 (CADS 3)

In CADS 3, the cells of Component Carrier 1 (CC1) and Component Carrier 2 (CC2) are collocated with one another, then the CC2 antenna is directed to the cell boundaries of CC1; thus, the cell-edge throughput can be increased. CC1 has sufficient coverage, but CC2 can be a blank area due to the high path loss. The mobility is based on coverage from CC1. This scenario occurs when CC1 and CC2 are in different frequency bands [14].

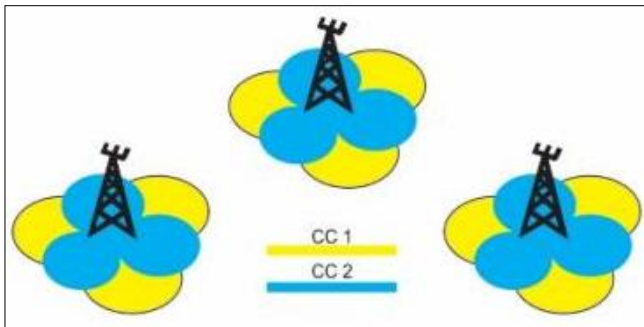


Fig. 3 CADS 3

2.3.4. Carrier Aggregation Deployment Scenario 4 (CADS 4)

In CADS 4, CC1 provides macrocoverage; meanwhile, CC2 RRHs (Remote Radio Heads) provide extended throughput in hotspot areas. The mobility is based on coverage from CC1. This scenario can be used in different frequency bands but is not prioritized on Rail-10.

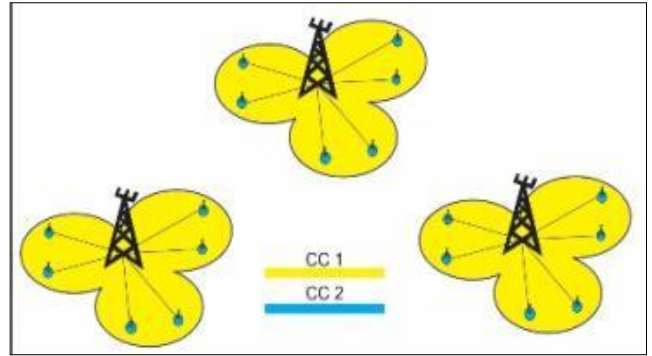


Fig. 4 CADS 4

2.3.5. Carrier Aggregation Deployment Scenario 5 (CADS 5)

CADS 5 provides repeaters to expand coverage, strengthen the signal, and increase throughput in the specified area. The repeater placement method uses the main beam from the donor transmitter as the minimum distance for repeater placement [15].

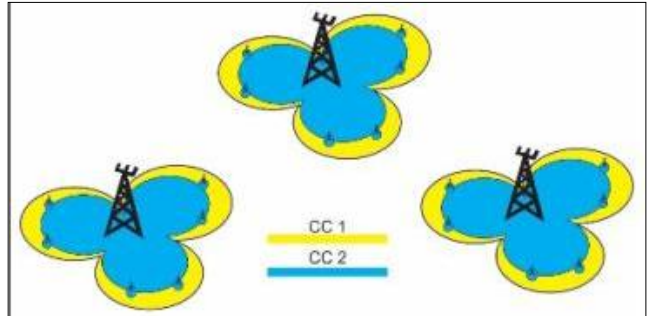


Fig. 5 CADS 5

2.4. Parameter Radio Frequency (RF) of LTE

Reference Signal Received Power (RSRP) is a parameter of the received signal strength level. RSRP states the signal power received by the user (dBm). The farther the distance between the site and the UE, the smaller the RSRP received by the UE, and vice versa [16]. The standard value of RSRP for operator X is shown in Table 1.

Table 1 RSRP parameters

Value (dBm)	Category	Color
-80 to -40	Excellent	Blue
-90 to -80	Good	Green
-100 to -90	Fairly Good	Yellow
-110 to -100	Fairly Poor	Pink
-140 to -110	Poor	Red

Signal to Interference Noise Ratio (SINR) is a comparison parameter between the strength of the received signal and the noise/interference signal. SINR represents the quality of the signal received by the user (dB). The more obstacles between the site and the UE, the smaller the SINR value received by the UE, and vice versa. The standard value of SINR for operator X

is shown in Table 2.

Value (dBm)	Category	Color
12 to 30	Excellent	Blue
8 to 12	Good	Green
6 to 8	Fairly Good	Yellow
0 to 6	Fairly Poor	Pink
-20 to 0	Poor	Red

Throughput is the average number of bits received by the UE in a network. Throughput states the data transfer rate, which is measured per unit time (bps). The standard throughput value for operator X is shown in Table 3.

Value (dBm)	Category	Color
30000 to 100000	Excellent	Blue
20000 to 30000	Good	Green
10000 to 20000	Fairly Good	Yellow
5000 to 10000	Fairly Poor	Pink
1000 to 5000	Poor	Red

3. Results and Discussion

3.1. The Scenario of Carrier Aggregation Configuration

In the comparative simulation, it is necessary to configure each simulated scenario. The configuration is as follows:

No.	Scenario	Method	Carrier 1 Component	Carrier 2 Component	Carrier 1 Component Bandwidth	Carrier 2 Component Bandwidth
1	Non - CA	Normal Deployment	1.8 GHz	-	15 MHz	-
2	CA non-repeater	Scenario 2 Deployment	1.8 GHz	2.1 GHz	15 MHz	20 MHz
3	CA repeater	Scenario 5 Deployment	1.8 GHz	2.1 GHz	15 MHz	20 MHz

In Table 4, the configuration is conducted on three simulation scenarios of LTE-Advanced networks in comparison with the Inter-Band Non-Contiguous Carrier Aggregation method in the Siliwangi Stadium area.

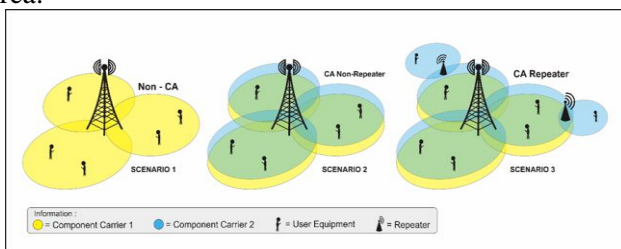


Fig. 6 Comparative simulation scenario

Fig. 6 illustrates three simulation scenarios of comparative LTE-Advanced networks with the Inter-Band Non-Contiguous Carrier Aggregation method in Siliwangi Stadium.

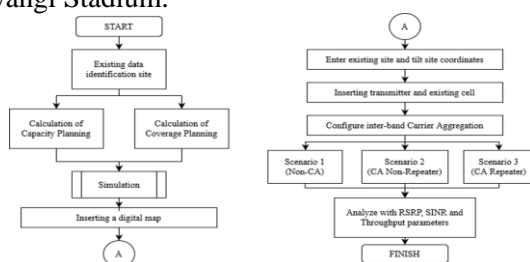


Fig. 7 Simulation flowchart

Fig. 7 presents the steps in the comparative simulation process between the CA Non-Repeater and CA Repeater methods on the atoll software. The steps started by identifying the existing site data, then calculating capacity and coverage planning. This was followed by simulating the comparison of CA Non-Repeater and CA Repeater by entering digital maps, site data, antenna data, which were obtained from Operator X. Then, a comparative analysis of the simulation results was carried out with the observation parameters, including RSRP, SINR, and throughput.

3.2. Result and Comparative Simulation Analysis

The simulation results analysis was conducted to determine the performance improvement after the comparative simulation of LTE networks in the Siliwangi Stadium using the Inter-band Carrier Aggregation method [15]. The comparative simulation used Atoll 3.3.0 software to overview LTE network planning equipped with RF parameters such as RSRP, SINR, DL throughput, and UL throughput [17].

3.2.1. The Result of Comparative Simulation on RSRP

Prediction with CA Non-Repeater configuration and (c) Scenario 3 is a simulation of RF parameter

prediction with CA Repeater configuration. The simulation results can be seen in Fig. 8.

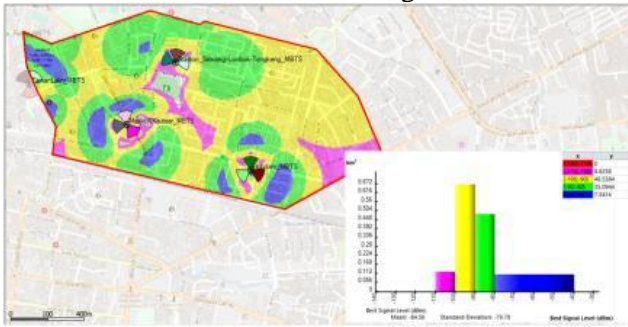


Fig. 8(a) Non-CA RSRP

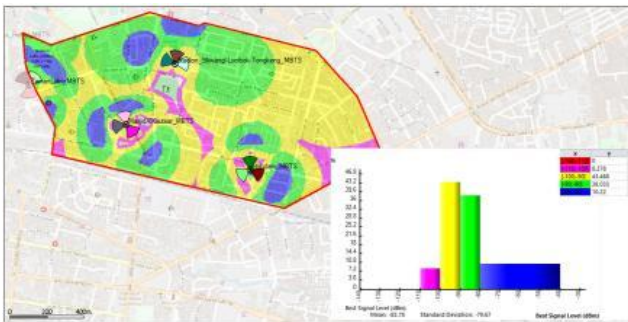


Fig. 8(b) CA Non-repeater RSRP

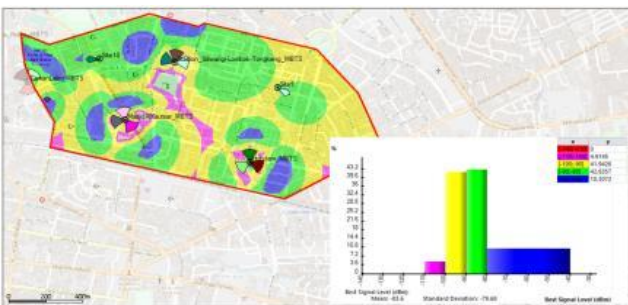


Fig. 8(c) CA Repeater RSRP

In Fig. 8, the value of the results of the RSRP simulation shows that the scenario of (a) non-CA RSRP by -84.56 dBm, while (b) CA Non-repeater RSRP by -83.78 dBm, and (c) CA Repeater RSRP by -83.60 dBm.

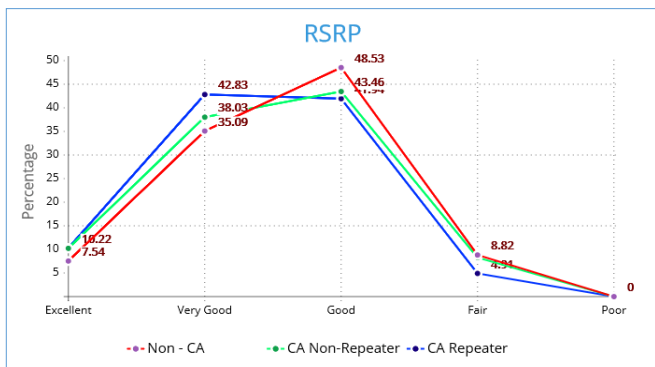


Fig. 9(a) The comparison of RSP values

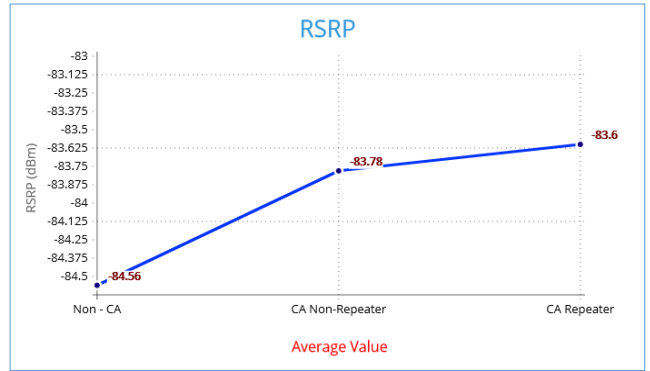


Fig. 9(b) Average value of RSRP

Fig. 9 shows a comparison of the RSRP simulation results based on the scenario of increasing the RSRP value and the average RSRP value generated in each scenario carried out. Here, an increase from Non-CA to CA Non-Repeater and the highest CA Repeater was found.

3.2.2. The Result of Comparative Simulation on RSRP

At the beginning of the comparison, it is necessary to do: (a) Scenario 1 is a simulation of RF parameter prediction from existing sites to determine the quality of existing services or called Non-CA, (b) Scenario 2 is a simulation of RF parameter prediction with a CA Non-Repeater configuration, and (c) Scenario 3 is a simulation of RF parameter prediction with CA Repeater configuration. The simulation results can be seen in Fig. 10.

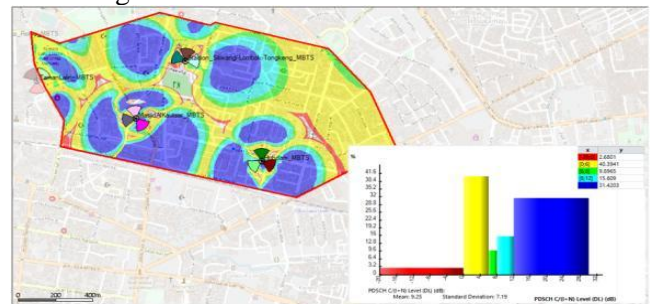


Fig. 10(a) Non-CA SINR

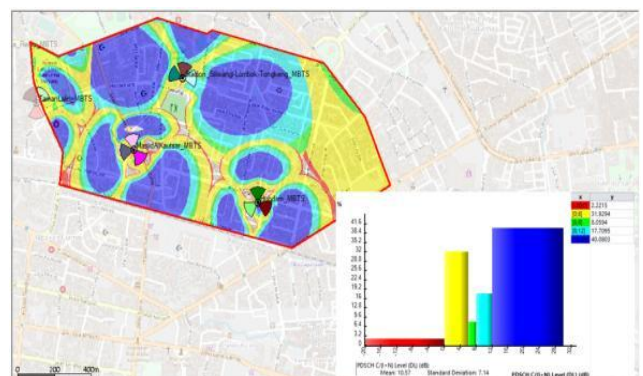


Fig. 10(b) CA Non-Repeater

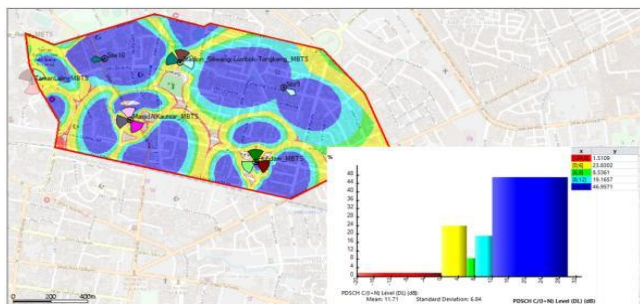


Fig. 10(c) CA Repeater SINR

In Fig. 10, the simulation results of the SINR comparison show that the scenario (a) non-CA SINR is 9.25 dB; (b) CA Non-repeater SINR is 10.57 dB; (c) CA Repeater SINR is 11.71 dB.

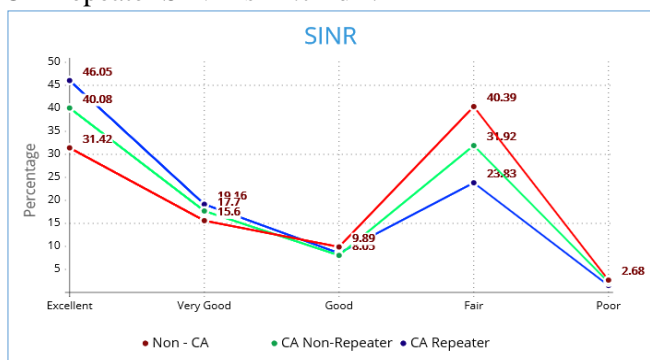


Fig. 11(a) Comparison of SINR value

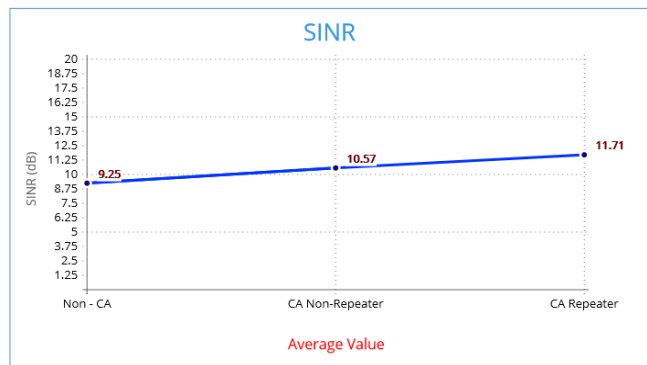


Fig. 11(b) SINR average value

Fig. 11 shows a comparison of the SINR simulation results based on the scenario of increasing the SINR value and average value generated in each scenario carried out. The results showed an increase from Non-CA to CA Non-Repeater and the highest CA Repeater.

3.2.3. The Result of Comparative Simulation on Downlink Throughput

At the beginning of the comparative simulation, it is necessary to do: (a) Scenario 1 is a simulation of RF parameter prediction from the existing site to determine the quality of existing services or called Non-CA, (b) Scenario 2 is a simulation of RF parameter prediction with CA Non-Repeater configuration, and (c) Scenario 3 is a simulation of RF parameter prediction with CA Repeater configuration. The simulation results can be

seen in Fig. 12.

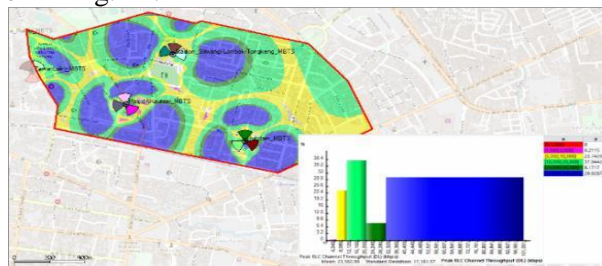


Fig. 12(a) Non-CA DL throughput

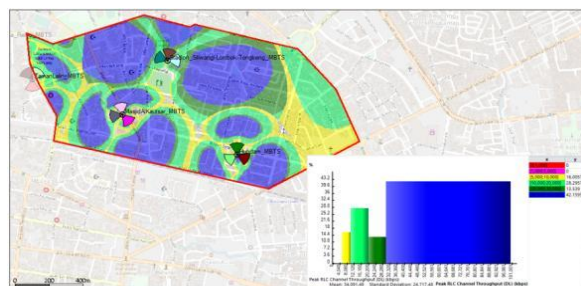


Fig. 12(b) CA Non-Repeater DL throughput

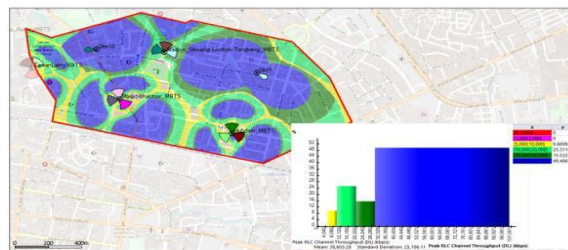


Fig. 12(c) CA Repeater DL throughput

The simulation results of the DL throughput comparison show that the scenario (a) Non-CA DL throughput gained 23582 Kbps, (b) CA Non-repeater DL throughput gained 34091 Kbps, and (c) CA Repeater DL throughput gained 38603 Kbps.

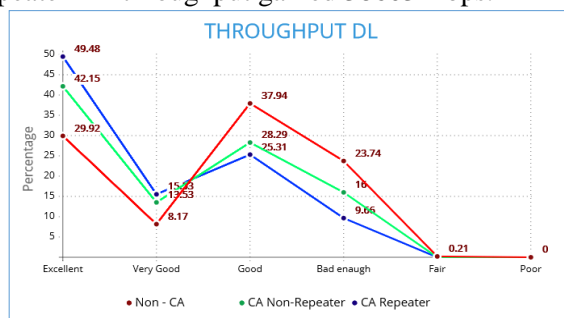


Fig. 13(a) Comparative DL throughput value

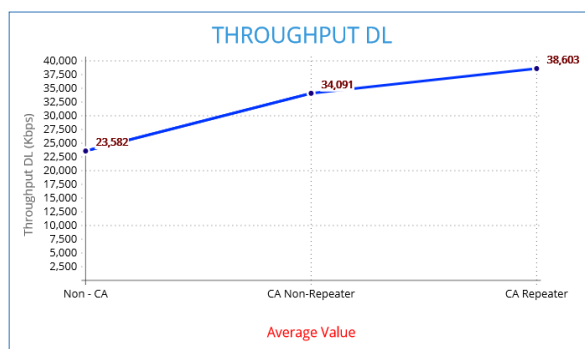


Fig. 13(b) DL throughput average value

Fig. 13 shows the comparative simulation results of the UL throughput based on the scenario of increasing the UL throughput value and the average UL throughput value generated in each scenario carried out. The results showed an increase from Non-CA to CA Non-Repeater and the highest CA Repeater.

In the comparison scenario that was conducted, the analysis of the simulation results with several comparison scenarios can be seen, including the analysis of RF parameters such as RSRP, SINR, DL throughput, UL throughput. The results of the comparative simulation analysis can be seen in Table 5 and Fig. 14.

Table 5. The Comparison of Simulation Result from Three Scenarios
Tab.5

Increased Percentage of the Simulation Result				
Condition	RSRP (dBm)	SINR (dB)	DL Throughput	UL Throughput
Non-CA	-84.56	9.25	23,582	20,098
CA Non-Repeater	-83.78	10.57	34,091	27,980
CA Repeater	-83.60	11.71	38,603	29,154
Increase from Non-CA to CA Non-Repeater	0.99%	15.71%	44.56%	39.22%
Increase from Non-CA to CA Repeater	1.21%	29.29%	63.70%	45.06%

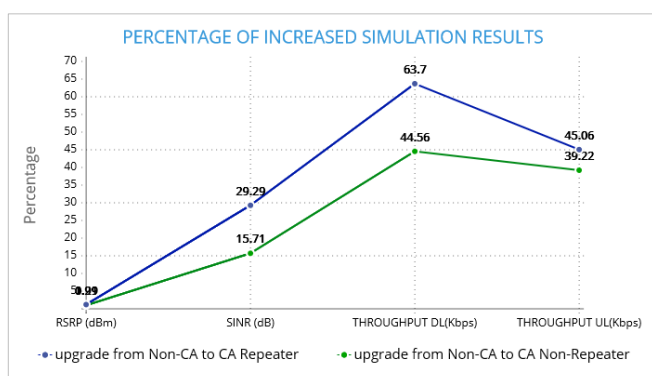


Fig. 14 Percentage of CA Non-Repeater and CA Repeater

Fig. 14 explains the comparison of the prediction simulation results. It can be concluded that the comparative simulation of LTE-Advanced networks with the Inter-band Carrier Aggregation method improved network performance around the Siliwangi Stadium area. By looking at the existing RF parameters such as RSRP, CA Non-Repeater showed an increase of 0.99% compared to the previous average value obtained, CA -84.56 dBm, which increased to -83.78

dBm. Meanwhile, in SINR CA Non-Repeater, the increase was 15.71%, with the previous average value obtained, 9.25 dB, which increased to 10.57 dB. Then, in the CA Non-Repeater DL throughput, it also revealed an increase of 44.56% with the previous average value obtained, 23,582 kbps, increased to 34,091 kbps, while in the CA Non-Repeater UL throughput increased 39.22% from the previous average value, CA 20,089 kbps, improved to 27,980 kbps.

Then, by looking at the existing RF parameters such as RSRP, CA Repeater 3 showed an increase by 1.21% compared to the previous average value obtained, CA -84.56 dBm, which then increased to -83.60 dBm. While, in SINR CA Repeater, an increase of 29.29% occurred with the previous average value, CA 9.25 dB increased to 11.71 dB. Then, on the CA Repeater DL throughput, the increase of 63.70% occurred with the previous average value, CA 23,582 kbps increased to 38,603 kbps; furthermore, in the CA Repeater UL throughput, the increase was 45.06% with the previous average value, CA 20,089 kbps improved to 29,154 kbps.

4. Conclusion

a. Implementing the Carrier Aggregation method is one of the optimization methods to improve service performance, mainly on the capacity, and manage to overcome network problems in areas with high traffic. Then, the application of inter-band carrier aggregation based on the frequency band used by operator x, namely in band 3 (1.8 GHz) with a bandwidth of 15 MHz and band 1 (2.1 GHz) with a bandwidth of 20 MHz, increases the value of RSRP, SINR and downlink throughput and uplink throughput in each scenario;

b. Carrier Aggregation enables overcoming network capacity problems, mainly to increase data traffic due to the large number of users occupying one cell simultaneously, by combining several carriers to produce a higher value than that without Carrier Aggregation;

c. The simulations were carried out using Software atoll 3.3.0, comparing two types of Deployment Scenario, such as CA Non-Repeater with the primary and secondary cell principle. At the same time, CA Repeater had additional repeaters in the planning area, which indicated low coverage and throughput;

d. Based on the CA Repeater simulation results, it increased the average value of RSRP parameters by -83.60 dBm, SINR by 11.71 dB, DL throughput by 38.603 kbps, and UL throughput by 29.154 kbps for each user. The simulation results of these four parameters met the standard of operator x and its KPI standard;

e. Based on the CA Repeater simulation results,

it increased the average value of RSRP parameters by -83.60 dBm, SINR by 11.71 dB, DL throughput by 38.603 kbps, and UL throughput by 29.154 kbps for each user. The simulation results of these four parameters met the standard of operator x and its KPI standard.

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