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Analysis of The Implementation of Carrier Aggregation Combinations That Occupy Non-Continuing Frequency Bands on The Existing LTE Network

Khalidya Igna Fillah[a], Sri Yusnita[b*], Zurnawita[c], Yulindon Khaidir[d], Widya Andriani[e], Lin Fitri Alif Aisyah[f]

[abcdef] *Department of Telecommunication Engineering, Politeknik Negeri Padang, Padang, West Sumatera, Indonesia*

[*] *Corresponding author: sriyusnita@pnp.ac.id*

***Abstract*—This study analyzes the effect of implementing Carrier Aggregation (CA) on non-adjacent frequency bands on LTE network performance in the Alai Parak Kopi area, Padang City, by measuring SINR parameters, uplink throughput, and downlink using the drive test method and TEMS application. The results show that CA affects the SINR value, with the highest value at a frequency of 1800 MHz (19.2 dB), followed by a combination of 1800 + 2300 MHz (18.5 dB), and 1800 + 2100 MHz (13.6 dB). CA also affects throughput, with the highest uplink at a combination of 1800 + 2300 MHz, while the highest downlink at 1800 MHz.**

***Keywords*— LTE, LTE-A, Carrier Aggregation, Bandwith**

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I. INTRODUCTION

The development of cellular technology, especially LTE, continues to increase to meet high communication needs, especially with the preservation of online activities due to the COVID-19 pandemic [1]. The surge in data service users demands an increase in service quality and data speed from cellular service providers [2]. To meet this, large capacity, bandwidth, and wide coverage are needed. Carrier Aggregation (CA), a feature introduced by LTE-Advanced Release 10 [3], is a solution to overcome bandwidth limitations by combining two or more Component Carriers (CC). This study will analyze the effect of implementing a combination of CAs on non-accompanying band frequencies on LTE network performance, focusing on SINR parameters, uplink and downlink throughput, and PRB [4].

Long Term Evolution (LTE) technology is a fourth generation (4G) broadband wireless technology that continues [5] to experience rapid development. Starting from LTE which offers high data rates and spectrum efficiency, then LTE-Advanced (LTE-A) comes with the Carrier Aggregation (CA) feature to increase capacity and data rates by combining several carrier components. LTE-A Pro, often referred to as 4.5G, enhances LTE-A capabilities by increasing the number of supported CCs and introducing Licensed Assisted Access (LAA) to utilize licensed and unlicensed frequencies [6]. This LTE development is an important foundation for the 5G network.

Carrier Aggregation (CA) is a technology that allows the combination of multiple carrier components (CCs) to increase bandwidth and data rates on LTE networks. Each CC can have a bandwidth of up to 20 MHz, and initially CA can aggregate up to five CCs (100 MHz), which was later expanded to 32 CCs (640 MHz) [7]. CA supports both FDD and TDD modes, with the number and bandwidth of CCs that can differ between the downlink and uplink. Based on the frequency domain, there are three types of CA: intra-band contiguous, intra-band non-contiguous, and inter-band non-contiguous [8].

In this study, several software applications were selected based on their capabilities and relevance to the research objectives [9]. TEMS Pocket version was chosen because of the accuracy and completeness of the measured LTE parameters.

TEMS Pocket was used to collect LTE network data in the field, such as RSRP, SINR, and throughput. Data collection was carried out in a special mode by making phone calls during the drive test. TEMS Discovery version was chosen because of its comprehensive data analysis capabilities and interactive data visualization [10].

TEMS Discovery was used to analyze data that had been collected by TEMS Pocket, for example by comparing SINR and throughput values at different frequencies [11]. NetMonster version was chosen because of its ease of use and the real-time information displayed [12]. NetMonster was used to aggregate real-time network information on a smartphone, such as identifying the frequency band used. Google Earth was chosen because of its detailed and accurate map display. Google Earth was used to display the location of data collection visually on a map [13], for example by marking measurement points on a map.

This study uses several software for measurement and analysis of LTE network data, namely TEMS Pocket to collect RSRP, SINR, and throughput data in the field, TEMS Discovery to analyze data, NetMonster to monitor network information in real-time, and Google Earth to display data collection locations [14]. These parameters are Key Performance Indicators (KPIs) used to measure the quality of LTE networks, where RSRP indicates signal strength, SINR indicates signal quality, and throughput indicates data transfer speed [15].

II. MATERIALS AND METHOD

This study analyzes the implementation of Carrier Aggregation (CA) on 4G LTE networks by conducting drive [16] tests on existing BTS sites in Alai Parak Kopi Village, Padang Utara District, Padang City. To achieve these objectives, the study is divided into four main stages. First, planning a drive test route which includes determining the measurement route by considering variations in environmental conditions and traffic density in the research area [17]. The drive test route is designed to cover areas with different characteristics, such as residential areas, offices, and highways, in order to obtain representative data.

Second, collecting drive test data using TEMS Pocket software on smartphones and NetMonster to monitor LTE network parameters in real-time. The parameters measured include SINR, uplink & downlink throughput, and PRB (Physical Resource Block) at a frequency of 1800 MHz as the main frequency and a combination of 2100 MHz and 2300 MHz as additional frequencies [18].

Data is collected by recording the values of these parameters at each measurement point along the drive test route. Third, analyzing the drive test results using TEMS Discovery software to process and analyze the collected data. The analysis was conducted by comparing the network performance parameter values under CA and non-CA conditions, and identifying the effect of CA on LTE network quality [17]. Fourth, a comparison of 4G network performance parameters before and after the implementation of Carrier Aggregation to evaluate the effectiveness of CA in improving the quality of LTE network services. The research flow is shown in Figure 1.

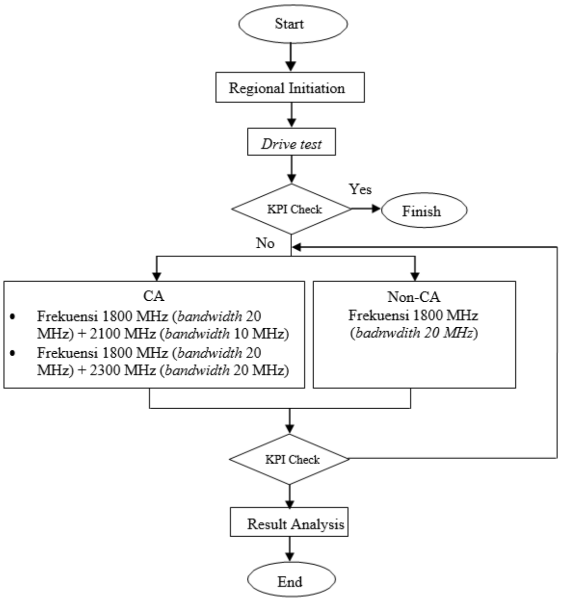

Figure. 1 Diagram of Design

A. *Regional Initiation*

In this study, several software were used for data measurement and analysis. TEMS Pocket version was chosen because of the accuracy and completeness of the measured LTE parameters, such as RSRP, SINR, and throughput. Data collection was carried out in a special mode by making phone calls during the drive test. TEMS Discovery version was used to analyze the data collected by TEMS Pocket, for example by comparing SINR and throughput values at different frequencies [17]. NetMonster version was used to aggregate real-time network information on smartphones, such as identifying the frequency bands used. Google Earth was used to display and plan the location of data collection visually on a map [19].

Regional initiation was carried out by determining the service area or mapping the area to be studied using Google Earth and MKOM (Mobile Communication) data from Telkomsel cluster operators in Padang City. The author took data in the Alai Parak Kopi Village area, Padang Utara District, Padang City, because in that area there is an eNodeB that has implemented Carrier Aggregation and has a variety of environmental conditions that are suitable for research. MKOM data is used to identify the eNodeB location and protect its signal, so that the drive test route can be planned optimally [19]. The following is a view of the drive test path shown with a blue line in Figure 2 below.

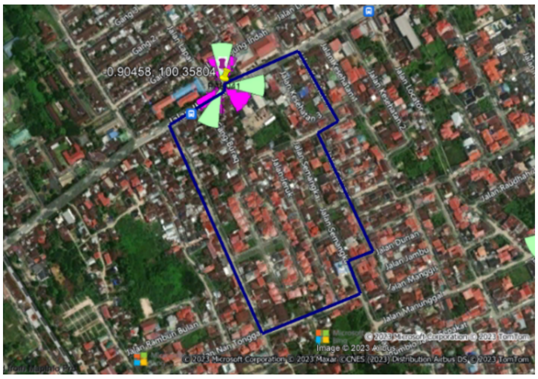

Figure 2. Research Area

B. *Drive Test*

After determining the path to be traversed according to the azimuth direction of the eNodeB antenna, the next stage is data collection. Data collection is carried out using the drive test method using TEMS Pocket software version on a smartphone that has been configured to record LTE network parameters. The smartphone uses a Telkomsel operator SIM card and is set to always be connected to the eNodeB that implements Carrier Aggregation. This is done to ensure that the data collected represents the performance of the LTE network with CA [19] [20].

During the drive test, the smartphone is placed on a motorcycle mount and connected to an external Global Positioning System (GPS) that has high accuracy to record locations in real time. The use of external GPS aims to improve the accuracy of location recording, so that the data obtained is more representative [19]. The drive test is carried out by taking a predetermined route and covering various environmental conditions, such as residential areas, housing, and highways. During the trip, TEMS Pocket will record LTE network parameters such as RSRP, SINR, and throughput periodically and save them simultaneously with location data from GPS.

Data collection in the field was carried out using the drive test method using TEMS Pocket software version [sebutkan versi TEMS Pocket]. This method was conducted in 2 rounds to obtain a comprehensive dataset and allow for a comparative analysis of network performance with and without Carrier Aggregation (CA). The first round of data collection focused on capturing data samples from areas where CA was actively applied. This involved selecting routes and locations where the network was configured to utilize CA, ensuring that the collected data reflected the performance of LTE networks with CA enabled.

The second round of data collection targeted areas where CA was not implemented. This provided a baseline dataset representing typical LTE network performance without the influence of CA. By comparing the two datasets, the impact of CA on network performance metrics, such as SINR and throughput, could be effectively assessed [20]. This two-round approach ensured a robust and balanced dataset for analysis, enabling a clear evaluation of the benefits and effects of CA on network performance in a real-world setting.

III. RESULT AND DISCUSSION

This section explains the research results and also the analysis of the results obtained. The author will discuss in detail the research results in the form of drive test results that have been conducted, explain the implications of the drive test results, and present them with the theoretical framework that has been put forward previously. The following are the drive test results obtained and the analysis of the drive test results.

Data collection was carried out using the drive test method by moving or moving along Jl. Jhony Anwar, Alai Parak Kopi Village, Padang Utara District, Padang City. The drive test was carried out using TEMS Pocket software on a smartphone that had been configured to record 4G LTE network parameters on the Telkomsel provider. The results of this drive test are in the form of a log file containing a recording of signal quality data based on 4G LTE parameters, such as RSRP, SINR, and throughput. The data was initially stored in the .trp file format in the TEMS Pocket application.

Drive test was conducted on the 1800 MHz frequency band with a bandwidth of 20 MHz as the main frequency. In addition, measurements were also carried out on two frequency combinations with the implementation of Carrier Aggregation (CA), namely:

a. Combination 1: 1800 + 2100 MHz band with a bandwidth of 20 + 10 MHz.
b. Combination 2: 1800 + 2300 MHz band with a bandwidth of 20 + 20 MHz.

Measurements were conducted at three frequency conditions, namely 1800 MHz (without CA), 1800 + 2100 MHz (CA), and 1800 + 2300 MHz (CA), to compare the performance of LTE networks with and without Carrier Aggregation (CA). This comparison was conducted to provide the effect of CA on increasing data rate (throughput), signal quality (SINR), and network coverage, as well as to analyze the performance differences between two different CA combinations. The collected data will be analyzed to identify factors that affect CA performance, such as distance, obstacles, and interference, in order to provide a comprehensive understanding of the impact of CA on LTE networks.

A. *Comparison of Maximum RSRP*

RSRP (Reference Signal Received Power) is a parameter used to measure the strength of the reference signal received by the user equipment (UE) from the eNodeB. The RSRP value indicates the quality of the radio link between the UE and the eNodeB. Low signal levels, indicated by low RSRP values, are one of the common problems that can result in decreased signal quality, which ultimately impacts the quality of service received by the user, such as connection drops or low data rates.

A low RSRP value can cause various problems for users, ranging from signal degradation to connection loss. Poor signal quality can result in low data rates, unstable internet connections, and difficulty making phone calls. In extreme cases, a very low RSRP value can cause the connection between the UE and the eNodeB to be lost, thus losing access to the LTE network for users. Therefore, ensuring and ensuring a sufficiently high RSRP value is essential to maintaining optimal service quality and user experience on LTE networks.

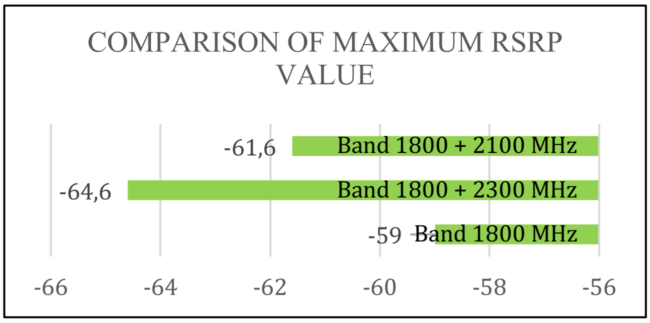

Figure 3. Comparison of Maximum RSRP Value

Figure 3 shows a comparison of the maximum RSRP values at three measured frequency conditions. It can be seen that the highest RSRP value is in the 1800 MHz band (20 MHz bandwidth) with a value of -59 dBm. The maximum RSRP value in the 1800 + 2100 MHz (20 + 10 MHz) band combination is -61.6 dBm, while in the 1800 + 2300 MHz (20

+ 20 MHz) combination it is -64.6 dBm. These results indicate that frequencies with larger bandwidths tend to have lower RSRP values.

B. Comprasion of Maximum SNR Value

SINR (Signal to Interference plus Noise Ratio) measures the quality of an LTE signal by comparing the strength of the primary signal to interference and noise. A high SINR indicates a strong and clear signal, resulting in a stable connection and high data rates. Conversely, a low SINR indicates a weak signal or one that is disrupted by interference, which can lead to unstable connections and low data rates.

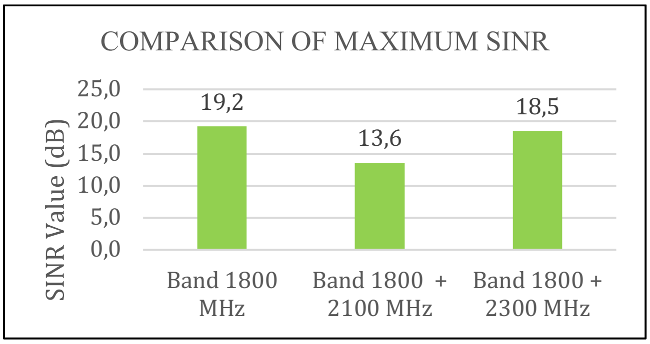

Figure 4. Comparison of Maximum SINR Value

Figure 4 shows a comparison of the maximum SINR values achieved at three frequency conditions. It can be seen that the 1800 MHz band (20 MHz bandwidth) produces the highest SINR value of 19.2 dB. The combination of the 1800 + 2300 MHz (20 + 20 MHz) bands achieves a maximum SINR value of 18.5 dB, while the combination of 1800 + 2100 MHz (20 + 10 MHz) has a maximum SINR value of 13.6 dB. The difference in SINR values indicates that the use of Carrier Aggregation (CA) can affect signal quality, where certain frequency combinations (1800 + 2300 MHz) produce signal quality that is close to a single frequency (1800 MHz), while other combinations (1800 + 2100 MHz) show a decrease in signal quality. This is likely due to factors such as interference between frequencies and signal propagation characteristics in each band.

C. Comprasion of Maximum Throughput Downlink Value

Analysis of downlink results at frequencies of 1800 MHz and 1800 + 2100 MHz shows that the average throughput value is in the intermediate category (4,000 kbps to 8,000 kbps), which indicates a fairly good downlink quality at both frequency conditions. Furthermore, a comparison of the maximum downlink throughput value will be carried out to determine the effect of Carrier Aggregation on data speed on the LTE network.

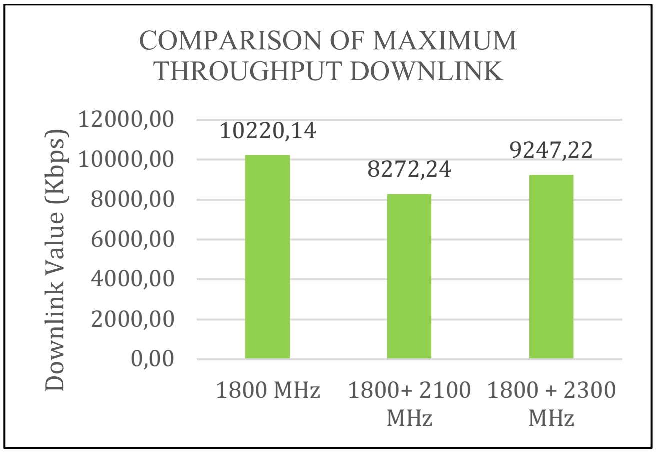

Figure 5. Comparison of Maximum Throughput Downlink Value

Figure 5 shows that the maximum downlink value is in the 1800 MHz band (20 MHz bandwidth) which is 10220.14 kbps. In the combination of 1800 + 2300 MHz (20 + 20 MHz) bands, the maximum downlink value is 9247.22 kbps, while in the combination of 1800 + 2100 MHz (20 + 10 MHz) it is 8272.24 kbps. These results indicate that the 1800 MHz band without Carrier Aggregation (CA) produces higher downlink throughput compared to the frequency combination using CA. This indicates that at certain locations and measurement conditions, CA does not necessarily always increase downlink throughput, and other factors such as interference and network configuration can affect CA performance.

D. Comprasion of Maximum Throughput Uplink Value

Uplink throughput is an important factor in determining the quality of LTE network service, especially for applications that require data delivery from users to the network, such as video streaming and cloud storage. In this section, we will analyze the comparison of uplink throughput at three frequency conditions to evaluate the effect of Carrier Aggregation on uplink performance. Adequate uplink speed is also important to support various other services, such as video calls, online gaming, and IoT (Internet of Things) which require real-time data delivery.

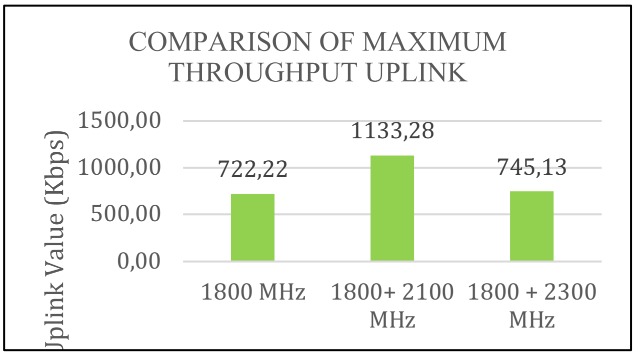

Figure 6. Comparison of Maximum Throughput Uplink Value

Figure 6 shows a comparison of the maximum uplink values at three frequency conditions. It can be seen that the combination of the 1800 + 2100 MHz (20 + 10 MHz) bands produces the highest uplink value, which is 1133.28 kbps. The combination of the 1800 + 2300 MHz (20 + 20 MHz) bands reaches a maximum uplink value of 745.13 kbps, while the

1800 MHz (20 MHz) band without Carrier Aggregation (CA) produces an uplink value of 722.22 kbps.

E. Comprasion Uplink and Downlink Value

Comparing uplink and downlink values is important to understand because they have different characteristics and are influenced by different factors. To get a comprehensive picture of LTE network performance, a comparative analysis between uplink and downlink throughput is needed. This analysis aims to identify differences in uplink and downlink characteristics at each frequency condition.

In the previous section, we have discussed the analysis of downlink and uplink throughput separately. However, to understand the performance of LTE networks holistically, it is necessary to compare uplink and downlink throughput. This comparison will show how Carrier Aggregation affects the characteristics of uplink and downlink, and provide important information for mobile operators in optimizing their networks.

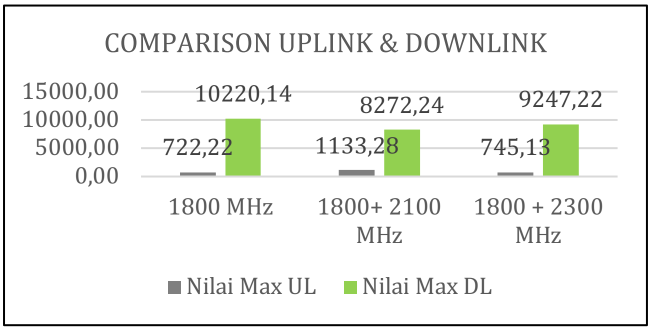

Figure 7. Comparison Uplink and Downlink Value

Figure 7 shows the comparison of uplink and downlink values at three frequency conditions. In general, the downlink value is much better than the uplink value. The downlink value is in the range of >4000 kbps, which indicates good downlink quality and meets the intermediate criteria based on the established standards. Meanwhile, the uplink value is in the range of <2000 kbps, which indicates poor uplink quality and needs to be improved. This significant difference between uplink and downlink can be caused by several factors, such as unbalanced resource allocation, differences in transmit power between uplink and downlink, and different signal propagation characteristics in the two transmission directions.

F. Comprasion Maximum PRB Value

In LTE networks, radio resources are divided into units called PRBs (Physical Resource Blocks). The number of PRBs allocated indicates the network capacity used to send and receive data. Comparative analysis of the maximum PRB values will provide information on how Carrier Aggregation affects resource usage and LTE network efficiency.

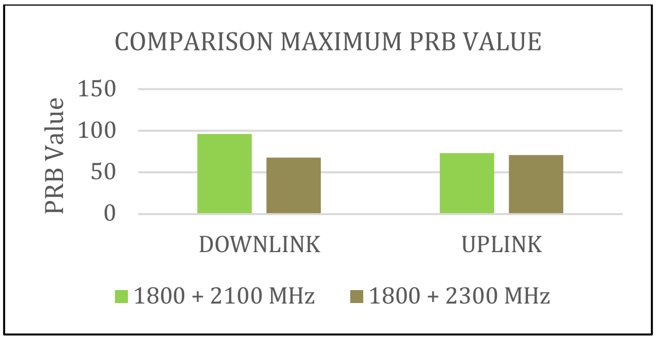

Figure 8. Comparison Maximum PRB Value

Figure 8 shows a comparison of the maximum PRB values at the frequency combinations of 1800 + 2100 MHz and 1800 + 2300 MHz. In the downlink direction, the combination of 1800 + 2100 MHz reaches a maximum PRB value of 96 RB, while the combination of 1800 + 2300 MHz reaches 68 RB. In the uplink direction, the combination of 1800 + 2100 MHz reaches a maximum PRB value of 73 RB, while the combination of 1800 + 2300 MHz reaches 71 RB. Interestingly, the combination of 1800 + 2100 MHz shows a higher PRB value than 1800 + 2300 MHz, although in theory, the combination of 1800 + 2300 MHz should have more PRB due to its larger bandwidth. This difference is likely due to the use of different methods on both bands, where the 2300 MHz frequency uses the TDD (Time Division Duplex) method while the 2100 MHz frequency uses the FDD (Frequency Division Duplex) method.

IV. CONCLUSION

Based on the results of measurements and analysis conducted in Alai Parak Kopi Village, Padang Utara District, Padang City, it can be concluded that the implementation of Carrier Aggregation (CA), which aims to increase capacity and data speed on the LTE network, affects network performance. Although the highest SINR value was achieved in the 1800 MHz band without CA (19.2 dB), which indicates the best signal quality, the CA combination of 1800 + 2300 MHz showed a SINR value close to (18.5 dB), while the combination of 1800 + 2100 MHz produced a lower SINR value (13.6 dB). CA improves uplink performance, by significantly increasing uplink speed, with a maximum value at the combination of 1800 + 2300 MHz, followed by 1800 + 2100 MHz, and finally 1800 MHz. However, for the downlink, the best performance is achieved in the 1800 MHz band without CA, followed by the combination of 1800 + 2300 MHz and 1800 + 2100 MHz. This shows that the effects of CA on uplink and downlink performance are different, and factors such as bandwidth, frequency combination, and duplex method (FDD/TDD) can affect its effectiveness. Overall, CA has the potential to improve LTE network performance, but its implementation needs to be optimized by considering these factors.

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