

## Comparative Analysis of TDD Frame Structure Technology LTE-Advanced (A Case Study in Cibitung Area Indonesia)

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**Abstract:** Based on the results of the drive-test, it showed that 72.22% of the Gramapuri Tamansari Cibitung area had downlink throughput quality below the standard of Key Performance Indicator (KPI) parameter, which was less than 8 Mbps. In addition, based on the Operation and Support System (OSS) data, in this area, the value of Physical Resource Block (PRB) utilization reached 83.93%; thus, an additional capacity from the downlink was needed. This study aims to compare Time Division Duplexing (TDD) frame structure and Inter-Band Carrier Aggregation FDD-TDD method in the Cibitung area, with band 3 FDD 1800 MHz and band 40 TDD 2300 MHz by simulation using Atoll 3.3 software. The parameters measured are downlink throughput, uplink throughput, RSRP, SINR, and connected user. The simulation results showed improving downlink throughput by 63%, uplink throughput by 65%, and connected users by 4%.

**Keywords:** LTE, inter-band carrier aggregation, capacity, Time Division Duplexing frame structure.

### 時分雙工幀結構技術四代網-先進的對比分析 (以印度尼西亞西比通地區為例)

**摘要：**根據路測結果顯示，72.22% 的格拉馬普里塔曼薩里西比通區域的下行吞吐量質量低於關鍵性能指標參數的標準，低於 8 兆比特每秒。此外，基於運營與支持系統數據，該區域物理資源塊利用率達到 83.93%；因此，需要額外的下行鏈路容量。本研究旨在通過使用環礁 3.3 軟件進行仿真，比較西比通地區的時分雙工幀結構和頻段間載波聚合頻分雙工-時分雙工方法，以及頻段 3 頻分雙工 1800 兆赫和頻段 40 時分雙工 2300 兆赫。測量的參數是下行吞吐量、上行吞吐量、參考信號接收功率、信幹噪比和連接用戶。仿真結果表明，下行吞吐量提高了 63%，上行吞吐量提高了 65%，連接用戶提高了 4%。

**关键词：**四代網、帶間載波聚合、容量、時分雙工幀結構。

## 1. Introduction

Each year the cellular users in Indonesia significantly increased from 2011 to 2019, which reached 341.27 million users [1]. It makes user needs change from the cellular network to high-speed internet. To meet these demands requires adequate speed [2], which makes mobile communication service providers use more Frequency Division Duplexing (FDD) techniques. Because the constant downlink and uplink of Time Division Duplexing (TDD) techniques and deployment on FDD bands, in general, can provide symmetrical division to large-scale users. Therefore, FDD systems have become widely applied worldwide [3-4].

However, the rapid development of Mobile Broadband services causes an imbalance between the downlink and uplink traffic loads. The use of FDD becomes inefficient in physical resources employment, in which FDD requires two separate frequency channels for uplink and downlink. Compared to FDD, TDD mode can benefit the system in using more optimal physical resources because it is asymmetrical. Therefore, the physical resources can be regulated [4].

Research [5] shows that the workload comparison on the downlink channel was more significant than the data transmitted on the uplink channel. The comparison ratio on macrocell reached 4:1 for DL: UL because most of the services required more video data

downloading, video streaming services, browsing, and internet. Undoubtedly, it unbalanced the utilization of physical resources on the uplink because the data traffic load was higher on the downlink. In reports [6], [7], most current networks deployed more downlink channels than uplink channels. Hence, to make better use of physical resources, it is suggested to use TDD duplex mode. One of the advantages of TDD mode is that the uplink and downlink resource allocation can be configured according to the time domain. Thus, it can be adjusted according to traffic needs, which is the main advantage of TDD mode over FDD [7-8].

However, the deployment of TDD has shortcomings in terms of coverage, such as TDD mode requires more base stations than FDD mode with the same frequency. It impacts the cost of building e-NodeB [9-10]. Therefore, the alternative solution that operators can make is to utilize the carrier aggregation technique using FDD-TDD. In release 12, the 3rd Generation Partnership Project (3GPP) introduced a carrier aggregation (CA) feature that allows operators to use the spectrum of FDD and TDD frequency bands together. It can increase throughput, especially in downlink channels; it can also divide the data traffic load on FDD. In short, CA FDD-TDD extends CA to operators with spectrum allocation in the FDD and TDD bands [11]. Moreover, it also can provide broad coverage [12].

Generally, the operators apply the lower frequency band FDD, so it is more likely to be a primary cell (PCell); meanwhile, the TDD is applied in a higher frequency band to be a secondary cell (SCell). Previously in carrier aggregation on release 10, both bands had either FDD band or TDD band [13]. Based on the data from OSS (Operation Support System)

Operator X, the PRB utilization value in the region reached 83.93%; additional capacity was needed from the downlink. Therefore, the TDD frame type configuration method was appropriate for the capacity issues. Meanwhile, based on the drive-test data, the throughput value in the Cibitung area was below the KPI operator X standard.

Based on the drive-test data, OSS data, and literature studies, in this study, a comparison of TDD frame structure and inter-band carrier aggregation FDD-TDD method was conducted in the Cibitung area. It aimed to increase network capacity, especially in the downlink channel in the Cibitung area. This study employed operator X services with five comparison scenarios based on the TDD frame structure that focused on increasing the capacity of the downlink channel, namely TDD frame types 1 to 5. The comparison simulation was carried out using Atoll 3.3 software. While the parameters measured include throughput (downlink and uplink), RSRP, SINR, and connected user for each TDD frame type.

## 2. LTE Network Capacity Enhancement Method

### 2.1. Radio Frame Structure

The radio frame structure is the longest time in the LTE frame system, in which one radio frame is 10 ms or 20 slots. In LTE, data is transmitted in one radio frame so that data transfer occurs every 10 ms. Fig. 1 shows that one resource block consists of 7 OFDM symbols, which are one slot of 0.5 ms so that in 1 TTI (Time Transmission Interval), which is 1 ms, it can transmit data for two resource blocks.

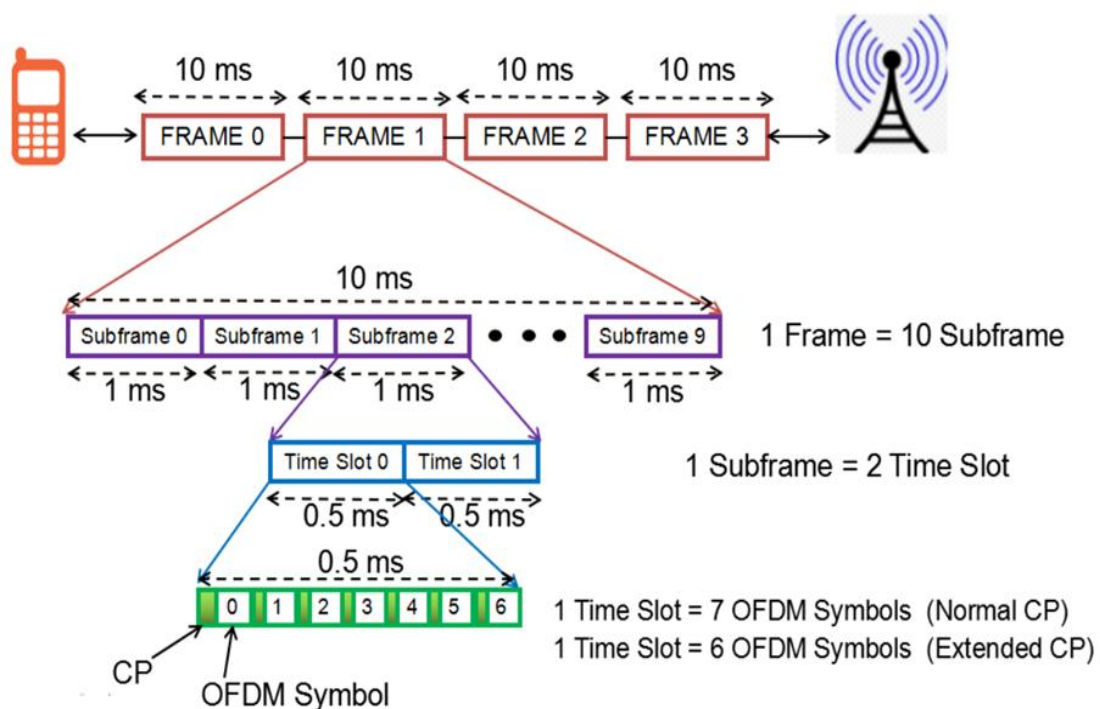


Fig. 1 Radio frame structure

### 2.2. Resource Block

Fig. 2 is the illustration of the resource block. The resource block is the allocation of time and frequency for data transfer. In LTE, one resource block *consists*

of 12 subcarriers with each subcarrier of 15 KHz, and there are 7 OFDM symbols or one slot of 0.5 ms. Thus, in 1 resource block, the bandwidth is 15 KHz x 12 subcarriers = 180 KHz.

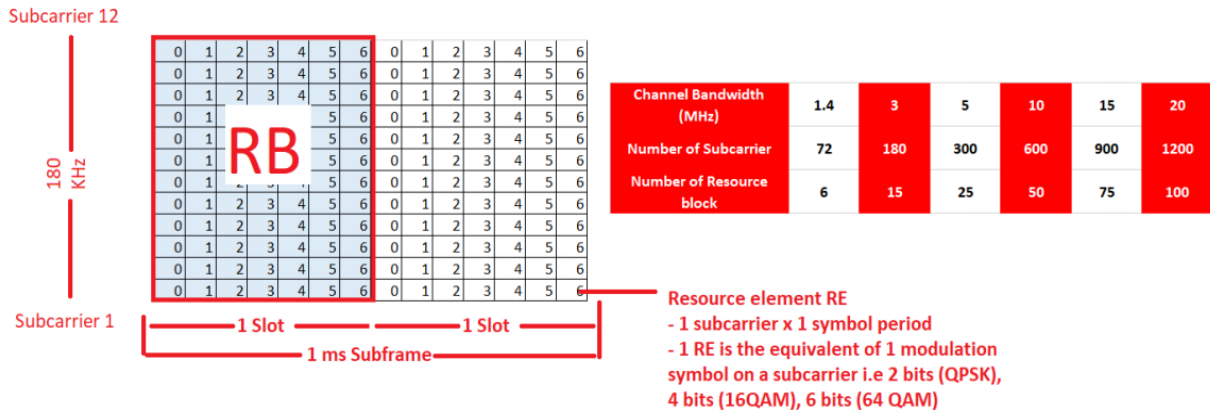


Fig. 2 Resource block

The equations 1 – 3 are used to calculate the resource blocks based on the bandwidth and the resource blocks in 10 ms.

$$N_{b\text{ actual}} = N_{bw} \times 100\% \tag{1}$$

$$N_{rb} = \frac{N_{b\text{ actual}}}{180\text{ KHz}} \tag{2}$$

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe} \tag{3}$$

where:

- $N_{b\text{ actual}}$  - actual number of bandwidth after being reduced 10% for guard band;
- $N_{rb}$  - resource block number based on bandwidth;
- $N_{subframe}$  - subframe number used;
- $NRb_{frame}$  - resource block number in one frame 10 ms.

### 2.3. TDD Frame Configuration

Fig. 3 describes the seven modes of TDD transmission. Subframes are divided into subframes (DL/UL) and special subframes. The special subframe consists of three, namely Guard period (GP), Downlink Pilot Time Slots (DwPTS), and Uplink Pilot Time Slots (UpPTS). In the TDD frame, the configuration is more flexible in adjusting traffic. When an area has high downlink traffic, TDD frame type can use type 5. Therefore, it can be the strength of TDD over FDD.

Configuration	Downlink to Uplink switch point (ms)	Subframe number										Number of Subframe		
		0	1	2	3	4	5	6	7	8	9	D (DL)	U (UL)	S (SSF)
0	5	D	S	U	U	U	D	S	U	U	U	2	6	2
1	5	D	S	U	U	D	D	S	U	U	D	4	4	2
2	5	D	S	U	U	D	D	S	U	D	D	6	2	2
3	10	D	S	U	U	U	D	D	D	D	D	6	3	1
4	10	D	S	U	U	D	D	D	D	D	D	7	2	1
5	10	D	S	U	U	D	D	D	D	D	D	8	1	1
6	5	D	S	U	U	U	D	S	U	U	D	3	5	2

Fig. 3 TDD frame configuration

### 2.4. Carrier Aggregation

Carrier Aggregation was introduced in release 10. Several operators have used the feature of LTE-Advanced in the field. The principle of CA allows operators to combine the bandwidth of their frequency spectrum, which makes it possible to combine up to

five carriers. CA directly impacts the data transfer rate; otherwise, CA can also be applied for FDD and TDD.

### 3. The Comparison of TDD Frame Structure

This study implemented inter-band Carrier Aggregation because it applied different frequency bands, namely 1800 MHz (Pcell) and 2300 MHz (Scell). In general, non-contiguous inter-band CA is applied in two frequency bands with different duplex

techniques FDD and TDD. The LTE network has been deployed on several frequencies, including 900 MHz, 1800 MHz, 2100 MHz, and 2300 MHz. In this study, CA FDD-TDD was applied with a frequency bands combination on the operator and using the planning on a frequency band of 2300 MHz with 10 MHz bandwidth.

Table 1 Planning of bandwidth and frequency

Scenario	Frequency	Bandwidth
The Scenario of TDD Frame Structure Type 1-5 (CA FDD-TDD)	FDD 1800 MHz	20
	TDD 2300 MHz	10

Table 1 shows the comparison scenario of the TDD frame structure by applying the Interband - Carrier Aggregation FDD-TDD method with a frequency of 1800 MHz as Pcell and a frequency of 2300 Mhz as Scell. Fig. 4 presents a flow chart of the research methodology carried out. The first stage begins with data collection in the form of GCell data, antennas, and maps aimed to see the condition of the site has problems. The second stage is identifying densely populated areas and analyzing the area through GCell using MapInfo software. The third stage, conduct a driving test to measure network quality by tracing areas identified as having poor data transfer quality and analyzing the driving test results. The fourth stage is to perform simulations with two scenarios: comparing the TDD frame structure scenario with the inter-band method carrier aggregation FDD-TDD. In the fifth stage, comparison simulation using FDD frequency at 1800 Mhz and TDD at 2300 MHz, any configuration scheme TDD is compared to find the right solution for the region. The sixth stage analyzes LTE network parameters in the form of RSRP, SINR, downlink throughput, uplink throughput, and user connection for each scenario. This comparison uses the CADS2 scheme with PCell 1800 and SCell 2300.

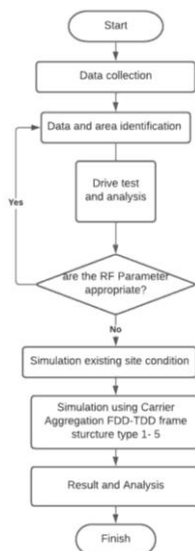


Fig. 4 Flowchart of research methodology

#### 3.1. The Calculation of Resource Block Based on Bandwidth

The resource block calculation process was conducted by considering two values, namely bandwidth and radio frames [14]. Resource block calculation based on bandwidth used 20 MHz and 10 MHz bandwidth.

- Bandwidth 10 MHz

$$N_{b actual} = N_{bw} \times 100\%$$

$$N_{b actual} = 20 \text{ MHz} \times 100\%$$

$$N_{b actual} = 18 \text{ MHz}$$

$$N_{rb} = \frac{18 \text{ MHz}}{180 \text{ KHz}}$$

$$N_{rb} = \frac{18000 \text{ KHz}}{180 \text{ KHz}}$$

$$N_{rb} = 100 \text{ resource block}$$

- Bandwidth 20 MHz

$$N_{b actual} = N_{bw} \times 100\%$$

$$N_{b actual} = 9 \text{ MHz}$$

$$N_{rb} = \frac{9 \text{ MHz}}{180 \text{ KHz}}$$

$$N_{rb} = \frac{9000 \text{ KHz}}{180 \text{ KHz}}$$

$$N_{rb} = 50 \text{ resource block}$$

$$N_{b actual} = 10 \text{ MHz} \times 100\%$$

#### 3.2. The Calculation of Resource Block Based on Radio Frame

Resource block calculation based on radio frames was performed to determine the number of resource block allocations used in each TDD Frame Structure [15]. The different resources between the TDD and FDD frames need to be considered in calculating the radio frame-block resources. TDD frames are asymmetrical to be configured in seven different frame types. The radio frame structure is the longest time on the LTE frame system. One radio frame is 10 ms or ten subframes.

- Bandwidth 10 MHz (TDD) Configuration 1 Downlink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 4$$

$$NRb_{frame} = 400$$

#### Uplink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 4$$

$$NRb_{frame} = 400$$

- Bandwidth 10 MHz (TDD) Configuration 2

#### Downlink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 6$$

$$NRb_{frame} = 600$$

#### Uplink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 2$$

$$NRb_{frame} = 200$$

- Bandwidth 10 MHz (TDD) Configuration 3

#### Downlink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 6$$

$$NRb_{frame} = 600$$

#### Uplink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 3$$

$$NRb_{frame} = 300$$

- Bandwidth 10 MHz (TDD) Configuration 4

#### Downlink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 7$$

$$NRb_{frame} = 700$$

#### Uplink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 2$$

$$NRb_{frame} = 200$$

- Bandwidth 10 MHz (TDD) Configuration 5

#### Downlink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 8$$

$$NRb_{frame} = 800$$

#### Uplink

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 1$$

$$NRb_{frame} = 100$$

- Bandwidth 20 MHz (FDD)

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 100 Rb \times 2 \times 10$$

$$NRb_{frame} = 2000$$

$$NRb_{frameDL} = \frac{2000}{2} = 1000$$

$$NRb_{frameUL} = \frac{2000}{2} = 1000$$

- Bandwidth 10 MHz (FDD)

$$NRb_{frame} = N_{Rb} \times 2 \times N_{subframe}$$

$$NRb_{frame} = 50 Rb \times 2 \times 10$$

$$NRb_{frame} = 1000$$

$$NRb_{frameDL} = \frac{1000}{2} = 500$$

$$NRb_{frameUL} = \frac{1000}{2} = 500$$

Table 2 FDD duplex mode is symmetrical with a ratio of DL: UL = 1:1 [16]. The resource block value is divided into two; thus, 1000 resource blocks are obtained for uplink channels and 1000 for downlink channels in one LTE radio frame. The calculation results of resource blocks in one radio frame bandwidth of 20 MHz (FDD) and 10 MHz (TDD) can be seen in Table 2.

Table 2 Calculation of resource block

Duplex	Bandwidth	Configuration	Resource Block (Rb)	
			UL	DL
TDD	10	1	400	400
TDD	10	2	200	600
TDD	10	3	300	600
TDD	10	4	200	700
TDD	10	5	100	800
FDD	20	-	1000	1000

Table 2 is the calculation result in the resource block calculation stage based on the duplex mode used and the TDD frame type configuration in one LTE radio frame.

Table 3 is the calculation result of resource block allocation for comparison simulation of carrier aggregation based on duplex and bandwidth in one LTE radio frame. TDD frame type 5 has the most downlink resource allocation, which is 1800 resource blocks, and the least uplink resource allocation in one LTE radio frame, 1100 resource blocks. The allocation of resource blocks on LTE influences the throughput speed.

Table 3 The calculation of resource block in one LTE frame

Scenario	Frequency	Bandwidth	Resource Block (Rb)	
			UL	DL
TDD Frame Type 1 (CA FDD-TDD)	FDD: 1800MHz TDD:2300MHz	30	1400	1400
TDD Frame Type 2 (CA FDD-TDD)	FDD: 1800MHz TDD:2300MHz	30	1200	1600
TDD Frame Type 3 (CA FDD-TDD)	FDD: 1800MHz TDD:2300MHz	30	1300	1600
TDD Frame Type 4 (CA FDD-TDD)	FDD: 1800MHz TDD:2300MHz	30	1200	1700
TDD Frame Type 5 (CA FDD-TDD)	FDD: 1800MHz TDD:2300MHz	30	1100	1800

## 4. Simulation Result Analysis

After calculating the resource block, the next step is planning with the simulation method using Atoll 3.3 software. The simulation was conducted by comparing

the TDD frame structure with the carrier aggregation FDD-TDD method using the observation parameters according to the KPI parameters of operators. The simulation results are shown in Table 4-7.

**4.1. The Results of RSRP Parameters Simulation**

Table 4 shows the comparison between TDD Frame Type 1 to 5. TDD type 1 to 5 frame had the same RSRP value, with an average of -94.79 DBM. Meanwhile, the RSRP value in the TDD Carrier Aggregation FDD-TDD type had the same value due to the TDD frame 1 to 5 configuration carried out in the resource block capacity, so it did not affect the RSRP value.

Table 4 RSRP parameter

Value (dBm)	TDD Frame Type 1	TDD Frame Type 2	TDD Frame Type 3	TDD Frame Type 4	TDD Frame Type 5
>= -85	10.68 %	10.68 %	10.68 %	10.68 %	10.68 %
-90 to -85	12.48 %	12.48 %	12.48 %	12.48 %	12.48 %
-100 to -90	54.98 %	54.98 %	54.98 %	54.98 %	54.98 %
-105 to -100	18.32%	18.32%	18.32%	18.32%	18.32%
-115 to -105	3.51 %	3.51 %	3.51 %	3.51 %	3.51 %
-140 to -115	0 %	0 %	0 %	0 %	0 %
Average (dBm)	-94.79	-94.79	-94.79	-94.79	-94.79

**4.2. The Results of SINR Parameter Simulation**

Table 5 shows the simulation results for the value of the SINR parameter. The average value generated for each scenario shows that the mean value for TDD Frame Structure Type was 18.72 dB.

Table 5 SINR parameter

Value (dBm)	TDD Frame Type 1	TDD Frame Type 2	TDD Frame Type 3	TDD Frame Type 4	TDD Frame Type 5
20 to 50	40.84 %	40.84 %	40.84 %	40.84 %	40.84 %
10 to 20	42.40 %	42.40 %	42.40 %	42.40 %	42.40 %
3 to 10	15.03 %	15.03 %	15.03 %	15.03 %	15.03 %
0 to 3	0.73 %	0.73 %	0.73 %	0.73 %	0.73 %
-5 to 0	0.97 %	0.97 %	0.97 %	0.97 %	0.97 %
-20 to -5	0 %	0 %	0 %	0 %	0 %
Average (dBm)	18.72	18.72	18.73	18.73	18.73

**4.3. The Simulation Result of Downlink Throughput Parameters**

Table 6 shows the enhancement in the initial conditions scenario compared to the FDD-TDD Carrier Aggregation Scenario. The more resource blocks are allocated, will affect the throughput speed. On TDD frame types 1 to 5, resource blocks were allocated more

on the downlink. The resource block allocation can be seen in table 3, in which the TDD frame type 5 allocation mainly occurred DL; meanwhile, the TDD frame type 1 allocation mainly occurred in UL.

Table 6 Downlink throughput parameter

Value (dBm)	TDD Frame Type 1	TDD Frame Type 2	TDD Frame Type 3	TDD Frame Type 4	TDD Frame Type 5
>= 80	0 %	0 %	0 %	0 %	0 %
50 to 80	7.40 %	10.30 %	10 %	10.60 %	11.90 %
20 to 50	50.20 %	49.60 %	49.40 %	50.10 %	50.40 %
8 to 20	33.20 %	31.80 %	32.30 %	30.90 %	31.10 %
0 to 8	9.50 %	8.60 %	8.50 %	8.50 %	6.70 %
Average (Mbps)	24.9	27.12	26.95	28.03	29.10

Fig 5 and 6 shows the comparison between downlink and uplink throughput for each TDD frame type.

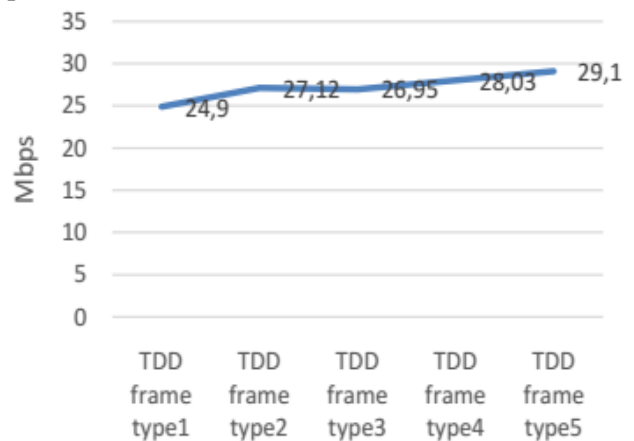


Fig. 5 Mean value of TDD frame downlink throughput

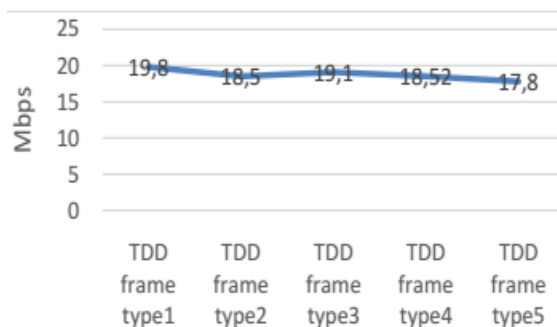


Fig. 6 Mean value of TDD frame uplink throughput

**4.4. The Simulation Result of Uplink Throughput Parameter**

Based on the data in Table 7, the most significant enhancement occurred in TDD frame type 1, with an average throughput value of 19.8 Mbps. It occurred because the allocation of resource blocks on the uplink channel was more than the other TDD frame types. Table 3 shows the allocation of resource blocks on the

uplink channel, which proved that block resource allocation could affect throughput speed.

Table 7 Uplink throughput parameter

Value (dBm)	TDD Frame Type 1	TDD Frame Type 2	TDD Frame Type 3	TDD Frame Type 4	TDD Frame Type 5
>= 40	0 %	0 %	0 %	0 %	0 %
25 to 40	30.40 %	30 %	30.20 %	30 %	29.70 %
10 to 25	38.10 %	35.60 %	38 %	35.60 %	35.60 %
4 to 10	25.60 %	28.40 %	25.90 %	28.40 %	28.60 %
0 to 4	6.10 %	6.20 %	6.10 %	6.10 %	6.20 %
Rata-rata (Mbps)	19.8	18.50	19.10	18.52	17.80

#### 4.5. The Simulation Result of User Connected Parameter

Based on Table 8, the enhancement for each scenario was revealed. It is directly proportional to the average speed of downlink throughput in the simulation results of Fig. 3.

Table 8 Connected user parameter

TDD Frame Type 1	TDD Frame Type 2	TDD Frame Type 3	TDD Frame Type 4	TDD Frame Type 5
2891	2948	2965	2992	3008
Connected Users	Connected Users	Connected Users	Connected Users	Connected Users

## 5. Conclusion

Based on the comparison of TDD frame type simulation results by applying the FDD-TDD Carrier Aggregation method, the difference in RSRP and SINR parameters was revealed. Due to the TDD frame type configuration carried out in the resource block capacity; thus, it does not affect the RSRP value and SINR. Conversely, Downlink Throughput Parameters, Uplink Throughput, and Connected User revealed significant changes. TDD Frame Structure Type 5 simulation had the highest average downlink speed of 29.1 Mbps and 3008 connected users; meanwhile, TDD Frame Structure Type 1 had flat speed, with the highest uplink average was 19.1 Mbps, and the connected user was 2891. The comparison results of TDD frame structure according to the calculation of physical resource block shows that the more physical resources allocated, the higher the data transfer obtained. Research can be continued on the 5G generation using the Carrier Aggregation FDD-TDD method.

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