Performance analysis of packet scheduling algorithm for Femtocell-Macrocell Scenario in LTE Network

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Abstract—The increasing number of users has led to various challenging issues especially when providing coverage to the users in the building. The indoor coverage deteriorates since the signal cannot pass through the wall completely. The coverage signal will become weaker and affect the Quality of Service to the customers. Operators have tried to overcome this problem by providing small cells (femtocells) inside the building. In this paper, we have investigated the performance of packet scheduling algorithms; Proportional Fairness (PF), Round Robin (RR), Priority Set (PSS), Blind Equal Throughput (BET) and Maximum Throughput (MT) in the LTE environment where a dual stripe block type apartment is included in the network topology. Each apartment is assumed to have two femtocells where each cell is serving five customers. Meanwhile, the number of users in the Macrocell is varied between 50 to 200. Three types of services are delivered during the simulation which are VoIP, video and FTP. The simulations results are presented in the terms of throughput and delay. It can be concluded that PF and RR algorithms are the most compatible to be deployed in the Macrocell-Femtocell environment.

Index Terms—femtocell, long term evolution (LTE), macrocell, ns-3, performance, quality of services, scheduler.

I. Introduction

LONG Term Evolution (LTE) is introduced [1] to improve data speed transfer since LTE has a broad range of bandwidth that can be use which are between 1.4 MHz and 20 MHz [2]. The peak data rate for downlink transmission is 100 Mbps and for the uplink transmission is 50 Mbps [2], [3]. This shows that the performance of LTE is better than the previous 3G networks [4], [5].

Research on LTE is still on-going and in the limelight especially in the deployment of small cell. Wireless cells operators will continue to increase their focus on the small coverage since 80% of all mobile traffic is generated indoors, thus ensuring 24/7 connectivity can yield significant challenges especially at peak times. It is difficult to maintain good service because the signal strength will drop off when piercing the wall of the building.

To overcome this, most mobile network operators offer the femtocell service. Femtocell has become one of the solutions that can help to improve the coverage inside the building. The main idea behind the implementation of femtocell is to enhance the network coverage in the building [6], [7]. The coverage is much consistent and the mobile terminal will not use as much power, hence giving more battery life.

In order to ensure users will experience good Quality of Experience (QoE), the Resource Allocation (RA) of the networks need to be managed carefully. Each user should receive the amount of data suitable to the traffic requirements. RA between femtocells and macrocell is more complicated than the normal RA since both cells have different specification and problems such as interference between the cells could happened[8], [9]. Packet scheduling are responsible for managing the RA. There are many packet scheduling algorithms that are applied for managing network, such as Proportional Fairness (PF), Round Robin (RR) and Priority Set (PSS). Each algorithm has different approach to manage the network.

There are several researches that have been done on femtocell. In [10]–[12], the authors have compared their proposed algorithms with PF, RR and MT. Several types of traffics are included in order to evaluate the performance of the proposed scheduler. In [11], the authors performed a simulation using NS-3 to evaluate the performance of their proposed RA. The authors proposed a dynamic priority-based resource allocation policy where the available RA are allocated among the active users in the cells. The authors concluded that video traffic has the highest priority because of the higher amount of data being delivered and the proposed RA has shown improvement in terms of throughput.

In [13] the authors presented the performance of Macrocell scheduling algorithm in femtocell network. Real Data Rate

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Control (DRC) that was collected from the actual femtocell network was analyzed using computer simulation. Several scheduling methods were used for the analysis such as Round Robin (RR), maximum Data Rate Control (DRC), exponent DRC and (expDRC). The types of traffic that were deployed for the study are the Best Effort (BE) and Voice over IP (VoIP). The authors concluded that expDRC and maxDRC-PF schedulers provide better performance since they delivered the lowest delay and high throughput and fairness.

The authors in [14] analyzed the performance of LTE-Femto network scenario using three types of scheduling algorithms which are PF, Maximum Largest Weighted Delay First (MLWDF) and Exponential Proportional Fairness (EXP/PF). The traffic services that were used for the study are VoIP, video and BE flows. From the simulation, MLWDF algorithm performs better for VoIP and video flows and EXP/PF shows good performance for best effort flows.

The objective of this paper is to study the performance of the schedulers in the Femtocell-Macrocell environment. The network is setup with one eNodeB and two dual stripe block type apartments is positioned in each Femtocell with 5 active users in each block of the apartment. The number of users in the Macrocell is varied between 50 to 200 users. Finally, the performance of the network is analyzed for both Macrocell and Femtocell in terms of throughput and delay.

This paper is organized as follows: Section II discusses on the resource allocation techniques in the Femtocell-Macrocell networks. Section III describes on the packet scheduling algorithms and section IV explains on the performance matrices. Simulation design and results are discussed in Section V and VI respectively. Lastly, Section VII concludes the paper

II. RESOURCE ALLOCATION TECHNIQUES

Radio resource management (RRM) is very important in LTE systems especially in managing the networks[11]. Resource allocation is one of the main functions in RRM to ensure good QoE. Several techniques of resource allocation have been proposed in the Femto-Macro networks [11] such as:

1) *Frequency Scheduling*
The most basic method to allocate the Physical Resource Blocks (PRBs) to the users in Macrocell and Femtocell based on the information of interference and channel quality
2) *Frequency reuse*
This technique is the most efficient in maximizing the resource utilization.
3) *Femtocell Aware Spectrum Allocation:*
The available spectrum is divided into two partition which are Macro-dedicated spectrum and Femto sharing spectrum. The interference between femtocell is managed by eNodeB, and users in the Femtocell will be allocated PRBs from the macro-dedicate spectrum.
4) *Priority based Spectrum Allocation:*
In this configuration, Home eNodeB (HeNB) will divide the available bandwidth into chunk and each chunk will be given to the available Femtocells in the network. The chunks have been set with different values of priority and the PRBs is allocated according to the desired priority.

III.PACKET SCHEDULING ALGORITHMS

Packet scheduling algorithms is one of the functions in Radio Resource Management (RRM) which is responsible for user selections and packets transmissions to satisfy the QoS requirements and radio resources utilizations [1]. Proportional Fairness (PF), Round Robin (RR), Priority Set (PSS), Blind Equal Throughput (BET) and Maximum Throughput (MT) are the types of schedulers to be discussed in this section.

A. Proportional Fairness (PF)

The Proportional Fair (PF) scheduler works by maximizing the throughput of the user being served and at the same time maintaining other users' throughput at minimal services. This scheduler works by assigning the resource block to the UE with the best relative channel quality[15][16].

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$$M = \arg\max\left(\frac{R_i(t)}{\overline{R}_j(t)}\right) \qquad (1)$$

B. Round Robin (RR)

The scheduler assigns resources cyclically to the users without taking channel conditions into account. This is a simple procedure giving the best fairness but it would offer poor performance in terms of cell throughput [16].

$$P = \frac{T^{\alpha}}{R^{\beta}} \qquad (2)$$

Where $\alpha = 0$ and $\beta = 1$.

C. Priority Set (PSS)

The Priority set scheduler (PSS) is the combination of two packet scheduling algorithms which are the time domain (TD) and frequency domain (FD). By defining specific target bit rate (TBR), PSS scheduler is able to control the fairness among the UEs. The UEs are divided into are two sets of groups where this set is categorized based on the TBR and will take part in TD scheduling. PSS will select those UEs with non-empty Radio Link Control (RLC) and proceed to selection of the suitable sets.

UEs with lower past average throughput than TBR will be assigned to set 1 while UEs with larger past average throughput will be assigned to set 2. The scheduler that will be used for TD is the Blind Equal Throughput (BET) and will also be used for Set 1. The PF algorithm served the Set 2. UEs that are assigned in. Set 1 has higher priority than those in Set 2. Then, to proceed to FD scheduler, PSS will select UEs with the highest metric in terms of N mux and allocates the RBG first. There are two types of scheduler that can be choose in PF scheduler which are Proportional Fair scheduled (PFsch) and Carrier over Interference to Average (CoIta) [13].

D. Blind Equal Throughput (BET)

Fairness can be achieved with BET scheduling which stores the past average throughput achieved by each user and uses it as metric to calculate user weight for scheduling. BET scheduler provides throughput fairness among all active users regardless of their channel conditions. The weight of each user for next TTI is calculated as the inverse of its past average throughput [17]

In [10]

$$\hat{i}_k(t) = \arg\max_{j=1,....N}\left(\frac{1}{T_j(t)}\right) \quad (3)$$

E. Maximum Throughput (MT)

The maximum throughput (MT) scheduler [5] aims to maximize the overall throughput of an eNB. It allocates each RB to the user that can achieve the maximum expected data rate in the current TTI [18].

$$\hat{i}_k(t) = \arg\max_{j=1,....N}(R_j(k,t)) \quad (4)$$

IV. METHODOLOGY

The LTE-Femto network scenario in this paper is developed using NS-3. Each user is streamed with VoIP, video and FTP in order to resemble the real environment. The simulations are analyzed in terms of throughput and delay. Fig. 1. shows the flowchart of this research from the beginning until end.

V. PERFORMANCE METRICES

The performance of the schedulers is analyzed using the NS3 simulator. The results are presented and compared in the terms of throughput and delay.

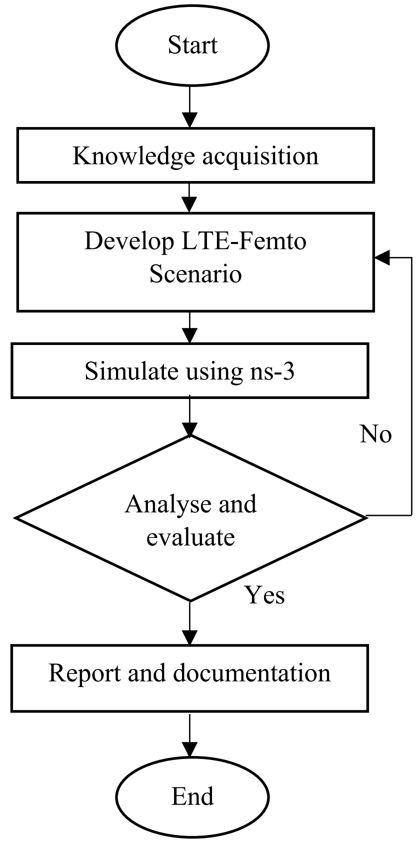

Fig. 1. Research Flowchart

A. Throughput

Throughput can be described as the maximum rate of work done in a certain time. It can be expressed in kilobits per second (kbps), Megabits per second (Mbps) or Gigabits per second (Gbps). In the context of telecommunication networks, only successful message arrived being focused and message that error or unsuccessful on time will be ignored

$$T_{avg} = \frac{\sum_{k=1}^{n} T_k}{n} \quad (5)$$

where Tk is the total throughput for kth user and n is the total number of users [19].

B. Delay

Delay is one of the important performance characteristics in the networks services. It indicates the amount of time taken for a message or packets to travel successfully from the source to the destination. Delay is measured in milliseconds (ms) and only successful arrived packets are counted.

VI. Simulation Design

NS3 simulator is used to analyze and evaluate the performance of the scheduler. The network topology is shown in Fig. 1 with a Macrocell of 1 km in radius and two Femtocells. The parameters used for this simulation is tabulated in Table 1. In this analysis, a dual stripe blocks is representing the femtocell as shown in Fig. 2. It is a square type apartment and the area of each apartment is 100 m^2. The activity ratio parameter for the femtocell is set to 1 where all 10 users in the femtocells will be active during the simulation. The number of users inside the Macrocell varies between 50 to 200 while the number of users in the femtocell is fixed to 5 for each cell.

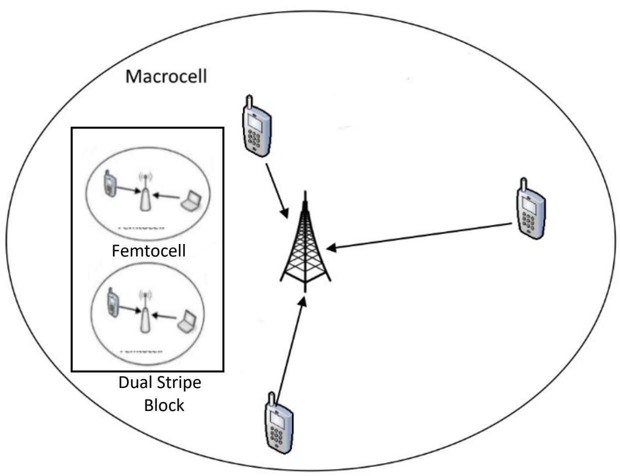

Fig. 2. NS3 scenario: One Macrocell and Two Femtocells

TABLE 1.
SIMULATION PARAMETERS

Parameter	Description
Simulation Duration	10 s
Number of cell	1
Cell Radius	1 km
Number of Macro User	Min = 50 Max = 200
Number of Femto User	10
Number of RB	50 (Macrocell – 25, Femto - 25)
QoS Services	GBR Conversational video, GBR Conversational VoIP and Non-GBR FTP
VoIP Codec	G.711
VoIP Guaranteed Bit Rate	64 kbps
Video File	st_highway_cif (MPEG-4)
Video Guaranteed Bit Rate	242 kbps
FTP Send Size	8192 bits
Pathloss Model	Cost231 (Hata Model PCS extension)
Scheduling Algorithms	PF, RR, PSS, BET and MT
User speed	30 km/h
Maximum delay	0.1 s

Users in the Macrocell are in the moving state (30 kmph) while the users in the femtocells are static (0 kmph). Each of the user is receiving VoIP flow, video flow and FTP flow simultaneously. VoIP and video rates are 64 kbps and 242 kbps respectively. The system bandwidth is 10 MHz and made up of 50 RBs. The Macrocell and Femtocell received 25 RBs each and the allocation of the RBs is fixed. There are two types of access mode that can be used for the Femtocell during the simulation which are Closed and Open access. Closed access restricts the use of the femtocell to the users explicitly approved by the owner while the Open access allows an arbitrary nearby cellular user to use the femtocell. For this simulation, the femtocells are configured to the closed mode.

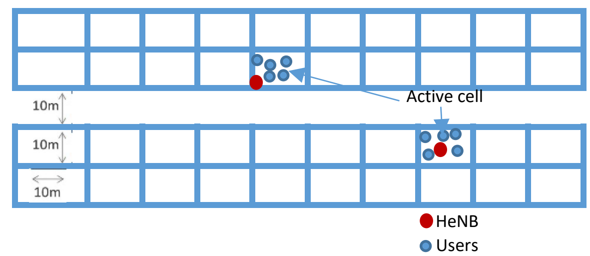

Fig. 3. Dual stripe blocks building type

VII. Simulation Results

The simulation results are discussed in this section and the scheduling algorithms that are being investigated are PF, RR, PSS, BET and MT.

A. Macrocell Users

The performance of throughput and delay by varying the number of users in the Macrocell are shown in Figures of 3 to 6. The simulation results showed that PF scheduler has better performance from the other schedulers when delivering the VoIP and video flows. PF allocates the resources to the users by maximizing the throughput and keeps the services at the minimum.

The BET scheduler has the lowest performance of the throughput in VoIP and video traffic flows because the scheduler works by prioritizing users with the lowest throughput in the past.

For the FTP traffic flow, MT performs better. This is because MT allocates the available resources to the user with highest Channel Quality Indicator (CQI). If the users move to the cell-edge, the users will probably have lost the chance of not receiving any resources from the Macrocell. Since the users mostly located nearby the Macrocell, the throughput for FTP services shows the highest from other schedulers. In order to maximize the total throughput of the network, MT scheduler give the highest priority to the less important traffic which in this case the FTP. As a result, the MT delivers highest throughput of FTP.

The performance of delay for all the traffic flows is plotted in Fig. 7 to Fig. 9. For VoIP and video traffic flows, the delay performance for MT shows the best followed by the RR scheduler. Since MT scheduler delivers low throughput for

VoIP and video traffic, thus the delay of the services is the lowest.

BET scheduler has the highest delay because the algorithm is designed to cater the fairness issue and neglecting the delay requirement. For FTP traffic flow, BET has the lowest delay and it is mainly due to the low throughput being delivered as in Figure 5.

Based on the results on the performance of Macrocell, it can be concluded that for Macrocell-Femtocell scenario, RR and PF schedulers perform better than other scheduling algorithms. MT algorithm has the lowest delay and has the worst performance of throughput. The performance of throughput and delay for FTP service is not consistent because the numbers of RBs might be depleted since the RBs have been distributed to the VoIP and video services. FTP has the lowest priority as compared to VoIP and video.

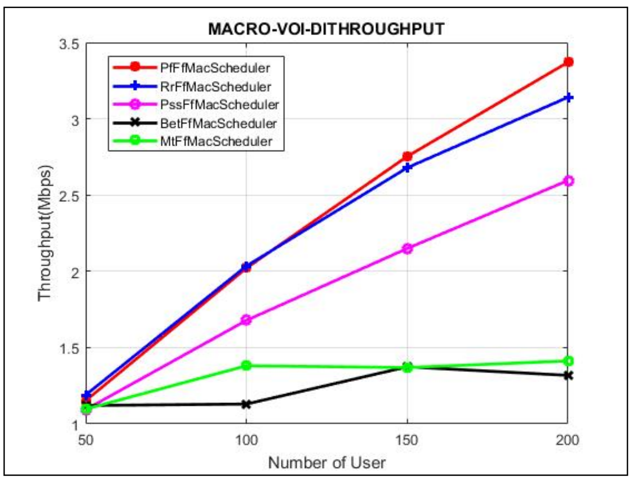

Fig. 4. VOIP Throughput vs Number of Users

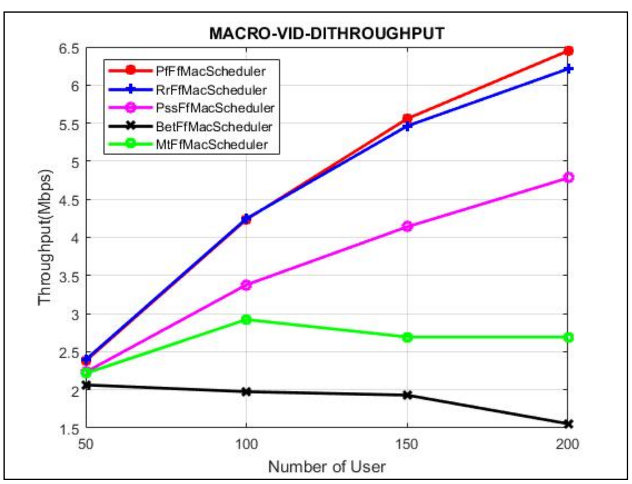

Fig. 5. VIDEO Throughput vs Number of Users

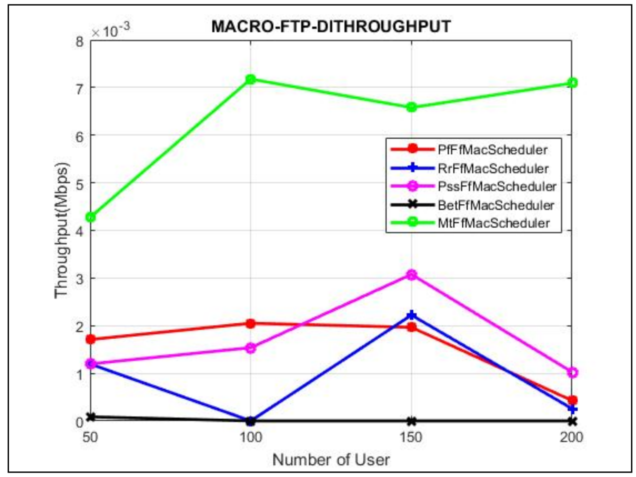

Fig. 6. FTP Throughput vs Number of Users

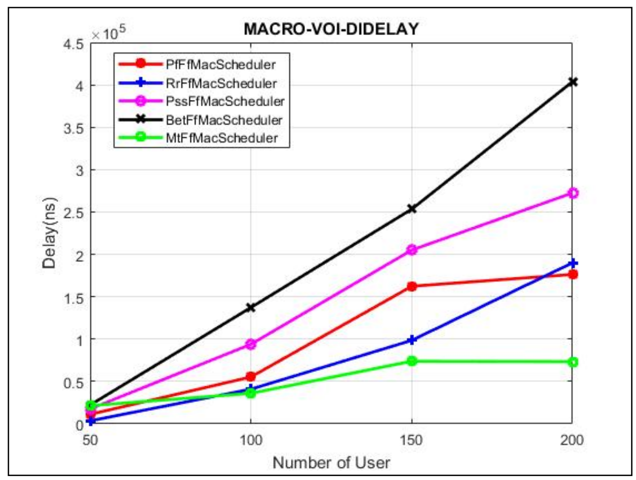

Fig. 7. VOIP Delay vs Number of Users

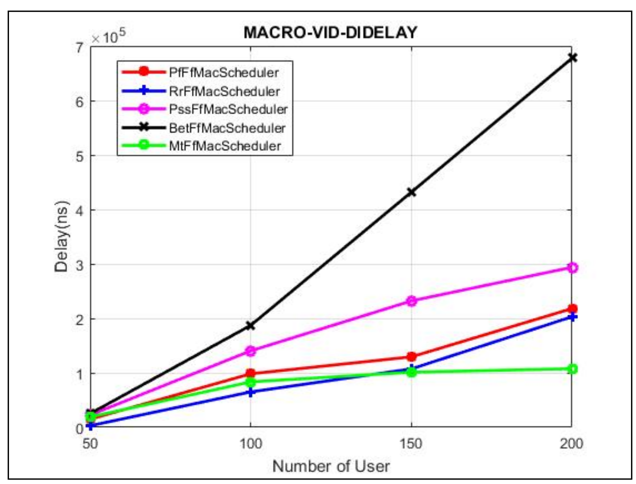

Fig. 8. VIDEO Delay vs Number of Users

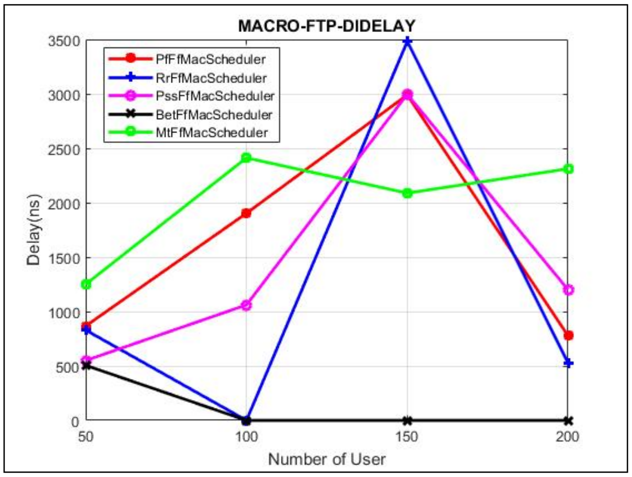

Fig. 9. FTP Delay vs Number of User

B. Femtocell Users

The performance of the femtocell when the number of userin the Macrocell is varied is analyzed in the terms of throughput and delay. The results of throughput for femtocell are plotted in figure 10 to 12. Figure 10 shows the performance of throughput for VoIP traffic. It is observed that PF scheduler delivers the highest throughput amongst all the algorithms. RR algorithm shows good performance after the PF scheduler.

Figure 11 shows the results of video traffic flows. It is perceived that the RR algorithm is the best which is then followed by the MT algorithm. MT scheduler is the best when delivering the FTP flows while BET scheduler shows the worst performance. This might be due to the BET algorithm which only focus on maximizing the users with the lowest throughput which cause the total throughput to be low.

Figure 12 shows the performance of throughput for FTP. It is observed that MT scheduler performs better than the other schedulers because MT maximizes the total throughput by prioritizing the least important traffic which is the FTP. Meanwhile, other schedulers deliver lesser amount of throughput because most of the available resources are already being allocated to the VoIP and video traffics.

The performance of delay for femtocells is plotted in 13 to Fig. 15. For VoIP and Video traffic flows, RR and PF schedulers show similar trending followed by the MT scheduler. BET and PSS schedulers have the highest delay when it comes to VoIP and video flows. It is because BET algorithm does not consider the delay requirement in the scheduling decision and focus on fairness among the users.

MT has the lowest delay for the FTP because the algorithm focuses on maximizing the total throughput by giving priority to FTP. Thus, high throughput being delivered contributes to low delay as shown in Figure 12 and 15 respectively. On the other hand, BET has the highest delay when the number of users is between 50 to 100. The main reason of the increase in delay is might due to the packet loss. When reliable delivery is necessary, packet loss increases latency due to additional time needed for retransmission.

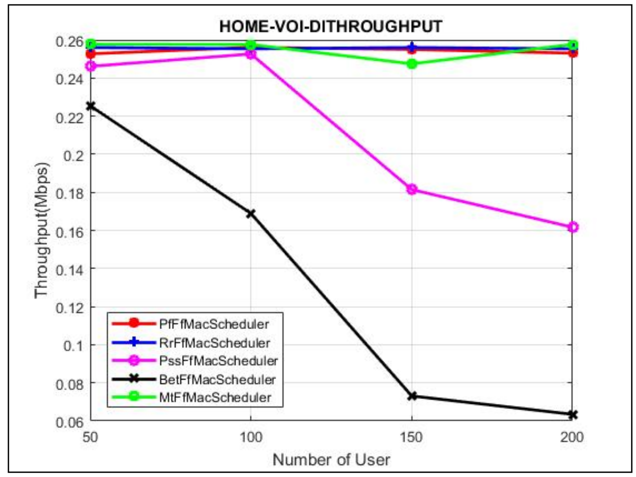

Fig. 10. VOIP Throughput vs Number of Macrocell User

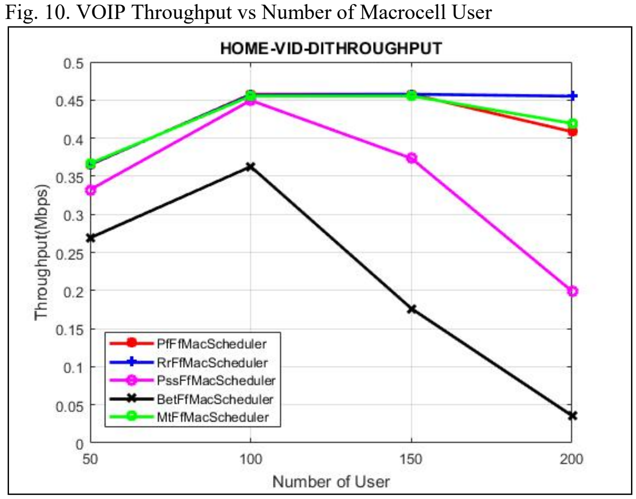

Fig. 11. VIDEO Throughput vs Number of User

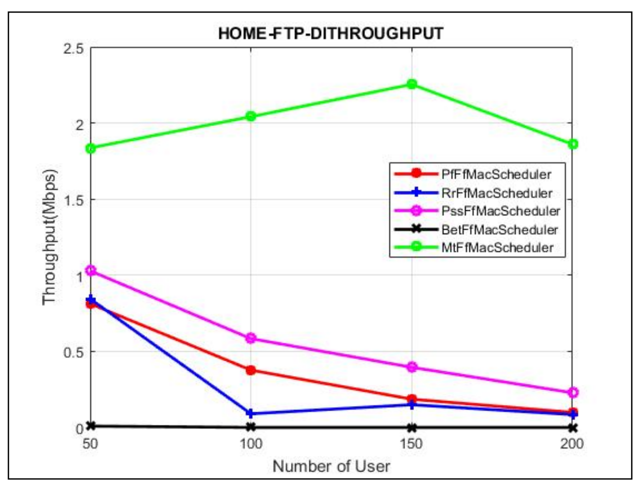

Fig. 12. FTP Throughput vs Number of User

VIII. CONCLUSION

A Macrocell-Femtocell Scenarios of LTE network have been simulated using NS3 simulator. A dual stripe block has been used to present the femtocell in the network. In this study, several algorithms such as PF, RR, MT, BET and PSS algorithms were analyzed to gauge the performance. The users in Macrocell are set to moving condition while users in Femtocell are set to be static. Each user delivers similar types of traffic services which are the VoIP, video and FTP. The results showed that PF and RR schedulers outperformed the other schedulers for Macrocell scenario. In the Femtocell environment, RR scheduler is the most suitable to be deployed because of its good performance for both throughput and delay. For future work, a new resource allocation scheme and scheduling algorithm should be developed in order to improve on the QoS of Macrocell and Femtocell users.

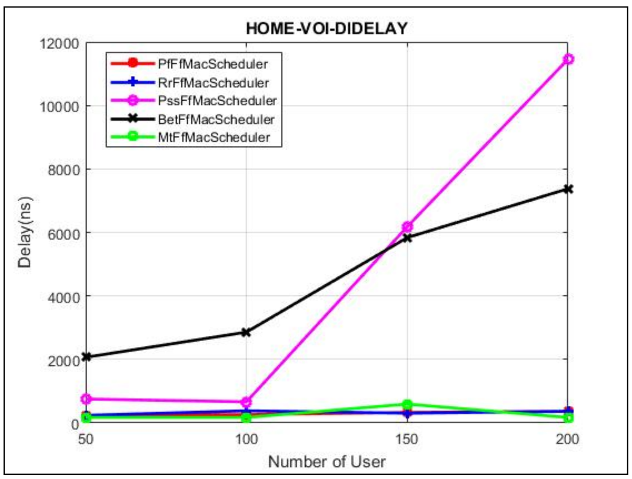

Fig. 13. VOIP Delay vs Number of Users

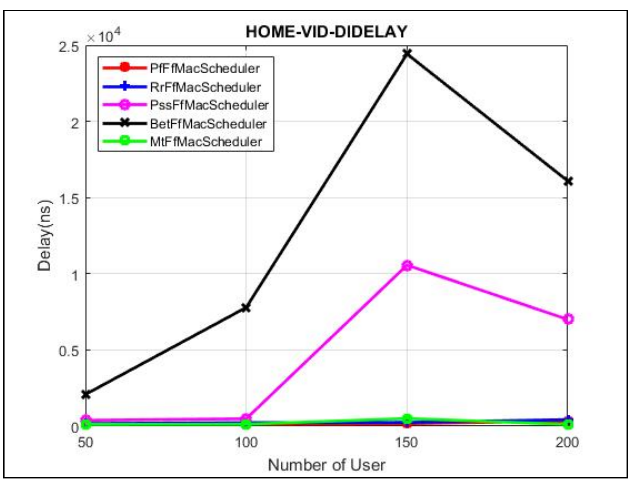

Fig. 14. VIDEO Delay vs Number of Users

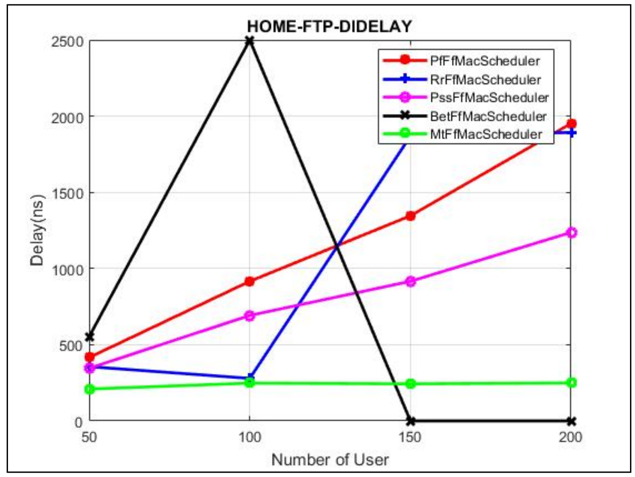

Fig. 15. FTP Delay vs Number of Users

ACKNOWLEDGMENT

The authors would also like to thank Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM) and Mybrain scholarship for supporting the research.

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