Performance Investigation of Joint User-Proportional Fair Scheduling Algorithm in LTE-Advanced System with Carrier Aggregation

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Abstract- *Carrier Aggregation (CA) is a promising technology that proposed by 3GPP in the latest LTE-Advanced (LTE-A) criterions in order to satisfy the future IMT-Advanced mobile networks demands. While CA allows aggregation of component carriers (CCs) dispersed within and transversely in diverse bands (intra/inter-band), CA is expected to offer a powerful boost to the user throughput in LTE-Advanced system. In addition, it will permit the achievement of the target peak data rates in excess of 1 Gbps in the downlink and 500 Mbps in the uplink in which the users has the right to use up to 100 MHz total of bandwidth. The mixture of LTE-A and LTE users within a multi-carrier LTE-A network may perhaps exist simultaneously. Each of them has various CA capabilities. The former has the ability to assign on multiple CCs, whereas the later can allocate on one CC. Moreover, they demand diverse QoS requirements which present new challenges to optimize the performance of LTE-Advanced system. Therefore, the choice of scheduling strategies plays a key role in guaranteeing desirable end to end system performance. The study of this paper will be beneficial for understanding the radio resource management (RRM) function with carrier aggregation feature. In addition, this article presents the Joint User- Proportional Fair scheduling scheme (JUS-PF) for resource allocation and its impacts on two deployment scenarios which are LTE-A users and mixture (LTE/LTE-A) users' scenario in terms of average user throughput, cell edge user throughput, and fairness.*

Keywords: *Carrier Aggregation, Component Carriers, LTE User, LTE-A User, RRM, JUS-PF.*

I. INTRODUCTION

In recent years, mobile networks have grown dramatically to provide a large variety of services like internet browsing, video downloading, and interactive gaming, etc. As such, divers types of Quality of Service (QoS) requirements like packet loss ratio and packet delay are demanded by these services. In fulfilling these requirements, high data rate should be provided by the mobile network. Bandwidths are increased and data rates are raised to meet the increasing traffic requirements. In order to maximize the mobile network bandwidth, the CA technology is introduced to LTE-Advanced system by 3GPP for offering the peak data rates of 1 Gbps for low mobility and 100 Mbps for high mobility [1].

In LTE-Advanced network with CA feature, the eNodeBs are capable for serving the users on multiple CCs based on the users CA capabilities. The users can be classified to narrowband (LTE) users and broadband (LTE-A) users which are able to transmit and receive on single or multiple CCs respectively. The aggregated CCs could be contiguous or non-contiguous with different bandwidths which offer significant flexibility for efficient spectrum utilization. The former is simpler for implementation due to the need of only a single Fast Fourier Transform (FFT) and Radio Frequency (RF) unit while the later is more complicated [2],[3].

This paper analyses the performance of two deployments LTE-A network with CA scenarios by using a system level simulator. Diverse users in LTE-A systems demonstrate new challenges to optimize the network performance, especially for the OFDMA-based systems. In an OFDMA-based system, efficient resource allocation becomes a very important issue. It is difficult to fairly distribute throughput amongst diverse users. The LTE users could utilize the resource blocks (RBs) from a single allocated CC while the LTE-A users are more capable to use the RBs from multiple CCs. The performance is evaluated in terms of per-user average throughputs, cell edge user throughput, and fairness index. This research shows the limitations of existing JUS-PF scheduling algorithm which needs more focus on to provide optimum system performance.

The rest of this paper is organized as follows: Section 2, present the RRM framework process. In section 3, the model of the system is demonstrated. In Section 4, JUS-PF Scheduling Scheme is described. In Section 5, the network deployment scenarios illustrated while section 6, presents the simulation model. The results obtained by simulation for the evaluation of system performance are presented in Section 7. Finally, Section presents the conclusions of this work.

II. RRM FRAMEWORK PROCESS

The composition of RRM layer in LTE-A system with CA is demonstrated in Figure 1. The eNodeB foremost execute the admission control for the establishment of a new radio carrier and configure the QoS parameters. Then, the Layer-3 CC assignment is utilized according to the users CA capabilities which assign one CC to the LTE users and multiple CCs to LTE-A users. For the optimum network performance, the load across CCs should be balanced. After the users are allocated onto CC(s), the Layer-2 Physical Resource Block Scheduling (PRBS) is executed immediately for allotting time frequency resources for every assigned user on the different CCs. Moreover, the independent Layer-1 which composed of link adaption (LA) and a hybrid automatic repeat request (HARQ) per CC is employed to optimize transmission on dissimilar CCs [4]. However, the LTE and LTE-A users maybe exist simultaneously in LTE-Advanced network. For full exploit channel sensitive multi-user scheduling in optimize the truncking efficiency, the eNodeB should select a suitable CC for the LTE users.

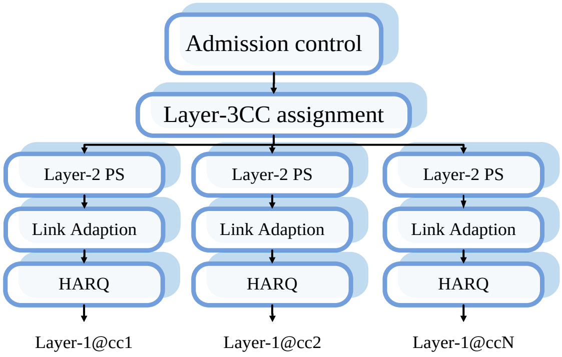

Fig. 1 Structure of a LTE-Advanced system with carrier aggregation system model

III.SYSTEM Model

In this article, the downlink OFDMA transmission method is proposed in LTE-A network along with CA and two deployment scenarios are configured which include a set of eNBs and users are dispersed randomly in the network. Each eNB can serve the users with *n* CCs which composed of *m* physical resource blocks (PRBs) to carry data, each of which has 12 subcarriers in frequency domain with 15KHz and o.5 msec time slot in time domain. Additionally, the full buffer continuous data stream is considered. Proportional Fair downlink scheduling algorithm is performed at each TTI due to it pursues the maximum throughput and assure that none of users is starving. According to user CA capability, a multiple PRBs of a single CC can be assigned to LTE user while the eNB is capable to allocate numerous PRBs from multiple CCs to LTE-A user. Based on the channel conditions which may vary with time, the Channel Quality Indicator (CQI) for each user is evaluated individually on each PRB of each CC and sends back to eNB. The employed Adaptive Modulation and Coding (AMC) module in eNB will choose the suitable Modulation and Coding Scheme (MCS) to achieve the high data rate according to Channel Quality Indicator (CQI) reports [5].

IV. JUS-PF SCHEDULING ALGORITHM

In order to obtain the optimum system performance, the carrier scheduling algorithm which namely, Joint User Scheduling (JUS) as illustrated in Figure 2 is proposed in this research which consider throughput from the all CCs [6].

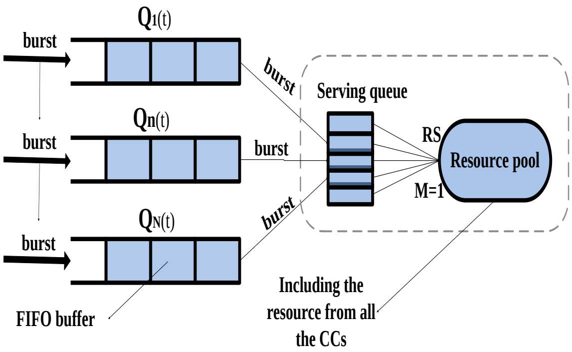

Fig. 2 Illustration of the JUS scheme

However, for the large number of CCs, the Proportional Fairness is more suitable PRBs allocation scheme that can compromise the trade-offs between the maximum throughput and fairness index, which ensures that no user is starved. Based on the priority function, the users are ranked and the resource scheduler allocates PRBs to the user with the highest priority metric on all CCs as follows:

$$k_{i,m} = arg_{k=1,2,....,K}\, max\,\{P_{k,i,m}\} \qquad (1)$$

Where $k_{i,m}$ is the selected user k at $i-\mathrm{th}$ CC of the $m-\mathrm{th}$ PRB. K is the total number of users and the PF metric $P_{k,i,m}$ of user k is as follows:

$$P_{k,i,m} = \frac{R_{k,i,m}(t)}{\overline{R_{k,total}}(t)} \qquad (2)$$

$R_{k,i,m}(t)$ is estimated data rate for user k at the $m-\mathrm{th}$ PRB group of the $i-\mathrm{th}$ CC at time slott. $\overline{R_{k,total}}(t)$ is user i throughput divided by the total of CCs and is calculated as:

$$\overline{R_{k,total}}(t) = \sum_{i=1}^{N} \overline{R_{k,i}(t)} \qquad (3)$$

Where $\overline{R_{k,i}(t)}$ is the average throughput for user on the $i-th$ CC. Hence an updated equation can be expressed as:

$$\overline{R_{k,i}(t)} = \left(1 - \frac{1}{T_{PF}}\right)\overline{R_{k,i}(t-1)} + \frac{1}{T_{PF}}\overline{R_{k,i}(t-1)} \quad (4)$$

Where by T_{PF} is the average proportional window length.

In JUS scheme, every LTE-A user needs to get a signal from all CCs concurrently, while some of them can just utilize a single CC for data transmission. This greatly increases the complication of the signal processing and the power consumption at UE's. In contrast, the LTE user is capable to allocate on a single CC. Meanwhile, the LTE-A users have more chances to get extreme bandwidth than LTE users.

V. DEPLOYMENT SCENARIOS

In this research, there are two deployment scenarios that have been studied and analyzed for LTE-Advanced system, they are as follows:

A. *All Users Support CA Feature*

In this deployment scenario, all users have the capability of assigning on more than one Component Carriers (CCs) as presented in Figure 3 (a). All CCs belong to the different 3GPP frequency bands. In different frequency bands, the used CCs have numerous broadcast features and the CCs coverage will be different. Nevertheless, prior to the transmission, the scheduler requests to identify the users' Channel Status Information (CSI).

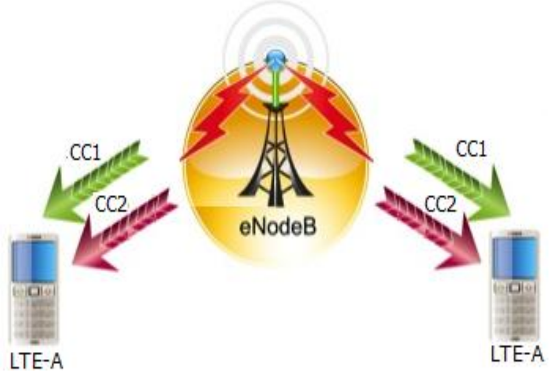

Fig. 3(a) LTE-A user's scenario

B. *Mixture (LTE/LTE-A)Users*

One of the most distinctive scenarios is assigning 50% of the users on more component carriers (CCs) and others for one random CC based on the users' capabilities as shown in Figure 3 (b). All CCs will fit to diverse 3GPP frequency bands and the users that support CA feature in this scenario are able to access more physical resources than others which improving their data rate.

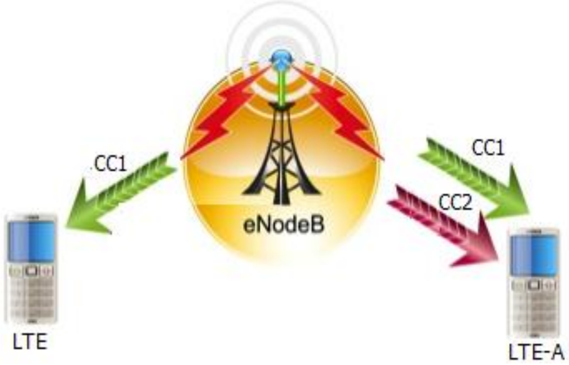

Fig. 3(b) Mixture (LTE/LTE-A) user's scenario

VI. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

A. *Simulation Model*

The LTE-Advanced downlink system-level simulator is carried out to evaluate the performance of JUS-PF scheduling algorithm. In the simulation, cluster of 7 tri-sector cells is proposed and the wireless channel is modeled including pathloss, shadow fading, and multipath fading. Moreover, there are three component carriers to be aggregated and the frequency of each CC is 2.14GHz, 2.4GHz and 2.6GHz. All the CCs possess the equal transmission power. The good signal to Interference in addition to the Noise Ratio Mapping (MIESM) model is utilized to add the SINR on every subcarrier to the RBs SINR. The Proportional Fair (PF) scheduling, with the window length average, T = 25 is considered in the simulation. Other parameters of the simulation are stated in Table 1.

Table 1. LTE-Advanced Simulation System Parameters

Parameter	Setting and Value
Cell Layout	Hexagonal grid, 7 cell-site, 3 sectors per eNB per CC
Number of users per sector	2,4,6,8,10,12
Aggregation configuration	3 CCs, with 20 MHz per CC
Subframe (TTI) Length	1 ms
MIMO Configuration	2×2 CLSM
CCs Scheduling Scheme	JUS
RBs Scheduling Algorithm	PF

Pathloss Model	Hata Model
Shadow Fading Model	Longnormal Fading Model
Modulation and Coding Scheme	QPSK, 16QAM, 64QAM
Granularity of Scheduling	1 TTI
Traffic Model	Full Buffer
UE Distribution	Uniform

B. Results Analysis

The performance of JUS-PF scheduling algorithm is appraised in this section based on the average user throughput, cell edge user throughput and fairness index.

Figure 4 shows that the average user throughput of LTE and LTE-A user decrease in both deployment scenarios with increasing number of users. The increase in the number of users leads to difficulty in meeting the bandwidth requirement. Since the same bandwidth resource (CC) needs to be divided among a higher number of users, then the bandwidth allocation for a specific user decreases. With an increasing number of users, the JUS-PF gives better average LTE-A user's throughput performance in mixture users' scenario when compared with the average LTE user's throughput in the same scenario and LTE-A users in the other scenario. This is due to the fact that the smallest number of packets to be lost due to higher bandwidth resource allocation for LTE-A users in mixture users scenario.

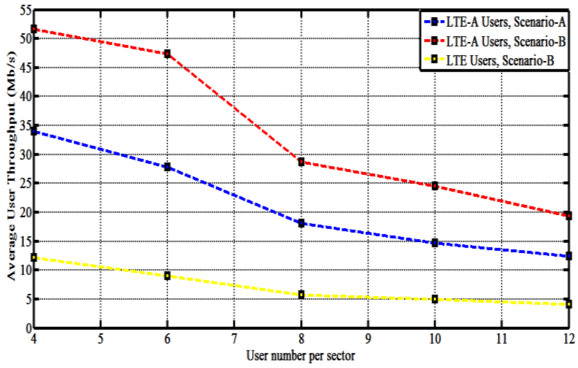

Fig. 4 Average user's throughput comparison

Figure 5 is the average throughput curve of the cell edge users of the two deployment scenarios. It can be seen that when using the JUS-PF, throughput of cell-edge user in LTE-A user's scenario is higher than the cell edge user in mixture user's scenario. The reason is that the cell edge users have less priority for allocating on radio resources. Moreover, LTE user has able to assign on a limited bandwidth "single component carrier".

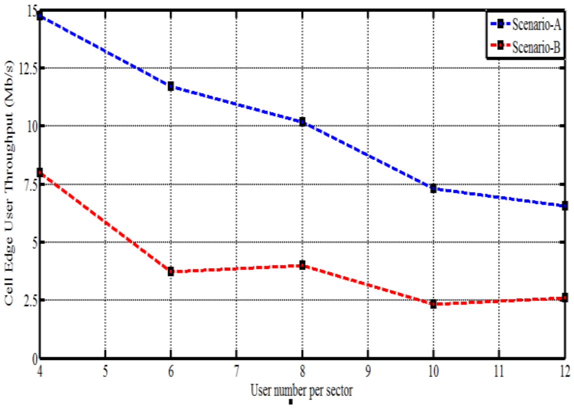

Fig. 5 Average throughput of cell edge users

It can be seen from the simulation results and analysis that the JUS-PF resource scheduling algorithm in LTE-A user's scenario is able to maximize the average user throughput with good level of fairness. On the other scenario, the JUS-PF has offered higher throughput to LTE-A users when compared with LTE users due to the user CA capability. However, it does not able to distribute system bandwidth fairly amongst diverse users.

Figure 6 shows the JUS-PF algorithm performance by fairness index with respect to the number of users for Full Buffer traffic flows. It can be noted by comparing the two deployment scenarios, that better performance was obtained for all users support carrier aggregation feature scenario over the mixture users' scenario because the users have able to use all resource blocks in all component carriers.

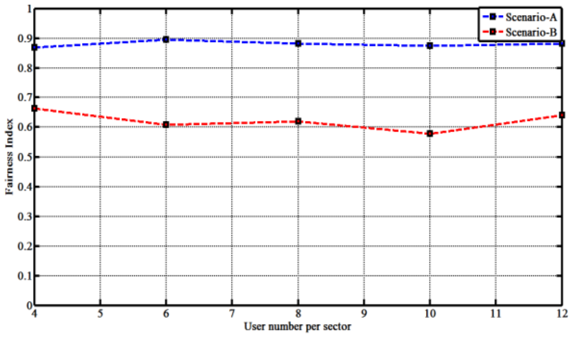

Fig. 6 Fairness index

VII. CONCLUSIONS

The embedded of carrier aggregation feature in LTE-A network is an influential trait that allows ultimate flexibility and effective use of frequency resources which resulted in significant improvement in user data rates even though the rate of improvement is slows down at higher traffic loads. The analysis of the JUS-PF radio resource allocation algorithm performance for two diverse deployment scenarios of different users' locations in the cell has shown that, the JUS-PF offers the optimum performance of LTE-A cell center users in both scenarios while the LTE and cell edge users have lower throughput. For this, the existing JUS-PF scheduling algorithm which based on channel variations should be improved by considering QoS requirements to offer sufficient fairness amongst different users.

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