



# RADIO RESOURCE SCHEDULING IN LTE-ADVANCED SYSTEM WITH CARRIER AGGREGATION

Mohammed Abdul Jawad M. Al-Shibly, Mohamed Hadi Habaebi and Md. Rafiqul Islam

Electrical and Computer Engineering Department, Faculty of Engineering, International Islamic University Malaysia, Gombak, Kuala Lumpur, Malaysia

E-Mail: [eng.mohammed1980@yahoo.com](mailto:eng.mohammed1980@yahoo.com)

## ABSTRACT

This study attaches the downlink radio resource allocation problem in the LTE-Advanced system by introducing an enhanced cross component carrier proportional fair algorithm. The importance of the study comes from the fact that almost all prior studies were not able to create a balance between the throughput and fairness of the system to optimize its efficiency. Therefore, this study attempts to overcome this difficulty by proposing an enhanced cross component carrier proportional fair algorithm in order to maximize the system throughput while at the same time maintaining fairness of radio resource allocation among all UEs. The simulation results show that the proposed algorithm exceeds the previous studies, which involves that the enhancement of the algorithm manages to guarantee a balance between increasing the average system throughput and maintaining good fairness among all UEs.

**Keywords:** LTE-Advanced, component carrier, carrier aggregation, and radio resource scheduling.

## INTRODUCTION

One of the main aims of the Long Term Evolution (LTE)-Advanced standard is to achieve a peak data rate of higher than 1Gbps in the downlink (DL) and 500Mbps in the uplink. The LTE-Advanced standard introduces a Carrier Aggregation (CA) as a new feature that will increase system capacity to support wider bandwidth up to 100 MHz [1-2]. The CA technology enables user equipments (UEs) to be scheduled on continuous and non-continuous Component Carriers (CCs) [3]. Moreover, UEs with different terminal classifications in the LTE-Advanced network may have access to only one CC or multiple CCs. Therefore, achieving the optimal throughput and maintaining fairness in a backward compatible LTE-Advanced system, where LTE-Advanced UEs should be able to coexist with the LTE UEs is considered the majority challenging task when it comes to packet scheduling algorithm.

Most of the prior studies suppose only one type of UEs [4-5]. However, one of the distinctive features of the LTE-Advanced system is the fact that it is backward compatible. Therefore, other studies have examined the packet scheduling algorithm in LTE-Advanced system with two types of UEs [6], mainly the LTE UE, which is constrained to accessing only one CC and the LTE-Advanced UE, which can simultaneously access multiple CCs. However, it can be observed that analytical modeling in such studies has so far either focused on giving priority for LTE UEs [4, 7-8] or providing priority for LTE-Advanced UEs. In contrast, the aim of this study is to strike the fairness between LTE-Advanced UEs and LTE UEs.

In order to enhance the system throughput without reducing the system fairness, an enhanced PF

(EPF) algorithm based on Cross-CCs PF is proposed. In this study, the linear balance factor is proposed to balance between LTE UEs and LTE-Advanced UEs system throughput in order to outperform the fairness between different categories UEs. The simulation results prove that the system performance of the proposed EPF algorithm can achieve better average system throughput without decreasing the fairness compared to the original Cross-CCs PF algorithm and improved Cross-CCs PF algorithm [6].

The rest of the paper is organized as follows. Section 2 presents the system model to be used in the LTE-Advanced network. Next, Section 3 provides the environmental settings of our simulation, as well as compares the simulation results of the proposed approach with the Cross-CC PF algorithm and improved algorithm [6]. Finally, conclusion is stated in Section 4.

## SYSTEM MODEL

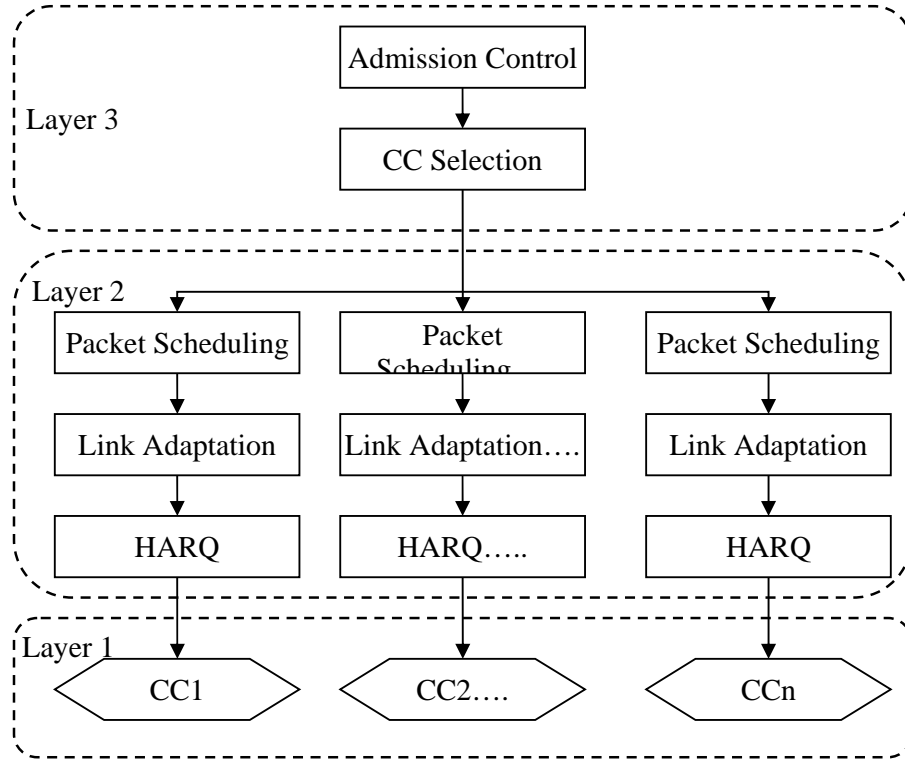
The system model that is employed in this paper includes two types of UEs, mainly LTE-Advanced UEs and LTE UEs. LTE-Advanced UEs will be assigned more than one CC simultaneously to maximize throughput and increase the UE experienced performance, whereas LTE UEs can only be assigned one CC. The structure of multiple CCs LTE-Advanced networks is shown in Figure-1.

The downlink non-continuous CCs LTE-Advanced system model consists of K UEs, L non-continuous CCs, and M Physical Resource Blocks (PRBs). The model in this study, each CC is located on a different frequency band with different radio nature (i.e. path loss and Doppler frequency shift). Thus, UEs which are located in different positions can be assigned various numbers of



CCs. This means that each LTE-Advanced UE can aggregate multi-CCs and each CC has the same bandwidth of physical resource blocks (PRBs). Therefore, an efficient radio resource scheduling algorithm is necessary in order to optimize system performance.

In this section, first the concept of the traditional Independent-CCs PF [7] and Cross-CCs PF algorithm [5] will briefly be demonstrated. Next, an EPF algorithm based on the Cross-CCs PF criterion will be presented. The PF algorithm in LTE-Advanced system can be implemented in two ways: Independent-CC and Cross-CC.



**Figure-1.** The structure of cell with non-contiguous inter band Multi-CCs scenario.

#### Independent packet scheduling per CC

The objective of the PF PS algorithm is to maximize system performance via maximizing the performance of the index metric as shown below [7]:

$$Metric_{k,l,m} = \frac{R_{k,l,m}}{\tilde{R}_{k,l}} \quad (1)$$

$$\tilde{R}_k(t) = (1 - \frac{1}{t_c})\tilde{R}_k(t-1) + \frac{1}{t_c}R_k(t-1) \quad (2)$$

$$k_{i,m} = \arg \max_{k,l,m} Metric_{k,l,m} \quad (3)$$

where  $Metric_{k,l,m}$  is the PF performance index metric that is used to select the UE  $K_{i,m}$  on the  $l^{th}$  CC at the  $m^{th}$  physical resource block (PRBs) by maximizing it.  $R_{k,l,m}$

and  $\tilde{R}_{k,l}$  are the estimated throughput and the average delivered throughput for UE  $K_{i,m}$  respectively.  $t_c$  is a time constant. The main limitation of this algorithm is the fact that it is identical to the packet scheduling algorithm used in a single carrier aggregation. Therefore, the poor performance of the Independent-CC comes from the critical unfairness between LTE-Advanced and LTE UEs.

#### Cross CCs packet scheduling algorithm

The Cross-CCs PF algorithm overcomes the drawbacks of independent CCs PF algorithm by using statistic average to maximize the system performance as shown in Equation (4) [5]:

$$Metric_{k,l,m} = \frac{R_{k,l,m}}{\sum_{l=1}^L \tilde{R}_{k,l}} \quad (4)$$



However, the main disadvantage of the Cross-CCs method is constraining the LTE-Advanced UE, since it will deal with its average data rate in the same way as dealing with one CC UE. In contrast to the above-mentioned studies, this study attempts to analytically examine the packet scheduling algorithm for different types of UEs with the aim of conducting verifying simulations to create a balance between average system throughput and fairness.

### Proposed EPF PS algorithm

Our enhanced PF algorithm attempts to strike a balance between the conventional PF and improved approaches [6]. This study introduces a new metric formula to assign UEs to CCs by using a linear balance factor to balance between system throughputs and fairness as follows:

$$Metric_{k,l,m} = \frac{R_{k,l,m}}{\left( \frac{\sum_{l=1}^L \tilde{R}_{k,l}}{F_k} \right)} \quad (5)$$

$$F_k = \frac{N_k}{N_i} \quad (6)$$

where  $N_k$  is the number of CCs assigned to UE<sub>k</sub> and it is varied based on the number of CCs that user actually operates on.  $N_i$  is the number of CCs that are available and it's varied based on the transmission channel characteristics such as distance and interference level for each CC.

### SIMULATION RESULTS

This section evaluates the performance of the EPF scheduling algorithm and benchmarks it against the results of the standard cross-CC PF algorithm, and the improved Cross-CC PF algorithm [6]. In simulation, there are two CCs which belong to different frequency band 800 MHz and 2.1 GHz. The percentage of the LTE-Advanced UEs form 50% of the total number of UEs. Most of the simulation parameters are based on the 3GPP LTE specifications [9] and summarized in Table-1. The Simulation results will express the major weaknesses of the afore-mentioned algorithms

In terms of average cell throughput, Figure-2 shows the average system throughput of EPF and abovementioned algorithms plotted against the LTE-Advanced UEs 50 percent based on a different number of UEs per cell. According to Figure-2, if the system adopted improved algorithm [6], the throughput of LTE-Advanced UEs are far larger than LTE UEs. On the other hand, if the system uses EPF algorithm, LTE UEs' throughput are just slightly less than that of the LTE-Advanced UEs. These results clearly show that the EPF algorithm strikes more balance between LTE UEs and LTE-Advanced UEs when compared to the improved [6] algorithm.

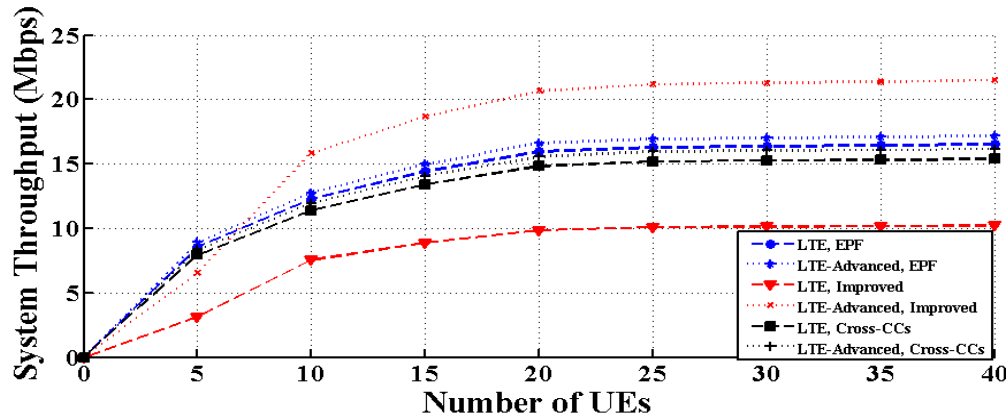
Figure-3 shows that both the enhanced EPF and Cross-CC PF algorithms outperforming improved Cross-CCs PF algorithms [6] in terms of fairness. In this regard, the simulation clearly shows that the novel EPF algorithm was able to remarkably outperform the improved PF algorithm [6]. This result further confirms the superiority of the proposed EPF PS algorithm. The fairness index [10] is defined as follows:

$$Fairness \quad Index(FI) = \frac{\left( \sum_{k=1}^K R_k \right)^2}{N \sum_{k=1}^K R_k^2} \quad (7)$$

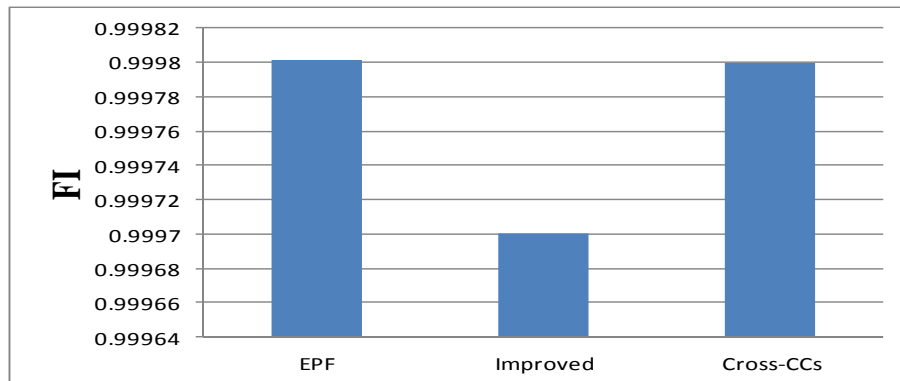
where  $R_k$  denotes the individual UE mean throughput and FI is the fairness index, which takes a continuous value between 0 and 1.

**Table-1.** System simulation parameters [9].

Parameter	Settings
Test scenario	7 hexagon cells
Cell distance	500 m
CC configuration	2 CCs at 800MHz and 2.1 GHz frequency, and 5 MHz per CC.
Number of PRBs per CC	25RB each CC
UE location	Uniformly dropped in all cells
UE speeds of interest	3km/h
Path Loss	$58.83 + 37.61 \log(10 R_n)$ $+ 21 \log(10 f_n)$
Shadow fading type	Lognormal



**Figure-2.** System throughput using EPF as compared to other PF algorithms with different numbers of UEs equally divided between LTE and LTE-Advanced UEs.



**Figure-3.** Fairness of the system using EPF as compared to other PF algorithms.

## CONCLUSIONS

The study has proposed a new radio resource scheduling algorithm for downlink LTE-Advanced networks by introducing a linear balance factor which is used to strike the balance between system throughput and fairness. The comparison of the proposed EPE Cross-CCs with other algorithms is carried out regarding average system throughput and fairness. The results have shown that the EPF algorithm can essentially balance between LTE UEs and LTE-Advanced UEs to outperform the fairness between different categories UEs.

## ACKNOWLEDGMENT

This work was funded by E-Science grant SF13-002-0052 from Malaysian ministry of Science, Technology and Innovation (MOSTI).

## REFERENCES

[1] Al-Shibly M. A. M., Habaebi M. H., and Chebil J. 2012. Carrier aggregation in long term evolution-

advanced. in Control and System Graduate Research Colloquium (ICSGRC), 2012 IEEE, pp. 154-159.

- [2] Holma H. and Toskala A. 2009. LTE for UMTS-OFDMA and SC-FDMA based radio access. John Wiley and Sons.
- [3] Yuan G., Zhang X., Wang W., and Yang Y. 2010. Carrier aggregation for LTE-advanced mobile communication systems. Communications Magazine, IEEE, 48(2), pp. 88-93.
- [4] Takeda K., Nagata S., Kishiyama Y., Miki N., and Tanno M. 2009. Effects of wideband scheduling and radio resource assignment in OFDMA radio access for LTE-advanced downlink. In Vehicular Technology Conference Fall (VTC 2009-Fall), 2009 IEEE 70th (pp. 1-5).



- [5] Wang Y., Pedersen K., Mogensen P. E., and Sørensen, T. B. 2009. Carrier load balancing methods with bursty traffic for LTE-Advanced systems. In Personal, Indoor and Mobile Radio Communications, 2009 IEEE 20th International Symposium on (pp. 22-26).
- [6] Nguyen S. C., and Sandrasegaran K. 2012. Optimised proportional fair algorithm for longterm evolution-advanced system with multiple component carriers. Communications, IET, 6(11), pp. 1579-1586.
- [7] Chen L., Chen W., Zhang X., and Yang D. 2009. Analysis and simulation for spectrum aggregation in LTE-Advanced system. In Vehicular Technology Conference Fall (VTC 2009-Fall), 2009 IEEE 70th (pp. 1-6).
- [8] Songsong S., Chunyan F., and Caili G. 2009. A resource scheduling algorithm based on user grouping for LTE-advanced system with carrier aggregation," in Computer Network and Multimedia Technology, 2009. CNMT 2009. International Symposium on, pp. 1-4.
- [9] 3GPP TR 36.211 V10.3.0. "E-UTRA physical channel and modulation", September 2011.
- [10] Jain R., Chiu D.-M., and Hawe W. R. 1984. A quantitative measure of fairness and discrimination for resource allocation in shared computer system: Eastern Research Laboratory, Digital Equipment Corporation Hudson, MA.