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FAIR SCHEDULING ALGORITHM IN LTE-ADVANCED NETWORKS

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ABSTRACT
The Long Term Evolution Advanced (LTE-Advanced) transmission bandwidth can be expanded by Carrier Aggregation (CA), where CA technology expands effective bandwidth supported to User Equipment (UE) by utilizing of radio resources across multiple carriers. Recently, many studies have been conducted on the radio resource allocation with CA. However, most of these studies are based on Proportional Fair (PF) packet scheduling algorithms. Indeed, these algorithms are not adequate to meet the requirements for supporting mixture real-time applications; they ignored channel condition; and finally, they are unable to support real-time application with delay constraint. Therefore, this paper proposes novel Packet Scheduling (PS) condition algorithm that attractively enhances the average system throughput by designing a weighting factor to modified largest weighted delay first PS algorithm. The novel algorithm is implemented in a PS module for LTE-Advanced via system level simulations. The results demonstrate that the effectiveness of enhanced Modified Largest Weighted Delay First (M-LWDF) algorithm in improving throughput.

Keywords: scheduling algorithm, LTE-advanced, component carriers aggregation.

1. INTRODUCTION
The support of a peak data rate greater than 1Gbps in the downlink is considered as the target of LTE-Advanced System. To achieve this requirement, LTE-Advanced has established carrier aggregation (CA) technology as a new feature to expand the system bandwidth up to 100 MHz [1]. CA is one important feature to increase system capacity and performance across multiple component carriers (CCs). By using CA technology, a user can be scheduled on continuous or non-continuous CCs [2]. LTE-Advanced networks are also necessitated to be backward compatible, so that user equipments (UEs) may have access to only one or multiple CCs, depending on their classification category [3].

Lately, many studies have been focusing on the radio resource allocation with CA system, such as [2]. Most of these works based on PF packet scheduling algorithm. However, these algorithms were not adequate to meet the requirements for supporting mixture real-time applications because they only considered delay constraint while they ignored channel condition or being unable to support-real time application with delay constraint [4]. In order to overcome the above limitation, The Modified Largest Weighted Delay First (M-LWDF) [5, 7-10] is an extension of LWDF [6] and supports constrained packet delivering delay. However, the main disadvantage of the M-LWDF algorithm will restrict LTE-Advanced UE; therefore its average data rate is same as a single CC UE.

Therefore, based on the limitation of the previous algorithms, this paper proposes novel packet scheduling algorithm namely Enhanced M-LWDF (EM-LWDF) packet scheduling algorithm that absolutely responds to that aim and best outfits for LTE-Advanced network CA. The enhanced algorithm takes into account the different frequency band, and could guarantee the throughput.

The organized of this paper is as follows. The system model of the multiple CCs network and the proposed EM-LWDF algorithm is described in Section 2. The performance evaluation of the proposed algorithm via system level simulation is provided in Section 3. Finally, the conclusion of the paper is presented in Section 4.

2. SYSTEM MODEL
LTE-Advanced network has two kinds of UEs: LTE-Advanced and LTE UEs. A LTE-Advanced UE will be assigned on more than one CC to maximize throughput and increase the UE experienced performance.

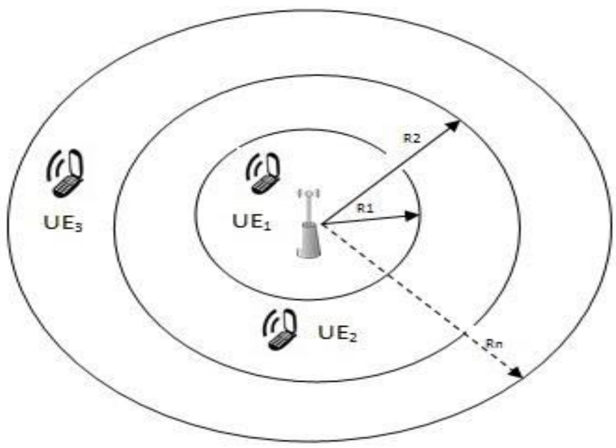

Figure-1. The structure of cell with non-contiguous inter band Multi-CCs scenario.

The CCs scenario in this paper is non-continuous where varied CC is located on different frequency band which have different radio's nature, for example path loss and Doppler frequency shift. Therefore, CCs in higher frequency band have bigger pathless, so far CCs in lower frequency band have wider coverage, UEs located in different positions can select various numbers of CCs as shown in Figure-1.

Firstly, the concept of the standard M-LWDF [7-10] M-LWDF algorithms [11] is briefly discussed. Then, an enhancement packet scheduling algorithm based on the M-LWDF criterion is demonstrated.

a) M-LWDF Algorithm Description

In LTE-Advanced real time application, eNodeB usually keeps multiple qualities of service classes indicators (QCI) of traffic session connections with UEs. A scheduler in the eNodeB will manage one session queue per class of traffic session per UE and decide the scheduling order by a priority index metric. Generally, the scheduling priority metric can be a function of Channel Quality Indicator (CQI), QoS requirements, session queue's state or information related to the packet in the head of line (HOL).

M-LWDF algorithm is dedicated for RT services. The scheduling decision of the M-LWDF algorithm depends on both current channel states and the states of the queues. The scheduling metric formulation is [7-10]:

$$Metric_{k,i,j} = a_k \frac{r_{k,i,j}}{\sum_{i=1}^{N} \widetilde{R}_{k,i}} D_{HOL_k} \quad (1)$$

$$a_k = -\frac{\log(\delta_k)}{T_k} \quad (2)$$

$$k_{i,j} = \arg_k \max Metric_{k,i,j} \quad (3)$$

Where Metric k, j, i is the M-LWDF performance index metric is used to select UE $K_{i,j}$ on the i^{th} CC at the j^{th} physical resource blocks (PRBs) by maximizing it. $r_{k,I,j}$ and $\widetilde{R}_{k,i}$ is the estimated throughput and the average delivered throughput for UE $K_{i,j}$, respectively. $D_{HOL\ k}$ is the HOL packet delay, and δ_k is the probability of the unvalued delay. T_k is the delay which is tolerated by UE_k. However, this is a difficulty of M-LWDF algorithm that might make it infeasible. There are two UEs– one LTE and one LTE-Advanced – with the identical channel quality indicator (CQI) overall transmission duration, their data rates in all PRBs are assumed identical. In the case that LTE-Advanced UE wants to be allocated any PRBs, so that its performance index metric must be greater than LTE UE's metric. As a result, this is not possible due to the use of the statistic in eq.(1). Hence, overall the period of a connection, the LTE-Advanced UEs' average data rate will not be able to exceed the LTE UE average data rate. In order to solve this problem, authors in [11] proposed a new metric formula which gives a biased continuous priority for LTE-Advanced UEs over LTE UEs at any time. Our PS-enhancement algorithm challenges to strike a balance between both approaches.

b) Proposed PS Algorithm

Our PS-enhancement algorithm attempts to strike a balance between the M-LWDF [7-10] and modified [11] approaches. If the average data rate of LTE-Advanced UE is greater than average data rate of LTE UE, but the available CCs is less than or equal number UEs. Then, LTE-Advanced UEs will not be allocated favorably any extra PRBs. Instead, LTE-Advanced UEs are treated equally just like LTE UEs. Once the number of CCs becomes greater than the number of UEs, our PS-enhancement algorithm is triggered using the following new metric formula to assign UEs to CCs as following:

$$Metric_{k,i,j} = a_k \frac{r_{k,i,j}}{\left(\frac{(\sum_{i=1}^{N} \widetilde{R}_{k,i})}{W} \right)} DHOL_k \quad (4)$$

$$W = \frac{N_k}{N_i} \quad (5)$$

where N_k is the number of CCs assigned to UE k^{th} and it is changed according to the number of component carriers that UE 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.

3. SIMULATION RESULTS AND ANALYSIS

The evaluation performance of the EM-LWDF algorithm and benchmark against standard M-LWDF algorithm is shown in this section. First, the simulation parameters and assumptions for DL of LTE-Advanced system and the definitions are given before the discussion results. The majority of the parameters are based on the 3GPP LTE specifications [12].

a) Simulation Parameters

1. Cells topology: A scenario of 7 cells is supposed, where each cell is divided into three 120^{o} sectors. The Site-to-site distance is 500 m radius and UEs are uniformly distributed in the cell.
2. Carrier aggregation pattern: Two CCs are aggregated in the frequency bands of 800 MHz and 2.1 GHz. The operation bandwidth per CC is 5 MHz with the equal transmitting power.
3. Wireless channel model: it is modeled counting path loss, shadowing fading and multipath Rayleigh fading.
4. Traffic model: The static UEs population traffic model is supposed.
5. Transmission time intervals (TTIs): The window length T is 100 TTIs in the simulation.

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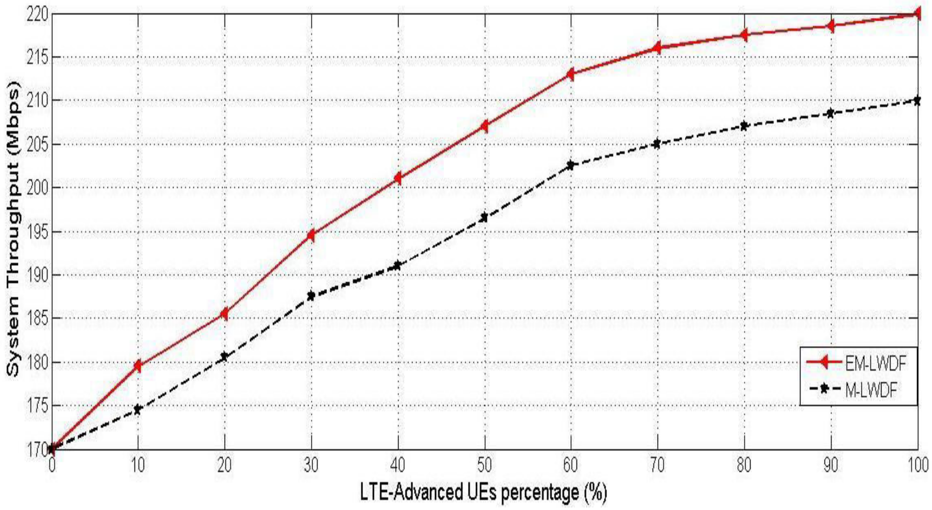
Additional simulation parameters are listed in figure-2.

Table-1. Average system throughput of EM-LWDF algorithm as compared to M-LWDF. The performance is evaluated with 40 UEs/cell with different ratios of LTE-Advanced UEs.



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/CC.
Number of PRBs per CC	25RB per CC
UE location	equally distributed in all cells
Traffic Model	real-time traffic
Path Loss	58.83 + 37.61 log(10 R_n) + 21 log (10 f_n)
Shadow fading type	Lognormal

Figure-2. Simulation Parameters [12].

RESULTS AND ANALYSIS

The performance of EM-LWDF scheduling algorithm against standard M-LWDF algorithm is evaluated and benchmarked in this section. The Simulation results state the major weakness of traditional M-LWDF algorithm. Table-1 illustrates the average system throughput overall cells of EM-LWDF and M-LWDF algorithms plotted against the LTE-Advanced UEs percentage from the total number of UEs of 40 per cell. When each UE in the cells is LTE (i.e. the LTE-Advanced UEs ratio is 0%), the average cell throughput is lower compared to the case when each UEs in the cells is LTE-Advanced (with ratio 100%). The result is reasonable where novel algorithm liberate the transmission capacity of LTE-Advanced UEs so it could twice its data rate since the UEs use CA.

CONCLUSIONS

An enhanced PS algorithm is proposed in this paper and validated to M-LWDF algorithm for a LTE-Advanced network. The M-LWDF scheduler is further enhanced by introducing a linear weighting factor wk which is used to adjust the priority of packet scheduling between UEs that have different channel qualities and different abilities in accessing the CCs. The results show that EM-LWDF algorithm essentially enhances the average throughput of LTE and LTE-Advanced UEs.

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