

System Level Performance Evaluation of Various Carrier Aggregation Scenarios in LTE-Advanced

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Abstract— The LTE-Advanced as an enhanced form of the LTE standardized at the 3GPP, is a promising technology for a higher spectral efficiency and reliable transmission. Carrier aggregation (CA) is the most important one among other technologies since it is difficult to ensure a single wide frequency band for operators. Despite active standardization of CA, little studies for system level performance have been made. This paper evaluates the performance of CA schemes in deployment scenarios 1 and 2 with different inter-site distances by using a LTE-A based system level simulator. Round robin and proportional fair schedulers are adopted for performance evaluation. The simulation results can help to provide an appropriate guideline for CA deployment and management in upcoming B4G mobile communications.

Keywords— carrier aggregation, scheduling, system level performance, LTE-Advanced

I. INTRODUCTION

In order to meet the demand for mobile communication services with increasing number of users, mobile communication has developed rapidly. The next generation mobile communication systems, entitled fourth-generation (4G) mobile systems or LTE-Advanced, is undergoing a standardization process. In 3GPP LTE-Advanced, there are promising technologies, e.g., enhanced MIMO, CoMP, eICIC, CA that can provide a higher spectral efficiency and reliable transmission [1]. Carrier aggregation (CA) has been considered as the most important technology among other technologies, where more than one component carriers are aggregated to support a higher data rate. The CA technology increases the affinity of the operators since it is difficult to ensure a single continuous wide frequency band. Many CA deployment scenarios and CA combinations have been suggested.

While standardization of CA has been progressed actively, little studies for system level performance have been made. This paper analyses the performance of various CA scenarios, by using a system level simulator. We added functionality to the existing system level simulator [8], [9]. The performance is evaluated in term of per-UE average throughputs and cell spectral efficiency with CA deployment scenarios 1 and 2. In particular, we investigate the impact of inter-site distance and carrier frequency by applying practical specific antenna patterns. This study can provide an appropriate guideline for

possible CA combinations and operations in upcoming B4G mobile communications.

The paper is organized as follows: in Section 2 the concept of CA and CA deployment scenario will be introduced, after which we explain the CA system level simulator configuration including specific antenna pattern and scheduler algorithm in Section 3. With and without the CA technique, simulation results are presented and discussed in Section 4. Finally, the conclusions are drawn in Section 5.

II. CARRIER AGGREGATION

The CA has been proposed to aggregate two or more component carriers (CCs) for supporting high data rate transmission over a wide bandwidth (up to 100MHz), while preserving backward compatible with LTE Release 8/9 [2]. In general, CA may be used in three different spectrum scenarios [3]-[6]. With an intra-band contiguous CA, a contiguous bandwidth wider than 20MHz is used for CA. With an intra-band non-contiguous CA, multiple CCs belonging to the same band are used in a non-contiguous manner. Multiple CCs belonging to different bands are used for an inter-band non-contiguous. In case of inter-band non-contiguous downlink CA, band1 (2110MHz~2170MHz) and band5 (869MHz~894MHz) have been taken into account in Release 10, and the standardization for a larger number of combinations have been proceeded in Release 11. Since a variety of frequency combinations have been suggested, it is necessary to categorize CA combinations and select the priority.

The CA deployment scenarios for two component carriers at frequencies of F1 and F2 are presented ($f_2 > f_1$) [7]. Deployment scenario 1 is that cells with carrier frequencies of F1 and F2 are overlaid with F1 and F2 in the same band. In this case, almost the same coverage is provided on both carriers due to the similar path loss within a same band. Deployment scenario 2 is that cells with carrier frequencies F1 and F2 are overlaid, where F1 and F2 are in different bands. Unlike the scenario 1, the coverage of each frequency is different. Deployment scenario 3 is that the antennas for cells of F2 are directed to the cell boundaries of F1 to improve the cell edge data rate and throughput. Deployment scenario 4 is that cells of carrier frequency F1 provide macro coverage, and remote radio heads of carrier frequency F2 are used to improve throughput at hot spots. Deployment scenario 5 is

that similar to deployment scenario 2, frequency selective repeaters are additionally deployed.

III. SIMULATION MODEL

A. Simulation Parameter

For CA simulation, system level simulator is set as follows. Seven cells, each of which is divided into three sectors are considered, and 20 users randomly placed per sector. In order to analyze the performances of CA deployment scenarios 1 and 2 with different inter-site distances, two CCs with 10MHz bandwidth in 800MHz band and 2100MHz band respectively are aggregated. Both CC1 and CC2 are simulated in 800MHz band or 2100MHz band in CA deployment scenario 1, while CC1 and CC2 are simulated in 800MHz band and 2100MHz band respectively (and vice versa) in CA deployment scenario 2. The inter-site distances of 500m and 1732m are used. Other simulation parameters are given in Table 1.

TABLE 1. SIMULATION PARAMETERS

Parameters	Value
Carrier frequency	800MHz, 2100MHz
Bandwidth	10MHz
Network configuration	7cell(site)/3sector
Path loss model	HATA model
Shadowing std	10dB
Penetration loss	20dB
Transmit power	46dBm
Number of Tx/Rx antenna	2/2
Noise figure	9dB
Transmission mode	CLSM
Channel model	PedB
HARQ process	IR
Averaging algorithm	MIESM

TABLE 2. ANTENNA PATTERN PARAMETERS

Parameters	800MHz band	2100MHz band
Gain (average) (dbi)	14.1	17.2
Front-to-back ratio	>30dB	>32dB
Horizontal beamwidth	68°	61°
Vertical beamwidth	16.5°	6.7°
Electrical downtilt	7°	7°

For CA simulation, we use a practical dual antenna. Other antenna parameters are set according to 800MHz band and 2100MHz band. Since we assume the dual antenna, 800MHz band and 2100MHz band antenna have the same physical size. Therefore, the antenna gain is better in 2100MHz band than 800MHz band. The detail antenna parameters are given in Table 2. For system level simulation, antenna patterns in msi

or pln file format, offered by antenna manufacturers, are applied.

B. CA Scheduler

This paper used Round Robin scheduler and Proportional Fair scheduler in system level simulations. We used two general types of CA Proportional Fair schedulers for performance evaluation with different inter-site distances.

Figure 1 shows the detailed procedure for CA Proportional Fair scheduler. In case of CA proportional fair scheduler 1, scheduling is performed for each of CC independently. For every CC, throughput is calculated per TTI, determining appropriate average user throughput. However, in the period of being scheduled, exchanging of information between CCs is not possible, leading the scheduling performed independently. In contrast, CA Proportional Fair scheduler 2 proceeds as if there is only one wide bandwidth. First, scheduling of CC1, referred as primary CC, is processed in each resource block. As soon as this tasks finish, information of updated average user throughput for proportional fair scheduling is sent to CC2, enabling CC2 scheduled as if it is contiguous bandwidth.

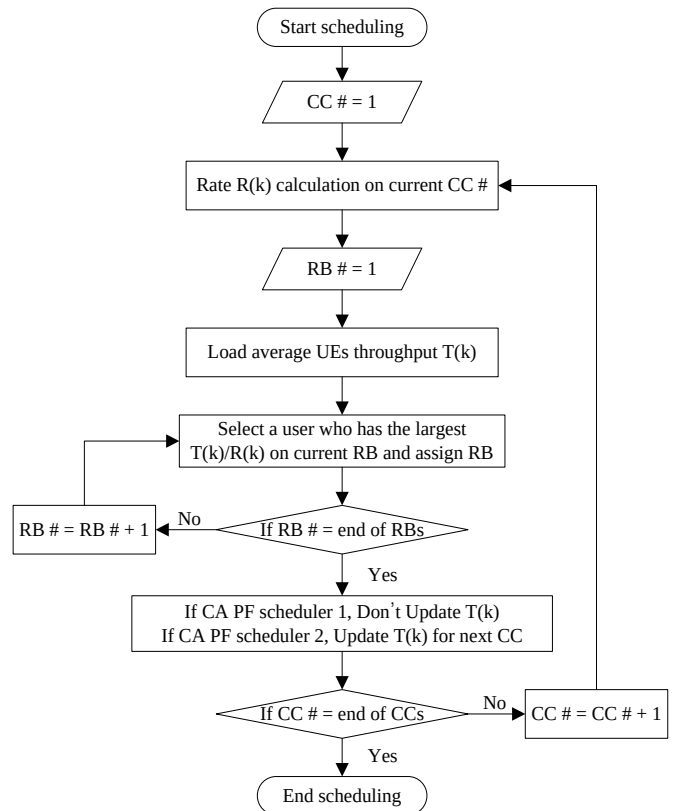


Figure 1. Flow diagram for the CA Proportional Fair scheduler

IV. SIMULATION RESULTS

A. Single Carrier Results

When only a single carrier is used, which is called no CA situation hereafter, 800MHz band and 2100MHz band are considered with different inter-site distances (ISDs). Figure 2

shows the cell spectral efficiency in no CA situation. In case of ISD=500m, it shows the performance is better in 2100MHz band than in 800MHz band regardless of the scheduler. Due to a larger path loss exponent in 2100 MHz band, less interference from neighboring cells is generated compared to 800MHz band. However, in a large inter-site distance case, interference limitation has little effect on both cases, but effect of noise becomes larger, causing noise limited situation. Therefore, in case of ISD=1732m, the performance is better in 800MHz band than in 2100MHz band owing to a lower path loss.

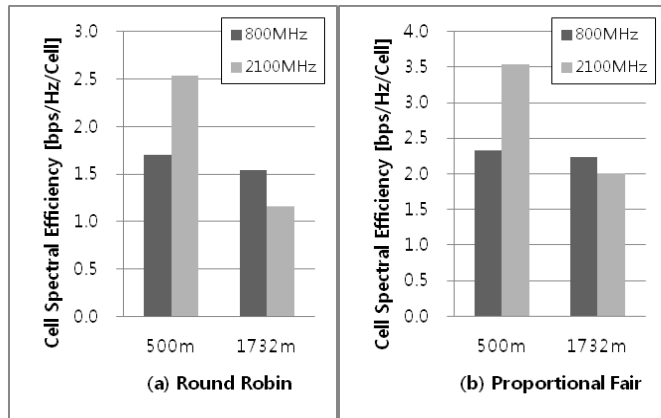


Figure 2. Cell spectral efficiency for inter-site distance and center frequency with (a) Round Robin and (b) Proportional Fair scheduler

B. Carrier Aggregation Results

In CA deployment scenario 1, both CC1 and CC2 using frequency of 800MHz band or 2100MHz band. In CA deployment scenario 1, the results show the same trend as in non-CA case. The average user throughput is roughly doubled in this scenario. When using CA in scenario1, no additional gain is obtained except doubled user throughput with doubled bandwidth. It only has advantage of larger bandwidth available. In order to show the effect of CA, Figure 3 shows average user throughput color map for inter-site distance of 500m.

In CA deployment scenario 2, two cases are considered; case 1 in which CC1 uses 800MHz band while CC2 uses 2100MHz band and case 2, in which CC1 uses 2100MHz band while CC2 uses 800MHz band. Figure 4 shows the cell spectral efficiency in CA deployment scenario 2. In case of Round Robin scheduler, a worse performance can be observed with a large inter-site distance as with Proportional Fair scheduler (CA Proportional Fair scheduler 1 in section III.B).

However, in case of CA Proportional Fair scheduling no matter what inter-site distance being considered, 2100MHz band always shows a better performance in Figure 5. In case of CA Proportional Fair scheduler 1, each CC undergoes scheduling independently but average throughput is acquired per TTI in both CCs. Therefore, the CC in 800MHz band has a smaller average user throughput than expected due to the CC in 2100MHz band. The smaller average user throughput may worsen the scheduling performance. In contrast, the CC in 2100MHz band is able to acquire a higher average user

throughput than expected without CC, which results in a better performance regardless of inter-site distance.

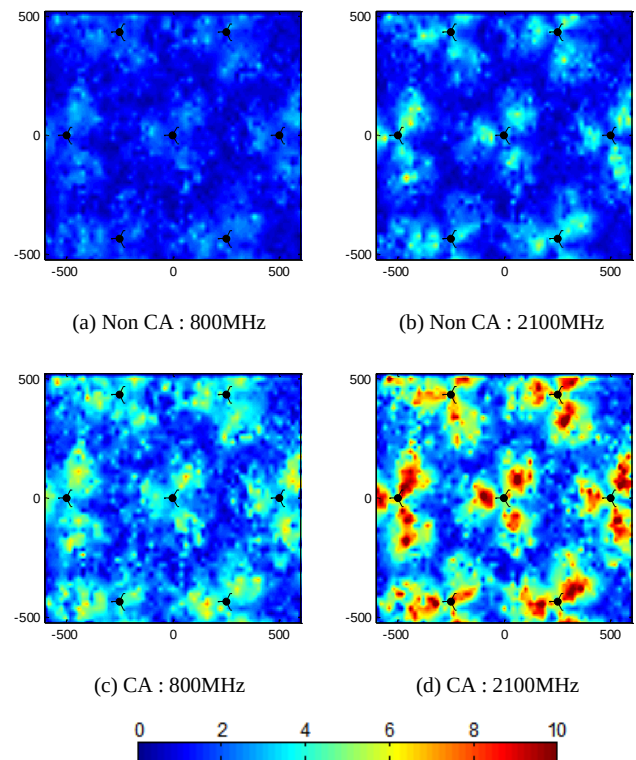


Figure 3. User throughput [Mbps] color map obtained through system level simulations with an inter-site distance of 500m in CA deployment scenario 1.

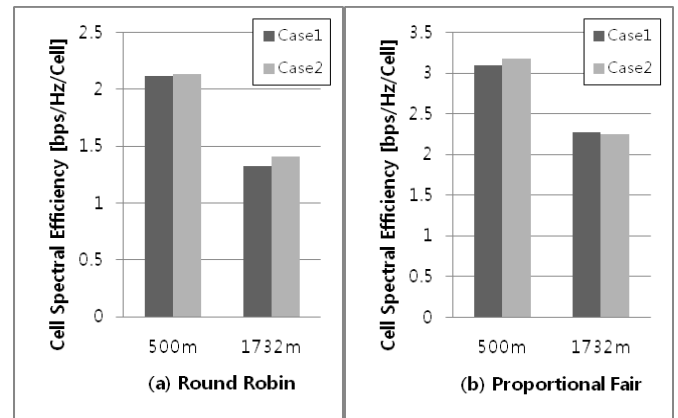


Figure 4. Cell spectral efficiency (a) Round Robin and (b) Proportional Fair scheduler in CA deployment scenario 2. Case 1, in which CC1 uses 800MHz band and CC2 uses 2100MHz band, and Case 2, in which CC1 uses 2100MHz band and CC2 uses 800MHz band.

In case of CA Proportional Fair scheduler 2, it is shown that with an inter-site distance of 1732m, the performance CC1 in 2100MHz band and CC2 in 800MHz band is better than the other case. It should be noted that the coverage of the CC in a high frequency band is smaller than that in 800MHz band. In other words, it is beneficial that the CC in 2100MHz band is allocated for users in the center of cell while the CC in

800MHz band is allocated for cell-edge users. If the CC in 2100MHz band becomes CC1 and is scheduled first, the probability of allocating a larger amount of resource blocks for cell-center users increases. If the CC in 800MHz band is scheduled first as the CC1, the amount of average user throughput for cell-center users increases, which causes the resource blocks of the CC2 in 2100MHz band less probable for cell-center users. So, the case2, in which the CC in 2100MHz band is CC1 shows a better performance. With an inter-site distance of 500m, since the coverage of 2100MHz band is enough, this performance gain is very small.

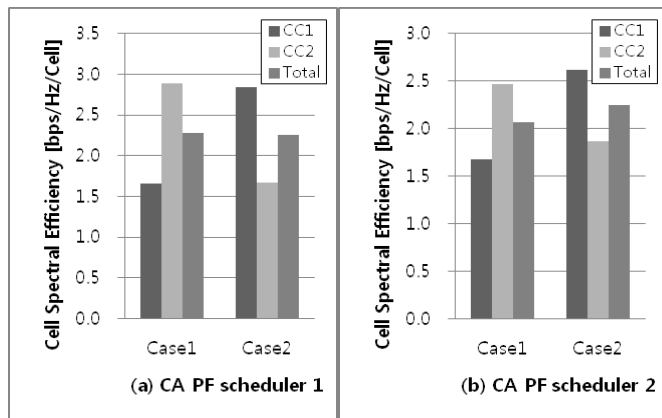


Figure 5. Cell spectral efficiency (Inter-site distance of 1732m. CA Proportional Fair scheduler in CA deployment scenario 2). Case 1, in which CC1 uses 800MHz band and CC2 uses 2100MHz band, and Case 2, in which CC1 uses 2100MHz band and CC2 uses 800MHz band.

V. CONCLUSION

We evaluated the performance of CA deployment scenario 1 and 2 with different inter-site distances by using a LTE-A based system level simulator. The CA deployment scenario 1 has no additional advantage when compared with the case of non CA. The CA just has an advantage of larger bandwidth

available. The CA deployment scenario 2, however, shows a scheduling gain when a practical antenna pattern is adopted in each frequency band. If we use a proper scheduling algorithm, this gain is expected to be larger. The simulation results help to decide an appropriate guideline for CA combinations and operations.

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