

A SPF-PF crossing Component Carrier joint scheduling algorithm

ZHAO Ji-hong^{1,2}, LI Hui², Qu Hua¹

¹*School of Electronic Information, Xi'an Jiaotong University, Xi'an, Shannxi 710049, China*

²*Department of Communication Engineering, Xi'an University of Posts and Telecommunications, Xi'an, Shannxi 710061, China*

Email:tg0506hui@126.com

Abstract— When adopting Carrier Aggregation (CA) in the LTE-Advanced Systems, it needs Joint Scheduling crossing multiple Component Carrier. For Component Carrier (CC) located in different frequency band, this issue presented a new Component Carrier selection algorithm-Similar Proportional Fairness (SPF) algorithm which is based on traditional scheduling algorithm of Proportional Fairness (PF) in crossing CC joint scheduling. It could calculate the users' selection weight on each Component Carrier, then combine it with PF scheduling algorithm and calculate the ultimate scheduling weight on each resource block, and allocate the resource finally. The result of simulation shows that crossing CC joint scheduling could greatly improve the throughput of the system, and compare with pre-existing Component Carrier selection algorithm, the propositional method has well fairness.

Keywords— Carrier Aggregation ; similar proportional fairness; scheduling weight;selection weight; Crossing CC joint scheduling

I. INTRODUCTION

In order to achieve the request of future global mobile communication , the 3rd generation Partnership Project proposed the 4th global mobile communication system of LTE-Advanced which is beyond the 3rd generation system. It needs heavy bandwidth in LTE-Advanced system, but the resource of frequency spectrum is insufficient. For this reason it proposed Carrier Aggregation in LTE-Advanced system, which aggregated two or more Component Carriers which belong to the same range of frequency band or different range of frequency band, and it must be compatible with 3G/LTE[1][2].

In Carrier Aggregation, there are two ways of aggregation: continuous and discontinuous. As the current situation, the most of frequency spectrums which could be aggregated are decentralized and belong to different range of frequency band. Therefore in order to use frequency spectrum flexibly, it should lay stress on the discontinuous carrier aggregation [3].

When adopting CA in LTE-Advanced system , it needs to further consider resource scheduling, and the researchers proposed crossing CC scheduling. Compared with pre-existing scheduler, the crossing CC scheduler is able to cross multiple CC to allocate resource for users, so at first it must select CC for users. At present there are two primary CC selection methods: one is Crossing CC Joint Scheduling (CCJS) which allocates all CC to each user, it has highest spectrum

efficiency, but with the increase of CC number the complexity of scheduling will be higher. And another one is Crossing CC Separate Scheduling(CCSS) which just select one CC for one user during one scheduling period, this method is simple , but the spectrum efficiency is low. The above both methods are suitable for continuous CA rather than discontinuous CA. However if it aggregates higher-frequency CC and lower-frequency CC, for guaranteeing the cell coverage and well system performance, the system should scheduling on the basis of the different radio wave propagation characteristics of different frequency band.

Therefore according to limitation of the above methods , we proposed a SPF-PF crossing CC joint scheduling algorithm, it considers the different radio wave propagation characteristics of different frequency band, and could ensure the throughput, further more it has good fairness of resource allocation. This method uses SPF algorithm to select CC for users , it neither selects all CC to each user, nor selects only one CC to one user, but combines each CC's spectrum characteristic with the user's location characteristic and selectively calculates each user's selection weight on certain CC, then adopts PF algorithm to allocate Resource Block (RB) on each CC for users.

The paper is organized as follows. In Section II ,it provides the system model of SPF-PF algorithm. Section III describes the CC selection algorithm of SPF. In Section IV , the RB allocation algorithm of SPF-PF is provided. Section V presents the simulation result and performance analysis. Finally Section VI concludes this paper.

II. THE SYSTEM MODEL

In crossing CC joint scheduling based on SPF-PF algorithm , a user can transmit data on the resource blocks of different CCs. When the scheduler is allocating resource, it uses SPF algorithm to choice CC on the basis of the CC's physical propagation characteristic and the user's geographic position, then employ the PF algorithm to allocate the CC's RBs for users, as shown in Figure 1 shows.

Supposed there are M users, n CCs in different frequency bans, each CC has same bandwidth and contains N RBs. The CC_k 's frequency is f_k and its coverage radius is R_k , there are $f_1 < f_2 < f_3 < \dots < f_n, R_1 > R_2 > R_3 \dots > R_n$.

The CCs in different frequency band have different wireless channel conditions, for example path loss and Doppler frequency shift. Because the CCs in lower frequency band can coverage wider range, yet the CCs in higher frequency band can coverage narrower range[6][7], different UEs located in

different position can select various number of CCs. As shown in Figure 2(a), UE1 has right to use RBs on the CC1~CCn, UE2 can occupy RBs on CC1 and CC2, but UE3 just can select RBs on CC1. That is only located in the CC's coverage range could the UE has the right to occupy the CC.

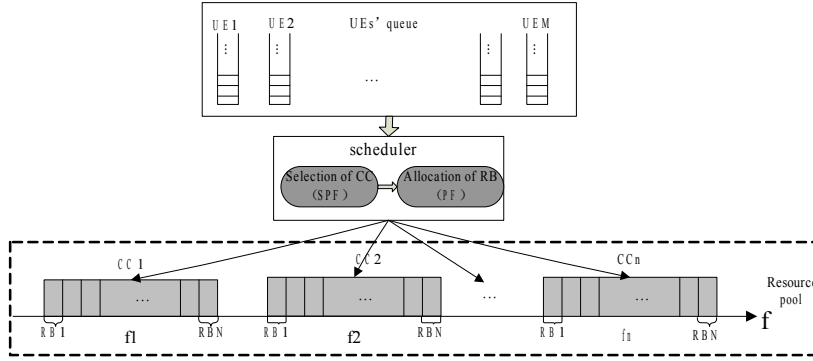


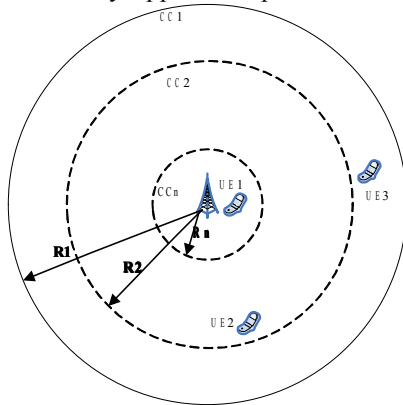
Figure 1. system model of crossing CC joint scheduling based on SPF-PF algorithm

III. THE SPF CC'S SELECTION ALGORITHM

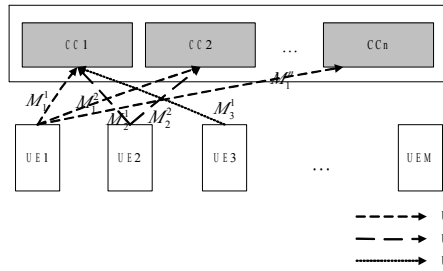
Because the UEs' distance of eNB is random distribution in the cell and various, and when the UEs request resource in the different frequency band for transmission, the traditional CC selection methods will not only appear the problem of load

imbalance and make the band frequency efficiency lower, but also because of the various number of UEs' available CCs, the random resource allocation will influence the fairness [8].

The SPF algorithm considers the fairness, and calculate i 'th UE's selection weight M_i^k on the k 'th CC, as shown in Figure 2(b).



(a) the coverage characteristic of CCs



(b) UE's selection weight on CCs in SPF algorithm

Figure 2. the system model and the selection way of SPF

In order to determine the UE's available CCs, it must satisfy the CC's coverage requirement, so the maximum path loss on a CC can not be higher than a threshold L_{th} and the SPF algorithm as follows:

①The i 'th UE's path loss on the k 'th CC can be calculated as

$$L_i^k = 58.83 + 37.6 \log(10d_i) + 21 \log(10f_k) \quad (1)$$

Where d_i is the distance between UE_i and eNB, f_k is the frequency of the k 'th CC.

The coverage radius of the k 'th CC, denoted as R_k , can be calculated by

$$58.83 + 37.6 \log(10R_k) + 21 \log(10f_k) = L_{th} \quad (2)$$

②According to d_i to decide if the UE_i has right to use the RBs of the CC_k , Ω_k is the set of UEs who can occupy resource of the CC_k , described as follows:

$$\Omega_k = \{i | d_i < R_k, 0 < i < m\}, 1 \leq k \leq n \quad (3)$$

Statistic the number of UEs who can occupy resource of the CC_k , denoted as Num_k ;

Under the situation of exactly fair, each CC can service

$$\bar{N} \text{ UEs and } \bar{N} = \frac{Num_n}{n}.$$

③ The UE_i 's selection weight, denoted as M_i^k , can be described as:

$$M_i^k = \begin{cases} \frac{L_{th}}{L_i^k} \cdot \frac{\bar{N}}{Num_k}; & \text{else} \\ 0 & ; \frac{R_k}{d_i} < 1 \end{cases} \quad (4)$$

In Figure 3 we describe the flow diagram about the calculation process, and we can see that the calculation of selection weight not only considers the CC's frequency spectrum characteristics and the UE's position according to path loss, but also tries to make each CC's load balanced. This can improve the utilization of the CCs, on the other hand ensure the fairness when users choose the CCs.

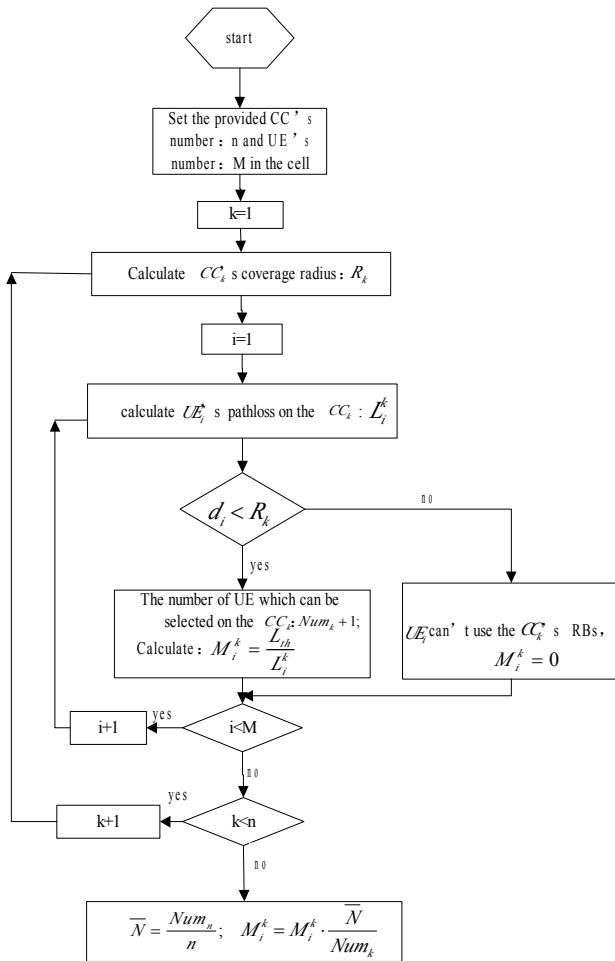


Figure 3. The flow diagram of the CC's selection weight calculation

IV. THE SPF-PF RESOURCE ALLOCATION ALGORITHM

The classical PF algorithm which meanwhile considers the system performance and fairness, can be expressed formula (5), and then allocate the j 'th RB to the i^* 'th UE.

$$i^* = \arg \max \{M_{i,j}\} = \arg \max \left\{ \frac{r_{i,j}}{r_i} \right\} \quad (5)$$

Where $r_{i,j}$ is the UE_i 's instantaneous rate on the j 'th RB, $\bar{r}_i$ is the UE_i 's average rate after the end of last TTI (1ms) which is the period of the scheduling.

In crossing CC joint scheduling, the SPF-PF algorithm finally employ the PF method to allocate RBs on the CCs after the CCs has been selected used SPF algorithm, so when to compute the scheduling factor about each UE on the RBs of the CCs, it needs consider the selection weight about each UE on the CCs, and the scheduling weight can be modified as:

$$M_{i,j}^k = M_i^k \cdot \frac{r_{i,j}^k}{r_i^k} = \frac{L_{th}}{L_i^k} \cdot \frac{\bar{N}}{Num_k} \cdot \frac{r_{i,j}^k}{r_i^k} \quad (6)$$

Where $M_{i,j}^k$ is the UE_i 's scheduling weight on the j 'th RB of the CC_k , M_i^k is the UE_i 's selection weight on the CC_k , $r_{i,j}^k$ is the UE_i 's instantaneous rate on the j 'th RB of the CC_k .

At last according to formula (7) to allocate the j 'th RB of the k 'th CC to the UE_{i^*} .

$$i^* = \arg \max_{i \in \Phi} \{M_{i,j}^k\} \quad (7)$$

V. THE SIMULATION RESULT AND PERFORMANCE ANALYSIS

In order to make the simulation process simple, we supposed there are four CCs, and their frequency is $f_1 = 860MHz$, $f_2 = 2.3GHz$, $f_3 = 3.2GHz$, $f_4 = 3.6GHz$. each CC includes 100 RBs, the simulation scene is urban-macro and others simulation parameters are as Table 1 shows.

TABLE 1. SYSTEM PARAMETERS

Parameter	Value
Site-to-site distance	500m
UE speeds of interest	3km/h
Channel model	Space channel model
Minimum distance between UE and cell	35m
Traffic Model	Full Buffer
User location	Random distribution
Thermal noise spectral density	-174dBm/Hz
Penetration loss	20dB
Total eNB Tx power	46dBm (40W)

The main computational formulas are as follows:

$\bar{r}_i(t)$ means the UE_i 's average rate at t moment, it can be expressed

$$\bar{r}_i(t) = (1 - \frac{1}{t_c}) \cdot \bar{r}_i(t-1) + \frac{1}{t_c} r_i(t-1) \quad (8)$$

in which $r_i(t-1) = \sum_{j=1}^{10} \delta_{i,j}^k(t-1) \cdot r_{i,j}^k(t-1)$;

Where $\delta_{i,j}^k$ reflects the resource allocation situation, if $\delta_{i,j}^k = 1$, it means that allocate the RB_j on the CC_k to the UE_i , otherwise the situation was opposite. t_c is the size of sliding window.

$r_{i,j}^k(t)$ means the UE_i 's instantaneous rate on the j 'th RB of the k 'th CC at t moment, can be expressed [9]:

$$r_{i,j}^k(t) = L \times \Delta f \times \min_{(j-1)L+1 \leq l \leq jL} C_{i,l}^k(t) \quad (9)$$

In LTE-Advanced system, the $L=12$, $\Delta f=15KHz$; $C_{i,l}^k$ means the UE_i 's instantaneous rate on the l 'th subcarrier of the k 'th CC at t moment, can be calculated by $C_{i,l}^k(t) = \Delta f \cdot \log_2(1 + SNR)$, in which

$$[10] SNR = \frac{P_{i,l}^k \cdot |H_{i,l}^k|^2}{N_0 \cdot \Delta f}, \text{ where } P_{i,l}^k \text{ is the } i\text{'th UE's power on the } l\text{'th subcarrier of the } CC_k, |H_{i,l}^k|^2 \text{ is the } UE_i\text{'s channel gain, and } N_0 \text{ is the power spectrum density of AWGN.}$$

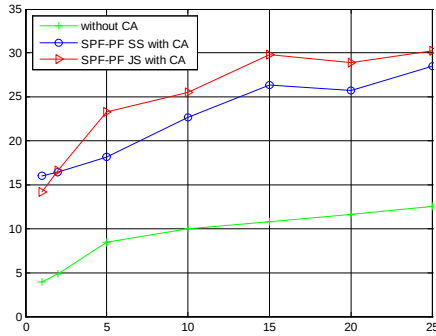


Figure 4. The comparison of the system throughput among SPF-PF JS, SPF-PF SS and scheduling without CA.

Figure 4 shows the comparison of the system throughput among SPF-PF CCJS, CCSS, and scheduling without CA. According to the result we can see that with the increase of user's number, all of them improved the system throughput because of multi-users diversity gain. Compared to the scheduling without CA, it with CA due to its more resource could bring obvious throughput improvement and the performance of SPF-PF CCJS is superior to SPF-PF CCSS.

Figure 5 shows the comparison of the system throughput between SPF-PF algorithm and PF algorithm. Because the SPF-PF algorithm take into account the CC's coverage characteristic, load balance and fairness, the former

throughput performance is inferior to the latter. The throughput acquired by PF algorithm can be the upper bound of the crossing CC scheduling.

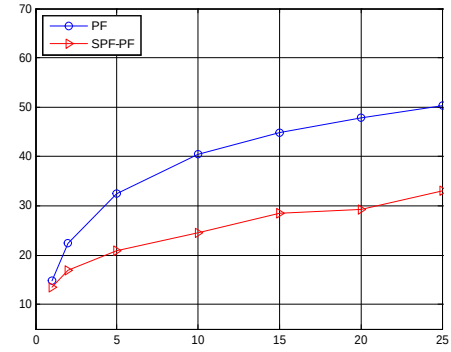


Figure 5. The comparison of the system throughput between SPF-PF and PF

The fairness is an important performance metric for resource scheduling algorithm, so in Figure 6 we contrast the fairness of SPF-PF and non-SPF-PF. By means of the comparison among forth CCs' selection weights, SPF-PF algorithm has well fairness.

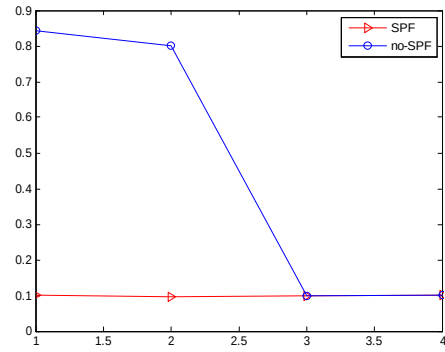


Figure 6. The fairness index of SPF-PF and non-SPF-PF

VI. CONCLUSION

In this paper we proposed a SPF-PF crossing CC joint scheduling algorithm, at first compute the users' selection weight on the CCs in terms of SPF algorithm, and then combine it with PF scheduling algorithm to calculate the scheduling weight, finally provided service for the user's weight is maximum. The result of simulation shows that SPF-PF algorithm not only improved the throughput of the system, but also ensured fairness and the load balance on each CC.

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