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Study on Frequency Resource Management Scheme in LTE-A

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Abstract: In LTE-Advanced systems, as for the problems of the deficiency of higher system blocking probability and lower customer satisfaction in static CoMP frequency management Scheme, a dynamic CoMP frequency management scheme is proposed, this scheme include two parts which establishes a transitional frequency band and Paired In-Out Scheme (PIOS). System-level simulation results show that, the transitional frequency band can reduce the system blocking probability effectively; And the Paired In-Out Scheme can not only further reduce the blocking probability, but also improve the system throughput and the level of Quality of Experience, effectively.

Key words: LTE-A, CoMP, transition frequency band, paired in-out scheme

INTRODUCTION

With the development of wireless mobile communication development, demands for enjoying the broadband service everywhere are growing. As a result, LTE (Long Term Evolution) technology and the followed LTE-Advanced technology have drawn more and more attention at home and abroad.

In LTE system, due to serious inter-cell interference, the current coordination technology cannot solve the low spectrum efficiency problem suffered by cell-edge users. In order to figure it out, Coordinated Multi-point Transmission and Reception (CoMP) has been introduced into the LTE-Advanced system (3GPP, 2009) which is an multi-cell application of the Multi-Input Multi-Output (MIMO) technology. By means of inter-cell joint-scheduling or cooperative transmission, it can make the best of the independence of the distributed multi-antenna channel to get more spatial multiplexing gain or diversity gain for the purpose of the throughput enhancement of communication links so as to reduce inter-cell interference (Lee *et al*., 2009) and improve the QoS (Quality of Service) of cell-edge users. There are lots of ways to realize inter-cell coordination/avoidance. For example, a typical scheme for the limiting of resource scheduling is Soft Frequency Reuse scheme (Huawei, 2005) which controls the cell load by flexible regulation of the bandwidth occupied by cell-center users and cell-edge users. But, by such scheme, the frequency utilization ratio of cell-edge bands is very low. And a typical scheme for the limiting of transmitting power is Fractional Frequency Reuse scheme (Wu and Zhang, 2007) by which the cell-edge users can be subject to little interference from adjacent cells. Similarly, the frequency utilization ratio of cell-edge bands is low by this scheme as well.

In order to solve the above-mentioned problems, frequency assignment and admission control in single-user CoMP (SU-MIMO) are studied in this study. First, a dynamic frequency resource management scheme under the mode of CoMP-SU-MIMO is proposed by use of the static frequency resource management scheme under the mode. For the overloading of CoMP users or non-CoMP users, establishment of transition frequency band is put forward. And for the overloading of CoMP users and non-CoMP users at the same time, a Paired-In-Out Scheme is put forward. The simulation proves that the performance of the dynamic CoMP frequency management scheme can improve a lot compared to that of the static CoMP frequency management scheme.

DYNAMIC COMP FREQUENCY MANAGEMENT SCHEME

The center frequency band and CoMP frequency band size in the static CoMP frequency management scheme is determined by network and will be a constant value for a long period. The corresponding result might be that when one type of resources is fully occupied, another type of resources is still with plenty of spare resources. It is unfair to users due to the improper resource utilization (Li *et al*., 2010; IMT-A_LTE+_09153, 2009). In addition, when the system resources are fulled occupied, how to ensure the access of the users with higher priority and higher spectrum effectiveness to the system and to minimize the influence on current users' QoS is another

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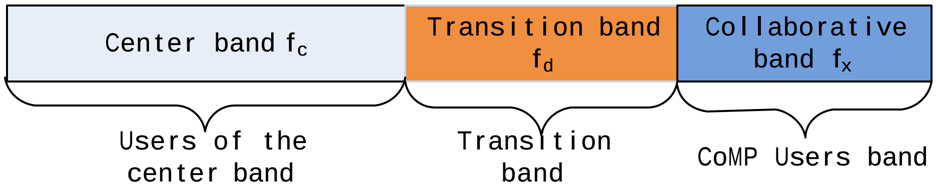

Fig. 1: Allocation of transition frequency band

problem that needs to be addressed. Consequently a dynamic frequency management scheme is proposed based on such scheme in this study. The scheme consists of the establishment of transition frequency band and Paired-In-Out Scheme.

Establishment of transition frequency band: According to the statistics after a medium-to-long period, the ratio of CoMP users to non-CoMP users is acquired and the ratio of CoMP frequency band to non-CoMP frequency band is determined. And the transition frequency band is determined by means of lots of simulations. CoMP frequency band is f_x, non-CoMP frequency band is f_c and the transition frequency band is f_d. In the study, the non-CoMP frequency band, CoMP frequency band and transition frequency band are respectively set to occupy 60%, 20% and 20% of the system bandwidth. The frequency band allocation scheme after the definition of transition frequency band is shown in Fig. 1.

Dynamic borrowing process of transition frequency band: After the allocation of transition frequency band, a user who wants to access becomes a CoMP user or a non-CoMP user based on the network determination and occupies corresponding frequency band. When a user becomes a CoMP user or a non-CoMP user and there is no free corresponding band resources, it will determine whether there are suitable transition frequency bands available to be borrowed and if yes, the user will access the band, the band will be marked as being occupied and the adjacent cells will be notified M_2 (t). is defined as the load of CoMP users who need to borrow transition frequency band and M_2 (t) as that of non-CoMP users who need to borrow transition frequency band. Then, if the system is finally fully occupied, the size of the frequency bands occupied by the total CoMP users is:

$$f_{CoMP} = f_1 + \frac{M_1(t)}{M_2(t)+M_1(t)} f_d \quad (1)$$

And the size of the frequency bands occupied by the total non-CoMP users is:

$$f_{N-CoMP} = f_1 + \frac{M_2(t)}{M_2(t)+M_1(t)} f_d \quad (2)$$

Paired-in-out scheme: If the system load continues to increase, the three frequency bands will be all marked being occupied and there will be no bandwidth resources for new users, However, in view of that the CoMP users occupy amount of bandwidth resources and the new users may be with higher spectrum frequency or have higher service priority, it may be considered that some CoMP users can be get out of CoMP service to become non-CoMP users as long as a certain extent of QoS is satisfied. In this scheme, instead of getting out of service, the original CoMP users just turn to be non-CoMP users. The key of this scheme is to find the most suitable CoMP user for a new user, i.e. the discovery of the optimum pairing is the key for the realization of the access of the new user and the exit of the CoMP user. This algorithm is called Paired-In-Out Scheme (PIOS). During pairing, the service priority which is applied to access shall be considered and only the users who use Non-GBR service shall be considered as the candidates for pairing. The priority of the new users and the candidates for pairing shall be compared and the pairing is valid only when the priority of the new users is not inferior to that of the candidate for pairing. The process of the scheme is described below:

Step 1: Determination at the entrance. If there is a new user who applies to access the system and the system determines that the three frequency bands have been fully occupied, the paired-in-out algorithm begins

Step 2: Determination of the candidates set for pairing. There are only two kinds of services in the system, GBR service and Non-GBR service, abbreviated as G and NG (suppose all the users in the system only use one service, then here the user and the service are conceptually equivalent.) and the ratios of GBR users and Non-GBR users to the total users are respectively d% and (1-d%). All the services in the system are divided into N levels, respectively as P_1, P_2...P_N According to the analysis on the service priority of the new user μ, the priority of the service which is applied for is $P^u_i(i\in[1, N])$. At this time, the set consisting of all CoMP users in the cooperative system is M; the number of users in M is C; the service priority of cth CoMP user is $P^c_n(m\in[1, C], n\in[1, C])$; then the set of candidates for pairing is $S\{s_i\}$ and s_i meets the following two conditions:

$$\begin{cases} P_{s_i} \le P^n_i \\ s_i \in NG \end{cases} \quad (3)$$

Step 3: Analysis of the optimum pairing. The access speed range of the users who apply to access is r_1~r_2. The cooperative bandwidth of s_i in the candidate set S is w_i, the desired speed to schedule w_i to the user is v_i and then the optimum user for pairing is s_k who shall meet the condition below:

$$r_1 \ge v_k \le \alpha r_2 \left(\alpha \ge \frac{r_1}{r_2}\right) \quad (4)$$

Wherein, α means pairing precision coefficient. The bigger the pairing precision coefficient is, the bigger the success pairing probability will be and the poorer the resources utilization efficiency will be. If not only one who satisfies the condition above is obtained, the one with lowest service priority shall be determined as the optimum paired user.

Step 4: If the optimum paired user S_k cannot be obtained in Step 3, the paired-in-out algorithm fails and the user will be refused to access. If there is one, the algorithm succeeds and the optimum paired user S_k will get out CoMP service and become a non-CoMP service user. It will apply for the user who applies for access to access the paired resource to become a CoMP user. Then switching in physical layer and access will be finished to end the pairing process

The involvement of PIOS algorithm in the system has increased the number of service users with the cost of QoS deterioration of the original CoMP users. Hence, how to balance the relationship between the system's unity gain and the loss of the users concerned for pairing becomes a judgment criteria for the practicality and effectiveness of PIOS algorithm. QoE (Quality of Experience) is introduced for the quantitative analysis of the rationality and effectiveness of PIOS algorithm.

QoE is defined as the general acceptance of a service or an application. It reflects the perception of end users on the QoS of them. QoE value is subject to users' expectations and environment and it is a statement of the QoS level (Huang and Wang, 2007; Zhao *et al*., 2010):

$$Q = \frac{\sum_{n=1}^{N}\sum_{i=1}^{K} w_i \sum_{j=1}^{M} q_{ij} p_{ij} \beta}{N} \quad (5)$$

Wherein, N means the number of users who apply to access in the system, K means the number of the service types, w_i means the percentage of the service, M means the KPI of one service, q_{ij} means the weight of the KPI, p_{ij} means the KPI subjective evaluation score, β means the successful access indication, $\beta\in(0,1)$. When the user has successfully accessed the system, β = 1; when not, β = 0.

SIMULATION AND DEMONSTRATION

In order to verify the performance of dynamic CoMP frequency management scheme, the scheme is simulated and analyzed from the view of user blocking probability, system throughput and system's average QoE value. Comparison with static CoMP frequency management scheme is carried out as well.

In order to highlight the performance under these situations, the communication duration is set infinite when all users have accessed the system. With the increasing number of the new users who apply to access, the load of the system begins to be subject to a progressive increasing mode.

Known from the blocking probability simulation of users shown in Fig. 2a, the blocking doesn't show until the number of the users who apply to access reaches 45 and the blocking rises rapidly after the applicant number reaches 50 because at this time the system's resources nearly run out and the system has almost been saturated. Thus it can be seen that upon the involvement of transition frequency band, it becomes much easier for users to access the system if there is any free resources.

However, when the system is saturate, the blocking probability will rise rapidly. If PIOS algorithm is adopted on this foundation, when the number of users who apply to access reaches 50 to 60, there is still a certain probability of successful access because the adoption of PIOS algorithm allows the access of the users with higher priority or higher spectrum efficiency.

Figure 2b shows success rate of users and the system throughput upon successful access. Single simulation can better reflect the influence of successful or failed access on system performance. Nevertheless, as the users' features are randomized, it is unavailable to reflect the average system performance.

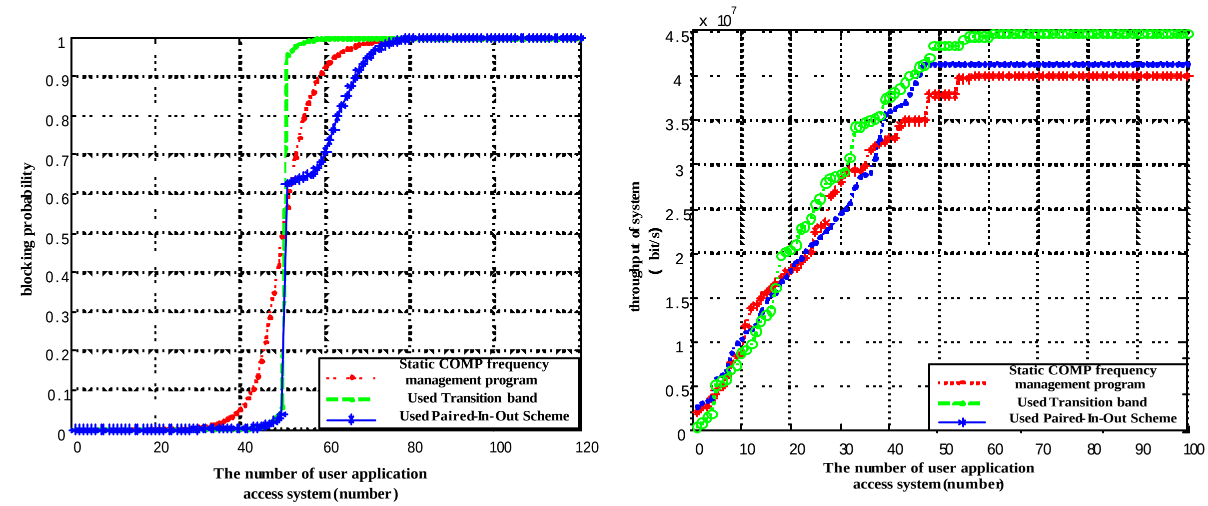

Fig. 2(a-b): (a) Blocking probability and (b) System throughput of single simulation

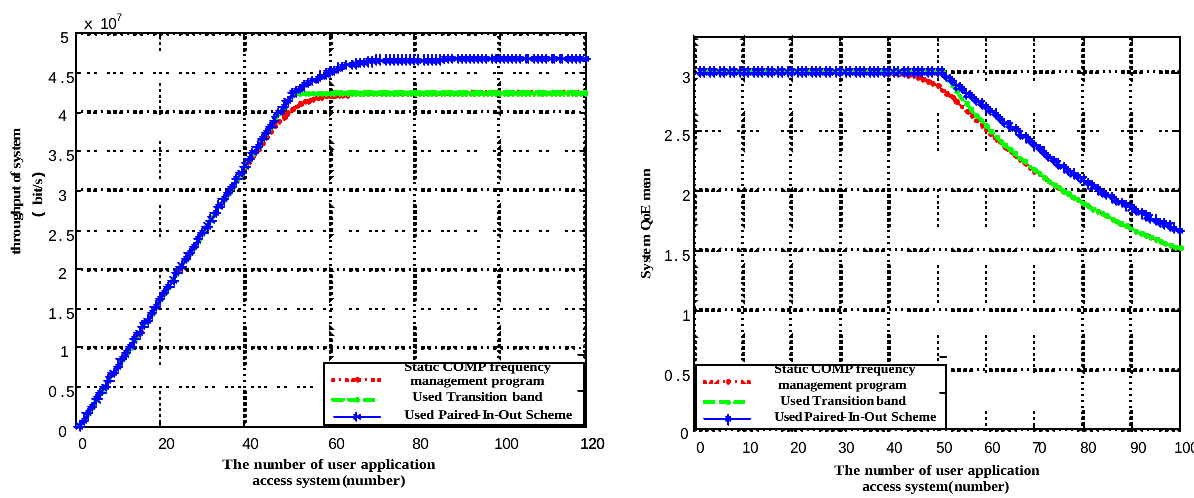

Fig. 3(a-b): (a) System throughput of multi-simulation and (b) Simulation of system average QoE value

It can be told from Fig. 3a that it becomes difficult to access the system and the system throughput rises slowly when the number of system users reaches 40 in static CoMP frequency management scheme. After the adoption of transition frequency band, the system throughput will continue going up and reach the maximum when the number of users reaches 47. And after the adoption of PIOS algorithm, the system throughput will continue rising further on this foundation which means that the PIOS algorithm is effective to a certain extent for the improvement of system throughput after successful execution.

However, with the increasing of the number of users, the success rate of pairing drops gradually to zero and the system throughput gradually levels off.

In addition, the adoption of transition frequency band is unavailable to raise the upper limit of system throughput; instead, it can only quicken the speed of throughput saturation; while the adoption of PIOS algorithm can raise the upper limit of the system throughput to a certain extent. It can be improved by 9.7% under the simulation environment in this study

Figure 3b shows the simulation results of system average QoE value. It can be seen from Fig. 3b that when the total number of users who apply to access is lower than 35, the system is with sufficient resources and each user enjoys the optimum QoE, the system average QoE value is 3 (the maximum). With the increasing of the number of users who apply to access, due to the appearance of a certain probability of blocking, the system average QoE value begins to drop gradually under the static CoMP frequency management scheme. Upon the adoption of transition frequency band, when the number of system users is between 35 and 55, the average QoE value increases obviously; while when the users outnumbers 55, the QoE tends fall by about the same percentage of the two schemes. Upon the adoption of the Paired-In-Out Scheme, the system QoE improves more compared to that in static CoMP frequency management scheme and the scheme with transition frequency band while the improved amount decreases with the increasing of the number of users who apply to access.

CONCLUSION

A dynamic CoMP frequency management scheme is proposed for the problems of big blocking probability and low quality of experience in static CoMP frequency management scheme. In this scheme, CoMP transition frequency band is established which can effectively reduce the system blocking probability while is unable to improve the system throughput or to ensure that the user with higher priority can enjoy better services. In order to solve these problems, a paired-in-out scheme is put forward. The simulation shows that the paired-in-out scheme can effectively improve the system throughput and the average QoE value and can reduce blocking probability as well.

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