# A Joint Resource Allocation Algorithm in HetNet Based on Game Theory

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***Abstract*—In this paper, the problem of inter cell interference suppression which under the multi cell heterogeneous network system model is studied. Game theory is used to build the model of frequency and timeslot selection. The analysis shows that the proposed resource reuse model is a potential game, which can improve the throughput of the network.**

***Keywords—multi cell; game theory; frequency***

## I. INTRODUCTION

As more than 70% of the mobile traffic happens indoors[1-3], macro/femto heterogeneous network (HetNet) is expected to be widely employed in the next-generation wireless network such as the LTE-A network. For a HetNet, which composed of multiple macro cells, the service area of high power nodes and low power nodes is covered by each other, and the femtocells are unplanned deployment. They also share the same spectrum. That causes the co-channel interference of the whole system[1-4]. It has been shown that the interrupt probability of the soft frequency reuse (SFR) can be lower than other traditional multiplexing schemes and improve the capacity [5]. Due to the deployment density of small cells is far outweigh than the macro cells, the topology mechanism of heterogeneous network is complex. It urgently needs extensible and self-organized interference management. As a mathematical tool for analyzing the strategies among decision makers, game theory is considered as a typical method to study the problem. In [6], the interference matrix based game theory was set up to protect the performance of macro users. This method reduced the time complexity of the algorithm. However, it was excessive to protect the performance of macro users. Literature [7] modeled a non-cooperative game mechanism to solve the resource allocation problem in heterogeneous network. The method can be used to decompose the eigenvalues of each femto base station (FBS). In reference to the interference problem caused by FBSs in multi macro cells' model, an algorithm introduced almost blank subframe (ABS) to solve the interference problem caused by FBSs[8]. In [9], the authors sated up a time-frequency resource allocation algorithm based on game model for traditional homogeneous net, but the author did not analyze the scheme of heterogeneous environment.

In this paper, the concept of soft frequency-timeslot reuse mechanism is introduced into the heterogeneous network environment, and a potential game based resource allocation model is established. The SFR technology and the ABS technology is applied to reduce the inter cell co-layer interference and the cross-layer interference. Finally, the system throughput is improved.

## II. SYSTEM MODEL

Considering a downlink HetNet framework with two tiers in this paper. The community contains $M$ macro base stations and $N$ femtocells. We suppose that the BSs in each tier obey an independent homogeneous Poisson point process $\Phi_i$ with density $\lambda_i$. Users are scattered randomly in the area. We adopt the SFR technology, the main frequency spectral is expressed by $B_m$, and the remaining part is defined as $B_c$. It stipulates users of center base stations can reuse all the spectrum, but the edge users can only use the main frequency spectral. The maximum transmission power of the center FBSs and the macro cells are $\theta \cdot P_{\max-F}$ and $\theta \cdot P_{\max-M}$ respectively. And for the base stations distributed in the edge area, the transmission powers are $P_{\max-F}$ and $P_{\max-M}$. $\theta$ is the proportion of the main frequency spectral to the total frequency band. In order to solve the serious cross-layer interference of the FBS to its closed macro users, we measure the interference according to appropriate parameter standards. Then determines whether the user can be accessed to the near FBS which is allowed to extend the cell. And we introduce these users communicate with the ABS to reduce the cross-layer interference of the system. In order to obtain the unload effect from the macro cells to the FBSs, the compensation value must be introduced. Base station users choose the cell based on the following standards,

$$SINR_i = \arg\max_{0\le i\le N_F} SINR_i^{'}, \begin{cases} SINR_i^{'} = SINR_N \\ SINR_i^{'} = SINR_A + \alpha \end{cases} \quad (1)$$

where $i$ and $N_F$ are the cell index and the number of FBSs, respectively. $SINR_i$ is the cell index selected according to SINR standard. $SINR_N$ and $SINR_A$ are the mean SINR value of the cell with non-ABS and ABS. It is noteworthy that the higher density of FBSs in a macro cell, the higher ABS density will perform better performance.

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Therefore, the proportion of ABS to the total slots $\beta$ is very important. By using different ABS density, the system efficiency can be maximized.

## III. RESOURCE MODEL BASED ON GAME THEORY

Because the transmission power of the base station is different in each timeslot and sub-channel, the average throughput of each user can be represented as follows:

$$C(t) = \sum_{k=0}^{N_{RB}} BN_{RB} \log_2(1 + SINR(t)) \quad (2)$$

where $B$ is the bandwidth of each resource block, $N_{RB}$ propose the number of resource blocks which users obtaine. The average throughput of the user in the system is represented as follows:

$$r_{n,M} = \frac{[T_e(C_{m,M}(t) + C_{f,F}(t)) + T_c(C_{m,M}(t) + C_{f,F}(t))]}{W(T_e + T_c)} \quad (3)$$

where $W$ is the overall bandwidth.

To reduce the interference and improve the overall performance of the system, the proportion of the main frequency spectrum and the main timeslot, that is, the value of $\theta$ and $\beta$ need to be considered carefully. Therefore, the optimal goal of this paper is to allocate the best proportion to maximize the throughput of the system. In order to get closer to the actual situation and improve the performance, we introduce the potential game to model the problem. Each cell not only aims at achieving its best throughput, but also takes into account the throughput of adjacent cells in the choice of its own strategy. So this chapter defines its utility function as follows,

$$U_M(a_M, a_{-M'}) = \sum_{n \in m} r_{n,M}(a_M, a_{-M'}) + \sum_{k \in M'} \sum_{n \in k} r_{n,k}(a_k, a_{J_k}) \quad (4)$$

The first item proposes the throughput of macro base station $M$ . And the second item is the throughput of all adjacent macro stations when $M$ chooses this problem. Based on this, we can define the joint frequency-time reuse game model as $\mathcal{G} : \max U_M(a_M, a_{M'})$ . According to the definition of the potential, we can see that this is a complete potential game with some good properties. 1) Every potential game has a pure strategic solution at least. 2) Any global or local maximum value of a potential game function is a pure strategy. So, the optimal strategies can be solved in an iterative way.

## IV. SIMULATION RESULT AND ANALYSIS

In this paper, we consider the simulation results of three algorithms, which are simple use of ABS, simple use of SFR and the algorithm proposed in this paper. The simulation parameters of the system are configured according to LTE specifications. Figure 1-2 are the simulation diagram of the system throughput. The joint resource allocation scheme proposed in this paper can effectively reduce the interference in the system.

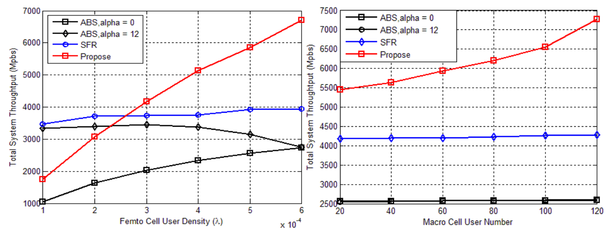


Fig. 1. System throughput with femtocells' densty
Fig. 2. System throughput with macro users' densty

## V. CONCLUSIONS

For the multi-cell interference management problem, the scheme of SFR is first adopted. Then the introduction of ABS establishes a selection model of frequency and timeslots under the heterogeneous network. We use the game theory to solve the optimization problem and the simulation results shows the effectiveness of the improved algorithm.

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