

A Resource Allocation Policy for Macro-Femto Double-layer Network

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Abstract—Currently double-layer network model based on Macrocell and low power nodes can effectively increase the capacity of the communication system. So traffic congestion at data service can be solved in the model. But the multiple interference between Macrocell base stations and femtocells will seriously damage communication quality and reduce system performance. To solve this problem, we propose a hierarchical scheduling resources- joint interference suppression algorithm. Firstly the system model which includes inside and outside layer (I-O model) is constructed. Then cross-tier and hybrid interference is analyzed between inside and outside layer. Furthermore two scheduling algorithms are presented for inside and outside layer. Allocation strategy of time - frequency resource scheduling strategy based on sub-channel and power level. Finally the whole system is simulated. Simulation results show that the proposed algorithm can achieve good results at some aspects such as the spectrum efficiency of cell - edge user and the average throughput of system.

Keywords—the double-tier and heterogeneous network; I-O model; resource allocation; interference suppression

I. INTRODUCTION

The evolution of 3GPP organization gradually to 4G mobile communication system whose representative is LTE-A promotes the development and standardization of home base stations and other major technologies. The homebase station has a smaller transmit power, coverage within 50 m, and data transmission is by multiplexing frequency resources of macrocell, thus forming a double-tier and heterogeneous network in which macrocell and homebase station coexist. Wherein the different tiers refer to different types of cellular networks, while heterogeneous emphasizes a significant difference in the power transmission and the coverage of a signal. Femtocell technology has become one of an important technology promoted in LTE-Advanced standard R12 version currently [1], despite the small coverage, but the FUE (Femtocell User Equipment) still exist strong mutual interferences with the adjacent MUE (Macrocell User Equipment). This form of isomeric interference has seriously affected the quality of communication and impedes a further enhancing of system capacity and performance. So how to schedule resources to achieve a goal of user signal interference suppression or coordination is one of the most challenging issues in femtocell deployment under the coverage of existing macrocell.

Authors in [2] propose a method for optimizing homebase station, which aims to limit a downlink

interference of home base station to outdoor macrocell user. The authors model the optimization problem as a mixed integer programming problem, resulting in Femto's maximum transmission power and operating frequency. However, in the actual FAP (Femtocell Access Point), due to high complexity, taking too long, it is not feasible to implement this technique. In [3], the authors develop a simple technique to avoid the homebase interfering the macrocell users nearby. But it is based on the assumption: Femtocell can get information about the MUEs from the macrocell base station. Once the macrocell users suffer interference, nearby Femtocell will reduce its transmit power[4].

In this paper, we consider system hierarchy, we simplify the complex interference between the LTE-A double network users by constructing inner and outer layer system model, and proposed a way of scheduling resource method to suppress interference. Finally, system-level simulation platform have proved that both Macro and Femto layers have been better interference management and suppression after using the algorithm. Research and simulation of this paper can provide a reference for future communication network planning and optimization.

II. SYSTEM MODEL AND INTERFERENCE ANALYSIS OF MICRO-FEMTO

A System Architecture and Model

Homebase station, as a powerful solution of indoor coverage, was introduced in 3GPP Rel-8 and was in-depth research in 3GPP Rel-12[6], in which added a new paradigm for operators. Till 2015, the shipment of femtocell will reach 54 million, of which China and

North American markets will be the two key market of femtocell development [7]. The heterogeneous network architecture composed by macrobase station and home base station is shown in Fig. 1. Its characteristic parameters listed in Table I:

TABLE I. CHARACTERISTIC PARAMETERS OF THE DOUBLE-TIER AND HETEROGENEOUS NETWORK.

	Macrocell	Femtocell
The transmit power of base station	46 dBm	<23 dBm
The effective coverage	1-3 km	<50 m
Interface Type	S1	IP internet
Purposes	Providing open access to a large range of users	For some activation users in served family or businesses

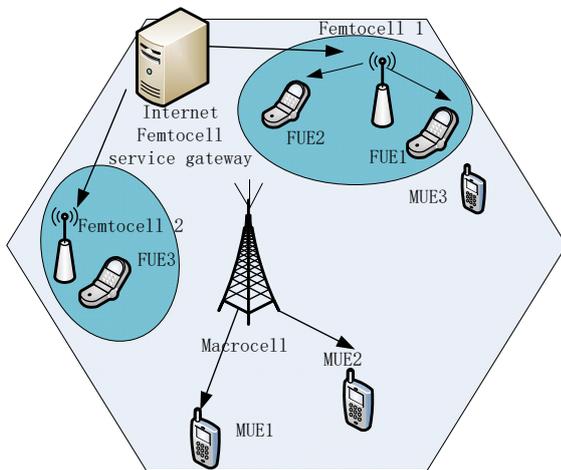


Fig.1 The Heterogeneous Network Architecture of Macro-Femto

From figure 1, we can see that the model of the inner and outer layer system, namely I-O model, can be constructed to allocate hierarchically these resources. The system is divided into inner and outer layers, and the former means the coverage of the main scheduler by homebase station, while the later refers to coverage of the macro base station.

B Cross-mixing Interference Analysis

The introduction of femtocell makes the network divided into two layers, not only bringing a high edge-coverage, but also leading two interferences: inner-layer interference and inter-layer interference [8]. Inner-layer interference happens between two or more femtocell interference. Due to the flexibility of femtocell deployment location and geographical proximity between them, result in an overlapping coverage when

covering different ranges [9]. However, if two or more femtocells using the same frequency or subchannel, then it is easy to generate co-channel interference. Inter-layer interference refers to that the source of interference and UEs interfered with are

coming from different layers. For example, MUEs near femtocells receive interference from downlink signal transmitted from the femtocell, and FUEs are interfered by macrobase station [10]. In LTE-A system, we usually adapt base adaptive power control technology and intelligent channel allocation techniques to solve the interference problem [11]. Figure 2 realistically shows a few uplink-downlink interference problems brought by femtocells and macrobase stations being combined together to distribute network.

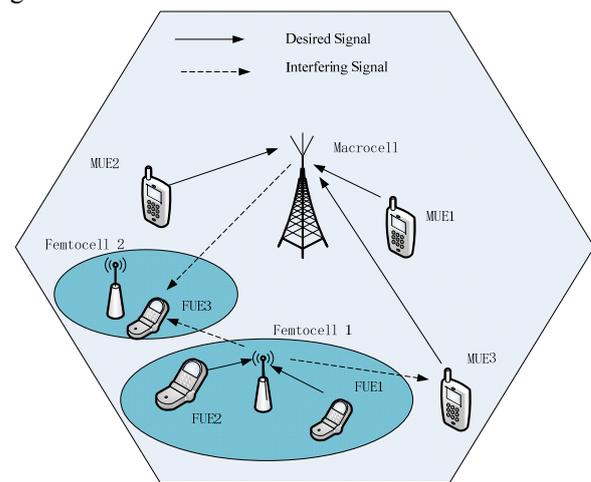


Fig.2 Situation of uplink-downlink interference in Macro-Femto double network

In the case of macrobase station in center, we discuss

the downlink resource allocation in Macro-Femto network. System bandwidth is divided into N orthogonal RBs [12]. Assume that effective coverage radius of the enteral base station is R m, and the base station shares C subcarriers with F Femtos, and then uth MUE has an effective SINR on subcarrier c, as follows:

$$\gamma_u^{eff} = \left[\left(\frac{1}{12N_u} \sum_{n \in N_u} \sum_{c=1}^{12} \frac{P_{u,n,c} \gamma_{u,n,c}}{1 + P_{u,n,c} \gamma_{u,n,c}} \right) - 1 \right]^{-1}$$

Where n_u means the set of RBs allocated to user u, $P_{u,n,c}$ is transmission power of user u on subcarrier c, $\gamma_{u,n,c}$ is SINR.

So the transmission power of the uth user is:

$$R_{c,u} = \frac{B}{M} \log_2 \left(1 + \frac{\gamma_{u,n,c}}{\Lambda} \right), \text{ where } \Lambda = \frac{-\ln(5BER)}{1.5} \text{ is}$$

represents the bit error rate under BER.

III. THE ALGORITHM OF RESOURCE ALLOCATION TO SOLVE THE INTERFERENCE PROBLEM

This paper presents an inner-outer layer collaboratively scheduling algorithms. The inner-layer use time-frequency-domain scheduling. Firstly, consider FUE’s channel quality information (CQI), and determine the set of pre-served users. Secondly, the scheduler set corresponding weights according to the related parameters of each FUEs, such as channel condition, throughput, and so on [13]. Then, we need to make a priority queue, according to which to allocate time-domain spectrum in general. If there exist retransmission users, they would be the preferred, or following the priority queue until the number of FUEs reaches a predetermined value [14]. Finally, we combine these FUEs and corresponding resource blocks (RBs) with pairs, and sort them in sequence under a new priority weights and through the entire queue to allocate frequency-domain resources.

In the outer-layer, we consider subchannel and power, and adopt the model of joint distribution. Specific steps will be detailed in the following sections.

The algorithm process:

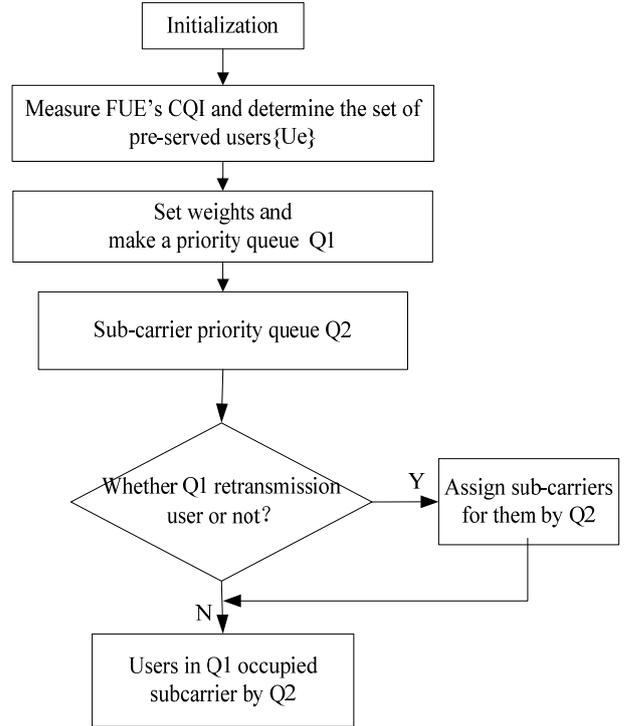


Fig.3 The flowchart of inner-layer scheduling algorithm

A User Classification and Distinction

In the initialization phase, all pre-served UEs within a cell are request to the macrobase station to allocate downlink resource, and femtos within the macrocell also request resources to the eNB, in order to obtaining its frequency resource that can be scheduling independently. The eNB firstly distinguishes femtos from UEs according to certain fields of request packets, then calculates path loss value PL_m or PL_f from UEs to MeNB and UEs to FeNB by Hata-Okumura model formula (2)

$$PL = 69.55 + 26.16 * \lg(f) - 13.82 * \lg(Hb) - a(Hm) + (44.9 - 6.55 * \lg(Hb) * \lg(d)) \quad (2)$$

ere, f is the operating frequency (150~1500MHz); Hb is the effective antenna height of the base station transmitter (30 ~ 200m); Hm is the effective antenna height of the mobile station receiver (1 ~ 10m); d is a distance (1~10km) from the send antennas to receive antennas. MeNB and FeNB choose the minimum path loss value of UEs as their users.

For near MUEs, assuming the coordinates points of FeNB and MUE respectively is (x_i, y_j) and (x_j, y_j) , the radius of interference MUE [6] is:

$$I_r = \sqrt{\frac{B_1^2 + B_2^2 - 4AC}{4A^2}} \quad (3)$$

Where,

$$A = P_f - P_u$$

$$B_1 = 2P_u x_i - 2P_f x_j$$

$$B_2 = 2P_u y_i - 2P_f y_j$$

$$C = P_f x_j^2 - P_f y_j^2 - P_u x_i^2 - P_u y_i^2$$

P_f means the transmit power of femtocell, while P_u represents the transmit power of mobile terminal. The interference radius of MUE depends on the actual physical location of UE and femtocell and their transmit power. Measuring the distance D between MUE and femtocell, when it meets $D \leq I_r$, the MUE is set to be an "interference with family", and be added to a "blacklist", which is willing to be sent to macrocell. Macrobase station counts all disabled subcarrier information according to the list, and then feedback to the femtocell to allocate additional resources.

B The Allocation Of Subchannel And Power

For Macrocell, we consult a method that described in [7], and directly use part of the power control algorithm. Define the u th MUE has a transmission power as follows:

$$P_u^{MUE} = \min \left\{ P_M^{\max}, P_0 + 10 * \lg(RB_{MUE}) + \alpha * L \right\} \quad (4)$$

Wherein, P_0 is MUE's special parameters, RB_{MUE} indicates the number of RBs assigned to MUE's, α is special path loss compensation factor for the cell, we use $\alpha = 0.6$ here, L is expressed as a downlink path loss measurement value for the u th MUE. Since femtocells are deployed indoors and the distance of its service users-FUEs and femtocell is very short, so you can assign its power averagely.

C Computing the Cell Throughput

Calculate the inner and outer layers network throughput. Inner C_1 , outer C_2 , the formula is as follows:

$$T_1 = \sum_{i=1}^{N_{sc}^m} x_i^u \frac{B}{N_{sc}} \lg \left(1 + \frac{1}{M} \sum_{m=1}^M \gamma_m \right) \quad (5)$$

$$T_2 = \sum_{j=1}^{N_{sc}^f} y_j^u \frac{B}{N_{sc}} \lg \left(1 + \frac{1}{N} \sum_{n=1}^N \gamma_n \right) \quad (6)$$

System throughput is $T=T_1+T_2$, the above two equations are transformed from Shannon formula.

Wherein N_{sc}^m and N_{sc}^f respectively are the number of

sub-carriers in RBs set of Microcell and Femtocell; x_i^u and y_j^u are pre-served MUEs and FUEs to be allocated sub-carrier i and sub-carrier j ; B indicates the system bandwidth; N_{sc} is the number of system sub-carrier; $\frac{1}{M} \sum_{m=1}^M \gamma_m$ and $\frac{1}{N} \sum_{n=1}^N \gamma_n$ respectively represent the average SINR of all MUEs and FUEs; γ_m and γ_n show the signal to interference noise ratio of inner and outer layer of the network.

IV. THE COMPARISON AND ANALYSIS

In order to obtain the simulation results, MUEs and FUEs use two kinds of modulation (4QAM, 16QAM), and three kinds of modulation (4QAM, 16QAM, 64QAM).

A. The simulation parameters are shown in Table II:

B. The performance analysis of algorithm simulation

Interference coordination algorithm based on power control, the algorithm of allocating resource randomly and the algorithm proposed in this article will be compared and analyzed in this section. Take three aspects in count: average throughput of the system user, the total interference power of network, and packet loss rate of real-time services.

TABLE II. THE SIMULATION PARAMETERS OF SYSTEM

Parameters	Setting / Description
System architecture	7 cells, 7*3 sectors
The distance between the base stations	500 m
Cell coverage radius	500 m/10 m
User maximum transmit power	23 dB
Carrier frequency	2 GHz
System bandwidth	20 MHz
Total number of available RBs	100
The number of sub-carriers in each RB	12
Transfer mode	Open-loop airspace
The number of antennas	2*2
Channel model	SCM
Shadow fading standard deviation	8 dB/10 dB

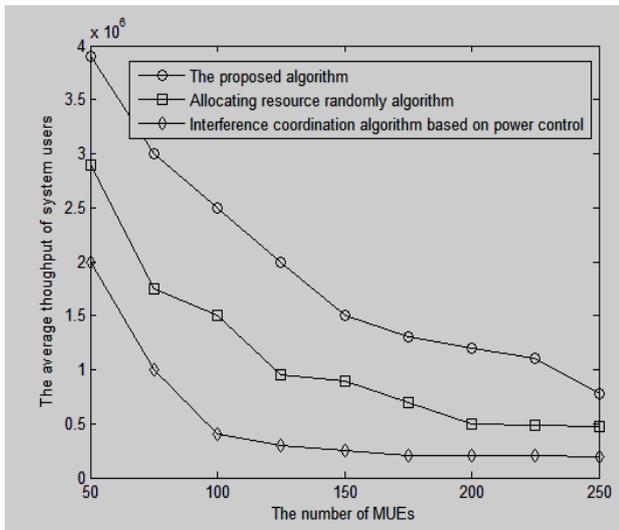


Fig.4 The average throughput of system users in different algorithms

As can be seen from Fig.4, with a increasing in the number of users, the average user throughput of the system is decreased obviously. Hierarchical scheduling resource—the algorithm proposed in this article can achieve higher average user throughput of the system than the algorithm of allocating resource randomly, because the former not only can uniformly schedule resources and UEs, and choose the most appropriate sub-carriers, but also reduce the serious inter-layer interference in double layer network. In the case of the number of MUEs gradually increasing, the throughput of FUEs decreases more significantly. Due to the increasing user, in order to achieve a predetermined target rate, the system should improve the transmit power of the user, thus adding to the inter-cell interference and inter-layer interference, resulting in a loss of throughput.

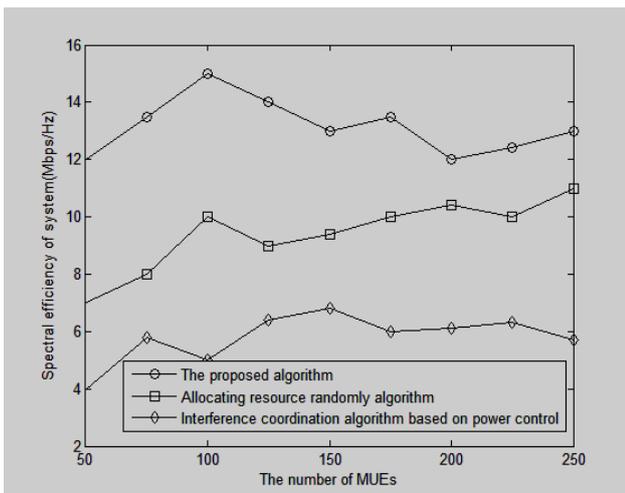


Fig.5 The system spectral efficiency in different algorithms

It is known from Fig.5, the system spectral efficiency of

three algorithms are enhancing smoothly. Wherein, the algorithm of allocating resource randomly does not solve the substance interference problem, thus the lifting of the system spectrum efficiency is very limited. Interference coordination algorithm based on power control focuses on solving complex interference, leading to a case that signaling interaction is bound to affect the spectrum utilization. The proposed algorithm has brought an increase in average user throughput, thereby increasing the overall system throughput. However, because the system bandwidth is certain, the improving of the overall system throughput will bring a rising in spectrum utilization.

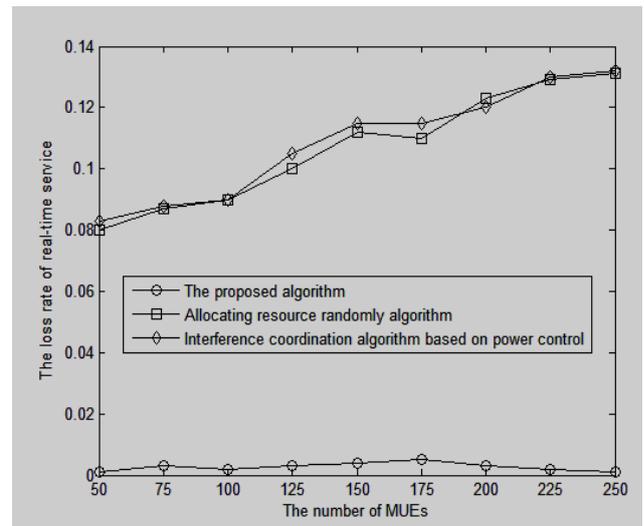


Fig.6 The loss rate of real-time service in different algorithms

In Fig.6, the new algorithm can suppress the packet loss rate of real-time service to minimize, and the maximum is only reached about 0.005. Its advantage is far more than the other two algorithms. Further, with the increasing number of MUEs, the total minimum spectral efficiency of femtos follows, which is due to the macro layer can provide a better diversity gain.

V. CONCLSION

This paper takes Macro-Femto double heterogeneous network as an example, and analyzes a variety of interference mechanisms in the network, thus proposing a resource allocation algorithm to solve the problem of inter-cell interference. The algorithm takes the complex inter-cell interference into account very fully, and applies the way of hierarchical scheduling - synergistic inhibition, reducing the system signaling overhead, operational complexity and effects of signaling delay on the overall performance. In addition, the algorithm also ensures fairness among FUEs and QoS between all MUEs. Simulation results show that the algorithm has significantly

improved in the average spectral efficiency and user throughput. In the future, the continuous development and demand for data services require a double-layer, or even multi-layer, with a low-power nodes (such as Femto, Pico) network has a high-speed, low interference characteristics, and this is the next step to be studied.

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