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ScienceDirect

June 2016, 23(3): 57–62
www.sciencedirect.com/science/journal/10058885

The Journal of China Universities of Posts and Telecommunications

http://jcupt.bupt.edu.cn

Resource allocation scheme based on game theory in heterogeneous networks

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Abstract

As an effective solution for indoor coverage and service offloading from the conventional cellular networks, femtocells have attracted a lot of attention in recent years. This study investigates the resource block (RB) and power allocation in heterogeneous networks (HetNets). Specifically, the concern here is to maximize the signal to interference-plus-noise ratio (SINR) of macrocell and energy efficiency of femtocell while providing the finite interference. In this paper, the system model is divided to two layers, in which the macro base station and clusters constitute the first layer network; femtocells in cluster make up the second layer network. Because of the different model structures, different game theories are used in different layers. Stackelberg game is used in the first layer, and non-cooperation game is used in the second layer. Meanwhile RB and power levels stand for the actions that are associated with each player in the game. The problem of resource allocation is formulated as a mixed integer programming problem. In order to minimize the complexity of the proposed algorithm, the resource allocation task is decomposed into two sub problems: a RB allocation and a power allocation. The result is compared with the traditional methods, the analysis illustrates the proposed algorithm has a better performance regarding SINR and energy efficiency of the heterogeneous networks.

Keywords game theory, resource block allocation, power allocation

1 Introduction

The HetNet deployment is investigated as a promising paradigm for enhancing network performance. The main idea of HetNet is to overlay low-power low-cost stations on the coverage holes and hotspot areas to complement the conventional macrocell for coverage extension and capacity enhancement. The femtocell is considered as a promising technology, which can enhance the HetNet coverage of indoor environment, provide ubiquitous high speed connectivity to users and offload traffic from the macrocell [1].

In the HetNets, energy saving and throughput become more important issues due to customer requirement and financial considerations. Because user’s requirement for data increases rapidly, the deployment number of femtocells is increasing rapidly worldwide, the throughput need to be improved and the power need to be fully used in the heterogeneous system. In order to reach the goal, we must maximize the throughput and the energy efficiency of HetNets.

Meanwhile, with the co-channel deployment of femtocells and macrocells, the interference becomes the most critical factor [2]. Primarily, there are two types of interference: co-tier interference and cross-tier interference. The former is the interference among femtocells while the latter is the interference between macrocell and femtocell. The interference is a key element affects users’ quality of service (QoS) and network performance. Therefore, the interference management is a critical technical challenge that has to be coped with for HetNets.

Many works have been done to design resource allocation schemes. Most articles use Stackelberg game or non-cooperative game theory. And throughput, energy efficiency, delay or signal-to-noise ratio (SNR) are

Received date: 21-12-2015
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DOI: 10.1016/S1005-8885(16)60033-X

considered as key elements. The Ref. [3], adopting a game-theoretic approach to implement a non-cooperative power control scheme, is a pioneering work that has paved the way to many interesting subsequent works both aiming at energy efficiency maximization and using the tools of game theory. In Ref. [4], the resource and power allocation problems are modelled as an operation research game, where imputations are deduced from cooperative game theory. In Ref. [5], the author proposes a Stackelberg game-based power control scheme to impose regulation on these non-cooperative femtocells.

Although the schemes mentioned above have good performance, the references mainly only consider energy efficiency or take the centralized regulation scheme. These algorithms certainly have severer interference or higher expenses. In this paper, we jointly considering three major challenges in the HetNets, including: (1) maximizing the throughput; (2) improving the energy efficiency; (3) minimizing network interference. Meanwhile, different object has different request. With enough transmission rate, femtocell hopes the energy efficiency high; With limited interference, macrocell hopes the throughput high. This is because the throughput of each family is limited, when their communication requests are fulfilled, they care about economic benefits; and social requirement for information is larger and larger, the operator cares more about throughput with limited interference. A new pattern resource allocation scheme is introduced. Here, resource allocation problem is modelled as resource allocation in two layers structure. And in the different layers, two types of game are used, including the Stackelberg game and non-cooperation game. By regulating the resource allocation of macrocell and femtocell respectively, the system has a good performance.

The rest of this paper is organized as follows. In Sect. 2 system model is presented. Sect. 3, by decomposing the original problem into two subproblems, the RB allocation and power allocation algorithms are proposed respectively. The simulation results and analysis are described in Sect. 4 and finally, Sect. 5 concludes the article.

2 System model and problem formulation

2.1 System model

In this section, we consider the downlink of two-tier HetNets, which consists of one central macrocell overlaid by W femtocells. We divide the network to two layers, we define the layer including macrocell and cluster as the first layer, and the layer including cluster and femtocell as the second layer. Then we apply static method to divide the femtocells to some clusters. The femtocell which has similar geographical environment and channel state is divided to one cluster. The users under macrocell is $u_m=\{u_1,u_2,\dots,u_M\}$. It is assumed that the femtocells have been sorted to K clusters, there are h_k femtocells in the kth cluster, the number of users in the h_kth femtocell is $u_{k,h}$ and M active macrocell users in macrocell. Let $k = \{1, 2,\dots,K\}$ denotes the set of clusters in the network, $h_k= \{1,2,\dots,H_k\}$ denotes the set of femtocells in the cluster, and $u_{k,h} = \{1,2,\dots,U_{k,h}\}$ denotes the set of femtocell users in femtocell k, so $\sum_{i=1}^{K}\sum_{j=1}^{H}\sum_{u=1}^{U}u_{i,j}=u$, which is the total number of active users in the network. Femtocells are assumed to operate in closed access mode and share the whole available spectrum with the macrocell. The system bandwidth is B. The RB set is denoted as $n = \{1, 2,\dots, N\}$.

The fading of all channels assigned to the same user is assumed to be independent and identically distributed. Perfect channel state information (CSI) can be available for both the transmitters and the receivers. In addition, the two interference components (co-tier and cross-tier) are represented by the delimiters I1, I2 in Fig.1, where I1 is the cross-tier interference component and I2 is the co-tier one. The frequency reuse is considered in this study.

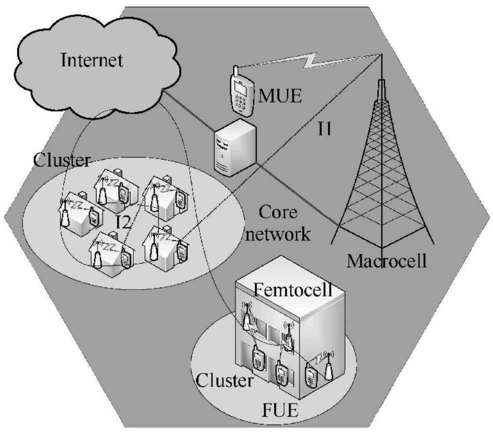

Fig. 1 Illustration of the architecture of a macro-femto HetNets

The transmission power of macrocell and the hth femtocell of cluster k on N acquired RBs is given by P_M^n and $P_{F,k,f}^n=\{P_{F,1,1}^n,\dots,P_{F,K,F}^n\}$. The analysis of the proposed game is carried out regarding energy efficiency. In order to achieve this, the signal-to-interference-plus-