Chapter 9

Distributed Dynamic Resource Allocation for OFDMA-Based Cognitive Small Cell Networks Using a Regret-Matching Game Approach

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ABSTRACT

Game theoretical approaches have been used to develop distributed resource allocation technologies for cognitive heterogeneous networks. In this chapter, we present a novel distributed resource allocation strategy for cognitive small cell networks based on orthogonal frequency-division multiple access. In particular, we consider a heterogeneous network consisting of macrocell networks overlaid with cognitive small cells that opportunistically access the available spectrum. We focus on a regret-matching game approach, aiming at maximizing the total throughput of the small cell network subject to cross-tier interference and quality of service (QoS) constraints. The regret-matching game approach exploits a regret procedure to learn the optimal resource allocation strategy from the regrets of the actions of cognitive users. Furthermore, the regret-matching game approach is extended to the joint resource allocation and user admission control problem. Numerical results are presented to demonstrate the effectiveness of the proposed regre-matching approaches.

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INTRODUCTION

The provision of a guaranteed quality of service (QoS) and high data rate to a large number of users is one of the most prominent challenges for system operators in future beyond-4G (B4G) and 5G networks. A small cell network (sometimes also called a heterogeneous network) has been recognized as a potential solution to offer better service coverage and higher spectral efficiency. In addition, a combination of a small cell network with cognitive techniques to opportunistically exploit unlicensed bands [e.g., the 2.4-GHz industrial, scientific, and medical (ISM) and 5-GHz Unlicensed National Information Infrastructure (U-NII) bands] and bands not occupied by the macrocell system can further improve the system throughput by offloading the traffic demands from mobile users. This idea has motivated the extension of the modern Long-Term Evolution (LTE)-Advanced system to an unlicensed spectrum, leading to the so-called LTE-U system. It is expected that advanced dynamic resource allocation strategies would serve one of the most important roles in future cognitive small cell networks in order to make the best usage of available resources while effectively controlling co-tier and cross-tier interference.

In this chapter, a heterogeneous network consisting of macrocell networks overlaid with cognitive small cell networks that opportunistically access the available spectrum is considered. In particular, the aim is to develop distributed dynamic resource allocation strategies, in which cognitive small cells manage to maximize their individual utility independently, subject to cross-tier interference and QoS constraints. To this end, a game-theoretic framework is proposed for distributed dynamic resource allocation for cognitive small cell networks.

This chapter contains two parts. In the first part, a distributed dynamic resource allocation problem for the interference management of cognitive small cell networks is studied. Specifically, the design problem is formulated as a regret-matching game problem that accounts for the sensing information gathered by the small cells. The regret-matching game approach is a type of adaptive learning algorithm in which the small cells learn the best resource allocation strategies (actions) based on certain “regret” values that are predictable from current and past actions. It is shown that the small cells can independently and selfishly maximize their individual utility and efficiently mitigate co-tier interference by integrating the regret-matching game approach with environmental sensing information. More importantly, it is provable that the approach can converge to a set of so-called coarse correlated equilibrium.

In the second part of this chapter, the regret-matching game approach is further extended to a joint resource allocation and user admission control problem. The considered joint design problem is important because mobile users in densely deployed small cell networks are subject to complex co-tier and cross-tier interference constraints. To ensure users that have accessed the network experience a uniform and guaranteed QoS, it is necessary to optimize both the resource allocation and admission control strategies jointly. Extensive simulation results will be provided to demonstrate the effectiveness of the proposed game-theoretic approaches. In addition, detailed discussions of the challenges and promising future research directions will be presented as well.

The rest of this chapter is organized as follows. In the next section, the background of the cognitive small cell network is briefly described. The system model and problem statements are then presented in the following section. Afterwards, the distributed dynamic resource allocation problem is studied, and it is shown how the regret-matching procedure in game theory can be used to solve it. Next, our work is extended to the joint resource allocation and user admission control problem. Finally, some numerical results of the proposed algorithm are presented with the conclusions.
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