Chapter 11
Auction-Based Resource Management in Multi-Cell OFDMA Networks

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ABSTRACT
This chapter addresses the complex scenario of multi cell OFDMA network resource allocation and interference control by auction theory. An auction framework that meets the properties of efficiency and incentive compatibility is proposed. We consider a multi-cell OFDMA network with Fractional Frequency Reuse (FFR) implementation. An auction is presented to allocate subcarriers. According to the proposed auction framework, users will avoid bidding for the subcarriers where they have a relatively low chance of winning. Optimal bidding strategy based on Bayesian Nash Equilibrium (BNE) is obtained in which users are maximizing their net profit. A focal distance which classifies the users into cell-center and cell-edge users is characterized. The proposed approach maximizes the total auctioneer revenue, while balancing a tradeoff between system performance in terms of total system throughput and quality of service provisioning for cell-edge users.

INTRODUCTION
Recently, there have been substantial advances in research which use game theory for analysis of communication networks. This is basically due to the need for developing autonomous and distributed mobile networks where the users can make independent and rational strategic decisions. Moreover, there is a need for low complexity distributed methods that can efficiently represent competitive behavior among network entities. To this end, game theory provides a mathematical tool for analysis of the network. The Orthogonal Frequency Division Multiple Access (OFDMA) is one promising candidate for next generation wireless communication systems. The combination of OFDMA with adaptive modulation and
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coding (AMC) and dynamic power allocation is of great prominence in the design of future broadband radio systems. Obviously resource allocation in which resources include subcarriers, power, and time slots and scheduling schemes play important roles in the design of OFDMA system.

In resource allocation there is always a trade-off between efficiency and fairness. Two end-point problems considering these factors are sum-rate maximization and max-min problem. To guarantee a trade-off between sum rate maximization and max-min fairness, proportional fairness tries to maximize the sum of logarithmic utility function. Even though proportional fairness can provide a balance between efficiency and fairness, but the provided fairness is not the result of users’ competition. A proposed solution is that users are allowed to compete for available resources. In this way, each user is responsible for his/her own action. This kind of fairness is called competitive fairness, in which users are receiving a fraction of resources through their competition. Auction game theory is a decentralized market mechanism to address the competitive behavior of nodes for available resources. It mimics the competitive behavior of users in which users are receiving resources through their competition process. Auctions as a subset of game theory have recently been introduced into several areas of wireless communications to handle the problem of resource competition among selfish users.

In a multi-cell OFDMA system, a user not only competes for resources with the users in its own cell, but also generates interference for adjacent cells. Advanced and intelligent radio resource management (RRM) schemes which consider the dynamic co-channel interference have to be designed. Moreover, RRM must take advantage of the opportunities and flexibilities of OFDMA system, and address the critical notion of fairness. Taking these challenges into consideration, introduces additional complexity into the problem of resource allocation. Meanwhile, the conventional centralized approaches do not scale well to the multi-cell networks where distributed algorithms are preferred. The next generation cellular network is increasingly required to provide guaranteed quality of service regardless of the user location in the cell. So, there is a need for algorithms which would provide a tradeoff between the rate improvement and cell coverage for cell-edge users. Fractional Frequency Reuse (FFR) is an attractive approach toward the frequency planning for multi-cell OFDMA network due to low complexity of implementation and significant gains in performance who especially for the cell-edge users usually encounter service starvation. The basic idea of FFR scheme is to apply a small frequency reuse factor for cell center users who have better SINR and large frequency reuse factor for cell-edge users who have worse SINRs. In this way, cell-edge users of adjacent cells do not interfere with each other. Moreover, interference from inner-cell users is reduced. The result is that FFR can achieve good tradeoff between the average network throughput and the performance of the cell-edge users.

In this chapter, we propose a comprehensive auction framework for multi cell OFDMA Network which takes into account the interference from adjacent cells. We obtain optimal bidding strategy based on Bayesian Nash Equilibrium (BNE). In a Fractional Frequency Reuse (FFR) implementation of frequency planning, we will find a focal distance ($R_f$) which classifies the users into cell-center and cell-edge users. The proposed approach aims to maximize the total auctioneer revenue, while providing a tradeoff between system performance in terms of total system throughput and quality of service provisioning for cell-edge users.

**Background**

Resource allocation and scheduling schemes play important roles in the design of an OFDMA system. The resource allocation problem can be modeled as an optimization problem subject to various QoS