Preface

Cellular networks are witnessing an unprecedented evolution from classical, centralized, and homogenous architectures into an extreme complex network structure, in which a large number of network devices are densely deployed in an irregular, decentralized, and heterogenous fashion. This shift in network architecture requires network devices to become more flexible, autonomous and cooperative, so as to meet the various performance requirements of different wireless services.

In this book, we focus on communication systems in which network devices need to coordinate with each other so as to increase the overall performance. Such coordination can, for example, take place between small access points that seek to coordinate their radio resource allocation in the same spectrum, ultradense small cells with massive MIMO that share the same limited pilot sequences, mobile users with nonorthogonal multiple access (NOMA) that share the same subchannels, nearby single-antenna users that can cooperatively perform virtual MIMO communications, or even unlicensed users that wish to cooperatively sense the spectrum of the licensed users.

Conventionally, the solutions of these cooperative scenarios have been based on either centralized optimization algorithms that require a large amount of computational resources (e.g., subchannel allocation in NOMA), or decentralized heuristic methods with suboptimal performances (e.g., pilot reuse in Massive MIMO). More recently, there has been a surge in models that adopt the framework of *cooperative games*, in which the coordination among network devices is formulated by the coalition formation process performed by self-interested players. These game theoretical methods typically seek to establish distributed solutions that are stable, in the sense that no device has an incentive to change its coalition membership. Their outcome can achieve a balance between the computational complexity and the network performance. Indeed, cooperative games, in general, and *coalition formation games* (CF games), in particular, have become a popular tool for analyzing wireless networks.

Most of the existing body of work focuses on coalition formation models in which the players form separate coalitions and achieve performance gain from the single coalition they join. However, in many cooperative scenarios of future wireless systems, a network device may need to join multiple groups of cooperative devices, and thus, these cooperative groups may overlap with each other. For example, in the subchannel allocation problem in NOMA, the mobile users share the same subchannel form a coalition, and thus, each mobile user join multiple coalitions as they access multiple subchannels. In this book, we introduce a mathematical framework from cooperative games, known as *overlapping coalition formation games* (OCF games), which provides the necessary analytical tools for analyzing how network devices in a wireless network can cooperate by joining, simultaneously, multiple overlapping coalitions. Therefore, the readers can utilize this book as a tool to address the cooperative scenarios in future wireless networks.

First, in Chap. 1, we introduce the basic concepts of CF games and OCF games in general, and develop two polynomial algorithms for two classes of OCF games, i.e., K-coalition OCF games and K-task OCF games, respectively. Then, in Chaps. 2 and 3, we present two emerging applications of OCF games in small cell-based heterogeneous networks (HetNets) and cognitive radio networks, in order to show the advantages of forming overlapping coalitions compared with the traditional nonoverlapping CF games. Finally, in Chap. 4, we discuss the potential challenges of using OCF games in future wireless networks and briefly present some other potential applications.

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