Chapter 16

Game Theory for Resource Allocation in Wireless Networks

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ABSTRACT

Wireless technologies and devices are becoming increasingly ubiquitous in modern society. Wireless resources are natural and fixed, whereas wireless technologies and devices are increasing day-by-day, resulting in spectrum scarcity. As a consequence, efficient use of limited wireless resources has become an issue of vital importance in wireless systems. As demand increases, management of limited wireless resources for optimal allocation becomes crucial. Optimal allocation of limited wireless resources results in quick and reliable dissemination of information to larger service areas. Recently, game theory has emerged as an efficient tool to help optimally allocate wireless resources. Game theory is an optimization technique based on strategic situations and decision-making, and has found its application in numerous fields. The first part of this chapter presents a review of game theory and its application in resource allocation at different layers of the protocol stack of the network model. As shown by a recent study, static assignment of frequency spectrum by governmental bodies, such as FCC (Federal Communications Commission) in the United States, is inefficient since the licensed systems do not always fully utilize their frequency bands. In such a scenario, unlicensed secondary (cognitive radio) users can identify the idle spectrum bands and use them opportunistically. In order to access the licensed spectrum dynamically and opportunistically, the dynamic spectrum access functionality needs to be incorporated in the next generation (XG) wireless networks. Different game theory approaches for dynamic spectrum access are discussed in the second part of the chapter.

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I. INTRODUCTION

Wireless networks, in general, refer to communication networks where the interconnection between users is achieved without the use of wires. Wireless communication systems and networks are regarded as the tools for “anytime-anywhere connection.” Wireless communications and networks have experienced booming growth in past few decades with billions of new wireless devices coming into use each year. With more wireless devices being used for different purposes and application scenarios, wireless technologies and devices are becoming more ubiquitous. But wireless resources (e.g. bandwidth) are natural and limited. Therefore, it is important to make efficient use of the limited wireless resources available. Optimal allocation of resources in wireless systems can thus, be thought as in terms of active management of wireless resources. Efficient allocation of resources in the wireless system results in fast and reliable dissemination of information to the destination region. In general, resource allocation in centralized systems, such as centralized cellular system and infrastructure-based ad-hoc networks, is somewhat easy and optimal. However, allocation is difficult and might not always be optimal in decentralized systems such as ad-hoc networks.

Government bodies, such as Federal Communications Commission (FCC) in the United States, assign a fixed RF spectrum to be used by service providers for a fixed duration over a specified geographic region. The fixed frequency allocation strategy has been one of the main techniques to mitigate the interference among adjacent spectrum-band users in conventional wireless systems. With the rapid spread and advancement of wireless technologies and increasing number of devices, there has been an increasing concern over the issue of spectrum scarcity. One of the common ways to solve the problem of spectrum scarcity in conventional wireless systems is to increase the system throughput or goodput (bits/second) in the given RF band by using optimization approaches. Researchers have used a variety of techniques for system optimization and this subject matter is still drawing a lot of research interest and effort from all over the world. Various factors causing spectrum scarcity have also been presented and discussed in the literature (Akyildiz, Lee, Vuran, & Mohanty, 2006; Haykin, 2005). One of them is the legacy command-and-control regulation, which limits the dynamic spectrum access users. While almost the entire RF spectrum has already been allocated to different service providers, the fact remains that the allocated spectrum is not being fully utilized at all time and in all spaces. This indicates that spectrum scarcity is not due to the actual lack of RF spectrum, but because of the wasteful static allocation to the service providers. Thus, with the rising concern over spectrum scarcity, dynamic spectrum access in wireless communications has recently become the focus of research in academia as well as in industries all over the world (Akyildiz, Lee, Vuran, & Mohanty, 2006). The primary objective of dynamic spectrum access is to utilize the frequency band dynamically and/or opportunistically without creating harmful interference to the primary users. There are numerous techniques proposed in the literature for optimal allocation of wireless resources in legacy systems as well as in dynamic spectrum access environments.

Recently, game theory has emerged as a viable tool for obtaining a socially optimal resource allocation in distributed ad-hoc networking (MacKenzie & Dasilva, 2005). This chapter will focus first of all on the basics of game theory, and then go on to explain frequently occurring terminologies and definitions in game theory approaches for resource allocation. The chapter will then present game theoretic approaches for resource allocation in different layers of the protocol stack of the network model, followed by game theoretic approaches for dynamic spectrum access (DSA) in cognitive radio networks (de Figueiredo, 2009; Haykin, 2005; Mitola & Maguire, 1999). It is important to note that dynamic spectrum access