Chapter 13
Game–Based Control Mechanisms for Cognitive Radio Networks

ABSTRACT

Comprehensive control mechanism in cognitive radio networks is an important research topic within the scope of empowering cognitive radio functionality in beyond-4G mobile networks. Providing control mechanism for secondary users without interference with primary users is an ambitious task, which requires innovative management architecture designs and routing solutions. Operational challenges such as opportunistic spectrum access, solving problems related to spectrum and network heterogeneities, and requests for the provisioning of Quality-of-Service to different applications must be resolved. As part of a novel management architecture, the control mechanism advances a new approach for cognitive radio networks. We explore this in this chapter.

TWO-WAY MATCHING GAME BASED BANDWIDTH SHARING *(TMGBS)* SCHEME

Bandwidth is an extremely valuable and scarce resource, and may become congested to accommodate diverse services in wireless communications. To enhance the efficiency of bandwidth usage, the concept of cognitive radio has emerged as a new design paradigm. Recently, S. Kim proposed a new Two-way Matching Game based Bandwidth Sharing (*TMGBS*) scheme for cognitive radio networks (Kim, 2013). Under dynamically changing network environments, the *TMGBS* scheme

formulates the bandwidth sharing problem as a two-way matching game model. In addition, modified game theory is adopted to reach a near Pareto optimal solution while avoiding bandwidth inefficiency. This approach can make the system more responsive to the current network situation.

Development Motivation

Recently, multimedia wireless applications are growing so rapidly that bandwidth scarcity has become a bottleneck of wireless communication development. Therefore, efficient bandwidth management becomes a key factor in enhancing

network performance. However, during traditional network operations, bandwidth is statically allocated to licensed users and regulated via a fixed assignment policy and; this static allocation approach is not efficient. Currently, it has been observed that allocated bandwidth bands are largely unused in any time and location; these are referred to as bandwidth holes (Niyato & Hossain, 2007), (Niyato & Hossain, 2008). To maximize bandwidth efficiency, bandwidth holes can be shared opportunistically while efficiently avoiding interference.

Cognitive Radio (CR) is a paradigm for wireless communications in which a wireless node changes its transmission or reception parameters to communicate efficiently with licensed or unlicensed users. By detecting unoccupied bandwidth holes in the radio spectrum environment, the CR technique can allow unlicensed users to use bandwidth holes as long as they cause no intolerable interference to licensed users. Therefore, CR has been developed as an emerging technique for the dynamic bandwidth sharing. Based on this technique, the bandwidth utilization and users' satisfaction can be enhanced dramatically (Liu, Shen, Song, & Wang, 2009). Under dynamically changing environments, licensed and unlicensed users have to coordinate with each other in order to obtain the best solution for all. The benefits of cooperation can be achieved through negotiation among the CR users. Therefore, the CR users have to bargain with each other to achieve a fair and efficient solution. It motivates the development of adaptive bandwidth sharing algorithms based on the cooperative bargaining model (Niyato, 2008).

The *TMGBS* scheme is a new adaptive CR bandwidth sharing scheme based on the game theory. The main goal of the *TMGBS* scheme is to maximize the revenue of primary users while maximizing the bandwidth efficiency along with the satisfaction of the secondary users. To satisfy the design goal, the methodologies that the *TMGBS* scheme adopted are the two-sided matching game (Kimbrough, & Kuo, 2010), (Malanchini, Cesana,

Gatti, 2009) and modified game theory (Mehmet, & Ramazan, 2001), (Kim, 2010). The proposed approach can model the dynamic behavior of each user and adapt their actions adaptively. Usually, most previous work in the area of cognitive radio emphasized the technical aspect of bandwidth sharing like as bandwidth sensing technique or dynamic access protocol (Niyato, 2008). However, the *TMGBS* scheme focuses on the economic aspect of bandwidth sharing; it refers to the bargaining process of selling-and-buying bandwidth in a CR environment.

To develop a two-sided matching game, two sets of individual players are given and asked to form pairs consisting of one member from each set; a player from one side can be matched only with a player from the other side. Matching can be regarded as stable only if it left no pair of players on opposite sides who were not matched to each other but would both prefer to be. A special property of two-sided matching game is that stable matching always exists (Li, Xu, Liu, Wang, & Han, 2010). In the *TMGBS* scheme, the bandwidth sharing problem in CR networks is designed as a two-sided matching model; licensed and unlicensed users are defined as primary and secondary users, respectively. One side set only consists of primary users, who offer the amount of sharing bandwidth to maximize their revenues. The other side set consists of secondary users, who can purchase bandwidth to improve their QoS satisfactions. Primary and secondary users are assumed to be self-regarding game players and select their strategies to maximize their perceived payoffs. Based on the dynamic bandwidth sharing strategy, the bandwidth utilization and users' satisfaction can be enhanced dramatically (Niyato, 2008).

To satisfy both primary and secondary users' purposes, multi-objective optimization techniques play a very important role. Over the past years, several studies dealing with this issue have been reported. Among various optimization techniques, the Modified Game Theory (MGT) is a well-known method to reach a near Pareto optimal

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