Chapter 7
Game Theory for Cognitive Radio Networks

ABSTRACT

A cognitive radio is an intelligent radio that can be programmed and configured dynamically. Its transceiver is designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in the wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management. In recent years, the development of intelligent, adaptive wireless devices called cognitive radios, together with the introduction of secondary spectrum licensing, has led to a new paradigm in communications: cognitive networks. Cognitive networks are wireless networks that consist of several types of users: often a primary user and secondary users. These cognitive users employ their cognitive abilities to communicate without harming the primary users. The study of cognitive networks is relatively new and many questions are yet to be answered. This chapter furthers the study.

INTRODUCTION

With the rapid deployment of new wireless devices and applications, the last decade has witnessed a growing demand for wireless radio spectrum. However, current wireless networks are characterized by a static spectrum allocation policy where governmental agencies assign wireless spectrum to license holders on a long-term basis for large geographical regions. This fixed spectrum assignment policy becomes a bottleneck for more efficient spectrum utilization under which a great portion of the licensed spectrum is severely under-utilized. The inefficient usage of the limited spectrum resources urges the spectrum regulatory strategy to review their policy and start to seek for innovative communication technology that can exploit the wireless spectrum in a more intelligent and flexible way. Recently, dynamic spectrum access techniques were proposed to solve these spectrum inefficiency problems. The key enabling technology of dynamic spectrum access is Cognitive Radio (CR) technology, which provides the capability to share the wireless channel with licensed users in an opportunistic manner (Akyildiz, Lee, Vuran, & Mohanty, 2008).

DOI: 10.4018/978-1-4666-6050-2.ch007

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Cognitive Radio (CR) networks will provide high bandwidth utilization to users via heterogeneous wireless architectures and dynamic spectrum access techniques. However, CR networks impose challenges due to the fluctuating nature of the available spectrum, as well as the diverse QoS requirements of various applications. Spectrum management functions can address these challenges for the realization of this new network paradigm (Akyildiz, 2008). Nowadays, game theory has been used in communication networks to model and analyze the interactive behaviors in a competitive area. Game theory is also a useful tool that can be used for radio spectrum management in a cognitive radio network. In the past several years, some of the game theoretic models were proposed for different CR control issues such as power control, call admission control, spectrum trading, spectrum competition, interference avoidance, spectrum sharing, and spectrum access (Akyildiz, 2008), (Zhang, & Yu, 2010).

Traditionally, a game is a model of interactive decision process, which includes at least two players. Each player is a decision making entity. In CR networks, the primary user (licensed users) and the secondary user (unlicensed users) are assumed both players. Their behaviors are rational and selfish. Each player has his action space and utility function, and the objective of game is to maximize his utility. Spectrum sharing is that the secondary users access the spectrum competitively and maximize its own income while the primary user is not interfered. This spectrum sharing process can be modeled as games. The game models for CR networks can be classified into three categories; non-cooperative, cooperative and economic spectrum sharing games.

NON-COOPERATIVE SPECTRUM SHARING GAMES

In this section, we discuss non-cooperative spectrum sharing games such as repeated game, potential game, supermodular game, and so on. In a non-cooperative game with rational network users, each user only cares about his own benefit and chooses the optimal strategy that can maximize his payoff function (Figure 1). Such an outcome of the non-cooperative game is termed as Nash equilibrium, which is the most commonly used solution concept in game theory (Wang, Wu, & Liu, 2010).

Repeated Game for Cognitive Radio Networks

In order to model and analyze long-term interactions among players, the repeated game model is used where the game is played for multiple rounds. A repeated game is a special form of an extensive-form game in which each stage is a repetition of the same strategic-form game. The number of rounds may be finite or infinite, but usually the infinite case is more interesting. Because players care about not only the current payoff but also the future payoffs, and a player's current behavior can affect the other players' future behavior, cooperation and mutual trust among players can be established (Wang, Wu, & Liu, 2010). In order to improve the cooperation among secondary users, distributed spectrum access mechanisms based on the repeated game approach have been developed to achieve efficient and fair spectrum allocation (Li, Liu, & Zhang, 2010).

Repeated game is the combination of a series of subgame with the same structure. Since the participants can learn and summarize the results of subgame after several repeated game, repeated game extends the strategic space. In 2009, a repeated spectrum sharing game was proposed by using cheat-proof strategy (Zhang, & Yu, 2010). In this model, two cooperation rules with efficiency and fairness were considered. Under the constraints of these rules, the spectrum sharing problem is modeled as a repeated game where any deviation from cooperation will trigger the punishment. In addition, two cheat-proof strategies were also proposed to enforce that selfish users would report their true channel information. This

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