Chapter 10
Power Control Schemes Based on Game Theory

ABSTRACT

Power control is the intelligent selection of transmitter power output in a communication system to achieve good performance within the system. The notion of good performance can depend on context and may include optimizing metrics such as link data rate, network capacity, geographic coverage and range, and life of the network and network devices. Power control algorithms are used in many contexts, including cellular networks, sensor networks, and wireless LANs. Typically, there is no simple answer to the problem of power control, and a good algorithm must strike a balance between the benefits and drawbacks associated with targeting a particular transmit power based on the performance criteria of most importance to the designer. This chapter discusses power control schemes.

EVOLUTIONARY GAME-BASED POWER CONTORL (*EGPC)* SCHEME

In view of the remarkable growth in the number of users and the limited network resource, an efficient network management is very important and has been an active area of research over the years. Especially, during wireless network operations, adaptive power control is an effective way to enhance the network performance. Recently, S. Kim proposed a new Evolutionary Game-based Power Control (*EGPC*) scheme based on the online approach (Kim, 2011). To converge a desirable network equilibrium, the developed scheme adaptively adjusts a transmit power level in a distributed online manner. For the efficient network management, the online approach is dynamic and flexible that can adaptively respond to current network conditions.

Development Motivation

Recently, wireless/mobile networking is one of the strongest growth areas of communication technology. The explosive growth of new communication services and the widespread proliferation of multimedia data have necessitated the development for an efficient wireless network system. However, due to the limited energy supply, an efficient energy management becomes a key factor in enhancing network performance (Meshkati, Poor, Schwartz, & Balan, 2006). In

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wireless networks, most of the wireless devices are battery-powered. Therefore, an adaptive power control strategy has been shown to be an effective way to maintain the energy efficiency in wireless devices. In addition, it can optimize the spatial reuse of wireless bandwidth by reducing the interference between wireless links. Therefore, the benefit of adaptive power control strategy is not just to increase battery life, but also to maximize the overall network performance (Feng, Mau, & Mandayam, 2004), (Holliday, Goldsmith, Glynn, & Bambos, 2004).

To understand the behavior of self-regarding applications or independent network users, a game model has some attractive features. However, due to some reasons, classical game theory cannot be directly applied to wireless network managements. First, players have very limited information. Therefore, it is usually impossible to delineate all conceivable strategies. Second, it is not easy to assign a payoff value to any given outcome, and also difficult to synchronize the activities of the different players. Third, due to the complexity of network situations, the mathematical modeling and numerical analysis have met with limited success (Xiao, Shan, & Ren, 2005).

In 1974, Maynard Smith introduced the fundamental concept of an evolutionary game theory. It has been developed in biological sciences in order to explain the evolution of genetically determined social behavior. In this theory, the payoffs depend on the actions of the co-players; strategies with high payoff will spread within the entire populations of players (Hofbauer, & Sigmund, 2003), (Tao, & Wang, 1997), (Menasche, Figueiredo, & Silva, 2005). Nowadays, the main idea of evolutionary game has emerged as an alternative perspective to classical game theory and become an interesting research field. It can be practically applied to wireless network managements without much deviation from its original form.

Usually, the performance in wireless networks is strongly related to power control algorithms. Power control decisions affect many aspects of the network performance such as the signal QoS, interference and energy consumption (Ginde, Neel, & Buehrer, 2003), (Long, Zhang, Li, Yang, & Guan, 2007). The *EGPC* scheme is designed as a new power control algorithm by using the evolutionary game theory. Based on the evolutionary learning mechanism, the developed algorithm can constantly adapt each device's power level to get an appropriate performance balance between contradictory requirements.

The *EGPC* scheme is a new adaptive online power control scheme based on the evolutionary game theory. In the developed scheme, wireless devices are assumed to be self-regarding game players and make their decisions for the goal of maximizing their perceived payoffs. By using an adaptive online approach, each player's behavior might affect the behavior of other players. Therefore, control decisions are coupled with one another; the result of the each user's decisions is the input back to the other user's decision process. The dynamics of the interactive feedback mechanism can cause cascade interactions of players and players can make their decisions to quickly find the most profitable solution. Finally, it can lead the network system to an efficient equilibrium state.

Related Work

Recently, several power control schemes based on the game theory have been presented in research literature. The *Rate and Power Control* (*RPC*) scheme is a control algorithm based on game model for wireless communication (Yang, Li, & Li, 2009). This scheme introduced the classic form of non-cooperative power control model as a new framework. By considering the joint transmission rate and power control issues, the Nash equilibrium solution for either the transmit rate or the transmit power is achieved in the cognitive radio. In addition, a pricing function that relates to both transmit rate and power is introduced for improving the Pareto efficiency and fairness of the obtained Nash equilibrium solution.