Chapter 15
Game-Based Control Approach for Smart Grid

ABSTRACT

The concept of smart grid to transform the old power grid into a smart and intelligent electric power distribution system is, currently, a hot research topic. Smart grid offers the merging of electrical power engineering technologies with network communications. Game theory has featured as an interesting technique, adopted by many researchers, to establish effective smart grid communications. The use of game theory has offered solutions to various decision-making problems, ranging from distributed load management to micro storage management in smart grid. Interestingly, different researchers have different objectives or problem scopes for adopting game theory in smart grid. This chapter explores the game-based approach.

BIFORM GAME BASED COGNITIVE RADIO CONTROL (BGCRC) SCHEME FOR SMART GRID COMMUNICATIONS

Smart grid is widely considered to be a next generation power grid, which will be integrated with information feedback communications. However, smart grid communication technologies are subject to inefficient spectrum allocation problems. Cognitive radio networks can solve the problem of spectrum scarcity by opening the under-utilized licensed bands to secondary users. In 2012, S. Kim proposed a new Biform Game based Cognitive Radio Control (*BGCRC*) scheme for smart grid environments (Kim, 2012). To enhance the efficiency of spectrum usage, the concept of biform game model is adopted as a new spectrum control paradigm. This approach can make the system be close to the optimized network performance.

Development Motivation

Smart grid has become a global concern as the next generation power grid. A crucial factor to realize smart grid features is timely access to meter data via reliable communication infrastructure. Therefore, two-way feedback communication plays an important role in smart grid; it directly affects the performance of the whole system. To accommodate the growth of the numbers and types of data, a significant challenge for the future smart grid is

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to ensure a large amount of bandwidth. Therefore, a key point in the success of smart grid technology is how to reduce the communication expenses as well as saving transmission bandwidth. Recently, many advanced wireless technologies are being investigated to be used for the communication layer of smart grid (Ghasemi, & Hosseini, 2010). Cognitive Radio (CR) is a new technique for wireless communications to improve the utilization of radio spectrum (Li, Xu, Liu, Wang, & Han, 2010).In the CR networks, unlicensed users (i.e., secondary users: SUs) are allowed to sense and temporarily access the unused bands originally allocated to the licensed users (i.e., primary users: PUs) when the PUs are inactive. For the accurate detection of idle spectrum bands, spectrum sensing is a crucial technology. Among spectrum sensing methods, cooperative sensing is an efficient and promising technique to obtain more trustable sensing results. This approach has been shown that sensing performance can be greatly improved (Liu, Shen, Song, & Wang, 2009).

Nowadays, the main idea of game theory has emerged as an effective way of designing this CR management process. Game theory is a field of applied mathematics that provides an effective tool in modeling the interaction among independent decision makers. In 1996, A. Brandenburger and H. Stuart introduced the fundamental notion of the biform game to shape the competitive environment in a favorable way. It is a hybrid noncooperative-cooperative game model to formalize the two-stage decision problem (Brandenburger, & Stuart, 2007). The first stage is the noncooperative component of a biform game. Each player chooses a strategy to maximize his expected payoff while regarding a subsequent effect of the chosen strategies on the second stage. The second stage is the cooperative component to model the resulting competitive environment. In this stage, players form a coalition to generate a surplus, which is shared fairly and optimally. Therefore, an actual payoff is realized after the second-stage game. Recently, it has been proven that the biform game model is efficient when it is applied to a business strategy (Stuart, 2005).

The *BGCRC* scheme is designed as a new biform game model for smart grid system. To support the fast growing demand, the *BGCRC* scheme presents a biform game based CR communication algorithm, which is mainly motivated to use the unlicensed bandwidth while ensuring the need of explosive data traffic. At the first stage, SUs estimate the current network condition and adaptively form clusters for the cooperative spectrum sensing. Clusters are made up according to the non-cooperative game model. At the second stage, the detected idle spectrum is shared based on the cooperative bargaining model. The main feature of the *BGCRC* scheme is to maximize spectrum efficiency while ensuring the sharing fairness. Under dynamically changing network environments, SUs compete or coordinate with each other in order to maximize their payoffs. Therefore, the developed biform game approach is suitable to get a globally desirable network performance.

SPECTRUM MANAGEMENT ALGORITHMS IN THE *BGCRC* SCHEME

To reach a desirable system performance, the CR spectrum is sensed and shared based on the biform game model. This approach can be concluded to be an effective solution for the adaptive CR spectrum management in smart grid communications.

Non-Cooperative Game Based Spectrum Sensing Algorithm

The main concept of smart grid is the employment of intelligent two-way communication networks. Therefore, a key determining factor is timely access to meter data via an effective communication infrastructure. However, in harsh smart grid environments, communication infrastructure can provide