Chapter 10
Self–Organizing Spectrum Access with Geo–Location Database

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ABSTRACT

Dynamic spectrum access is envisioned as a promising paradigm for addressing the spectrum underutilization problem. According to the recent ruling of Federal Communications Commission (FCC) for white-space spectrum access, white-space devices are required to query a geo-location database to determine the spectrum availability. This chapter adopts a game theoretic approach for the self-organizing white-space spectrum access network design. This chapter first models the distributed channel selection problem among the devices as a distributed spectrum access game, and shows that the game is a potential game. This chapter then designs a self-organizing spectrum access algorithm which can achieve a Nash equilibrium of the game without any information exchange among the devices. Numerical results demonstrate that the proposed algorithm is efficient and can adapt to the dynamical network context changing.

INTRODUCTION

Wireless spectrums are often licensed to service providers based on long-term agreements. A service provider will serve its primary users using its licensed spectrum. Due to the stochastic nature of primary users’ traffic, the licensed spectrum may not be fully utilized at all locations and all times. Field measurements by Shared Spectrum Cooperation in Chicago and New York City showed that the overall average utilization of a wide range of different types of spectrum bands is below than 30% (McHenry et al., 2005). Dynamic spectrum access is hence proposed as a promising technique to alleviate the problem of spectrum underutilization (Akyildiz et al., 2006). Dynamic spectrum access enables unlicensed wireless users (secondary users) to opportunistically share the vacant licensed channels owned by legacy
spectrum holders (primary users), and thus can significantly improve the spectrum efficiency (Wu et al., 2014) (Duan et al., 2014) (Huang, 2013) (Yan et al., 2013) (Li et al., 2013) (Chen and Huang, 2013b) (Gao et al., 2013) (Huang et al., 2006).

The Federal Communications Commission (FCC) is now actively formulating policy and regulations for dynamic spectrum access. The most recent FCC ruling requires that secondary TV spectrum users (i.e., white-space devices) must rely on a geo-location database to determine the spectrum availability (FCC, 2010). In such a database-assisted architecture, the incumbents (primary users of TV spectrum) provide the database with the up-to-date information including TV tower transmission parameters and TV receiver protection requirements. As illustrated in Figure 1, based on this information the database will be able to tell a white-space device the vacant TV channels and the allowable transmission power level at a particular location.

Although the database-assisted approach obviates the need of spectrum sensing (i.e., detection of spectrum opportunities by individual secondary users), the task of developing a comprehensive and reliable white-space spectrum access system remains challenging (Murty et al., 2011). A key challenge is how to choose proper vacant channel for each device in a distributed manner in order to avoid severe interference with other devices. In this chapter, we adopt the game theoretic approach to address the challenge. Game theory is a useful framework for designing distributed mechanisms, such that the white-space devices in the system can self-organize into a mutually acceptable channel allocation. The self-organizing feature can add autonomies into white-space networking and help to ease the heavy burden of complex centralized system management (Brunner et al., 2011).

Specifically, in this chapter we model the distributed channel selection problem among the devices as a distributed spectrum access game. We then propose a self-organizing spectrum access algorithm that can achieve the Nash equilibrium of the game. The main results and contributions of this chapter are as follows:

1. **General Game Formulation**: We formulate the distributed channel selection problem among the white-space devices as a distributed spectrum access game based on the general physical interference model.

*Figure 1. Distributed spectrum access with geo-location database*
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