Chapter 14

Distributed Mechanisms for Multiple Channel Acquisition in a System of Uncoordinated Cognitive Radio Networks

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ABSTRACT

Due to the constraint imposed by the Dynamic Spectrum Access paradigm, Cognitive Radio (CR) networks are entangled in persistent competition for opportunistic access to underutilized spectrum resources. In order to maintain quality of service, each network faces the challenge of acquiring dynamic enough channels to meet channel size requirement. The main goal of every CR network is to minimize the amount of contention experienced during channel acquisition and to maximize the utility derived from acquired channels. This is a major challenge, especially without a global communication protocol that can facilitate communication between the networks. This chapter discusses self-coexistence of CR networks in a decentralized system with no support for coordinated radio transmission activities. Channel acquisition mechanisms that can help networks minimize contention and maximize utility are also discussed. The mechanisms guarantee fast convergence of the system leading to an equilibrium state whereby networks are able to operate on acquired channel with minimal or zero contention.

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INTRODUCTION

Federal regulators have allocated most of the radio spectrum relevant for wireless communication. The static allocation makes it difficult for emerging wireless operators to meet up with bandwidth requirements. Studies have shown that the licensed owners underutilize allocated spectrum bands. Only about five percent or less of the allocated spectrum bands is actually utilized (First IEEE Symposium, November 2005). Dynamic Spectrum Access (DSA) was proffered as a possible solution to these problems of spectrum scarcity and underutilization. Different approaches have been suggested that allow secondary users to operate alongside the licensed owners while strictly adhering to interference constraints (Zhao & Sadler, 2007).

A cognitive radio (CR) is a radio device equipped with the capability to dynamically discover and access fallow spectrum bands. Formerly, cognitive radio is defined as radio that can change its transmitter properties based on interaction with its environment (Federal Communication Communication (FCC), 2003). Cognitive radios are characterized by their cognitive ability and reconfigurability (Haykin, 2005). The cognitive ability allows them to identify temporal unused spectrum at any specific location (Akyildiz, Lee, Vuran, & Mohanty, 2008). Cognitive radio can also be dynamically reconfigured to transmit and receive on a variety of frequencies and use different access technologies supported by its hardware design (Jondral, 2005). Cognitive radios are required to adhere to the DSA paradigm, which allows them to share spectrum bands with the licensed owners in an opportunistic manner. The most important regulatory aspect of the DSA is that cognitive radios must not interfere with the operation in the licensed bands and must identify and avoid such bands in timely manner (Federal Communication Commission (FCC), 2004) (Defence Advanced Research Project Agency (DARPA)). If any of the spectrum bands being used by the cognitive radios are accessed by the licensed incumbents, they are required to immediately vacate the spectrum band within the channel move time and switch to another channel (Cordeiro, Challapali, & Sai Shankar, 2005). A CR network is formed by a group of CR users that do not have the license to operate in any desired band. CR networks are sometimes referred to as secondary networks or DSA networks. One of the major challenges facing the existence of CR networks is the problem of self-coexisting with other CR networks operating in the same spectral space. Self-coexistence by definition simply means the ability of CR networks to independently exploit the spectrum to maintain quality of service with minimal conflict with neighboring networks.

Some suggestions have been made that permit distributed coordination among CR networks via the use of common control channels (Wu, Lin, Tseng, & Sheu, 2000) (So & Vaidya, 2004) (Zhao, Zheng, & Yang, 2005). But the availability of control channels is not always guaranteed. The common control channels are likely to be reclaimed by the licensed owners at any time. Their return to the control channels entails they can no longer be used for coordination between networks. In the case of a simple jamming attack the control channels will be rendered useless, disrupting the activities in the network. Similarly, in a situation where spectrum bands are scarce, using some of the channels as control channels would be inefficient and can lead to spectrum starvation. Those channels could be used instead for critical data transmission purposes. Thus, in our study we consider such situations where communication between CR networks is a major challenge, making it difficult for them to coordinate. Under such a condition, it becomes inconvenient for CR networks to operate in the vacant spectral space without getting into conflict with one another. For CR networks to remain functional amidst scarce spectrum resources, they need to implement mechanisms that maximize spectrum utilization. Such mechanisms should include some conflict avoidance mechanisms to minimize contention that could arise.