Chapter 10
MAC Layer Spectrum Sensing in Cognitive Radio Networks

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ABSTRACT

Efficient use of the available licensed radio spectrum is becoming increasingly difficult as the demand and usage of the radio spectrum increases. This usage of the spectrum is not uniform within the licensed band but concentrated in certain frequencies of the spectrum while other parts of the spectrum are inefficiently utilized. In cognitive radio environments, the primary users are allocated licensed frequency bands while secondary cognitive users can dynamically allocate the empty frequencies within the licensed frequency band, according to their requested quality of service specifications. In this chapter, the authors investigate and assess the performance of MAC layer sensing schemes in cognitive radio networks. Two performance metrics are used to assess the performance of the sensing schemes: the available spectrum utilization and the idle channel search delay for reactive and proactive sensing schemes. In proactive sensing, the adapted and non-adapted sensing period schemes are also assessed. Simulation results show that proactive sensing with adapted periods provides superior performance at the expense of higher computational cost performed by network nodes.

1. INTRODUCTION

In cognitive radio environments the primary users are allocated licensed frequency bands while secondary cognitive users can be dynamically allocated the empty frequencies within the licensed frequency band, according to their requested Quality of Service (QoS) specifications. Spectrum sensing is commonly recognized as the most fundamental task in cognitive radio based on dynamic spectrum access due to its important role in discovering the spectrum holes (Yucek & Arslan, 2009; Haykin, 2005). To achieve this goal the unlicensed user should monitor the licensed channels to identify the spectrum holes and to properly utilize them. In order to adopt the spectrum-agile features required

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by cognitive radios, enhancements in physical and MAC (Medium Access Control) layers are needed (Ying, Kwang, Li, & Mahonen, 2011).

In cognitive radio networks, MAC protocols can be categorized as Direct Access Based (DAB) or Dynamic Spectrum Allocation (DSA) (De Domenico, Strinati, & Di Benedetto, 2012). In DAB protocols, each transmitter-receiver pair aims to optimize its local optimization goal and no global network optimization is considered since the computational cost and latency are restricted by the simple protocol architecture. DSA protocols, on the other hand, aim at maximizing the global optimization goal for the whole network in an adaptive manner using complicated algorithms.

MAC layer protocols play important roles in cognitive radio networks. The main functionalities of MAC layer in cognitive radios includes: spectrum mobility, spectrum sensing, resource allocation, and spectrum sharing (Akyildiz, Lee, Vuran, & Mohanty, 2006). Spectrum mobility lets the secondary user to jump from one channel when it is re-occupied by its primary user to another vacant channel. Spectrum sensing is the process of detecting primary user's existence and maintaining a picture of the available channels from secondary usage. Resource allocation is responsible for resources assignment for secondary users according to their QoS requirements. Spectrum sharing handles the coordination among primary and secondary users to avoid harmful interference.

The task of sensing in the physical layer is to decide on the existence or absence of licensed user's signals on different channels. There are several proposed physical layer detection methods for performing this task such as energy detection (Kim, Xin, & Rangarajan, 2010), matched filtering detection (Kapoor, Rao, & Singh, 2011), feature detection (Liu & Zhai, 2008), and Eigen-values based spectrum detection (Yonghong & Ying-Chang, 2007). The channel-sensing outcome could be one of the following possibilities:

- The channel is idle.
- The channel is occupied by a licensed user but can be utilized by the unlicensed user with some power constrains so that the Quality of Service (QoS) of the licensed user transmission is not degraded to unacceptable level by the interference from the unlicensed user.
- The channel is not available to the unlicensed user.

For the aforementioned possible outcomes of physical layer sensing to be available, some important fundamental questions arise: when the available radio channels for the unlicensed usage should be sensed and in which order and how frequent? These tasks are the responsibility of MAC layer. Thus, in this chapter we address the potential need of MAC layer sensing schemes in cognitive radio networks aiming to find a clear policy describing how the available spectrum should be utilized to achieve as low idle channel search delay as possible. Both reactive and proactive sensing methods are considered. In proactive sensing the adapted and non-adapted sensing periods, schemes are also assessed. The assessment of these sensing schemes will be validated via two performance metrics: available spectrum utilization and idle channel search delay. According to the best of our knowledge, proactive and reactive sensing performance has not been extensively studied before.

This chapter is structured as follows. In Section 2 we briefly introduce the channel usage model and utilization factor definition. The MAC layer sensing modes (reactive and proactive) are presented in Section 3. In Section 4, the system model, simulation scenario and parameters used in the simulations are presented. In addition, the simulation results showing the performance of each scheme are also analyzed in this section. Finally, the conclusions and directions for future work are drawn in Section 5.

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