Chapter 8
MAC Layer Protocols for Cognitive Radio Networks

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ABSTRACT

In the last few decades, the Cognitive Radio (CR) paradigm has received huge interest from industry and academia. CR is a promising approach to solve the spectrum scarcity problem. Moreover, various technical issues still need to be addressed for successful deployment of CRNs, especially in the MAC layer. In this chapter, a comprehensive survey of the Medium Access Control (MAC) approaches for CRN is presented. These MAC technologies under analysis include spectrum sharing, multiple antenna techniques, cooperation, relays, distributed systems, network convergence, mobility, and network self-optimization. Moreover, various classifications of MAC protocols are explained in this chapter on the basis of some parameters, like signaling technique, type of architecture, sharing mode, access mode, and common control channel. Additionally, some case studies of 802.11, 802.22, and Mobile Virtual Node Operator (MVNO) are also considered for the case study. The main objective of this chapter is to assist CR designers and the CR application engineers to consider the MAC layer issues and factors in the early development stage of CRNs.

1. INTRODUCTION

Frequency spectrum is a limited resource for wireless communications and may become congested owing to a need to accommodate the diverse types of air interface used in cognitive radio networks. However, since conventional wireless communications systems also utilize the frequency bands allocated by the Telecom Regulatory Authority of India (TRAI) and Federal Communications Commission (FCC) in a static manner, they lack adaptability in the existing framework (Telecom Regulatory Authority of India, 2012). Also, several studies show that while some frequency bands in the spectrum are heavily used, other bands are largely unoccupied most of time. These latent

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vacant spectrums result in the under-utilization of available frequency bands. To defeat the over-crowding, different governing and non governing agencies and organization such as TRAI and FCC have been investigating new ways to manage Radio Frequency (RF) resources (FCC, 2003).

Today's the fixed spectrum assignment policy is used to characterize wireless networks. However, a huge portion of the allocated spectrums are used rarely and the environmental variation in the utilization of assigned spectrum ranges from 15% to 85%. The recent years have been seen major and remarkable development in the field of Cognitive Radio Network (CRN) technologies. Cognitive radio is a revolutionary technology; they guarantee to enhance the utilization of radio frequencies and make room for new and additional commercial data, emergency and military communication services etc. (Haykin, 2005). The influence of CRN's functions on the performance of the upper layer protocols such as routing and transport are complex and open research issues in these areas are also challenging in CRN (Cesana, 2011). Therefore, there is always requirement of CR-MAC (Cognitive Radio Medium Access Control) protocol to provide efficient, fair, and seamless services to user. One of the important factors which should be considered during design process of CRN is MAC layer issue (Chouhan, 2011).

1.1. Layered Architecture of Cognitive Radio Network

The introduction summarized above necessitates new communication protocols to be designed for awareness of the spectrum in CRN. This direct association requires the new MAC layer design in the entire CR networking protocol stack. The effects of the preferred spectrum bands and the variations due to spectrum mobility need to be carefully monitored in the design of these MAC protocols. The rapidly changing radio environment, more radio channels to utilize, number of factors to select during decisions taken by MAC and routing protocols, etc., makes design of CRN very challenging (Chouhan, 2011).

Typically, CRN consists of two types of users, i.e., Primary User (PU) and Secondary User (SU). PU or licensed user is the legitimate user who has more priority. SU is opportunistic user, who has less preference than the primary users. SU does not interrupt the transmission of the PU. So there is always requirement of dynamic algorithm to create separation between the transmission of the PU and SU. In the Figure 1, five layer architecture of CRN is shown. This layered architecture, is based on OSI reference model which represents bridge between the existing network architecture and the new CRN. Unlike from the existing models, spectrum sensing, spectrum sharing, scheduling, reconfiguration, Quality of Service (QoS), and mobility are very critical and challenging in the CRN (Akyildiz, Lee, Vuran, & Mohanty, 2006; Haykin, 2005). Therefore, CRN architecture requires spectrum management and spectrum mobility functions additionally (represented by vertical blocks in the Figure 1). The Second layer of this architecture is the MAC layer, which comprises two important functions: spectrum sensing and spectrum sharing of the CRN. Moreover, this architecture is primarily focused on the four basic functions (Akyildiz, Lee, Vuran, & Mohanty, 2006; Haykin, 2005):

1. **Spectrum Sensing:** Sensing is to identify vacant spectrum bands and distributing this spectrum with the tolerable interference to the PUs.
2. **Spectrum Management:** Selecting the best offered spectrum band to achieve high Quality of Service (QoS) requirements.
3. **Spectrum Mobility:** Preserving seamless and faultless network requirements during switch to better spectrum.
4. **Spectrum Sharing:** Offering the flexible and fair spectrum scheduling scheme simultaneously among SUs.