Chapter 9
MAC Protocols for Cognitive Radio Ad Hoc Networks:
Sensing Error–Aware and Spectrum Access Strategies

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ABSTRACT

In contrast to infrastructure-based networks, in wireless ad hoc networks nodes can discover and communicate with each other directly without involving central access points. In this mode of multi-hop networks, all nodes have equal right to access the medium. Hence, the performance of wireless ad hoc networks is mostly limited by traffic congestion. To alleviate such a problem, Cognitive Radio (CR) technology can be used. In this chapter, a CR-based Medium Access Control (MAC) layer for wireless ad hoc networks is investigated. The authors focus on Cognitive MAC protocols for an unlicensed user, which can be enabled to access the large amount of unused spectrum allocated for a licensed user in an intelligent way without causing any harmful interference. They propose a cognitive MAC protocol based on the theory of the Partially Observed Markov Decision Process (POMDP), which sense the radio spectrum, detect the occupancy state of different primary channels, and then opportunistically communicate over unused channels. The objective is to benefit as much as possible from the available spectrum opportunities by making efficient decisions on which channels to access, which ensures maximization of the throughput of the secondary user.

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1. INTRODUCTION

1.1. Wireless Ad Hoc Networks

Wireless ad hoc networks are multi-hop systems in which nodes assist each other in transmitting and receiving packets across the network. In contrast to infrastructure-based networks, in an ad hoc network nodes can discover and exchange information with each other directly without involving central access points. A node may join or leave the network at any time. In ad hoc networks, all nodes have equal right to access the medium. To be able to establish communication with each other, each node needs to be able to see the others. If a node wishes to communicate outside its range, another node within the same range operates as a gateway and forwards the contact in a multi-hop fashion. The recent work related to ad hoc networks focus on many issues such as network architecture and network capacity.

1.1.1. Capacity of Wireless Ad Hoc Networks

The problem of capacity is widely investigated and most researchers showed that the capacity can be increased as the size of the network is increased. In fact, capacity of wireless ad hoc networks is based on the traffic behaviour at the Medium Access Control (MAC) layer. As each node in wireless ad hoc networks has to transmit relayed data as well as its own, so we need to discuss the issue of fairness. In addition, in wireless ad hoc networks as the traffic might be directed to the gateways (e.g. Mesh and Sensor Wireless Networks) which are connected to external networks, these gateways would pose a bottleneck problem. In this case, we need to reduce the bottleneck wireless links along the path to the gateway. Other factors that influence the capacity of the network can also be considered, such as interference between simultaneous transmissions, fading, and environmental noise.

1.1.2. Channel Assignment

To address such above-mentioned problems, the existing MAC and routing protocols can be developed and enhanced to be convenient for wireless ad hoc networks. Multiple channels technique, for example, can be assigned between nodes to multiple radios at the same time, so such problems can be minimized and more data can be sent between nodes increasing the overall throughput of the network. In addition, different MAC protocols based on modification of the existed standards (e.g. IEEE 802.11, CDMA, and OFDM) were proposed for utilizing multiple channels. The notion of "soft" channel reservation, for example, was proposed to give preference to the channel that was used for the last successful transmission. Schemes that negotiate channels dynamically were also proposed to enable clients to communicate in the same region simultaneously. Other techniques such as single or multiple transceivers for each node have been widely discussed.

1.2. Cognitive Radio

With the rapid growth in wireless applications, the radio spectrum becomes of fundamental importance. Recent reports made by spectrum regulators such as Federal Communications Commission (FCC) in the United States (US) have shown that almost all the available spectrum has been allocated (Federal Communications Commission, 2003). However, extensive measurements made by Office of Communications (Ofcom) in the UK and Spectrum Policy Task Force (SPTF) in the US indicate that a large amount of licensed spectrum remains unused at a specific time or slot level (FCC, 2002; Office of Communications, 2005). As a result, in recent years, the FCC has been considering more flexible and comprehensive uses of the available spectrum (FCC, 2003). This phenomenon accelerated the emergence of Opportunistic Spectrum Access (OSA) concepts