Chapter 25
Quality of Service (QoS) Provisioning in Cognitive Wireless Ad Hoc Networks: Architecture, Open Issues and Design Approaches

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ABSTRACT

Cognitive Radio (CR) is a next-generation wireless communication technology that improves the utilization of the overall radio spectrum through dynamic adaptation to local spectrum availability. In CR networks, unlicensed or Secondary Users (SUs) may operate in underutilized spectrum owned by licensed or Primary Users (PUs) conditional upon the PU encountering acceptably low interference levels. A Cognitive Wireless Ad Hoc Network (CWAN) is a multihop self-organized and dynamic network that applies CR technology for ad-hoc mode wireless networks that allow devices within range of each other to discover and communicate in a peer-to-peer fashion without necessarily involving infrastructure such as base stations or access points. Research into Quality of Service (QoS) in CWAN is still in its infancy. To date, there is only a perfunctory attempt to improve the data-link and network layers of the Open Systems Interconnection (OSI) reference model for CR hosts, and so this is the focus of this chapter. We present a discussion on the architecture, open issues and design approaches related to QoS provisioning in CWAN. Our discussion aims to establish a foundation for further research in several unexplored, yet promising areas in CWAN.

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INTRODUCTION

Traditional static spectrum allocation policies have been to grant each wireless service, such as radio and TV stations, exclusive usage of certain frequency bands, whilst leaving several spectrum bands unlicensed for a wide range of purposes. Examples of unlicensed bands include the Industrial, Scientific and Medical (ISM) and Unlicensed National Information Infrastructure (UNII). In practice, the precious and limited unlicensed radio spectrums are shared by many wireless applications including Bluetooth, WiFi, WiMAX, and Zigbee. Other devices such as microwave ovens and cordless phones also operate in those bands. The unlicensed wireless devices are prohibited from using the licensed spectrum bands. However with the tremendous growth in ubiquitous low-cost wireless applications that utilize the unlicensed spectrum bands, network-wide performance of wireless communication networks will inevitably degrade in the future because of the increasing competition for spectrum especially in populated urban areas.

The Federal Communications Commission (FCC) Spectrum Policy Task Force (2002) pointed out that the current static spectrum allocation has led to overall low spectrum utilization where up to 70% of the allocated licensed spectrum remains unused (these are called white space), at any one time, even in a crowded area. Hence, the main reason of spectrum scarcity among the unlicensed users is, in fact, because of the spectrum allocation policy that is inefficient. White space is defined by time, frequency and maximum transmission power at a particular location. Consequently, Dynamic Spectrum Access (DSA) has been proposed so that unlicensed spectrum users or Secondary Users (SU)s are allowed to use the white space of licensed users' or Primary Users (PU)s' spectrum conditional on the interference to the PU being below an acceptable level. This function is realized using Cognitive Radio (CR) technology that enables an SU to change its transmission and reception parameters including operating frequencies. This enables the SUs to search for and use white space in the licensed spectrum. According to Cabric, Mishra & Brodersen (2004), the SUs are expected to operate over a wide range of non-contiguous frequency bands: 400-800MHz (UHF TV bands) and 3-10GHz. The time scale of the spectrum occupancy varies from milliseconds to hours depending on the activity levels of the PUs. An example of emerging standards based CR network is the IEEE 802.22 Wireless Regional Area Network (WRAN). The IEEE 802.22 working group has been working towards developing CR-based Medium Access Control-Physical (MAC-PHY) air interface for SUs to operate in TV bands, in this approach the SU access to spectrum is controlled by a centralized base station. As an alternative to this infrastructure oriented solution we can consider a cooperative peer to peer models such as traditional ad hoc networks. The ad hoc networks provide a dynamic mechanism to interconnect nodes through the provision of network relay functions and such networks can be mobile or fixed in nature.

The WRAN is a single-hop infrastructure-based static network which means that an SU can only have direct communication with the base station and without a base station, the SU would not function. This type of solution is not suitable for Cognitive Wireless Ad Hoc Network (CWAN), which is the focus of this chapter. In contrast the CWAN is a multihop self-organized and dynamic network that applies CR technology. The SUs are potentially mobile, capable of communicating among themselves, and nodes can act as relays to create multiple hop networks. Quality of Service (QoS) provisioning in CWAN is a daunting challenge as the capacity of the wireless channel on which the SUs are operating is apt to change dependent on the spectrum utilization of PUs, as well as any nodal mobility or adaptation actions to combat poor wireless conditions. Nodal mobility and network adaptation are currently being addressed in traditional