Chapter 6
Spectrum Handoff Management in Cognitive Radio Networks: Solutions, Modeling, and Future Directions

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ABSTRACT
Cognitive radio (CR) is a promising technology that can enhance the radio spectrum utilization by enabling unlicensed users to exploit the spectrum in an opportunistic manner. However, the main challenge is to share the licensed spectrum without interfering transmissions of other licensed users. A CR node needs to vacate the spectrum upon detection of licensed users on a particular frequency band (e.g., spectrum handoff or spectrum mobility) leading to significant network performance drops and switching overheads. This chapter aims to propose a proactive spectrum handoff management scheme to overcome the problem of handoff latency management in CR ad hoc networks. The proposed scheme is modeled and its performance is evaluated using an OPNET simulation tool. Simulation results are presented to evaluate the performance of the proposed system. The chapter concludes with a brief discussion and future research directions.

INTRODUCTION
The increasing demand for new wireless services and applications, as well as high capacity, the wireless networks become highly heterogeneous, with mobile devices consisting of multiple radio interfaces. In this context, it is essential to have updated information on radio environments to enhance the overall network performance. Most of the radio spectrum is predominantly assigned by the national authority to several service providers, companies or institutes for exclusive use over national areas on a long term basis. The outcomes of several investigations have shown that the lack of spectrum is not an issue, but the fact that radio resources are not being used efficiently. According to the Federal Communication Commission (FCC), up to 85% of the assigned spectrum is underutilized in major urban areas due to static spectrum allocation policy (FCC, 2002). On the other hand, the unlicensed portion of the 2.4 GHz ISM band has become overcrowded. To overcome
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spectrum scarcity, a promising functionality is required to be built terminals that have cognitive capability to assist with the Dynamic Spectrum Allocation (DSA) for efficient utilization of radio resources by changing the spectrum allocation on demand.

CR network architecture can be classified as ad hoc and infrastructure (Figure 1). In an infrastructure based network, CR node senses spectrum and pass this information to CR base station for spectrum decision to identify the unused spectrum. In Ad-Hoc networks, there is no base station so that intended transmitter and receiver nodes can exchange control information to make spectrum related functionalities such as spectrum decision, spectrum sharing as well as spectrum mobility. In dynamic radio environments, the unused spectrum or spectrum hole is varied in time and location over wide frequency range including both unlicensed and licensed bands. However, the most important challenge is to identify the spectrum holes and utilized them to maximize the throughput without interfering with licensed users. Therefore, CR nodes should immediately vacate the spectrum upon detection of licensed users on operating frequency band, known as spectrum mobility. In CR networks, spectrum mobility introduces a new type of handoff called spectrum handoff. Liodakis et al. (1994) defined handoff as a process of transferring the current communication channel to another associated with a call while maintaining it. In traditional cellular communication systems, handoff is occurred due to degradation of receive signal strength (RSS) when a mobile station (MS) moves from one cell to another cell through the cellular coverage area. Despite of degradation of RSS, spectrum handoff in CR networks can occur due to reappear of licensed users on serving channel leading to significant challenges such as licensed users detection and prediction, protocol adaptability with frequency changes, switching overheads, and most dominantly handoff latency. Research on CR networks mostly focused on spectrum sensing, spectrum decision and spectrum sharing whereas the spectrum handoff is less explored area in CR networks. In (CR) ad-hoc networks spectrum mobility is one of the main performance bottlenecks which include transmission delay, routing discovery as a consequence throughput degradation. This problem is related to multichannel MAC problem in traditional mobile ad hoc networks despite of fixed channel assignment. Thus, a novel spectrum assignment and management scheme is required to improve the handoff latency.

**SPECTRUM HANDOFF: PROBLEMS AND SOLUTIONS**

CR can significantly improve spectrum efficiency by allowing the secondary users to temporarily access the primary user’s under-utilized licensed spectrum (Mitola et al., 1999). If the specific portion of the spectrum in use is required by a primary user, the communication must be continued in another vacant portion of the spectrum. Therefore, spectrum handoff occurs when a licensed user further utilizes this unused licensed radio spectrum and find that CR nodes occupy the channel. Moreover, in a dynamic radio environment spectrum handoff can occur for CR users’ mobility in spatial domain and causes interference due to
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