Chapter 15
Asynchronous Channel Allocation in Opportunistic Cognitive Radio Networks

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ABSTRACT

In the case of Opportunistic Spectrum Access (OSA), unlicensed secondary users have only limited knowledge of channel parameters or other users’ information. Spectral opportunities are asymmetric due to time and space varying channels. Owing to this inherent asymmetry and uncertainty of traffic patterns, secondary users can have trouble detecting properly the real usability of unoccupied channels and as a consequence visiting channels in such a way that they can communicate with each other in a bounded period of time. Therefore, the channel service quality, and the neighborhood discovery (NB) phase are fundamental and challenging due to the dynamics of cognitive radio networks. The authors provide an analysis of these challenges, controversies, and problems, and review the state-of-the-art literature. They show that, although recently there has been a proliferation of NB protocols, there is no optimal solution meeting all required expectations of CR users. In this chapter, the reader also finds possible solutions focusing on an asynchronous channel allocation covering a channel ranking.

INTRODUCTION

A cognitive radio wireless network (CWNs) is a promising technology for solving spectrum underutilization problems thanks to the ability to operate both in unlicensed and licensed bands, so that spectrum holes can be utilized by unlicensed secondary users (SUs or cognitive radios, CRs). A spectrum hole (known as “white space”) is a band of frequencies, assigned to a licensed user (incumbent or primary user, PU), but not utilized by this PU at a particular time and specific geographic location (Wyglinski, Nekovee, & Hou, 2011). Unlicensed secondary users have an opportunistic spectrum access to these
bands, i.e., they may utilize the spectrum only if it is empty *ad interim*, namely, only when SU{s} do not interfere with high-priority PUs (Liang, Chen, Li, & Mähönen, 2011). Unlicensed secondary users must promptly vacate the currently occupied band, when the presence of a licensed primary user is detected. For this reason the link recovery data and a new detected common channel cannot be announced on the previously used spectrum band on account of the incumbent activity there. However, there is a need for on-demand discovery of a new common control channel by secondary users in order to continue or to establish a communication. Owing to all these unique characteristics of CWN{s}, the neighborhood discovery (rendezvous) phase is a burdensome problem with which wireless researchers have recently been contending. As the existence of a common control channel (CCC) (a typical assumption in distributed wireless networks) is not a practical solution in CWN{s}, we concentrate on another representative technique, which is a well-known frequency hopping (FH) technique, but here in this chapter we are interested in the solutions without any synchronization or coordination between radio users (both being unfeasible and unwanted in OSA). A FH technique is a usable and appealing approach for CWN{s}, since the probability of interference against incumbents decreases in comparison with other possible approaches. In a neighborhood discovery (rendezvous) protocol the term channel hopping (CHH) scheme (instead of frequency hopping) is rather used as default, where a radio in a time-slotted system hops (switches) from one channel to another at a given time slot. Radios switch to (or may stay on) different channels in consecutive slots according to their channel hopping sequence (CHHS). The period of time during which a CHHS is completed is often interchangeable called a cycle or period.

Cognitive radio, as conceived by Mitola (2000), allows intelligent utilization of the spectrum, enabling unlicensed SU{s} to sense the channel conditions, adjust operating characteristics to the real-time environment, and access time-varying spectrum holes opportunistically. However, in contrast to a classical distributed wireless network (ad hoc network), in an asymmetric OSA the available cognitive radio resources (channel set) are different for each cognitive radio of the same network because of geographical dispersion and licensed primary user activities (heterogeneous spectrum availability). The quality of unoccupied channels can also differ for various unlicensed secondary users, although neighboring users may experience similar channel characteristics, implying a high correlation among their channel ranking data, and e.g. between their channel switching patterns. Therefore, while estimating a channel ranking one should consider both current and prior knowledge of channel availability statistics. Spectrum history knowledge is key information, since channel selection based merely on the latest data can lead to frequent disruptions of PUs and SU{s}, whereas sensing periodically can detect the periods where a transmission could engender possible interference to incumbents. However, in practice noise is always present and causes detection and decision problems regarding spectrum allocation. In view of the uncertainty and complexity of a distributed CWN environment and consequently the difficulty of the formulation precise (crisp) values and formulas in some algorithms, fuzzy logic (FL) theory can be a promising approach thanks to its flexibility and tolerance to imprecise data. FL allows translating qualitative and heterogeneous data into homogeneous membership values, which are further processed through a set of fuzzy inference rules. Therefore, fuzzy logic system (FLS) applications found their place in different wireless communications areas, e.g., in order to determine the channel usability in CWN{s}.

Channel quality information can be, or, one could even argue, should be utilized by a neighborhood discovery protocol, which considers such information. However, despite a recent proliferation of NB protocols, there is no optimal solution meeting all required expectations of unlicensed second users. This is owing to the fact that the proposed protocols mostly focus narrowly on e.g., RDV guarantee in a single cycle or improving the performance of maximum time-to-rendezvous; or the comparison to a limited
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