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Routing and channel selection from cognitive radio network's perspective: A survey ☆

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ABSTRACT

The fixed spectrum allocation causes inefficient utilization of licensed spectrum bands, due to which Cognitive Radio Networks (CRNs) emerged as a promising solution. Cognitive radio networks opportunistically utilize the spectrum holes, i.e., spectrum not in use by Primary Users (or PUs or licensed users) and allocate the spectrum dynamically. For every network including cognitive radio networks, routing is very important. Routing is the backbone of communication for transferring data from one machine to another in a multi-hop fashion. A good routing protocol is required for efficient communication and a good routing protocol is based on channel selection strategy. Therefore, a good channel selection strategy is required for efficient routing protocol so that routes should be stable and exist for longer time. In this paper, we focus on joint channel selection and routing from the perspective of cognitive radio networks. In this context, we provide a comprehensive survey on routing and channel selection in CRNs. More specifically, the importance of joint channel selection and routing for cognitive radio networks is first highlighted. Then classification and challenges of channel selection and routing are discussed in details. Routing with efficient channel selection in cognitive radio networks is then discussed by describing many routing strategies for cognitive radio networks, routing metrics, performance parameters, primary user activity modeling and spectrum aware strategies. Then guidelines for the development of efficient routing protocols are discussed. Subsequently, in last, a case study for channel selection strategy 'Spectrum Aware Dynamic Channel Assignment' (SA-DCA) is presented and illustrated that how routing can get benefit from it.

1. Introduction

During the past few years, most wireless networks follow fixed spectrum assignment policy. Due to this fixed spectrum assignment policy, a large portion of spectrum was not utilizing with high variance in time [1]. In-order to utilize the spectrum efficiently, Cognitive Radio Networks (CRNs) emerged as a promising solution and solve the problems of fixed spectrum assignment. Federal Communications Commission (FCC) [2] approved the usage of unlicensed devices in licensed spectrum bands subject to the condition that licensed user should not be interfered. There are two types of users in CRNs, one is

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Primary User (PU or licensed user) which has a licensed spectrum band in which it operates and other is Secondary User (SU or unlicensed user), which operates either on unlicensed spectrum band or on licensed spectrum band whenever PU is not utilizing its spectrum band. While using licensed spectrum band by SU, if PU arrives on its spectrum band at any time, then SU has to vacate this spectrum band and switch to another one by selecting spectrum from spectrum pool [3] so that PU will not be interfered. This is known as spectrum handoff [1].

Packet is a primary unit of information in computer networks, and routing is the fundamental function for any wireless network. Routing is used for information exchange by transferring packets from one host to another across the network. Significant amount of work has been carried out for routing in different wireless networks. These networks include Wireless Sensor Networks (WSNs), Wireless Mesh Networks (WMNs), Mobile Ad-Hoc Networks (MANETs), Vehicular Ad-Hoc Networks (VANETs), etc. But in CRNs, routing is much complex due to the dynamic nature of the environment. This dynamicity is due to various factors such as PU activity, diversity in available channels, and heterogeneous channels.

Channel selection plays an important role in the performance and stability of routing protocol. In CRNs, if channel selection strategy selects channels with low PU activity, high availability and high connectivity with neighbors, then routing will be very efficient, stable and can exist for longer time. Therefore, channel selection should be properly investigated for routing in CRNs so that routing can be performed effectively and efficiently.

There are many applications of CRNs by which their importance can be highlighted. These applications include military applications [4], vehicular networks [5], Delay Tolerant Networks (DTNs) [6], etc. CRNs enables communication and restore network connectivity in situations when existing infrastructure is destroyed or disable by natural disasters in disaster response [7], emergency and public safety networks by using existing spectrum without needing any infrastructure. All of these applications require a good routing protocol so that their required data can be exchanged timely and without any loss. But for achieving this, a good channel selection strategy is required which will select good channels to be utilized in routing.

Therefore, in this paper, we have focused joint channel selection and routing in CRNs extensively and discussed that how channel selection can help routing in improving network performance. There exists some surveys on channel selection and routing in CRNs [8–13]. But none has focused on joint channel selection and routing in CRNs. However, channel selection plays a very important role in routing because it helps in establishing stable routes. Therefore, the focus of our paper is to present a survey on joint routing and channel selection for CRNs.

Main Contribution: The main contributions of this paper are summarized as follows:

- A comprehensive survey on routing, its classification and challenges.
- A detailed study on channel selection, its classification with goals, nature and types and its challenges.
- Extensive discussion on routing with efficient channel selection in CRNs.
- A case study on a channel selection strategy 'Spectrum Aware Dynamic Channel Assignment' (SA-DCA) and illustration that how this channel selection strategy can help in routing.

Moreover, channel aggregation technique combines several channels together as one channel and improves network performance by providing more bandwidth. Therefore, if channel aggregation is performed during channel selection, then applications' desired bandwidth can be achieved and routes will be stable. Channel aggregation in CRNs is performed by [14,15]. It provides channel adaptation which dynamically adjust channel occupancy by channels aggregation and improves network performance.

The remainder of this paper is organized as follows. Section 2 describes classification of routing protocols in CRNs. In Section 3, challenges of routing protocols in CRNs are discussed. Subsequently, classification of channel selection strategies with goals, nature and types are explained in Section 4. Afterwards, challenges of channel selection are discussed in Section 5. Then routing with efficient channel selection is discussed in Section 6 by discussing various routing strategies with routing protocols nature, routing metrics, performance parameters, PU activity modeling, spectrum awareness and various simulators. Next, some guidelines for the development of efficient routing protocol for CRNs are discussed in Section 7. After then, in Section 8, a case study of channel selection strategy SA-DCA is presented and it is illustrated that how efficient channel selection helps in routing. In last, the paper is concluded in Section 9.

Next we discuss classification of routing protocols in CRNs

2. Classification of routing protocols in CRNs

Routing protocols in CRNs can be classified into four main categories [12] which are illustrated in Fig. 1. These categories are: (1) delay based routing protocols, (2) link stability based routing protocols, (3) throughput based routing protocols and (4) location based routing protocols.

2.1. Delay based routing protocols

Delay-based routing protocols consider delay in-order to measure the quality of routing protocols. Generally there are three components of delay: