Interference Modeling and Analysis in Cognitive Radio Networks

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ABSTRACT

Cognitive radio networks (CRNs) have received considerable attention and viewed as a promising paradigm for future wireless networking. Its major difference from the traditional wireless networks is that secondary users are allowed to access the channel if they pose no harmful interference to primary users. This distinct feature of CRNs has raised an essential and challenging question, i.e., how to accurately estimate interference to the primary users from the secondary users? In addition, spectrum sensing plays a critical role in CRNs. Secondary users have to sense the channel before they transmit. A two-state sensing model is commonly used, which classifies a channel into either busy or idle state. Secondary users can only utilize a channel when it is detected to be in idle state. In this paper, we tackle the estimation of interference at the primary receiver due to concurrently active secondary users. With the spectrum sensing, secondary users are refrained from transmitting once an active user falls into their sensing range. As a result, the maximum number of simultaneously interfering secondary users is bounded, typically ranging from 1 to 4. This significant conclusion considerably simplifies interference modeling in CRNs. The authors present all the cases with possible simultaneously interfering secondary users. Moreover, the authors derive the probability for each case. Extensive simulations are conducted and results validate the effectiveness and accuracy of the proposed approach.

Keywords: Cognitive Radio Networks (CRNs), Interference Model, Primary User, Secondary User, Wireless Networking

1. INTRODUCTION

The recent decade has witnessed rapid proliferation of wireless technologies and their significant impact on all aspects of our lives. However, these disruptive wireless technologies exhaust the limited radio spectrum, which is referred to as spectrum scarcity (Wang et al., 2011; Peha, 2009). This issue leaves little or no spectrum for future demands. Spectrum scarcity has become increasingly serious leading to intensified attention. Cognitive radio network (CRN) is
commonly envisioned as a promising solution to relieve spectrum scarcity and significantly improve spectrum efficiency. In recent years, CRNs have been gaining considerable attention and related research on a variety of topics can be found in the literature (Gao et al., 2004; Qiu et al., 2012; Liu et al., 2008; Zhao et al., 2011; Lee et al., 2012).

A typical CRN is comprised of two types of users: primary users (PUs) and secondary users (SUs). PUs are authorized to utilize licensed bands/channels whenever they have demands. In contrast, SUs are not licensed users, but they are allowed to temporarily access channels without harmful interference to the PUs. If the interference from SUs to PUs is dominant and destructive, SUs have to take necessary actions to avoid it. For instance, SUs may need to withdraw from the channel immediately or reduce their transmission power. This distinct feature of CRNs raises an essential and challenging question, i.e., how to accurately estimate or predict interference from SUs to PUs. This topic has recently attracted considerable attention (e.g., Hong et al., 2008; Chen et al., 2010; Rabbachin et al., 2011). Most of the existing models and related analysis are significantly complex.

In this paper, our goal is to estimate the total interference from SUs at any PU receiver by developing a considerably simpler probabilistic interference model in which spectrum sensing is taken into account. Spectrum sensing plays a critical and fundamental role in CRNs. SUs have to continually monitor the channel before their transmission. The two-state sensing model is commonly used in the process of spectrum sensing, which classifies a channel into either busy or idle state (Zhao et al., 2012). Secondary users can only be allowed to utilize a channel when it is detected as idle.

With the two-state sensing model, the SUs that detect an active user, either a PU or another SU in their sensing ranges are prohibited from transmitting. As a result, it is interesting to observe that the maximum number of simultaneously interfering SUs is finite, typically ranging from 1 to 4 (Zhao et al., 2013). We are inspired by this significant conclusion and propose a simple probabilistic interference model for CRNs. All cases with simultaneously interfering SUs to a PU receiver are analyzed. Furthermore, in each case, the interference to primary users is derived and the corresponding probability is thoroughly investigated as well. This promising and effective approach is expected to shed light on interference modeling in CRNs with spectrum sensing.

The rest of the paper is organized as follows. In Section 2, we briefly introduce related work. Section 3 presents the network model along with assumptions. In Section 4, we introduce the proposed interference modeling along with in-depth mathematical analysis. The simulation results and discussions are presented in Section 5. Concluding remarks are stated in Section 6.

2. RELATED WORK

Spectrum sensing is a fundamental and essential process in CRNs, which can generally be classified into two groups: local sensing and cooperative sensing (Akyildiz et al., 2011). In local spectrum sensing, each SU makes a decision independently about the channel state from its own information. The local spectrum sensing techniques include matched filter detection (Shobana et al., 2013), energy detection (Zhang et al., 2009; Zhai, 2007) and cyclostationary detection (Sutton et al., 2008; Turunen et al., 2009). In cooperative sensing, multiple SUs cooperate with each other, in a centralized or distributed mode, to determine the channel availability (Song et al., 2012).

The common local sensing model is referred to as a two-state model. That is, there are two distinct channel states: idle and busy. Specifically, it is defined as below with energy detection (Oh et al., 2009):

\[
x_i = \begin{cases} 
n_i, & \text{idle} \\
 s + n_i, & \text{busy} 
\end{cases}
\]
Towards A Virtual Machine Migration Algorithm Based On Multi-Objective Optimization


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