Journal of Network and Computer Applications 43 (2014) 1–16

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

Primary radio user activity models for cognitive radio networks: A survey

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ARTICLE INFO

Article history:
Received 28 July 2013
Received in revised form
26 January 2014
Accepted 19 April 2014
Available online 29 April 2014

Keywords:
Cognitive radio networks
Primary Radio (PR) user
Cognitive Radio (CR) user
PR user activity

ABSTRACT

Cognitive Radio Networks have been emerged as a promising solution for solving the problem of spectrum scarcity and improving spectrum utilization by opportunistic use of spectrum. Cognitive radio networks utilize the spectrum which is licensed to primary radio users when they are not utilizing it, i.e., when the spectrum is idle. Thus, the performance of cognitive radio networks is highly dependent upon the activity of primary radio users. Hence, it is very important to model primary radio users activity in cognitive radio networks. By keeping this in mind, several models in the literature have been proposed for modeling primary radio users activity. But there is not any source which consolidate all these models into single platform. Therefore, this paper combines all the primary radio user activity models for cognitive radio networks at a single place. The goal of this paper is to provide a single source in the form of survey paper by which a reader can get an idea about which primary radio user activity models have been used in the literature for cognitive radio networks and how the modeling is performed. Furthermore, we also discuss issues, challenges and future directions for primary radio activity models. In fact, in this paper, different primary radio user activity models have been presented along with their classification. This paper also discusses those approaches which performed real implementation for spectrum occupancy along with spectrum bands on which the implementation is performed and location where implementation is carried out. In summary, this paper provides up-to-date survey of primary radio user activity models for cognitive radio networks.

Contents

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http://dx.doi.org/10.1016/j.jnca.2014.04.001
1084-8045/

1. Introduction

In the early 90s, the problem of spectrum scarcity was in its infancy stage and large portion of spectrum were available, therefore, wireless networks followed fixed spectrum assignment policy. But with the passage of time, when the usage of bandwidth-hungry wireless applications increases, the spectrum become scarce and the problem of fixed spectrum assignment policy was aroused. It was then analyzed that a large part of spectrum which is licensed to primary radio users was not utilizing with high variance in time (Akyildiz et al., 2009). In order to solve this problem, Federal Communications Commission (FCC) approved that unlicensed devices can utilize licensed spectrum in a way that licensed user or primary radio user would not be interfered. After this approval, Cognitive Radio Networks (CRNs) appear as a promising solution for solving the problem of fixed spectrum assignment policy by opportunistically utilizing the temporarily unused spectrum which is known as 'spectrum holes' or 'white spaces'. The concept of spectrum holes is also illustrated in Fig. 1.

In CRNs, two types of users exist, one is Primary Radio (PR) user and the other is Cognitive Radio (CR) user. PR user has licensed spectrum on which it operates while CR user has no licensed spectrum and it operates either on unlicensed spectrum or on PR user licensed spectrum when it is idle, i.e., not utilizing by PR user. If PR user arrives on its spectrum band while CR user is utilizing it, then CR user has to vacate this spectrum immediately without causing interference to PR user and to switch to another available idle spectrum band from spectrum pool (Weiss and Jondral, 2004).

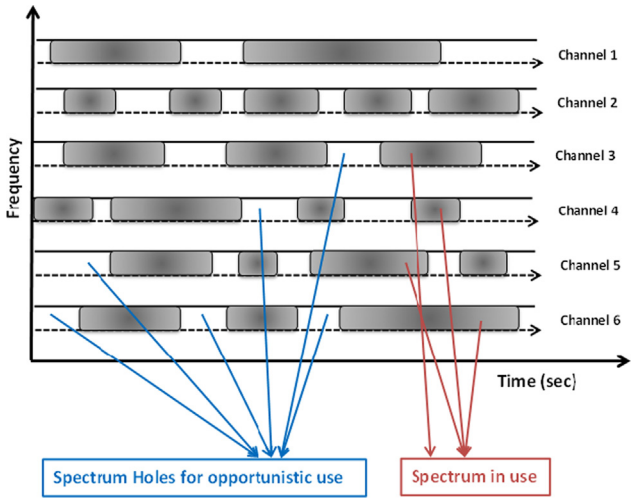

Fig. 1. Concept of spectrum holes.

Since FCC approved the usage of unlicensed devices on licensed spectrum on the condition that licensed users must not be interfered. Therefore, it is very important to save PR user from harmful interference. We can compromise on CRNs performance at some extent but we cannot compromise on interfering PR users. This is why, the performance of CRNs is highly dependent upon PR users activity pattern (Rehmani et al., 2011). Due to this fact, *PR user activity modeling is very important for the performance of CRNs*. In this point of view, many PR user activity models have been proposed in the literature. Their purpose is to provide a realistic model of PR user activity pattern which is considered in the network by CR users in taking decisions about spectrum.

PR users' networks can operate in any spectrum depending upon the underlying technology and this spectrum ranges from KHz to GHz. For instance, cellular networks usually operate in MHz spectrum, while TV bands operate on 40–80 MHz. Table 1 (Weiss and Jondral, 2004) shows different wireless technologies and the frequency band on which they operate. It is clear from Table 1 that wireless technologies use spectrum from a wide range, thus a single PR user activity model cannot capture the PR users'

Table 1
Frequencies used by different wireless technologies.

Wireless technologies	Frequency bands
IEEE 802.11g/WiFi and IEEE 802.11n/WiFi	2.4 GHz
ETSI Hiper LAN/2	5 GHz
IEEE 802.16/WiMAX	2–66 GHz
IEEE 802.16e/WiMAX	2–6 GHz
ETSI Hiper ACCESS	11–43.5 GHz
ETSI Hiper MAN	<11 GHz
WiBro	2.3–2.4 GHz
HAP	28–31 GHz and 42–43 GHz
IEEE 802.20	3.5 GHz
IEEE 802.22	54–862 MHz
Satellite (GEO, MEO and LEO)	4–8 GHz (C Band), 10–18 GHz (Ku Band), 18–31 GHz (Ka Band), 37–50 GHz (Q/V Band)