Int. J. Electron. Commun. (AEÜ) 67 (2013) 35–39

Contents lists available at SciVerse ScienceDirect

International Journal of Electronics and Communications (AEÜ)

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

Capacity maximization in spectrum sensing for Cognitive Radio Networks thru Outage Probability

Krishnan Kalimuthu*, Ramamoorthy Kumar

Department of Electronics and Communication Engineering, SRM University, Chennai, India

ARTICLE INFO

Article history:
Received 12 May 2011
Accepted 2 June 2012

Keywords:
Cooperative
Energy detection
Outage probability
Rayleigh fading

ABSTRACT

With today's increase in the usage of wireless devices and the consequent spectrum allocation, radio spectrum is becoming scarce. In practice most of the allotted spectrum is not used for large periods of time. Cognitive radio has been proposed to exploit the presence of these unused spectrum band (called as spectrum hole). Cognitive radios perform radio environment analysis, identify the spectrum holes and operate in those holes. Several factors like fading and shadowing affects the ability of the cognitive radio to detect the primary user. The current research shows that cooperation among the cognitive users can increase the detection probability for a given probability of false alarm. We proposed the system that to have maximized the capacity in spectrum sensing for Cognitive Radio Networks thru Outage Probability for Rayleigh fading channel.

1. Introduction

The limitations of the natural frequency spectrum, it becomes obvious that the current static frequency allocation schemes cannot accommodate the requirements of an increasing number of higher data rate devices. As a result, innovative techniques that can offer new ways of exploiting the available spectrum are needed. Cognitive radio has been proposed to minimize bandwidth scarcity issues [1]. Spectrum sensing which is one of the most important function of cognitive radio, determines the efficiency with which the secondary users can use the primary spectrum, without causing interference to the primary users (PU). Therefore, secondary users (SU) need to have cognitive radio capabilities, such as sensing the spectrum reliably to check whether it is being used by a primary user and to change the radio parameters to exploit the unused part of the spectrum. In this paper, we focus on spectrum sensing performed by cognitive radios because of its broader application areas and lower infrastructure requirement. To improve the performance of these detection techniques in such scenarios, the centralized cooperative sensing scheme is proposed [2].

1.1. Organization of this paper

Further chapters are organized as: Section 2 discusses about local and cooperative spectrum sensing in cognitive radio with energy detection method in AWGN channel. Section 3 analyse capacity maximization for spectrum sensing in Rayleigh fading channel and concludes the proposed system in Section 4.

2. System model and analysis

2.1. Spectrum sensing in AWGN channel

2.1.1. Spectrum sensing

The block diagram for capacity optimization for local and cooperative spectrum sensing in cognitive radio network is shown in Fig. 1.

Primary users can claim their frequency bands anytime while cognitive radio users are operating on their bands. In order to prevent interference to and from primary users, cognitive radio should be able to identify the presence of primary users as quickly as possible and should vacate the band immediately. Hence, sensing methods should be able to identify the presence of primary users within the certain duration. This requirement poses a limit on the performance of sensing algorithm and creates a challenge for cognitive radio design [3].

Detection delay is a critical issue since primary user situations may have been already changed during the decision process. Fig. 2 shows an example of the problem that the detection delay may cause. At the beginning, secondary users detect the absence of the primary users and start using the available band. However, due to the processing time required by the comparative detection, secondary users may cause interference to the primary users before they detect their coexistence. On the other hand, after the primary

* Corresponding author.
E-mail addresses: kalimuthu.K@ktr.srmuniv.ac.in (K. Kalimuthu), kumar.r@ktr.srmuniv.ac.in (R. Kumar).

1434-8411/$ – see front matter © 2012 Elsevier GmbH. All rights reserved.
http://dx.doi.org/10.1016/j.aeue.2012.06.002

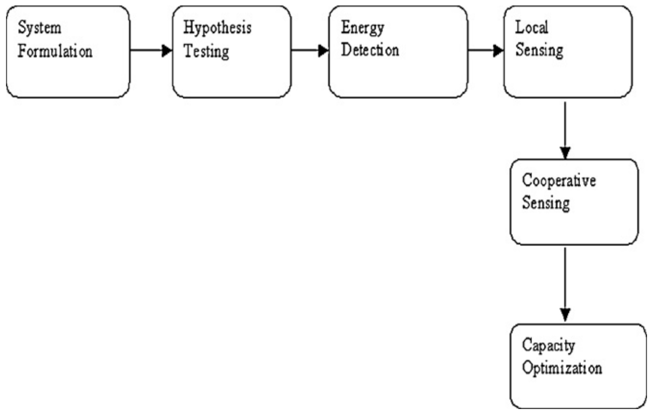

Fig. 1. Energy detection based sensing.

users abandon the channel, it takes some time before the secondary users find spectrum availability.

2.2. Local spectrum sensing

Consider a secondary user in a cognitive radio system sensing a frequency band W and the received demodulated signal is sampled at sampling rate f_s, and then $f_s \geq W$. Hence, the sampled received signal, $X[n]$ at the secondary user receiver will have two hypotheses as follows:

$$H_0 : X[n] = W[n]; \quad \text{if PU is absent} \tag{1}$$

$$H_1 : X[n] = W[n] + S[n]; \quad \text{if PU is present} \tag{2}$$

where $n = 1, \ldots, k$; k is the number of samples. The noise $W[n]$ is assumed to be additive white Gaussian (AWGN) with zero mean and variance. $S[n]$ is the primary user's signal and is assumed to be a random Gaussian process with zero mean and variance [5]. The goal of the local spectrum sensing is to reliably decide on the two hypotheses with high probability of detection (P_d) and low probability of false alarm (P_f). P_d and P_f can now be defined as the probabilities that the sensing secondary user algorithm detects a primary user under H_0 and H_1, respectively.

The energy detector is known as a suboptimal detector, which can be applied to detect unknown signals as it does not require a prior knowledge on the transmitted waveform as the optimal detector (matched filter) does. The decision statistic T for energy detector is given by

$$T = \sum_{n=1}^{k} (X[n]^2) \tag{3}$$

It is well known that under the common Neyman–Pearson detection performance criteria, the likelihood ratio yields the optimal decision [5]. Hence, the energy detector performance can be characterized by a resulting pair of (P_f, P_d) that is estimated as [4],

$$P_f = P(T > \beta | H_0) \tag{4}$$

$$P_d = P(T > \beta | H_1) \tag{5}$$

where β is a particular threshold that tests T. Since we are interested in low signal-to-noise ratio of primary user regime, large number of samples should be used. Thus, the test statistic chi-square distribution can be approximated as Gaussian based on the central limit theorem. Then

$$P_f = Q\left(\frac{\beta - K\sigma_w^2}{\sqrt{2K\sigma_w^4}}\right) \tag{6}$$

$$P_d = Q\left(\frac{\beta - K(\sigma_w^2 + \sigma_s^2)}{\sqrt{2K(\sigma_w^2 + \sigma_s^2)^2}}\right) \tag{7}$$

By fixing P_d at a satisfactory level, e.g. 90%, and trying to minimize P_f as much as possible. Thus, P_f is derived to be

$$P_f = Q\left(Q^{-1}(P_d^-)(1 + SNR_p) + SNR_p\sqrt{\frac{K}{2}}\right) \tag{8}$$

where the number of samples, k, is the product of sensing time and sampling frequency.

An increasing the sensing time can minimize P_f. However, at the same sensing time, increasing the PUs protection level by stating higher P_d values leads to decrease P_f and consequently, fewer chances for secondary users to utilize the spectrum. Therefore, there will be a tradeoff between these two conflicting objectives.

To standardize the spectrum utilization by SUs, as such, the P_f values should be fixed at lower values (e.g. ≤10%) while keep maximizing P_d which can be written in terms of a desired P_f as follows:

$$P_d = Q\left(\frac{Q^{-1}(P_f^-) - SNR_p\sqrt{K/2}}{(1 + SNR_p)}\right) \tag{9}$$

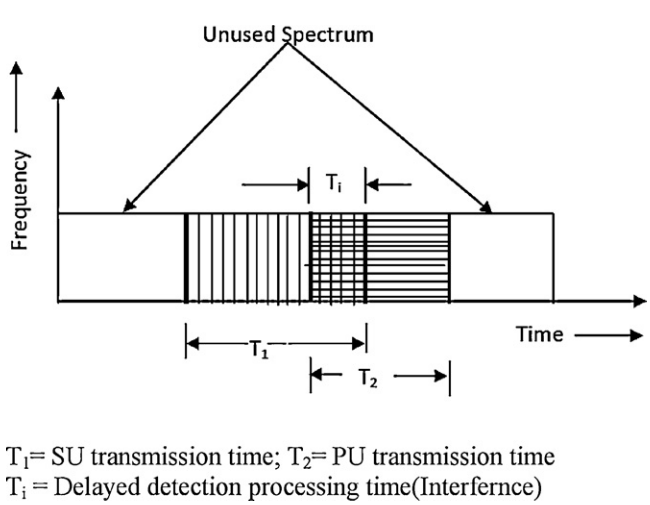

Fig. 2. Interference due to delay caused by detection processing time.

2.3. Cooperative spectrum sensing

The collaborative sensing aims to improve the detection sensitivity at low SNR environments as well as to tackle the hidden terminal problem where the PUs activities might be shadowed from the local SU receiver by any existing intermediate obstacles. This section presents the SU cognitive radio network model using some well-known fusion schemes.

Fusion Schemes for Local Secondary Users' Decisions: At the SUs base station, all local sensing information are combined and merged into one final decision using Chair–Varshney fusion schemes [7]. Two fusion schemes are used in this paper, OR- and AND-rule. In OR-rule fusion scheme, the final decision on the presence of a PU will be positive if only one SU of all collaborating users detects this PU. Assuming that all decisions are independent, the detection and