Cyclostationarity-Based Detection of Randomly Arriving or Departing Signals

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ABSTRACT
This paper addresses the problem of detection of randomly arriving or departing primary user (PU) signals in cognitive radio systems. The detection problem of the dynamic PU signal is modeled as a binary hypothesis testing problem where the PU signal might randomly depart or arrive during the sensing period. Then, we detect the cyclostationarity of the PU signal using a test statistic derived from the spectral autocoherence function in dynamic PU signal environments. Numerical results show that the proposed scheme offers an improved spectrum sensing performance than the conventional energy detector for dynamic PU environments.

Keywords: Spectrum sensing, CR, cyclostationarity, dynamic primary user signals.

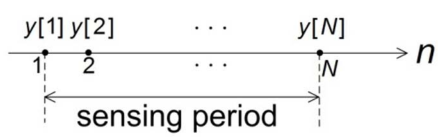
1. Introduction

The rapid growth of broadband wireless applications makes the frequency spectrum a scarce resource [1], [2], and thus, its more efficient use is needed [3]. The cognitive radio (CR) is a promising technology to exploit underutilized spectrum in an opportunistic manner and the spectrum sensing technique identifying spectrum holes is one of the most important techniques in CR [4]-[6]. Until now, various spectrum sensing techniques have been developed under static traffic circumstances where the spectrum band is assumed to be occupied by the primary user (PU) or vacant during the whole sensing period [7], [8]. In practical cases, however, the PU signal could depart or arrive during the sensing period, especially when a long sensing period is used to achieve a good sensing performance, or when the spectrum sensing is performed for a high traffic network, In dynamic PU signal environments, the performances of the conventional spectrum sensing techniques have been found to be degraded severely [9]. Although a spectrum sensing technique [10] was proposed based on the energy detection approach for dynamic PU signals, it performs poorly when the signal-to-noise ratio (SNR) is low.

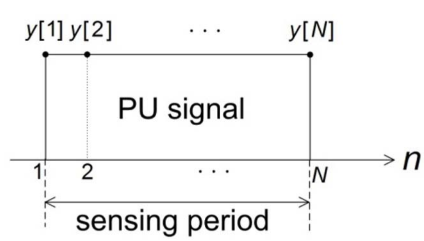
In this paper, we propose a novel spectrum sensing scheme based on the cyclostationarity approach for randomly arriving or departing signals, which is referred to as the dynamic PU signals. We first formulate the spectrum sensing problem in dynamic PU signal environments as a binary hypothesis testing problem and develop the corresponding generalized likelihood ratio (GLR). Obtaining an estimate of spectral autocoherence function (SAF) of the PU signal and applying it to the GLR, we propose a test statistic for spectrum sensing in dynamic PU signals. The proposed cyclostationarity-based scheme is expected to perform better than the conventional energy detection-based scheme of [10], since the cyclostationarity-based detection has an advantage over the energy detection approach in that its detection performance is generally better than that of the energy detection approach, and also, it can distinguish the PU signal from the interference unlike the energy detection approach.

2. System model

In the conventional researches without considering the dynamic behavior of PU signals, the received signal $y[n]$ in the absence of noise can be depicted as shown in Figure 1. However, the PU signals can randomly depart or arrive during the sensing period as shown in Figure 2, where the event of random departure (random arrival) is assumed to occur between the samples $J_0\left(J_1\right)$ and $J_0+1\left(J_1+1\right)$. The goal of the spectrum sensing is to estimate the existence of the PU signal after $n = N$ by detecting the samples in the sensing period (that is $n = 1, 2, ..., N$). For example, in the random departure case, the PU signal is absent after the sensing period meanwhile the PU signal is present after the sensing period in the random arrival case.

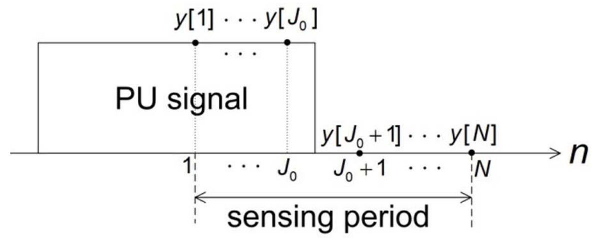


(a) When the PU signal is absent.

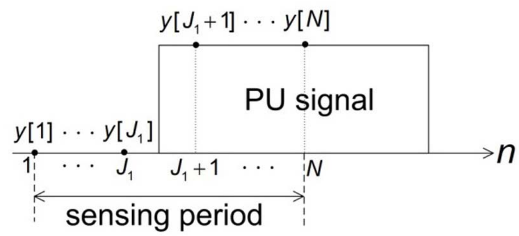


(b) When the PU signal is present.

Figure 1. The received signal model without considering the dynamic behavior of PU signals.



(a) Random departure.



(b) Random arrival.

Figure 2. The received signal model for randomly departing or arriving PU signals.

We model the spectrum sensing problem in dynamic PU signals where the PU randomly departs or arrives during the sensing period of CR user as a binary hypothesis testing problem: Given the received signal, a decision is to be made between the null hypothesis H_0 and the alternative hypothesis H_1 defined as

$$H_0 : \ y[n] = \begin{cases} x[n] + w[n], \ \text{for } n = 1,2,\ldots,J_0, \\ w[n], \ \text{for } n = J_0+1, J_0+2,\ldots,N \end{cases} \quad (1)$$

and

$$H_1 : \ y[n] = \begin{cases} w[n], \text{for } n = 1,2,\ldots,J_1, \\ x[n] + w[n], \text{ for } n = J_1+1, J_1+2,\ldots,N, \end{cases} \quad (2)$$

respectively, where and represent the sample of the baseband equivalent of the received and PU signals, respectively, $w\left[n\right]$ represents the nth sample of an additive white Gaussian noise (AWGN) with mean zero and variance σ^2, and N is the number of samples available during the sensing period. Under the hypothesis H_0, the random departure of the PU