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Noise Variance Estimation for Spectrum Sensing in Cognitive Radio Networks

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Abstract

Spectrum sensing is used in cognitive radio systems to detect the availability of spectrum holes for secondary usage. The simplest and most famous spectrum sensing techniques are based either on energy detection or eigenspace analysis from Random Matrix Theory (RMT) such as using the Marchenko-Pastur law. These schemes suffer from uncertainty in estimating the noise variance which reduces their performance. In this paper we propose a new method to evaluate the noise variance that can eliminate the limitations of the aforementioned schemes. This method estimates the noise variance from a measurement set of noisy signals or noise-only signals. Extensive simulations show that the proposed method performs well in estimating the noise variance. Its performance greatly improves with increasing numbers of measurements and also with increasing numbers of samples taken per measurement.

Keywords:Noise Estimation and Analysis;Spectrum Sensing; Cognitive Radio Networks; Random Matrix Theory;

1. Introduction

Cognitive Radio Systems (CRS) facilitate efficient optimization ofunderutilized radio resource through opportunistic radio spectrum exploitation. CRS require prior knowledge of spectrum utilizationto dynamically

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access the radio spectrum, andspectrum sensing is an active approach used in CRS to locate spectrum holes in underutilized spectrum for opportunistic access. In spectrum sensinganopportunistic useractively measures the radio environment foravailable spectrum holes. There are many different types of spectrum sensing approaches depending on the hardware used for sensing, the sensing entities, sensing dissemination and sensing techniques [1].Reliability of a sensing technique depends whether it can accurately ascertain the presence or absence of a licensed user signals in the band of interest. The sensing techniques can be classified as transmitter detection, interference-based detection and receiver detection [2]. The underlying hypotheses of primary signal detection are as follows [2]:

$$H_0 \;:\; x(t) = n(t)$$
$$H_1 \;:\; x(t) = h*s(t) + n(t)$$

where n(t)is the Additive White Gaussian Noise,
h is the channel gain, and
s(t)is the licensed transmitter signal.

H_0 represents the null hypothesis, that a primary transmitter *isnot* present, whereas hypothesis H_1 states that a primary transmitter *is* present.

2. Problem Statement

Commonly used primary user detection techniques include energy detection [3], matched filter detection [4], cyclostationary feature detection [1, 2], self-correlated detection [5], eigenvalue based spectrum sensing [6-8], and multi-taper and filter bank estimation [9]. The RMT based spectrum sensing proposed in [10] suggests acriterion based on the Marchenko-Pastur law [11] which relies on the known variance of noise which suffers the same problem as faced by energy detection.

In this paper we present a techniquefor noise variance estimation that addresses the limitations of current blind spectrum sensing techniques. That is, both energy detection and eigenvaluebased techniques use the noise variance in their hypothesis testing criteria, so both are reliant on the correct estimation of noise variance. Any uncertainty in noise variance estimation will greatly affect theiraccuracy, resulting either in missed detection of spectrum holes or interference to the primary user.Our proposed method for noise variance estimation could be used for setting the decision thresholds for energy detection based spectrum sensing and also for calculating the upper and lower bounds of the eigenvalues using the Marchenko-Pastur law.

The performance of the proposed scheme is tested through extensive simulations and is found to be efficient in terms of estimating the noise variance. In our simulations we have considered various signalswhile evaluating the proposed scheme. In the next section, the performance of the scheme is evaluated through extensive simulations, and the mean error in estimated noise variance has been evaluated by varying the SNR, number of measurements and number of samples per measurement.

3. Proposed Noise Estimation Scheme

To address the noise estimation problem, we consider multiple measurement sets, M in number, from the same portion of the radio spectrum, i.e. multiple measurements of the same signal under analysis. We assume N numbers of samples are collected for each measurement set. Let a single measurement set of the signal be represented by $\mathbf{S}_M(N)$where M represents a separate measurement and N represents the number of samples for the measurement, such that $\mathbf{S_1}$ represents a complete sample set for the first measurement, $\mathbf{S_2}$ represents a complete sample set of second measurement, and so on. $\mathbf{S_M}$ represents the complete sample set for the last measurement, i.e.