Welcome to the 35th IEEE Sarnoff Symposium - 2012

Since 1978 the IEEE Sarnoff Symposium has been bringing together a tremendous and rich diversity of telecom experts from industry, universities, and government. The popularity of the Sarnoff Symposium, being held at New Jersey Insitute of Technology (NJIT) in Newark, New Jersey, continues to grow as the premier forum for researchers, engineers, and business executives in the North East drawing an attendance from all over the world. Besides the technical paper presentations, the symposium will include:

- Keynote Presentations
- Banquet
- Tutorials
- Executive Panels
- Student Poster Presentations.

Announcements

- 05/23/2012: Thank you all for attending the 35th Sarnoff Symposium, 2012
- 05/23/2012: List of attended posters is posted on "Student Posters" page
- 05/19/2012: The detailed conference program (updated) is posted on "Conference Program" page
- 05/18/2012: Joel S. Bloom (President, NJIT) will open the 35th Sarnoff Symposium on May 21, 2012
- 05/17/2012: Free parking at the "Parking Deck" for attendees on May 21-22, 2012
- 04/20/2012: Driving direction to NJIT is posted on "Conference Venue" page
- 04/15/2012: List of accepted posters is available on "Student Posters" page
- 04/10/2012: Final version instruction for full paper and student poster are available
- 03/31/2012: Visa letter is available through each attendee’s EDAS account under "My papers" link
- 03/22/2012: Final version of all accepted papers and student posters are due on Apr 15, 2012
- 03/20/2012: Student poster deadline is extended to Apr 06, 2012
- 03/15/2012: Notification of paper acceptance is on Mar 22, 2012 (revised)
- 03/09/2012: Free one-day registration for student poster presenters!!
- 02/17/2012: Student poster deadline is extended to Mar 20, 2012
- 02/03/2012: Paper, panel, and tutorial proposal deadline is further extended to Feb 15, 2012
- 01/27/2012: Discounts on registration fee for students presenting only posters are available
- 01/19/2012: Paper, panel, and tutorial proposal deadline is extended to Feb 03, 2012
- 10/26/2011: Paper registration is open
- 10/25/2011: Website is online
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Nonlinear Schemes for Spectrum Sensing in Cooperative Cognitive Radio Networks

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Abstract—In this paper, we propose and analyze nonlinear schemes for the spectrum sensing in cooperative cognitive radio networks under impulsive noise circumstances. By jointly employing the order statistics, generalized likelihood ratio test, and counting rule, the proposed scheme exhibits a better performance than the conventional counterparts.

I. INTRODUCTION

The concept of cooperative (or collaborative) spectrum sensing (CSS) has been introduced to overcome the effects of fading and shadowing without incurring excessive processing time for detection [1]. In most studies on the CSS schemes, it is assumed that the noise distribution is Gaussian: Although the assumption is usually reasonable from the central limit theorem, communication systems could frequently be exposed to impulsive noise environments [2].

In this paper, when the noise environment could be impulsive and might differ from a cognitive radio (CR) to another, we consider CSS schemes for the cooperative CR network (CCRN) comprised of one fusion center (FC) and a multiple of CRs. Based on the observation that nonlinear schemes have successfully been applied to mitigate the effects of impulsive noise in many signal processing applications [3], we propose to use nonlinear schemes for the spectrum sensing in the CCRN.

II. SYSTEM MODEL

Consider a CCRN composed of one FC and a number M of CRs. For m = 1, 2, · · · , M and n = 1, 2, · · · , N, the low-pass discrete-time observation ym(n) = ym,t(n) + jym,q(n) of the m-th CR at time instant n can be expressed as

ym(n) = wm(n)  

when the frequency band is not being used by the primary user (PU), and as

ym(n) = hm,n s(n) + wm(n)  

when the frequency band is being used by the PU.

In (1) and (2), s(n) = s1(n) + js2(n) denotes the transmitted complex signal of the PU at time instant n, and the complex additive noise wm,n(n) = wm,t,n(n) + jwm,q,n(n) is independent over m and n. The transmitted signal s(n) is distorted by the complex channel fading gain hm,n.

III. PROPOSED SPECTRUM SENSING SCHEMES

A. Generalized likelihood ratio test

Since the signal information of the PU is usually unavailable at the CR in practice, the generalized likelihood ratio test (GLRT) can instead be employed, in which the maximum likelihood estimate (MLE) of the distorted transmitted signal hm,n s(n) is adopted at the m-th CR.

B. Nonlinear schemes with selection

Selecting some observations with smaller magnitudes via a nonlinear scheme based on order statistics would generally lead to a better performance than exploiting all of the observations in impulsive noise circumstances.

We first produce the order statistics [4] \( \{y_{m(1)}, y_{m(2)}, \ldots, y_{m(N)}\} \) of \( y_m \), where \( |y_{m(1)}| \leq |y_{m(2)}| \leq \cdots \leq |y_{m(N)}| \).

Then, \( J_m \) smallest observations are selected to produce the test statistic \( T_{GSO}(y_m, J_m) = \sum_{l=1}^{J_m} \ln \left( \frac{f_m(y_{m(l)})}{f_m(y_{m(l)_1})} \right) \) (3) of the detector for the m-th CR, where \( J_m \) is the number of observations selected in the m-th CR, ln(·) and \( f_m \) denote the natural logarithm and MLE, respectively, and \( f_m \) is the joint pdf of \( w_{m,1}(n) \) and \( w_{m,Q}(n) \) for \( n = 1, 2, \ldots, N \). The detector described by the test statistic (3) will be called the GLRT based on selected observations (GSO) detector.

With the GSO detector, the binary spectrum sensing information (SSI) \( x_m \) of the m-th CR is obtained and sent to the FC, where \( x_m = 0 \) and 1 denote the local decision on the vacancy and occupancy of the spectrum, respectively.

C. Fusion center

After the set \( x = [x_1, x_2, \ldots, x_M] \) of all the SSI from the \( M \) CRs is collected at the FC, the SSI is combined to produce the test statistic of the FC. In this paper, we consider three types of counting rules to combine the SSI.
TABLE I

<table>
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<tr>
<th>Noise environment</th>
<th>1st CR</th>
<th>2nd CR</th>
<th>3rd CR</th>
<th>4th CR</th>
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<td>(less impulsive) NE 1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>(more impulsive) NE 2</td>
<td>2</td>
<td>1</td>
<td>1</td>
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IV. Simulation Results

In this section, in terms of receiver operation characteristic (ROC), we investigate the performance characteristics of the CSS scheme incorporating GSO detectors under various noise circumstances. We assume that the CRs can be exposed to the bivariate isotropic symmetric $\alpha$-stable (BISO$\alpha$) noise with $\alpha = 2$ or 1.

A. Influence of the number $J_m$ on the performance

Assuming $M = 1$ and $J_m = J$, the notations $GSO_{\alpha}(J)$ and $GSO_{\alpha}(J)$ will be used to denote the GSO detectors obtained in Cauchy and Gaussian noise circumstances, respectively. As it is easily anticipated, GSO detectors with larger values of $J$ perform better than those with smaller values of $J$ in Gaussian noise circumstance. In addition, it is observed that the GSO detectors with $J = 0.2N$ outperform those with other values of $J$ in BISO$\alpha$S noise with $\alpha = 1$.

Let $G_C$ stand for the detectors $GSO_C(N)$ and $GSO_C(0.2N)$ when the noise circumstance is BISO$\alpha$S with $\alpha = 2$ and 1, respectively; similarly, let $G_G$ represent the detectors $GSO_G(N)$ and $GSO_G(0.2N)$ when the noise circumstance is BISO$\alpha$S with $\alpha = 2$ and 1, respectively.

B. Performances comparison of CSS schemes

For the comparisons of the performance characteristics of several CSS schemes, we consider two cases of noise environment (NE) as shown in Table I.

Figs. 1 and 2 show the performance characteristics of the CSS schemes based on the detectors $G_C$, $G_G$, $GSO_C(N)$, and $GSO_G(N)$ in NE 1 and 2, where $P_F$ and $P_M$ denote the false-alarm and missing rates, respectively, of a CSS scheme. It is clearly observed that, in impulsive noise environments, the CSS schemes with $G_C$ and $G_G$ significantly outperform those with $GSO_C(N)$ and $GSO_G(N)$ when the same counting rule is employed: This observation confirms that the detectors $G_C$ and $G_G$ can successfully mitigate the degradation in detection performance caused by impulsive noise.

V. Concluding Remark

We have addressed spectrum sensing in cooperative cognitive radio networks under impulsive noise circumstances. The nonlinear scheme of cooperative spectrum sensing proposed in this paper adopts a selection of the order statistics of observations. From the results of numerical simulations, it is confirmed that the proposed scheme for cooperative spectrum sensing outperforms the conventional schemes in impulsive noise environment with Rayleigh fading.

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REFERENCES