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Fusion based Hybrid Cooperative Spectrum Sensing in Cognitive Radio Framework

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Abstract – **Cognitive radio sensor network (CRSN) demands energy efficient and a cost effective cooperative spectrum sensing techniques which perform well in fading and shadowing environment. The work presented in this paper is the Fusion technique for hybrid cooperative spectrum sensing using AND fusion of three secondary users for decision making. Transmission by primary user is how many times detected at secondary users shows the probability of detection. The results of simulation shows that probability of detection improves using AND fusion for the three secondary users. Performance of proposed system is evaluated using SNR, probability of false alarm and Sensing Time.**

Keywords –**Cognitive Radio, FCC, SDR, Spectrum Sensing.**

I. Introduction

The rapid growth in wireless communications has contributed to a huge demand on the deployment of new wireless services in both the licensed and unlicensed frequency spectrum. However, recent studies show that the fixed spectrum assignment policy enforced today results in poor spectrum utilization. To address this problem, cognitive radio (CR) has emerged as a promising technology to enable the access of the intermittent periods of unoccupied frequency bands, called white space or spectrum holes, and thereby increase the spectral efficiency. The fundamental task of each CR user in CR networks, in the most primitive sense, is to detect the licensed users, also known as primary users (PUs), if they are present and identify the available spectrum if they are absent. This is usually achieved by sensing the RF environment, a process called spectrum sensing. The objectives of spectrum sensing are twofold: first, CR users should not cause harmful interference to Pus by either switching to an available band or limiting its interference with PUs at an acceptable level and, second, CR users should efficiently identify and exploit the spectrum holes for required throughput and quality-of-service (QoS). Thus, the detection performance in spectrum sensing is crucial to the performance of both primary and CR networks. The detection performance can be primarily determined on the basis of two metrics: probability of false alarm, which denotes the probability of a CR user declaring that a PU is present when the spectrum is actually free, and probability of detection, which denotes the probability of a CR user declaring that a PU is present when the spectrum is indeed occupied by the PU. Since a miss in the detection will cause the interference with the PU and a false alarm will reduce the spectral efficiency, it is usually required for optimal detection performance that the probability of detection is maximized subject to the constraint of the probability of false alarm. Many factors in practice such as multipath fading, shadowing, and the receiver uncertainty problem may significantly compromise the detection performance in spectrum sensing.

The main objective of this paper is to implement a reliable spectrum sensing framework in cognitive radio sensor network to detect the spectrum holes for maximum spectrum utilization. Fusion based hybrid cooperative spectrum sensing for cognitive radio is more reliable including the sensing by multiple secondary users and combining their results to obtain the required threshold for decision making, rather than considering the sensed data from any one of the secondary user.

II. Proposed Methodology

Cooperative Spectrum Sensing

The main idea of cooperative sensing is to enhance the sensing performance by exploiting the spatial diversity in the observations of spatially located CR users. By cooperation, CR users can share their sensing information for making a combined decision more accurate than the individual decisions. The

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performance improvement due to spatial diversity is called cooperative gain. The process of cooperative sensing starts with spectrum sensing performed individually at each CR user called local sensing. Typically, local sensing for primary signal detection can be formulated as a binary hypothesis problem as follows:

$$x(t) = \begin{cases} n(t), & H_0 \\ h(t).s(t) + n(t), & H_1 \end{cases} \quad (1)$$

Where $x(t)$ denotes the received signal at the CR user, $s(t)$ is the transmitted PU signal, $h(t)$ is the channel gain of the sensing channel, $n(t)$ is the zero-mean Additive White Gaussian Noise (AWGN), H_0 and H_1 denote the hypothesis of the absence and the presence, respectively, of the PU signal in the frequency band of interest. For the evaluation of the detection performance, the probabilities of detection P_d and false alarm P_f are defined.

Covariance based Cooperative Spectrum Sensing

This paper is focused towards the development of user cooperation based spectrum sensing scenario using covariance based detection algorithm. Centralized data fusion centre (DFC) is used to fuse the results obtained from different sensing elements into a single decision, AND-rule and OR-rule based data fusion methods have been used in this paper. Data fusion Centre which is a centralized entity performs data fusion over sensing data received form several secondary users using data fusion rules given below:

AND based Data Fusion

AND based data fusion algorithm operates on logical AND operation performed over results obtained from several sensing elements. The output of the algorithm float over two states:

$$Primary\ Detected = \begin{cases} 1 & if all\ sensing\ elements\ report\ detection \\ 0 & otherwise \end{cases} \quad (2)$$

In this way AND based cooperative spectrum sensing outputs a detected primary signal if and only if each sensing elements reports detection of the presence of primary signal.

OR based Data Fusion

OR based data fusion algorithm operates on logical OR operation performed over results obtained from several sensing elements. The output of the algorithm float over two states:

$$Primary\ Detected = \begin{cases} 1 & if any\ sensing\ element\ reports\ detection \\ 0 & if\ none\ sensing\ element\ reports\ detection \end{cases} \quad (3)$$

In this way OR based cooperative spectrum sensing outputs a detected primary signal if any of the sensing element reports detection of the presence of primary signal.

Proposed Spectrum Sensing Method

Let the continuous time received signal be $X_c(t) = S_c(t) + W_c(t)$ where $S_c(t)$ is the detected primary signal and $W_c(t)$ is the modelled noise signal. Noise signal is modelled to be a stationary process with zero mean and a variance of σ_η^2. The received continuous time signals are sampled and made the two simple hypothesizes for the signal detection where H_0 implies that the signal does not exist; and H_1 implies the signal exists.

$$H_0: \mathrm{X(n) = W(n)} \quad (4)$$

$$H_1: \mathrm{X(n) = S(n) + W(n)} \quad (5)$$

The signal samples reflect the effects of path loss, multipath fading and time dispersion. The proposed hybrid scheme incorporates Eigen value spectrum sensing along with the energy detection. The algorithms are based on the ratio of maximum to minimum Eigen value (MME) and based on the ratio of average signal power to the minimum Eigen value (EME). Since MME has a performance edge over EME, MME algorithm has been suggested for the detection.

Maximum-Minimum Eigen value (MME) Detection:

1. The covariance matrix of the received signal samples is computed by considering N_s number of samples using the following equation:

   $$R_x(N_s) = \frac{1}{N_s} \sum_{n=L-1}^{L-2+N_s} x(n)x\dagger(n) \quad (6)$$

   Where † stands for Hermitian (transpose-conjugate) operation.
2. The maximum and minimum eigenvalues of the matrix $R_x(N_s)$, λ_{max} and λ_{min} are calculated then.
3. The final decision on signal detection is made by comparing the ratio of λ_{max} and λ_{min} with a threshold value γ.
4. Decision rule: if $\lambda_{max}/\lambda_{min} > \gamma$, signal exists; otherwise, signal does not exist.

Probability Parameters and Threshold Value for MME Detection:

Expressions for probability of false alarm and threshold value are derived out using the random matrix theory concepts and certain distribution functions. We have listed approximated expressions for the performance parameters and threshold value by treating $R_w(N_s)$ nearly as a Wishart random

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matrix and using Tracy-Widom distributions for its Eigen values.

1. The probability of false alarm (P_{fa}) for MME detection.

$$P_{fa} = 1 - F_1\left[\frac{\gamma\left(\sqrt{N_s}-\sqrt{ML}\right)^2-\mu}{v}\right] \quad (7)$$

Where $F_1(t)$ is the Tracy-Widom distribution function and its tabled values are available.

2. Threshold

We obtain the formula for threshold:

$$\gamma = \frac{\left(\sqrt{N_s}+\sqrt{ML}\right)^2}{\left(\sqrt{N_s}-\sqrt{ML}\right)^2} \cdot \left[1 + \frac{\left(\sqrt{N_s}-\sqrt{ML}\right)^{-\frac{2}{3}}}{(N_s ML)^{\frac{1}{6}}} \cdot F_1^{-1}\left(1 - P_{fa}\right)\right] \quad (8)$$

Where, L-smoothing factor, M-over sampling factor, N_s- Number of samples taken.

3. The probability of detection (P_d)

The approximated formula for the probability of detection is:

$$P_d = 1 - F_1\frac{\left[\gamma N_s + \frac{N_s(\gamma\rho ML-\rho)}{\sigma_n^2} - \mu\right]}{v} \quad (9)$$

It can be seen that the number of samples N_s and the maximum and minimum eigenvalues of the signal Covariance matrix have an effect on P_d.

III. Simulation And Results

MATLAB simulation is used to study proposed approach.

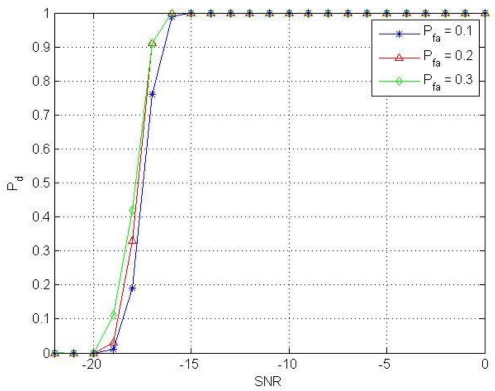

Figure 1: SNR v/s P_d graph for different values of P_{fa}

The above simulation result shows the comparative graph between the probability of detection and signal to noise ratio (SNR) for different values of P_{fa}. The X axis indicates the signal to noise ratio (SNR) and the Y axis represents probability of detection (P_d).

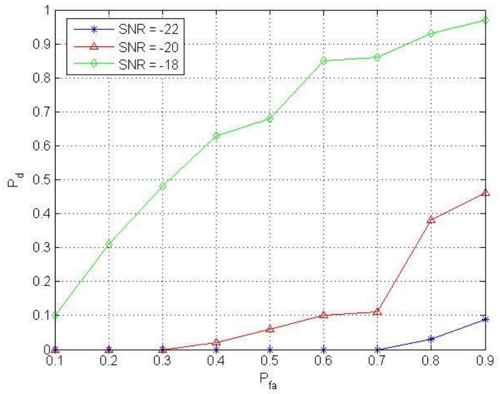

Figure 2: P_{fa} v/s P_d graph for different values SNR

The above simulation result shows the comparative graph between the probability of false alarm and probability of detection at different values of signal to noise ratio (SNR). The X axis indicates the probability of false alarm (P_{fa}) and the Y axis represents probability of detection (P_d). At low SNR value the probability of detection is high.

IV. Conclusion

In this paper, a cluster-based cooperative network architecture with the concept of detection is introduced which actually helps to reduce the power consumption and in turn increase the energy efficiency. A cooperative detection scheme which associates Eigen value based spectrum sensing with an energy detector has been proposed and it can be implemented for various signal detection application without knowledge of the signal, channel and noise power. It was found that the fusion based detection is more reliable instead of single secondary detection.

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