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Analysis of Spectrum Detection using Fusion Rule in Cognitive Radio Network

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Abstract:
Coordination of cognitive users can enable cooperative spectrum sensing in cognitive radio networks, improving the accuracy of primary user detection. This work investigates a hybrid cooperative spectrum sensing method that takes advantage of the double-fusion strategy to enhance the sensing performance. Both data fusion and decision fusion are examined in particular. Cognitive users transfer their energy to the fusion centre in the first stage, where data of each cognitive cell data is fused. In the second stage, each cognitive cell's fusion centre shares the decision with one another and uses decision fusion to reach a final judgment. Furthermore, we calculate the ideal number of cells and cognitive users for the suggested architecture. Comparing the sensing performance with single fusion conventional cooperative spectrum sensing, numerical findings demonstrate a considerable improvement.
Keywords: Cognitive Radio (CR), Cooperative Spectrum Sensing (CSS),Detection Probability, OR-AND Logic, Data Fusion, Decision Fusion

1. INTRODUCTION

Cognitive radio (CR), which introduces opportunistic usage of the frequency bands that are not significantly occupied by licensed users, appears to be a tempting solution to the spectral congestion problem in order to address the issue of underutilization of spectrum [1]. Primary users in cognitive radio networks are granted preferential rights to use a designated portion of the spectrum. Because they are less important than primary users, cognitive users make use of this spectrum without interfering with them. As a result, in order to take use of the portion of the spectrum that is not being used by a primary user, cognitive users must be able to consistently perceive the spectrum and adjust radio parameters [2].

The local sensing performance will suffer from the fading and shadowing effects. Consequently, a solution to the issue that occurs in spectrum sensing has been proposed: cooperative spectrum sensing. Miss-detection and false alarm probabilities are significantly reduced using cooperative sensing. Cooperation can also shorten sensing times and resolve concealed primary user issues. In centralized cognitive radio networks, decision fusion schemes have been the primary focuses of cooperative sensing research in recent times [3–4]. Specifically, [5–6] examines and analyses a cooperative spectrum sensing system in a cognitive radio network that is based on an optimal fusion strategy. Furthermore, in cooperative spectrum sensing, there are several fusion methodologies. For example, in [7], data fusion and decision fusion for multiple slots and numerous cognitive radio users are demonstrated. The trade-off between sensing and throughput is examined to determine the ideal sensing time for spectrum sensing. The energy fusion and decision fusion is suggested in [8] as a way to reduce reporting errors generated on by fading channels. But whether a network is decentralized or centralized, the fusion strategy is nearly always used. In order to enhance the sensing performance, double-fusion is used in this paper to examine a hybrid cooperative spectrum sensing method. According to the proposed method, the base station (BS) in the cognitive cell serves as the fusion centre and gathers all users' sensory data through data fusion. Then, utilizing decision fusion, BS communicates its decision to one another. Additionally, we determine the hybrid cooperative spectrum sensing scheme's ideal number of cognitive users and cells as well as the sensing performance.

This is how the remainder of the paper is structured. The hybrid cooperative spectrum sensing technique system model is explained. The problem optimization of the suggested fusion-based approach is covered. The numerical results are presented graphically and discussed.

2. SYSTEM MODEL

Because of its low compute complexity, energy detection is being extensively investigated for spectrum sensing in cognitive radio networks. As a result, this work also uses energy detection. The CR user must discriminate between the primary user's absence (H_0) and presence (H_1) in order to perform local sensing. Let K and L represent the number of CR users and samples, respectively. The observed energy value of the m[th] is then displayed as follows:

$$Y_m = \begin{matrix} \sum_{l=1}^{L} n_{ml}^2 H_0 \\ \sum_{l=1}^{L} (s_{ml}+n_{ml})^2 H_1 \end{matrix} \quad (1)$$

where, for each sample of the m^{th}CR user, s_{ml} and n_{ml}, $1 < m < K$, $1 < l < L$, represent the received primary signal and white noise, respectively; we assume that the noise at each sample is Additive White Gaussian Noise (AWGN). As stated earlier, additive noise in addition to a potential primary signal make up the observed signal. We make the assumption that the observed signal is normalized in relation to the noise standard deviation in order to make the discussion easier.

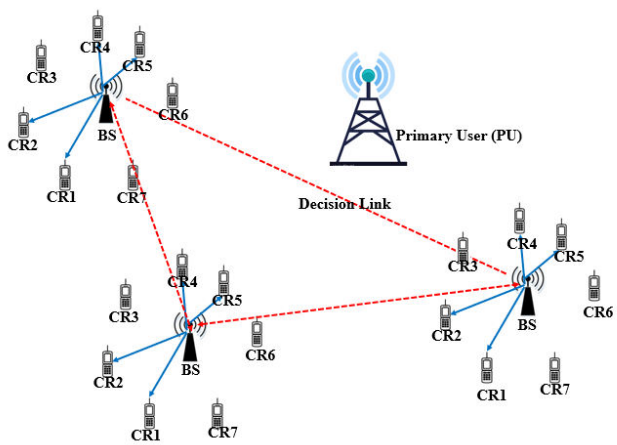

Fig.1: Proposed System Model

Whereas Y_m follows a non-central chi-square distribution with Ldegrees of freedom and a non-centrality parameter $L\Gamma_m$as in (2), whereΓ_m is denoted the instantaneous signal to noise ratio (SNR) of them^{th} CR user, Y_m follows a central chi-square distribution with Ldegrees of freedom if the primary signal is absent.

$$Y_m = \begin{matrix} \xi_L^2 H_0 \\ \xi_L^2 \, (L\Gamma_m) \quad H_1 \end{matrix} \quad (2)$$

For a given hypothesis, Y_m are taken to be independent. The Central Limit Theorem states that, for a large L, Y_m approximates the following Gaussian distribution:

$$Y_m = \begin{matrix} K(L,2L) & H_0 \\ K(L(1+\Gamma_m),2L(1+2\Gamma_m)) & H_1 \end{matrix} \quad (3)$$

The hybrid cooperative spectrum sensing system model shows in Fig. 1. Three cognitive radio cells and one major system are present in special. K CR users and one base station make up each cognitive cell. CR users employ data fusion to transfer their local energy to the BS in each CR cell, where they carry out energy detection for local sensing. Next, decision fusion between BSs in various cognitive cells is investigated; double-fusion will determine the final decision between $H_0$and H_1.

In the initial phase, each CR cell's users individually employ data fusion to feel the primary user's spectrum. Based on the energy received, each CR user determines whether to respond with 0 or 1, where 1 indicates the primary user is present and 0 indicates the primary user is absent. In Fig. 1, CR_m transmits its energy Y_m and decision $d_m$to the BS. Using the data fusion approach, BS_m's decision $D_m$is obtained as follows.

$D_m = \boldsymbol{\mathcal{F}}(d_m, Y_m)$(4)

In the subsequent phase, decision fusion is utilized in a decentralized cooperative sensing mode in Fig. 1, BS exchange decisions with one another. Each BS renders the D_{final}decision for the primary system in accordance with the decision fusion method.

$$D_{final} = \mathcal{G}(D_1.\ D_2 \ldots.. D_m) \qquad (5)$$

3. THE HYBRID COOPERATIVE SPECTRUM SENSING

Decision rules for cooperative spectrum sensing are typically broken down into three categories: OR, AND, and Majority Rules. Furthermore, in [9], the "Optimal Decision Fusion Rule" was also put forward. We shall outline the above-mentioned decision rule principle in the sections that follow. Let B_l represent the binary decision made at the l^{th}base station, where B_l for $l = 1, \ldots, P$ = {0, 1}.

“Logic-OR” Rule:

A straightforward decision rule known as the "OR rule" is as follows: The final judgment confirms the existence of a primary user if any of the decisions indicate the same. Mathematically, $\mathbb{E} = \sum_{l=1}^{P} B_l$, the primary user is present if $\mathbb{E} \geq 1$; if not, there isn't a primary user.

“Logic-AND” Rule:

The "AND rule" states that if a primary user is acknowledged in every choice, then that primary user is acknowledged in the final decision. Mathematically, $\mathbb{E} = \sum_{l=1}^{P} B_l$, the primary user is present if $\mathbb{E} = P$; if not, there is no primary user.

Majority Rule:

The majority of the individual decisions form the basis of another decision rule. The final decision announces the existence of a principal user if at least half of the decisions make this claim. Mathematically, $\mathbb{E} = \sum_{l=1}^{P} B_l$, the primary user is present if $\mathbb{E} \geq {}^{P}/_{2}$; if not, then absent.

For cooperative sensing for data fusion, the false alarm and detection probabilities are provided by [10]. Here m is the number of CR out of K CR users.

$$Q_f = prob\left\{{}^{H_1}/_{H_0}\right\} = \sum_{a=m}^{K} \binom{K}{a} p_f \left(1 - p_f\right)^{K-1} \qquad (6)$$

$$Q_d = prob\left\{{}^{H_1}/_{H_1}\right\} = \sum_{a=m}^{K} \binom{K}{a} p_d (1 - p_d)^{K-1} \qquad (7)$$

The m out of K rule becomes the OR and AND rules, respectively, when the values of m are taken to be 1 and K.

4. RESULTS AND DISCUSSIONS:

The performance of the proposed network has been analyzed using simulation results in this section. Performance of the system is analyzed in terms of detection probability for different values of number of samples.

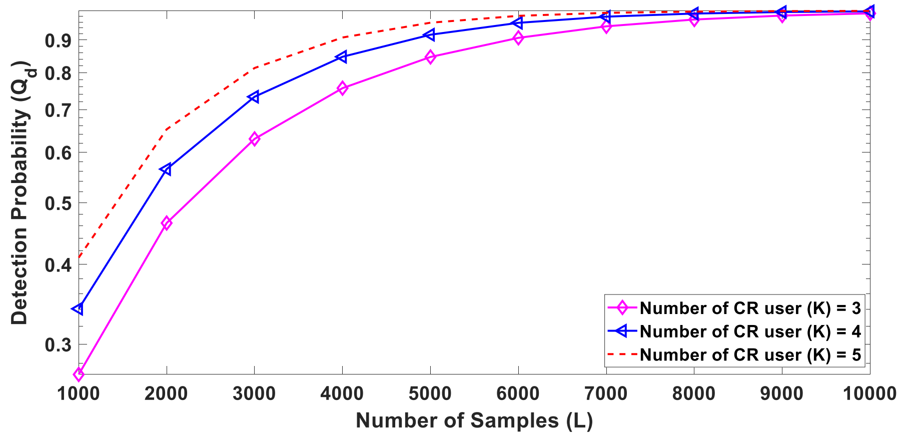

Fig.2: Impact of number of samples on detection probability for different values of K

Fig.2 depicts the variation of detection probability (Q_d) in terms of number of samples (L) for the number of CR user $K = 3, 4, 5$. Detection probability increases as number of samples are increasing. For a fixed value of L if number of CR user increases 3 to 5 then detection probability increases.

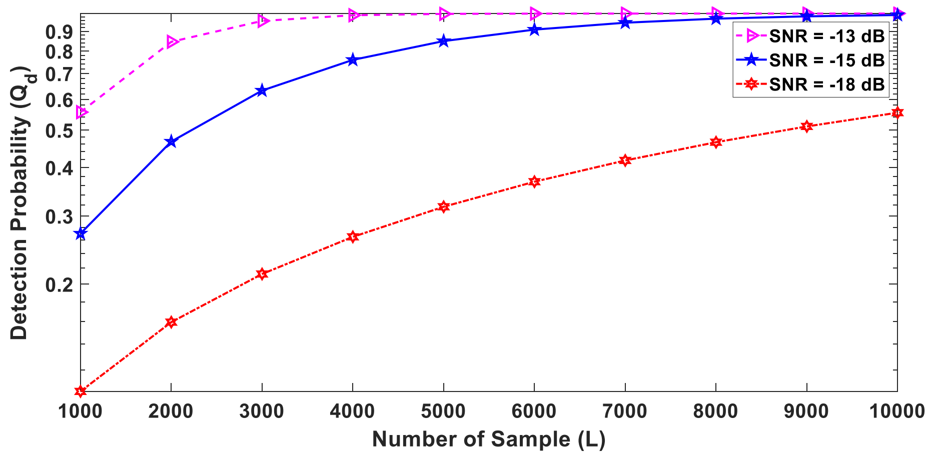

Fig.3:Impact of number of samples on detection probability for different values of SNR

Fig.3illustrates the variation of detection probability (Q_d) in terms of number of samples (L) for different values of SNR. Detection probability increases as SNR increases. For a fixed value of number of samples(L)for the increasing value of SNR detection probability increases.

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