IMPLEMENTATION OF DISTRIBUTIVE COOPERATIVE SENSING SCHEMES USING AND and OR FUSION RULES FOR SPECTRUM DETECTION

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ABSTRACT

Cognitive radio is a dynamic and inventive approach for proficient utilization of radio spectrum. Cognitive radios are designed to check the availability of spectrum holes without creating interference to the licensed users and to improve the spectrum’s utilization. The main issues which degrade the detection performance are shadowing, multipath fading and noise at the receiver channel. To overcome this issue, cooperative spectrum sensing is found to be more operational to improve the spectrum detection than the non-cooperative sensing. Even though we achieve improvement in detection performance, this sensing suffers from cooperation overhead. This overhead leads to additional sensing time, energy, delay and any performance deprivation caused by cooperative sensing. In this paper, we used a cognitive radio network that works on the methodology of distributed spectrum sensing. Here we propose two schemes called AND rule and OR rule to reinforce the distributed spectrum sensing. Our analysis and simulation results show that these approaches assures the accuracy in spectrum sensing and yields better results even when a huge number of secondary users are reporting false sensing information.

KEYWORDS: Cognitive Radio, Spectrum Detection, Distributed Cooperative Sensing, AND and OR rule, Fusion Rules & Secondary User

INTRODUCTION

Cognitive radio (CR) [1] is a technology which allows unlicensed (secondary) users to operate in the licensed spectrum bands. This technique is mainly used to improve [2] the spectrum utilization in wireless communications network. The primary task for a cognitive radio system is to proficiently detect the white spaces in the spectrum and make those spaces useable for the secondary user.

In the cooperative sensing model, the hidden terminal detection problem arises because of a single terminal or node. So, the multi-node cooperative strategy which is based on centre node has come into existence to resolve this hidden node problem [3-6]. Cooperative sensing models is classified as centralized and distributed. The centre node (i.e. fusion centre) processes the detected results of secondary users and then it decides whether the primary user is present or not. When the channel is under deep fading [5] the performance of the centre node is limited. The duty of the fusion centre is to accumulate all the individual spectrum sensing information, integrate them and take a decision about the white spaces.

In the literature there are many optimal and suboptimal strategies found for centralized data fusion. For maximizing the probability of detection the semi definite programming based on linear fusion used [7]. An online adaptive linear fusion based on orthogonal projections onto convex sets (POCS) is also proposed in [5]. If the system consists of a large number of nodes, the centralized cooperative sensing scheme is not a good
solution. One of the parameters for fusion centre is that it should be capable of processing a huge amount of data and should be sensitive to link failures. Furthermore, if there is an increase in distance between nodes, then the radios might need to use more power and in turn it increases network energy consumption [8]. Therefore, for several small distant neighbouring nodes, a distributed approach becomes a good alternative [8] and the data is shared only among nodes which are neighbours.

It is proposed by Cattivelli and Sayed, under dynamic propagation environments [9] we arrive at better results if cooperation between nodes are adaptive for this distributed spectrum sensing by reformulating the detection problem as a parameter estimation problem. But considering the parameters regarding user’s signal at every node is not so effective at all the times. In this paper, we propose a novel method for distributed spectrum sensing and the detection algorithms used is AND rule and OR rule in the fusion centre.

COOPERATIVE SENSING

Based on how the CR users share the sensing data, the cooperative spectrum sensing is classified. The Figure 1 shows the cooperative signal sensing model. Figure 2 represents the centralized and distributed types of cooperative sensing.

In centralized cooperative sensing, the fusion centre (FC) follows a three-step process of cooperative sensing. First, the FC decides on a channel or a frequency band and instructs all cooperating CR users to individually carry out local spectrum sensing. Second, all cooperating CR users via control channel they report their sensing results. Then the FC combines the received local sensing information, confirms the presence of PUs, and disseminates the decision back to cooperating CR users.
As shown in the above Figure 2 (a), CR₀ is FC and CR₁–CR₅ is cooperating CR users which perform local sensing and report the results back to FC. All the CR users will adjust to a needed frequency for local sensing. Now the data reporting between the CR user and the FC will happen on a commonly tuned control channel. Here any CR node can act as base station (BS) or a FC to receive and combine the data from the other CRs in the network. On the other hand, Distributed cooperative sensing will not depend on FC for making the cooperative decision. In distributed sensing CR users interconnect themselves and stick on to one decision about the white spaces in the spectrum hole by performing few repetitions. The Figure 2(b) explains the distributed cooperative sensing. According to this algorithm, each CR user will send the sensed data to other users. With the received sensing data, now this CR will decide the presence of PU. If the PU is present, then the CR users send their combined results to other CR users and repeat this process until it finds hole for the SU to occupy spectrum. In this manner, this distributed scheme may take several reprises to reach the congenial cooperative decision [10].

Conventional cooperative sensing is usually deliberated as a three-step process: local sensing, reporting and data fusion. Apart from these steps some other seven crucial elements to analyze the cooperative sensing. They are (i) cooperation models, (ii) sensing techniques, (iii) control channel and reporting, (iv) data fusion strategies AND logic and OR logic (v) hypothesis testing, (vi) user selection and (vii) knowledge base. In this paper we propose two methods for data fusion strategies AND logic and OR logic.

IMPLEMENTATION OF DISTRIBUTIVE SENSING SCHEMES

In this sensing scheme, while the CR user is sending the sensed data to other users, for example consider at the node (x), it first produces a local energy estimate of (Ex), where the energy is shared with its own neighbours within a transmission radius having the same index set (Nx). Now a weighted decision with the combination of local energy estimates from the neighbouring nodes a local binary decision is made referred to as the soft combining step. Finally, these weights of the node energy are shared among the nodes among all the neighbouring nodes and are combined within each node to yield a local consent result, referred to as hard combining step. The following sections describe the two above mentioned steps, i.e., the soft and hard combining steps. Let us consider that the secondary users nodes sense the environment under two hypotheses: H₀: absence of primary signal or H₁: presence of primary signal to make measurements about primary users at the beginning of detection or to establish communication links with their own neighbours to locally exchange information among them and then calculate the obtained data to make a local decision.
Soft Combining

Among the existing spectrum sensing algorithms, mainly cyclostationary feature detection [11], matched filtering [11] and energy detection [12, 13] are widely considered.

A matched filter [11] is theoretically optimal, but it needs prior knowledge of the primary system, which means higher complexity and cost in developing adaptive sensing circuits for different primary wireless systems. Energy detection is suboptimal and without any prior knowledge about primary user, the energy detection algorithm can be implemented and this is simplest of all the methods [13]. Cyclostationary feature detection can detect the signals with very low SNR, but it still requires some prior knowledge of the primary user [14].

In this paper, we considered a scenario where prior knowledge of the primary user is not known. Simply saying, an energy-detection spectrum-sensing method [12] is used. Figure 3 shows the block diagram of an energy detector.

\[ x(t) = \begin{cases} n(t), H_o \\ h.s(t) + n(t), H_1 \end{cases} \]  \hspace{1cm} (1)

Where \( x(t) \) is the signal received by the secondary user, \( s(t) \) is the primary user’s transmitted signal, \( n(t) \) is the additive white Gaussian noise, and \( h \) is the amplitude gain of the channel. We also denote the SNR as \( \gamma \). The output of integrator \( V \), serves as the decision statistic. \( V \) has the following form:

\[ V = \begin{cases} X^2_{2TW}, H_o \\ X^2_{2TW} (2\gamma), H_1 \end{cases} \]  \hspace{1cm} (2)

Where \( X^2_{2TW} \) and \( X^2_{2TW} (2\gamma) \) denote random quantities with central and non-central chi-square distributions, respectively. Under Rayleigh fading, the gain \( h \) is random, and the resulting SNR (\( \gamma \)) would have an exponential distribution; therefore, in this case, the distribution of the output energy depends on the average SNR (\( \gamma \)). When the primary user is absent, \( V \) is still distributed according to \( X^2_{2TW} \). CR users can quantize the local sensing results and send only the quantized data for soft combining to ease the control channel communication overhead [15].

Hard Combining

For hard combining the local decision is taken by the CR users to transmit one bit. At the FC it is better to use soft combining for a good detection, but at the expense of channel overhead. By quantizing, the soft and hard combining would
entail a small channel bandwidth but with deprived performance because of the loss of information due to quantization. If we wish to arrive at cooperative decision, then it is very apt to use linear fusion rules provided local decisions are made at FC. AND and OR rules are the commonly used fusion rules.

The cooperative decision made by the FC may be represented as:

\[ u_i, u \in \{0, 1\} \] (3)

Where \( u_i \) is the local decision of the individual CR user and \( u \) is the CR user. ‘0’ and ‘1’ indicate a PU’s absence (\( H_0 \)) and presence (\( H_1 \)) respectively.

The AND rule refers to the FC which determines \( u = 1 \) if \( u_i = 1 \) for all \( i \).

RESULTS AND DISCUSSIONS

The result of AND rule detection is shown in Figure 4. The Figure shows the cooperative sensing with AND rule. The graph is plotted between Probability of False Alarm \( P_{fa} \) and Missed Detection \( P_{md} \).

Similarly, the OR rule refers to \( u = 1 \) if \( u_i = 1 \) for any \( i \). The result of OR rule detection is shown in Figure 5. The probability of False Alarm \( P_{fa} \) and Missed Detection is shown in Figure 5.
Figure 5: Result of OR Rule Detection

Figure 4 shows complementary ROC of cooperative spectrum sensing with AND. Figure 5 shows complementary ROC of cooperative spectrum sensing with OR. All simulation was done on MATLAB version R2013a under AWGN channel. The simulation result were taken for the SNR =15dB and the number of users are 10. The figure 5 compares the false missed detection for AND rule for N=10 with the theoretical detection for various number of users. The result shows that the AND rule results gives the better results with theoretical values. The missed detection decreases with increasing PFAs. Similarly the figure 5 compares the missed detection using OR rule. Here also the results are better than the theoretical values. Comparing with AND rule the OR rule gives the better missed detection for various false alarms.

CONCLUSIONS

Even though spectrum sensing is one of the important parameters of cognitive radios, its problems related to security has not been concentrated properly. In this paper, we have come out with a distributed and scalable system for spectrum sensing. Cooperative spectrum sensing is modelled as a multi agent coordination problem. Secondary users can maintain coordination based on only local information exchange without a centralized receiver. Simulation results have been presented to show the usefulness of the proposed distributed sensing schemes. It has been shown that both missing detection probability and false alarm probability can considerably be reduced in the distributed spectrum sensing method over the non-cooperative sensing schemes.
REFERENCES
