Optimized Cooperative Spectrum Sensing in Cognitive Radio Networks Based on Dynamic Threshold Energy Detector

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Abstract **- Cognitive radio is a seemly hopeful technology for future. Spectrum sensing is the most important function of cognitive radio. Most of the spectrums sensing techniques proposed become dysfunctional at lower signal to noise ratio environments. This paper proposes a reliable spectrum sensing algorithm for cooperative cognitive network. A dynamic threshold updating method is developed for which threshold changes with the environmental noise impact. Energy detector will be used as basic block to development. The reliability of sensing technique is evaluated in terms of probability of error and minimum signal to ratio it tolerates. The work includes study of existing spectrum sensing techniques that are single threshold energy detector and double threshold energy detector and their implementation in the cooperative sensing environment. Finally they are juxtaposed in cooperative environment. Optimal number of cognitive radios required in the decision making process is also calculated.**

Index Terms **- Cognitive Radio, Spectrum Sensing, Dynamic Threshold, Cooperative Sensing, Optimized Sensing.**

I. Introduction

Due to the easy deployment and independent design of WSN for many applications in the ISM band, the frequency band is extremely crowded. This suggested the idea of cognitive communication. CRs can be largely classified in context to their method of spectrum management: spectrum sensing, spectrum sharing, spectrum decision, and spectrum mobility. Various methods used by CR devices to detect the available spectrum are all grouped as spectrum sensing. For reliable network we should have a reliable sensing methodology. The ideal sensing technique should have least probability of false alarm, maximum probability of detection, minimum probability of error, minimum usage of network resources like memory and power, should be computationally fast and less complex, robust in high noise conditions, reliable and should require no prior information about PU's transmitted data. In this paper we discuss the sensing techniques which are capable of sensing even if they have no clue of what is being transferred over the primary network. We propose an energy detection technique based on dynamic threshold updating mechanism used in cooperative network. Finally it is optimized to get minimum number of CRs required in decision making.

II. Single Threshold Energy Detection

Energy detection algorithm is considered here because it can be used without exact knowledge of received primary user signal. The measured energy 'Y' is compared to predetermined threshold 'T' and the result is represented by binary value according to the presence and absence of primary user signal. 'H_o' represents the hypothesis for presence of primary user and H_1 represents the hypothesis for absence of primary user. Based on the binary hypothesis False Alarm Probability 'P_f', Missed-detection probability 'P_m' , and probability of detection 'P_d'. They can be calculated as shown below.

$$Pd = P\{Y \geq T \mid H1\} \quad (1)$$

$$Pf = P\{Y \geq T \mid H0\} \quad (2)$$

$$Pm = P\{Y \leq T \mid H1\} \quad (3)$$

Total probability of error is P_e i.e sum of P_m *and* P_d.

III. DOUBLE THRESHOLD ENERGY DETECTION

This method uses two thresholds to make the decision. Two detection thresholds are selected i.e. T_1 and T_2. There is region of uncertainty in between these two thresholds. The decision hypothesis formed for double threshold detection is

$$L(t) = \begin{cases} 0 \text{ or } H_o \text{ for } Y(t) < T_2 \\ \text{No decision for } T_2 < Y(t) < T_1 \\ 1 \text{ or } H_1 \text{ for } Y(t) > T_1 \end{cases} \quad (4)$$

Based on the binary hypothesis, false alarm probability and detection probability can be defined as follows.

$$Pd = P\{Y \geq T_2 \mid H1\} \quad (5)$$

$$Pf = P\{Y \geq T_2|H0\} \quad (6)$$
$$Pm = P\{Y \leq T_1|H1\} \quad (7)$$

Here difference in both the thresholds is

$$\Delta T = T_2 - T_1 \quad (9)$$

IV. DYNAMIC THRESHOLD ENERGY DETECTION

Noise in the system is variable. Thresholds or SNR walls exists such that the detection of presence of signal becomes nearly impossible below that SNR wall. It may be too low to make noise to be detected as signal or too high to make signal be detected as noise. So threshold selection may favour Pd or Pf. Inappropriate selection of threshold could lead to degradation of detector's performance making it SNR dependent. There is need of a threshold selection mechanism which could deal with noise uncertainty problem. This gives the idea of a dynamic threshold selection mechanism dependent on noise in environment.

An algorithm for dynamically varying the decision threshold with respect to SNR is designed. Steps for threshold selection are shown below.

Algorithm for dynamic threshold selection

Step 1: Initialize samples P, SNR, Nt

Step2: Generate random noise signal (n) as function of SNR and transmitted signal (s). Received signal will be y=n+s.

Step 3: Calculate noise energy = $\frac{1}{P} * \sum |n|^2$ *and received signal energy*

Step 4: Arrange Nt samples of noise in descending order

Step 5: T=max (E_{noise})

Algorithm for calculation of Pd in dynamic threshold energy detector is shown in below

Algorithm for Pd calculation

Step 1: Initialize samples P, SNR, Nt, i=0

Step2: Threshold estimation

Step 3: Calculate received signal energy Y = $\frac{1}{P} * \sum |y|^2$ *and received signal energy*

Step 4: Arrange Nt samples of signal energy in descending order

Step 5: If Y>T

Then increment i= i+1

Else end

V. OPTIMIZED COOPERATIVE SPECTRUM SENSING

Hidden terminal problem is a major challenging issue in cognitive radio spectrum sensing. It escalates the detection error and interference. Cooperative spectrum sensing has been proposed in literature which can overcome the fading issues. Multiple CRs send their sensed decision to a fusion centre for a final decision. The minimum CRs required are obtained by finding out a probability of error minima. The number of CRs corresponding to those minima is optimal number of CRs.

VI. RESULTS AND DISCUSSION

In enhanced energy detector the threshold is updated each time when the SNR changes. The enhanced energy detection algorithm is designed and simulated at different number of samples. The low SNR value further shifts as the number of samples are increased. Figure. 1 depicts the change in probability of detection as SNR changes for different number of samples P= 100, 200, 400, 800, 1600, 3200. This shows that the number of samples taken plays crucial role in increasing detection probability.

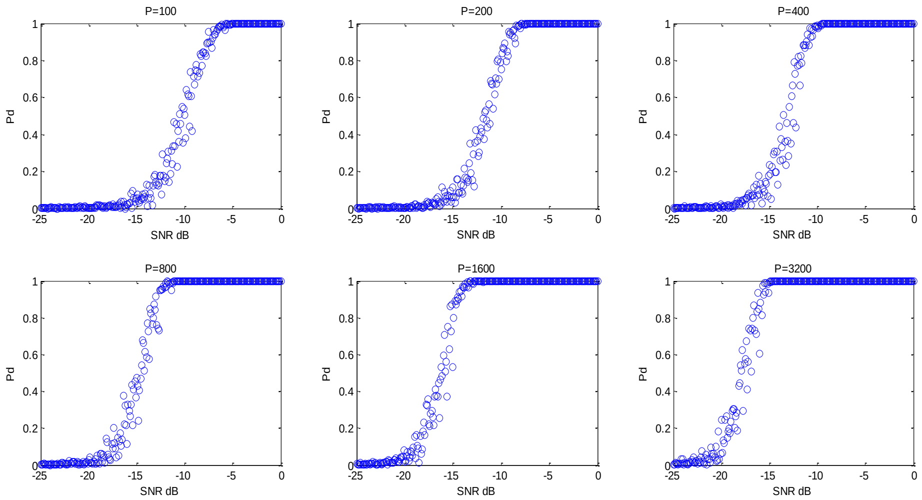

Figure 1. Pd=f (SNR) for different values of P

The approximate curve of min (SNR) = f (P) is shown in Fig. 7. It shows that the increase in number of samples makes the detection algorithm work for lower SNRs. SNR_{min} is calculated for Pd>0.9.

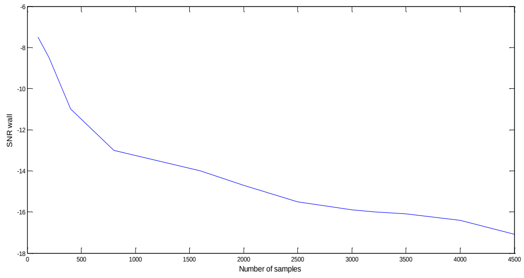

Figure 2. SNR_{min} vs. P

The P_e of cooperative sensing technique is calculated by varying number of decision making CRs out of total CRs present. Total number of CRs available are taken to be 20. The number of CRs corresponding to which minima of P_e is obtained, is called optimal number of CRs. Figure. 3 shows optimal cooperative spectrum sensing for single threshold and double threshold energy detectors. It can be seen that optimal number of CRs required for decision making is more in conventional energy detector based cooperative network. Simultaneously it has lesser probability of error as compared to double threshold energy detector.

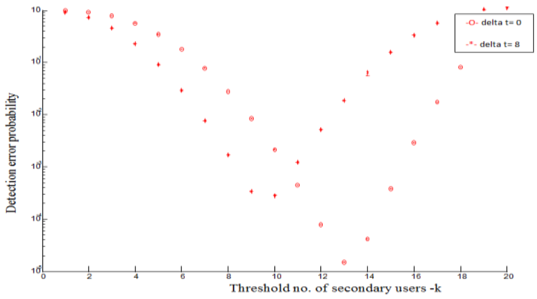

Figure 3. Optimal number of CRs for single and double threshold ED

The dynamic threshold based cooperative network is simulated at -20 dB for different number of samples. Two of them are shown in Fig. 3. Studying Fig. 2 and 3 it can be observed that P_e is least in dynamic threshold based energy detector. Also it can work at lower SNRs as compared to other techniques

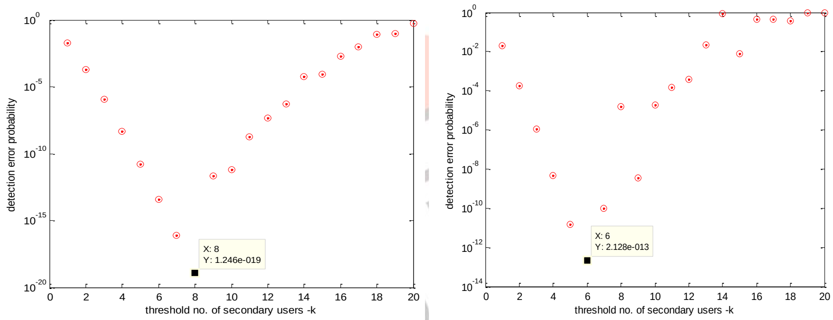

Figure 9. Optimal number of CRs for dynamic threshold ED based cooperative scheme for different number of samples

The observations made from above simulations are tabulated in Table 1. It shows the comparison of three techniques in cooperative environment.

Table 1 Enhanced Energy Detector Sensing Parameters

Parameter	Dynamic threshold ED
Minimum SNR	-11 to -20 dB
Optimal number of CRs	6 to 7
Error probability	Range of 10^{-12} to10^{-14}

VII. CONCLUSION

The proposed algorithm in the work is more suitable for CRSNs due to its promising features. Lesser probability of error is observed in comparison to existing techniques. The probability of detection error is of the order of 10^{-12}-10^{-14}. Interference to the PU as P_e is minimum. It uses minimum network resources. The optimal number of CRs required is 6 to 7. It would be able to work in robust conditions as SNR_{min} is very low i.e. -11 dB to -20 dB. Thus it is more tolerable to noise. Proposed algorithm can deliver IEEE 802.22 standard requirement at lower SNRs than existing techniques i.e. -20 dB.

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