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Single User Eigenvalue Based Detection For Spectrum Sensing In Cognitive Radio Network

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Abstract: *Scarcity of spectrum is the issue that wireless communication technology has to deal with. Primary user is the licensed user of the spectrum. When primary user is idle or not using the spectrum secondary user can utilize the spectrum. This sharing of spectrum can be enabled by cognitive radio (CR) technology. The heart of enabling this technology is spectrum sensing. Spectrum sensing involves detection of primary signal at very low SNR (in the range of -20 dB), under noise and interference uncertainty. This requirement makes spectrum sensing, a hard nut to crack. Another major issue in detection is hidden node problem wherein the node in vicinity of primary transmitter also indicates absence of the primary signal since it is hidden behind the large object. There are various algorithms for detection viz. energy detection, matched filter detection, feature detection (cyclostationary detection, eigen-value based detection etc.) These algorithms have limitations of complexity, requirement of signal knowledge and detection performance. In this paper the performance of eigenvalue based detection (EBD) method in presence of noise and low SNR of the received signal has been evaluated for a single user.*

Keywords-: *Cognitive radio, eigenvalue based detection, energy detector, spectrum sensing.*

I. INTRODUCTION

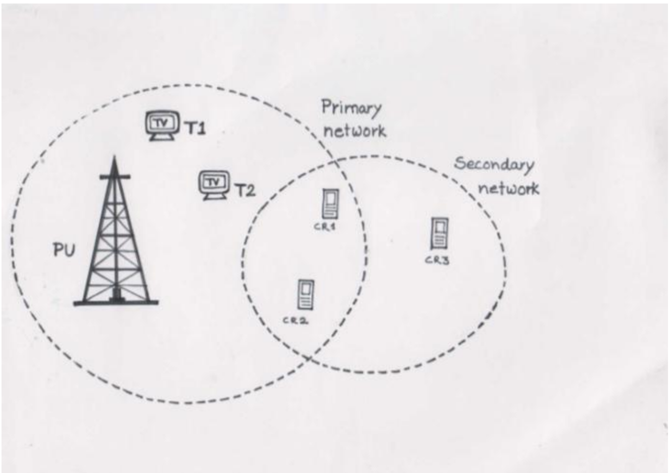
With new technologies and services in wireless communication, demand for spectrum has been evolved as major issue to deal with. Spectrum should be efficiently used and spectrum allocation should be dynamic to meet growing demand. A way out is to sense the spectrum and act as secondary user when primary user is not in picture. Figure (1) below demonstrates concept of opportunistic sharing. First image shows primary user is using the resource (laptop) while second one show when primary user is not utilizing the resource (laptop) secondary user can temporarily use it. This management is done by special system. In the same way to reduce and utilize unused spectrum a special system is been designed which can intelligently manage sharing of spectrum. Cognitive radio is one way to handle this issue. Cognitive radio is a transceiver having spectrum sensing capability to find temporarily holes in the spectrum and accordingly changes its transmission or reception parameters so that spectrum is never vacant and meets our demand for spectrum usage. This process is what called as dynamic spectrum management. Spectrum sensing is the main functionality in cognitive radio. [4]Cognitive radio is responsible for quality of service to primary user. Sensing the spectrum has many challenges first is finding exact noise model which is very difficult, secondly low signal to noise ratio and lastly to avoid hidden node problem. The hidden terminal issue occurs when a node is in coverage area of primary transmitter, but hidden by larger object so that it cannot receive the signal from primary transmitter or receiver. In this study it is assumed that the primary system is a broadcast system and primary receivers are passive (unable to transmit). Main challenge in spectrum sensing lies in low SNR. In the figure (2) shown below is the primary and secondary network. PU is the primary user and CR1 and CR2 are the cognitive radio 1 and 2 in coverage area of PU. Thus CR1 and CR2 can sense the spectrum used by primary user PU and if it is not active then cognitive radio 1 or 2 in secondary network can opportunistically use the spectrum. Once the primary user occupies the spectrum then secondary user discontinues its use and searches for another vacant space. Main issue to discuss with is if say cognitive radio 3 (CR3) is not in coverage area of primary user PU, CR3 may be behind big buildings or topologically crowded places then CR3 may erroneously decide that channel is vacant and use the channel causing interference in the primary user. [6][10]This particular situation is called as hidden node terminal and can be avoided by cooperative sensing. Thus decision whether channel is used by primary user or not is made by cooperation of cognitive radios. In the above eg CR1 and CR2 will inform CR3 that spectrum is occupied or not thereby avoiding interference with primary user. Taking all these into consideration we have to find a robust way of spectrum sensing wherein noise uncertainty makes no difference on the performance. Various detection methods include [1][9] i) Matched filter ii) Energy detection iii) Feature detection iv) Eigenvalue detection. Disadvantages of first three methods are given: The most important feature of matched filter is low execution time but knowledge of signal properties is needed which is not possible in cognitive radio case. Here receiver should agree with the source channel conditions and signal nature must be known.

Energy detection method has low computational and execution complexity. An energy detector sets a threshold according to the noise level and compares it with the energy of the data stream in input. This detector only requires minimal information, such as the signal bandwidth and carrier frequency Moreover the threshold depends of the noise level so it's very difficult to fix it in changing conditions but its performance depends upon number of samples the time required for sensing is larger which is undesired in cognitive radio.

In feature detection statistical properties that vary periodically with time, which are called cyclostationary features of the primary signal are detected to find out spectrum hole but this method leads to high computational efficiency hence sensing time is again large. Also, knowledge of some signal parameters such as carrier frequency is necessary. This method needs a great complexity computational and the knowledge of some signal parameters of the signal under test like the carrier frequency should also be known.

In this backdrop spectrum sensing techniques based on the eigenvalues of the received sample covariance matrix has recently been emerged as a promising solution, as they do not require a priori assumptions on the signal to be detected, and typically outperform the popular energy detection method.

Fig(1) Primary and secondary user



Fig(2) Primary and secondary network

II. System Model

Let s(n) = Primary users signal, x(n) = Received signal samples η(n) = received white noise , The detection problem can be formulated with two hypothesis no signal and only noise; signal with additive white noise [2]. First case signal is present is denoted as hypothesis H1 and second case signal is not present is denoted by hypothesis H0

$$H_0 : x(n) = \eta(n) \quad \text{------------------------- (1)}$$

$$H_1 : x(n) = s(n) + \eta(n) \quad \text{--------------- (2)}$$

Let N_s be the number of collected samples. Eigenvalue based detection is based on sample covariance matrix of received signal.
In practice number of samples are limited so sample covariance matrix is been considered. Following is the equation for sample covariance matrix of received signal.

$$R_x(N_s) = (1/N_s) \sum_{n=L-1}^{L-2+N_s} \hat{x}(n)\hat{x}^{\dagger}(n)$$

Where xˆ(n) is estimated received signal sample. And xˆ†(n) is transpose conjugate of estimated received signal sample. L being the number of consecutive outputs also called smoothing factor. Maximum and minimum eigenvalue of sample covariance matrix is obtained.
λ_{max} is maximum eigenvalue of sample covariance matrix and λ_{min} is minimum eigenvalue.
Maximum to minimum eigenvalue ratio is compared with threshold (γ). If ratio is greater than threshold signal is present otherwise signal is not present.

$$\frac{\lambda_{max}}{\lambda_{min}} > \gamma \quad \text{---------- signal exists}$$

$$\frac{\lambda_{max}}{\lambda_{min}} < \gamma \quad \text{--------- signal does not exist}$$

III. Flowchart

Eigenvalue based detection (EBD) schemes can be divided into two categories: methods that assume knowledge of noise level (referred to as semi-blind), and methods that do not assume this knowledge (blind)[8][9]. Methods belonging to the first class provide better performance when the noise variance is known exactly; on the other hand blind methods are more robust to uncertain or varying noise level. Spectrum sensing techniques based on the eigenvalues of the received sample covariance matrix provides efficient detection, as they do not require any information of the primary signal to be detected, and proves better than the popular energy detection method. EBD methods are based on eigenvalue calculation of received signal's sample covariance matrix. Maximum and minimum eigenvalue is found out from sample covariance matrix, thereafter ratio of maximum to minimum eigenvalue ratio is been compared with threshold. If the ratio is greater than threshold signal is detected means primary user is using the spectrum. If the ratio is less than threshold signal is not detected means primary user is not using the spectrum so secondary user can opportunistically use the spectrum.

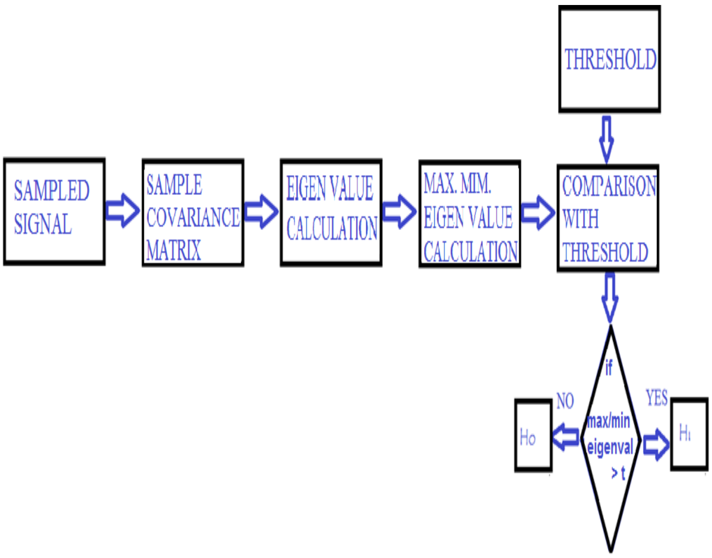


Fig. (3) Flowchart of EBD

IV. RESULTS

The results have been implemented using Matlab R2013a. Modulation for the input signal used is PSK. PSK modulated signal with noise added is shown in the results below.

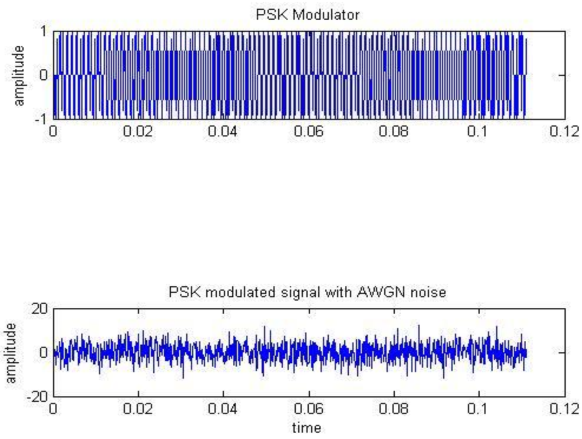


Fig. (4) Modulated output and modulated output with noise added

Plot of probability of detection vs SNR is been shown in results below in fig.(5). Plot represents the probability of detection versus SNR for probability of false alarm of 0.1. Graph shows that at low SNR with high probability of false alarm probability of detection is poor.

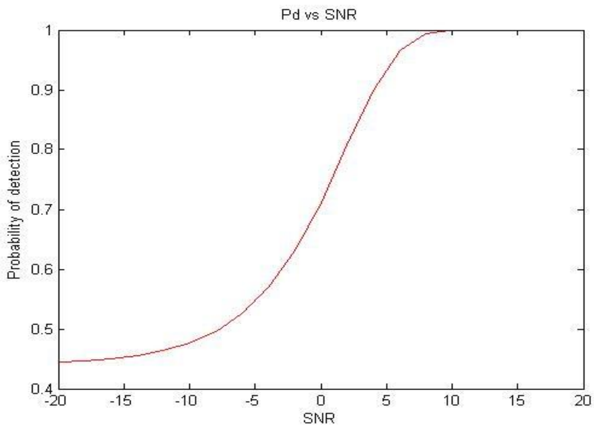


Fig. (5) P_d vs. SNR

Fig.(6) represents plot of probability of detection versus SNR for probability of false alarm of 0.04,0.2,0.3. Graph shows that at low SNR with high probability of false alarm probability of detection is poor.

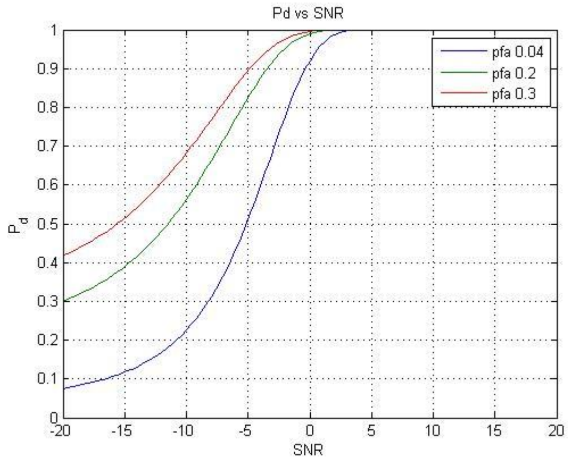


Fig. (6) P_d vs. SNR for different P_{fa}

V. Future Work

Eigenvalue based detection is done for a single user and single cognitive radio. Detection can be improved by taking into consideration more than one cognitive radio and avoid hidden node problem. More than one cognitive radio is been considered and with the cooperation of all the sensors hidden node issue is handled. Cooperative Eigenvalue based detection (CEBD) methods considers low SNR to avoid hidden node problem thereby protects primary user.

VI. Conclusion

Eigen value based detection methods use the received signal sample for detection and require no information on the transmitted signal, channel and noise power. EBD method overcomes the noise uncertainty difficulty

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