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# A Review on Two Stage Spectrum Sensing for Cognitive Radio Networks

**Aparna Singh Kushwah**[1], **Rohit Parashar**[2]

[1]Assistant Professor, Department of Electronics and Communication, University Institute of Technology, RGPV Bhopal, India

[2]M. Tech Scholar, Department of Electronics and Communication, University Institute of Technology, RGPV Bhopal, India

**Abstract:** ***With the rapid development of wireless communication, the problem of bandwidth shortage has become more prominent. On the other hand, the studies made by FCC (Federal Communications Commission) showed that in the licensed spectrum band, most of the time large portion of the spectrum vacant and users only utilize their allocated resources partially. So, to solve this problem of spectrum under-utilization, FCC allowed unlicensed user i.e. secondary users to utilize the licensed band when it is not in use and named it as Cognitive Radio. In cognitive radio the most important part is to sense spectrum. In this paper we proposed a two-stage spectrum sensing scheme for cognitive radios where in the first stage energy detection is used and combination of maximum-minimum eigen (CMME) value based detection used in the second stage. The detection parameters in both the stages is used in such way so as to maximize Probability of detection on the given constraints on the probability of false alarm. Also advantages and disadvantages of detection techniques are analyzed and summarized. also research issues and challenges are given.***

**Keywords:** Two-stage spectrum sensing, cognitive radios, energy detection, cmme detection, spectrum hole

## 1. Introduction

Nowadays, with the rapid growth of wireless communication, it becomes more and more congested for our limited spectrum at frequencies. Due to the ever-growing demand for the radio spectrum and the exclusive access to licensed bands, it has become difficult for the Federal Communications Commission (FCC) and regulators of many countries to assign spectrum for new wireless services [1]. However, studies indicate that allocated licensed frequencies are largely underutilized in specific regions. These findings open a new area of research to find a solution for spectrum shortage and spectrum underutilization and to achieve efficient spectrum use and high-quality services. Recent studies [2], [3] have proposed a new approach to spectrum management whereby secondary users to be able to detect the unused frequency and vacate this frequency at the time the licensed user accesses it without affecting its transmission. there are many techniques are available for vacant spectrum sensing these are classified as matched filter, cyclostationary feature detection , energy detection and maximum-minimum

Eigen value based detection. Among these techniques energy detection and maximum-minimum eigen value based detection are the blind spectrum sensing technique in which prior knowledge of transmitted signal is not required. Whereas cyclostationay property based detection is semi blind technique that requires some prior knowledge of the PU. Matched filter needs the prior knowledge of the primary user"s signal such as the modulation type and order, pulse shaping and packet format. Energy detectors [5] are the most common way of spectrum sensing because of their low computational complexity but energy detection technique performance degraded at low SNR. On the other hand cyclostionary detection and eigen value based detection technique performance is good at low SNR but suffer from computational complexity. to overcome these two stage spectrum sensing technique is proposed in which in first stage energy detection is used and combination of maximum-minimum eigen (CMME) value based detection used in the second stage[6].

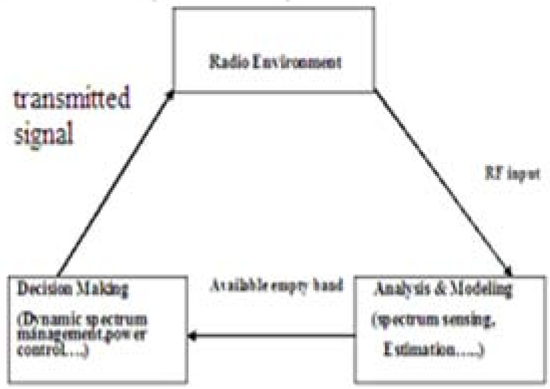


**Figure 1:** Concept of Cognitive Radio Network

## 2. Principle of Two Stage Spectrum Sensing

In the proposed two-stage spectrum sensing we assume that there are $L$ channels to be sensed and that channels are sensed serially. In the first sensing stage, the channel is sensed by using energy detection. If the decision metric is greater than that of the threshold $\lambda$, the channel is declared to be occupied. Else, the received signal is analyzed by second sensing stage consisting of CMME detection. If the constituent detection metric is greater than a threshold $\gamma$, the channel is declared occupied, else it is declared to be empty. In the following we shall discuss the two stages of energy detection [7], [9] and eigen value based detection [12], [13] in the context of two-stage sensing.

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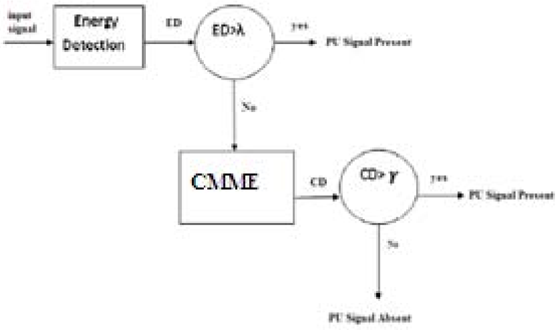


**Figure 2:** Two Stage Spectrum Sensing Scheme

## 3. Energy Detection

An energy detector which serially sensed every channel within the band is used as first sensing stage. The energy detector accumulates the energy of N samples and then compares it with a threshold $\lambda$ to decide whether the primary user is present or not. Denoting $H_1$ and $H_0$ as the respective probabilities of primary user presence and absence, the energy detector makes its decision based on N observations X(n), n=1,….,N given by

**x[n] = s[n] +w[n]** for $H_1$ hypothesis
**x[n] = w[n]** for $H_0$ hypothesis

with the primary user"s signal and receiver noise denoted by S(n) and W(n) respectively. The noise is assumed to be an independent identical distribution random Gaussian process with zero mean and variance $\sigma_w^2$, while the signal is assumed to be an independent identical distribution random process of zero mean and variance $\sigma_s^2$.

$$\text{ED} = \frac{1}{N}\sum_{n=1}^{N}|x[n]|^2$$

$$Y = \begin{cases} H_0 \, hypothesis; ED \le \lambda \\ H_1 \, hypothesis; ED > \lambda \end{cases}$$

## 4. CMME Detection

If in the first stage i.e., ED stage decision metric ED<$\lambda$ then the signal is again sensed by using CMME detection technique. Since as discuss previously that ED performance is very poor at low SNR irrespective of increasing sensing time. Whereas CMME performance is better in low SNR with correlated signals without any prior information about primary signal and channel noise [12] [13]. Assume that there are **K** secondary users. Then the received signal at the $i_{th}$ secondary user is denoted by $x_i(n)(i = 1,2, \ldots .K)$. then the statistical matrix can be defined as;

$$\text{x(n)}=[x_1(n), x_2(n), \ldots \ldots .., x_K(n)]^T$$
$$\text{S(n)}=[s_1(n), s_2(n), \ldots \ldots .., s_K(n)]^T$$
$$\text{w(n)}=[w_1(n), w_2(n), \ldots \ldots .., w_K(n)]^T$$

Where the received signal is given by x(n) (1,2,…,N) where N is the number of samples . s(k) is the transmitted signal passed through a wireless channel and w (k) is the additive white Gaussian noise (AWGN) with mean zero and variance $\sigma_w^2$

Therefore the received signal is written as:

**S = x + n ….(1)**

The statistical covariance of the received signal, transmitted signal and noise signal as,

$$R_x = E(xx^T)$$
$$R_s = E(ss^T)$$
$$R_w = E(ww^T)$$

Let us consider by computing the covariance matrix of equation (1) .$\beta_{max}$ and $\beta_{min}$ are the maximum and minimum eigen value of covariance matrix of eq.(1)

Than the decision metric of CMME stage CD is given as:

$$\text{CD} = \frac{\beta_{max}}{(\beta_{max} - \beta_{min})}$$

$$Y = \begin{cases} H_0 \, hypothesis; CD \le \gamma \\ H_1 \, hypothesis; CD > \gamma \end{cases}$$

## 5. Research Challenges and Issues

The biggest challenge regarding sensing is in developing sensing techniques which hare able to detect every weak primary signal while being sufficiently fast and low cost to implement. Spectrum sharing is allocation of an unprecedented amount of spectrum that could be used for unlicensed or shared services. Opportunistic communication with interference avoidance faces a multitude of challenges in the detection of sharing in multi-user cognitive radio systems. Because of the presence of user priority (primary and secondary), they pose unique design challenges that are not faced in conventional wireless systems. A major issue in a multiple secondary user environment is sharing, a topic that has generated a lot of research interest in the recent past. The flexibility of cognitive radios has significant implications for the design cross layer algorithms which adapt to changes in physical link quality, radio interference, radio node density, network topology or traffic demand may be expected to require an advanced control and management framework with support for cross-layer information.

## 6. Conclusion

Cognitive radio is a new intelligent radio technique proposed to overcome spectrum shortage and underutilization problems. This study has investigated spectrum sensing in cognitive radio. The importance and challenges of spectrum sensing have been demonstrated. The energy detection and CMME detection method are two widely used methods for spectrum sensing in cognitive radio. The energy detection method is a less computational complex technique but performs poorly at low SNR conditions. The CMME detection scheme is robust to noise and interference and thus performs well at low SNR, but is a high computational complex method. The two-stage spectrum sensing method incorporates both the detection schemes i.e. energy detection and CMME detection. It overcomes the demerit of both the methods and uses their merit to achieve a better sensing performance. So, the two-stage spectrum sensing method is a better detection scheme in comparison to both energy detection and CMME detection method.

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