Transmitter Detection Methods of Spectrum Sensing For Cognitive Radio Networks over Fading Channels

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Abstract - *Due to rapid advancements in wireless communication and broader application of these wireless networks in the world, efficient utilization of the spectrum has been a persuasive issue for researchers. This has enabled the development of an intelligent network that can adapt to varying channel conditions by analyzing available spectrum frequency band and increasing the efficiency of an otherwise underutilized spectrum. This paper focuses on the spectrum sensing function of the Cognitive Radio in order to detect and utilize empty spaces in the spectrum without creating interference to the primary user. In this paper a quantitative analysis of two broader groups of spectrum sensing techniques namely Energy detection and Matched filter detection has been presented. A performance analysis based on the Probability of detection and probability of false alarming at different SNR levels is conducted under different fading channel models i.e. Additive White Gaussian Noise (AWGN), flat fading and Rayleigh fading channels. A Comparison between the above mentioned spectrum sensing techniques proofs low probability of false alarm, when Matched filter detection is used.*

Key Words: **Cognitive Radio (CR), Spectrum Sensing, Energy Detection, Matched Filter Detection, Eigen Value Based Detection**

1. INTRODUCTION

The Electromagnetic spectrum available today is becoming overcrowded day by day due to remarkable increment in wireless devices. It has also been observed that available spectrum is underutilized most of the time[1]-[2].To overcome this problem The Federal Communications Commission (FCC) has been trying to find new ways to manage RF resources. They provide a guarantee of minimum interference to those who are the primary license holder. The issue of spectrum underutilization in wireless communication can be solved using Cognitive Radio (CR) technology. Cognitive Radios are designed to provide reliable communication for users and also effective Utilization of radio spectrum. Cognitive Radio will enable the Secondary user to determine the presence of licensed user, more over which portion of spectrum is available, in other words to detect the white spaces and which is known as spectrum sensing [2].

Spectrum Sensing is the capability to determine and sense whether license user is present or absent. Objective of cognitive radio is that unlicensed user needs to detect the presence of licensed user or shift to another frequency band or stay in the same band by changing its modulation scheme to avoid interference. Spectrum Sensing involves the detection of the presence of a transmitted signal, by a given Receiver. The ability of cognitive Radio to dynamically access the spectrum holes that dynamically appear is predicated upon its ability to detect these white spaces in the first place

2. SPECTRUM SENSINE TECHNIQUES FOR COGNITIVE RADIO

Spectrum sensing is the very task upon which the entire operation of cognitive radio rests. Spectrum sensing, defined as the task of finding spectrum holes by sensing the radio spectrum in the local neighborhood of the cognitive radio receiver in an unsupervised manner. The term spectrum holes stands for those sub bands of the radio spectrum that are underutilized (in part or in full) at a particular instant of time and specific geographic location. To be specific, the task of spectrum sensing involves the subtasks are Detection of spectrum holes; Spectral resolution of each spectrum vacancies; Identification of the spatial directions of incoming interferes; Signal classification.

Sensing of unused spectrum can be based on transmitter detection methods, interference based detection method or cooperative detection methods. Currently investigated transmitter detection methods are matched filter, Eigen-value based detection and energy detection. Transmitter methods sense the spectrum so as not cause interference to the primary transmitter.

2.1 System Model.

We have to find the primary transmitters that are transmitting at any given time by using local measurements and local observations. The hypothesis for signal detection at time *t* can be described as [3].

$$x(t) = \begin{cases} n(t), & H_0 \\ h \times s(t) + n(t), & H_1 \end{cases}$$

Where x(t) the received signal of an unlicensed user, s(t) is the transmitted signal of the licensed user, n(t)I s the noise like additive white Gaussian noise (AWGN) or Rayleigh fading channel, and *h* is the channel gain. Here, H0 and H1 are defined as the hypotheses of not having a signal from a licensed user in the target frequency band, respectively. Cognitive radio (CR) users will detect the presence or absence of users by using any of the spectrum sensing techniques like "Energy detection", "Matched filter detection" or "Cyclostationary feature detection

3. ENERGY DETECTION

Energy detection is the widely used spectrum sensing method since prior knowledge of the licensed user signal is not required, performs well with unknown dispersive channels and it has less computational and implementation complexity and less delay relative to other methods However, this method relies on the knowledge of accurate noise power and hence is vulnerable to the noise uncertainty. Energy detection is optimal for detecting independent and identically distributed (iid) signals in high SNR conditions, but not optimal for detecting correlated signals. Energy detection compares the energy of the received signal in a certain frequency band to a threshold value which is defined according to the SNR, to derive the two binary hypothesis; whether the signal present or not
H0: (primary user absent)

y(n) = u(n) n = 1, 2, . . . ,N

H1: (primary user present)

y(n) = s(n) + u(n) n = 1, 2, . . . ,N

Where u (n) is noise and s (n) is the primary user signal.

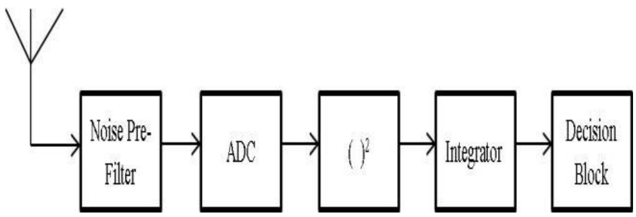


Fig -1 Block Diagram of Energy Detector

The block diagram for the energy detection technique is shown in the Figure 1.The band pass filter selects the specific band of frequency to which user wants to sense. After the band pass filter there is a squaring device which is used to measure the received energy. The energy which is found by squaring device is then passed through integrator which determines the observation interval, T. Now the output of integrator, Y is compared with a value called threshold, λ and if the values are above the threshold, it will consider that primary user is present otherwise absent.

The performance of the detection algorithm can be summarized with two probabilities: probability of detection P_d and probability of false alarm P_{fa}. P_d is the probability of detecting a signal on the considered frequency when it is really present. Hence a large detection probability is desired. P_{fa} is the probability that the test incorrectly decides that the considered frequency is occupied when it actually is not. The "probability of primary user detection" and the "probability of false detection" for the Energy detection method can be calculated by the given equations:

$$P_d = P_r(Y > \lambda/H_1) = Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right)$$

$$P_f = P_r(Y > \lambda/H_0) = \frac{\Gamma\left(u, \frac{\lambda}{2}\right)}{\Gamma(u)}$$

P_{fa} should be kept as small as possible in order to prevent underutilization of transmission opportunities. The decision threshold λ_E can be fixed for finding an optimum balance between P_d and P_{fa}. However, this requires knowledge of noise and detected signal powers. The noise power can be calculated, but the signal power is tough to estimate as itchanges depending on ongoing transmission characteristics and the distance between the cognitive radio and primary user. In practice, the threshold is selected to obtain a certain false alarm rate. Hence, knowledge of noise variance is sufficient for selection of a threshold.

The threshold value (λ) for the detector is determined either from the fixed probability of detection Pd or from the fixed probability of false alarm Pfa. The evaluation procedure of the detection threshold (λ) from the Probability of false alarm Pfa is called the Constant False Alarm Rate (CFAR) principle. An approach which involves the calculation of the detection threshold from the already fixed target Pd is called the Constant Detection Rate (CDR) Principle

Energy detection has following drawbacks:

1. It requires a longer sensing time to achieve good results.
2. It is unable to differentiate between sources of received energy i.e. it cannot distinguish between noise and primary User.

4. MATCHED FILTER DETECTION

Matched filter is able to perform efficiently and optimally when a user operates at secondary sensing node can perform a coherent detection of the primary signal [8]-[9]. However, within spectrum sensing to use the matched filter, the secondary sensing node must be synchronized to the primary system and it must be able to demodulate the primary signal.

Matched filter is a linear filter which works on phenomena of maximize the signal to noise ratio. Matched filter detection is then applied when the cognitive radio user having information about the type of primary signal. Matched filter operation is equivalent to correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal. The operation of matched filter detection is expressed as

$$Y[n] = \sum_{K=-\infty}^{\infty} h[n-k]\, x[k]$$

Where 'x' is not the known signal and is convolved with the 'h', the impulse response of matched filter that is matched to the reference signal for maximizing the SNR. Detection by using matched filter is useful only in cases where the information from the primary users is known to the cognitive users

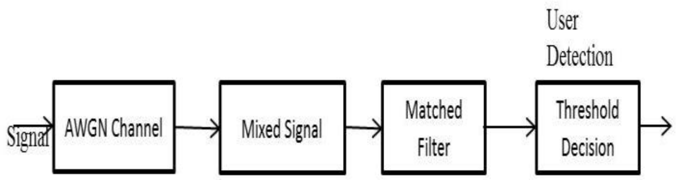


Fig -2 Block Diagram of Matched Filter Dection.

Matched filter detection require less detection time. When the information of the licensed user signal is known to the Cognitive Radio user, Matched filter detection is good Detection in noise [10].There are some drawbacks of this technique which are

1. It requires a prior knowledge of every primary signal.
2. CR would need a dedicated receiver for every type of primary user

5. EIGEN VALUE BASEDE DETECTION

Eigen value based detection is a novel method which is based on the Eigen values of the covariance matrix of the received signal at the secondary users. The expression for decision threshold has been derived based on the random matrix theory (RMT) which is also under research and in a developing stage.

This method achieves both high P_d and low P_{fa} without requiring information of the primary user signals, channel and noise power as a priori hence it can overcome the noise uncertainty problem faced by energy detectors. Further, no synchronization is needed as in matched filter detection. Since the covariance matrix incorporates the correlations among the signal samples, the Eigen value based detection outperform the energy detection in the presence of correlated signals while its performance is comparable to that of the energy detector in the presence of independent and identically distributed (iid) signals. But it is computationally more complex than the energy detector.

There are three main Eigen value based detection methods under study, which are classified according to the test statistic used to detect the signal. The test statistic is compared against a computed threshold. The three methods are the maximum minimum Eigen value (MME), energy with minimum Eigen value (EME) and maximum Eigen value detection (MED). MME method uses the ratio of the maximum Eigen value to minimum Eigen value of the sample covariance matrix as the test statistic. While EME method employs the ratio of the average power of the received signal to minimum Eigen value. In MED method the maximum Eigen value is used as the test statistic to be compared against a threshold.

6. RESULTS AND ANALYSIS

An extensive set of simulations have been conducted using the system model as described in the previous section. The emphasis is to analyze the comparative performance of two spectrum sensing techniques. The result is conducted on the basis of probability of false alarm and probability of primary user detection under different SNR in different channels which are AWGN, Flat fading and Rayleigh fading. The number of primary users kept 20 in this analysis

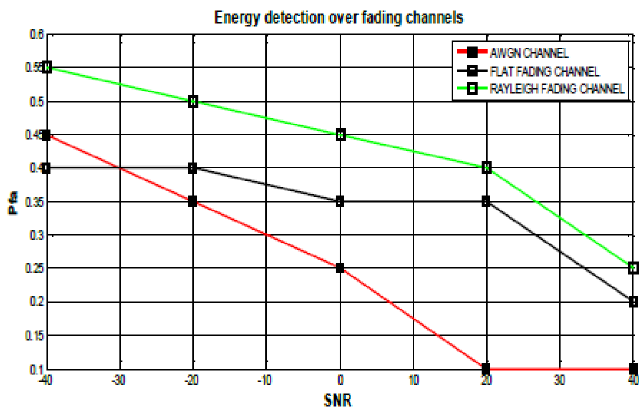


Chart -1 Probability of false alarm for Energy detection

Chart 1 represents the Comparative analysis between fading channels on the basis of "probability of false alarming" on different SNR levels. It is clearly seen that probability of false alarming decreases with the increment of SNR and the AWGN channel has minimum false detection as compared to other channels, while Rayleigh fading channel has maximum false alarm.

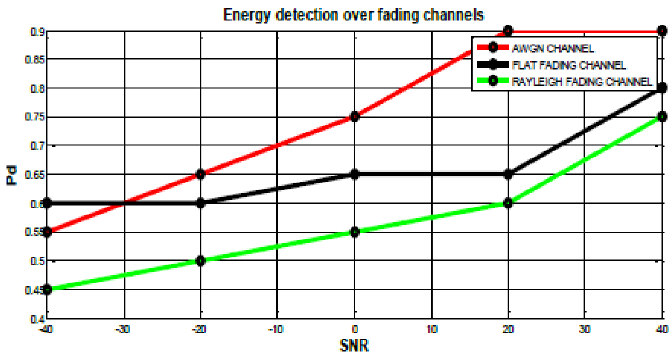


Chart -2 Probability of detection for Energy detection

Chart 2 represents the channels comparison on the basis of "probability of detection" and SNR. From graph, it is clear that probability of detection increase with the increment of SNR level

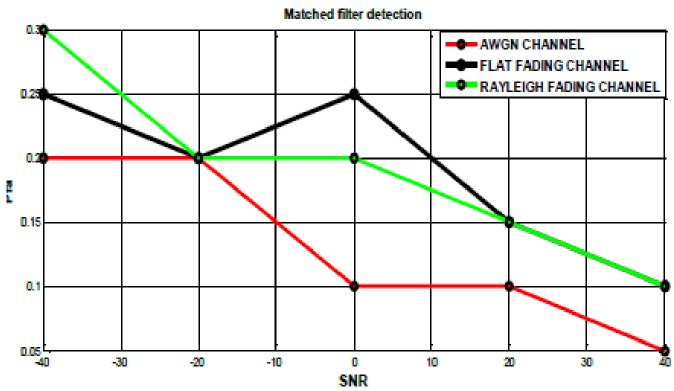


Chart -3 Probability of false alarming for Matched filter Detection

Chart 3 illustrates the "probability of false alarming" for the three channels at different SNR levels. It is observed that AWGN channel has minimum false alarming detection as compared to the others. While the Rayleigh fading channel has maximum false alarm as compared to the AWGN and flat fading channel

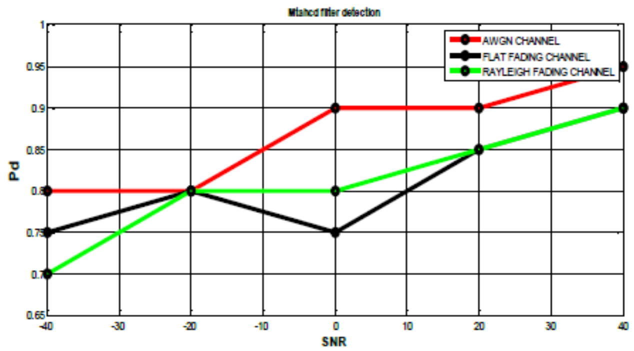
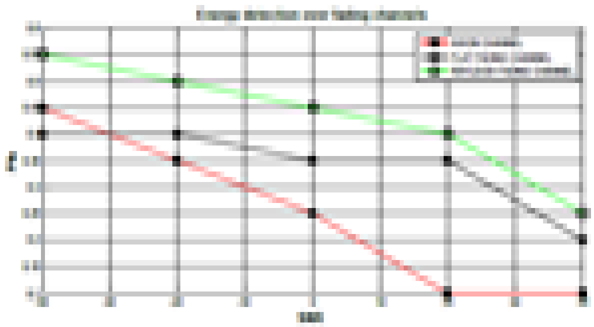


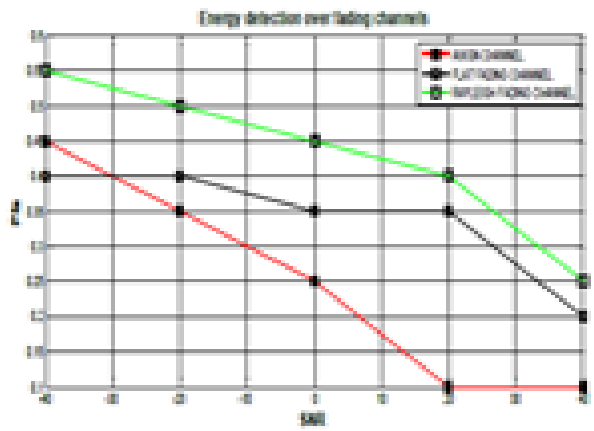
Chart -4 Probability of detection for Matched Filter

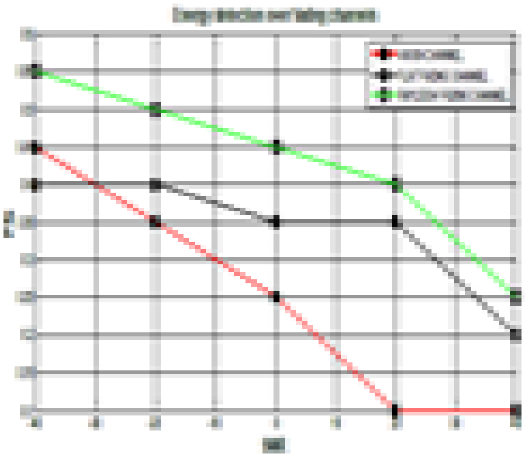
Chart 4 illustrates the "probability of detection for the three channels at different SNR levels. It is observed that probability of detection increases with the increment of SNR levels. It is also observed that AWGN channel has maximum detection as compared to the others. While the Rayleigh fading channel has maximum false alarm as compared to the AWGN and flat fading channel

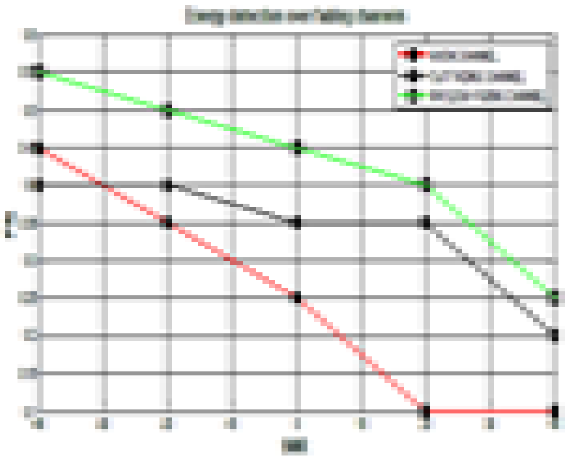
7. CONCLUSION

After the simulation and results it is observed that Energy detection performs best in AWGN channel as compared to other channels. But when the noise power is greater than signal-to-noise ratio (SNR) then the Energy Detection cannot work accurately. Main advantage of Energy detection is that it is easy to implement. From the simulation, it is also clear that Matched filter has better performance as compared to the Energy detection in all three channels but the main drawback is that the Matched filter requires the prior knowledge e.g. modulation type and order, the pulse shape and the packet format. And for every frequency a separate matched filter detector required for spectrum sensing. Overall it is concluded that Matched filter performs better than energy detector in all three channels (AWGN, Rayleigh fading and flat fading) channels









REFERENCES

[1] Shahzad A. et. al. (2010), "Comparative Analysis of Primary Transmitter Detection Based Spectrum Sensing Techniques in Cognitive Radio Systems,'' Australian Journal of Basic and Applied Sciences, 4(9), pp: 4522-4531, INSInet Publication.

[2] I.F Akyildiz, W Lee, M.C Vuran, S Mohanty,"Next Generation/ Dynamic spectrum access/cognitive radio wireless networks: A survey" Computer Networks 50(2006) 2127-2159, May 2006.

[3] EKRAM HOSSAIN, DUSIT NIYATO and ZHU HAN Dynamic Spectrum Access and Management in Cognitive Radio Networks Cambridge University Press 2009.

[4] Linda E. Doyle Essentials of Cognitive Radio

[5] EkramHossain, Vijay Bhargava (2007), "Cognitive Wireless Communication Networks",Springer.

[6] D. Cabric, A. Tkachenko, and R. Brodersen, (2006) "Spectrum sensing measurements of pilot, energy and collaborative detection," in Proc. IEEE Military Community Conf., Washington, D.C., USA, pp: 1-7.

[7] I.F Akyildiz,W Lee, M.C Vuran, S Mohanty,"Next Generation/ Dynamic spectrum access/cognitive radio wireless networks: A survey" Computer Networks 50(2006) 2127-2159, May 2006.

[8] D. Cabric, S. M. Mishra, and R. W. Brodersen, "Implementation issues in spectrum sensing for cognitive radios," in *Proc. Asilomar Conference on Signal, Systems and Computers*, Nov. 2004

[9] J. G. Proakis, *Digital Communications*, 4th ed., McGraw-Hill.

[10] International Journal of Next-Generation Networks (IJNGN) Vol.4.3, No.2, June 2011