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A Study of Spectrum Sensing Method for Cognitive Radio under Low SNR

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Abstract: Spectrum sensing is a key component of cognitive radio technology. Cognitive users employ smart dynamic access schemes to detect and use spectrum holes without causing any harmful interference to primary users, due to which the frequency band assignment is not handed over from secondary users to primary users, and thus, primary users might not be able to access and use the radio network. There are various techniques which used for Spectrum sensing of cognitive radio such as energy detection, matched filter detection, cyclostationary detection, feature based detection etc. Here I have discussed about the energy detection technique. And I derived simulation result for the same with the help of software tool MATLAB. Energy Detection technique is simple and it has low complexity and its computational is easy. It requires the knowledge about the noise level of the signal. By defining the threshold we define the hypothesis, and by this we conclude that which result is taken and we made a decision from that. Simulation results are based on the probability of detection and probability of false alarm Threshold, Signal to Noise Ration and probability of Miss Detection as Well. It shows the result of theoretical as well as analytical for basic energy detection method and various results are shown by taking different references.

Keywords: Cognitive Radio, Spectrum Sensing, Energy Detection, Probability of false alarm, Probability of Detection.

I. INTRODUCTION

According to survey of Federal Communications Commission (FCC) in 2002, it has been found that spectrum access is more significant problem than physical scarcity of spectrum [5]. With many technological advances in the field of wireless communication and 3G, 3.5G and 4G technology already are being employed. Multimedia Broadcast and Multimedia services (MBMS) demand has tremendously increased and with the standardization of MBMS it has gained significant interest in the market. Multimedia content requires more bandwidth, storage capacity and few applications pose tight delay constraints, so it is necessary to optimize the utilization of spectrum.

Today's wireless networks are regulated by a fixed spectrum assignment policy, i.e the spectrum is regulated by governmental agencies and is assigned to license holders or services on a long term basis for a large geographical regions. In addition, a large portion of the assigned spectrum is used sporadically as illustrated in Fig.1, where the signal strength distribution over a large portion of the wireless spectrum is shown. The spectrum usage is concentrated on certain portions of the spectrum while a significant amount of the spectrum remains unutilized. [4]

According to Federal Communications Commission (FCC) [9], temporal and geographical variations in the utilization of the assigned spectrum range of 15% to 85%. Although the fixed spectrum assignment policy generally served well in the past, there is a dramatic increase in the access to the limited spectrum for mobile services in the recent years. The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically [8].

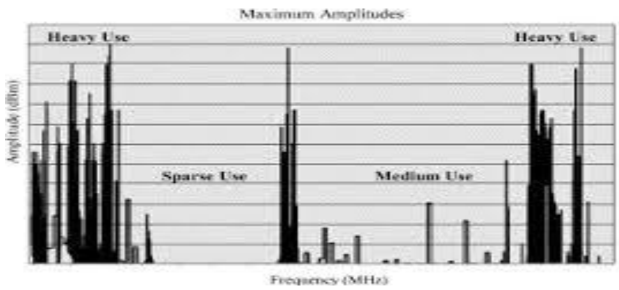

Fig1. Spectrum Utilization [3]

COGNITIVE RADIO

Cognitive Radio (CR) is a system or a model for wireless communication. It is built on software defined radio which an emerging technology is providing a platform for flexible radio systems, multiservice, multi-standard, multiband, reconfigurable and reprogrammable by software for Personal Communication Services (PCS). It uses the methodology of sensing and learning from the environment and adapting to statistical variations in real time. The network or wireless node changes its transmission or reception parameters to communicate efficiently anywhere and at any time avoiding interference with licensed or unlicensed users for efficient utilization of the radio spectrum. The definition adopted by Federal communications Commission (FCC) : "Cognitive Radio: A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to

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modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets." [6] Hence, one main aspect of cognitive radio is related to autonomously exploiting locally unused spectrum to provide new paths to spectrum access.

The concept was first originated by Defence Advance Research Products Agency (DARPA) scientist, Dr. Joseph Mitola and the result of that concept is IEEE 802.22, which is a standard aimed at using cognitive radio for Wireless Regional Area Network (WRAN) using white spaces in TV frequency spectrum while assuring that no harmful interference is caused to the incumbent operation, i.e., digital TV and analog TV broadcasting, and low power licensed devices.

One main aspect of cognitive radio is related to autonomously exploiting locally unused spectrum to provide new paths to spectrum access. By detecting particular spectrum holes and exploiting them rapidly, the CR can improve the spectrum utilization significantly. To guarantee high spectrum efficiency while avoiding the interference to the licensed users, the CR should be able to adapt spectrum conditions flexibly.

Spectrum sensing by far is the key important component for introduce cognitive radio. Spectrum sensing is the task of obtaining awareness about the spectrum usage and existence of primary user in a geographical area. Spectrum sensing is understood as measuring several aspects like spectral content, or measuring the radio frequency energy over the spectrum. When cognitive radio is considered, it is a more general term that involves obtaining the spectrum usage characteristics across multiple dimensions such as space, time, frequency, and code. It also involves occupancy of the types of signals in the spectrum including the modulation, waveform, bandwidth, carrier frequency, etc.

COGNITIVE CYCLE

A basic cognitive cycle comprises of following three basic tasks: Spectrum Sensing
Spectrum Analysis
Spectrum Decision Making

SPECTRUM SENSING

Spectrum sensing is the ability to measure, sense and be aware of the parameters related to the radio channel characteristic, availability of spectrum and transmit power, interference and noise, radio's operating environment, user requirements and applications, available networks (infrastructures) and nodes, local policies and other operating restrictions. It is done across Frequency, Time, Geographical Space, Code and Phase.

SPCTRUM SENSING METHODS

A number of different methods are proposed for identifying the presence of signal transmission all of which are in early development stage. Below is the table in which the comparison of different detection method is defined:

Table 1: Comparison of different detection methods[5]

Detection Technique	Merits	De Merits
Energy Detection	Simple, computationally easy and no complexity involved	Accuracy of threshold depends on how accurate noise level is considered. Change in noise leads to incorrect results.
Matched filter	Execution time is less	Information of primary signal characteristics is essential.
Feature detection	Detection method is accurate if cyclostationary features of primary signal are known beforehand	Complex method and prior information of signal properties makes this method unpractical
Eigenvalue based signal detection	No information of signal properties, channel and noise needed.	Computationally more complex as matrix operations are involved.

ENERGY DETECTION METHOD

It is one of the spectrum sensing technique. Energy detection is a spectrum sensing method that detects the presence/absence of a signal just by measuring the received signal power. This signal detection approach is quite easy and convenient for practical implementation. To implement energy detector, however, noise variance information is required. Block diagram of energy detection method is shown below:

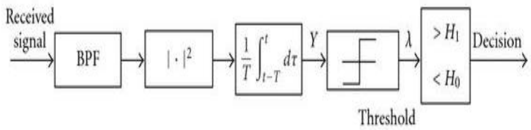

Fig 2. Block Diagram of Energy Detection Method[7]

Below are the blocks of Energy Detection method:
1) Band Pass Filter
2) Squaring device
3) Integrator
4) Threshold
5) Decision Making

The band pass filter removes the out of band signal after that signal is digitalized by an analog to digital convertor (ADC), squared and averaged to estimate the received 00signal energy. This estimated energy of the received signal is compared with a threshold to determine whether the band of interest is available or not. To implement energy detector, however, noise variance information is required. Energy detection method is easy to implement and it has low computational complexity.

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Energy detector based approach is the most common way of spectrum sensing because of its low computational and implementation complexities. In addition, it is more generic as receivers do not need any knowledge on the primary users signal. The signal is detecting by comparing the output of the energy detector with a threshold which depends on the noise floor. Some of the challenges with energy detector based sensing include selection of the threshold for detecting primary users, inability to differentiate interference from primary user and noise, and poor performance under low signal-to-noise ratio (SNR) values.

II. SYSTEM MODEL

Suppose that we are interested in the frequency band with carrier frequency fc and bandwidth W and the received signal is sampled at sampling frequency fs. We consider the problem of detecting a signal in additive white Gaussian noise (AWGN), and then the goal of spectrum sensing is to decide between the following two hypotheses, When the primary user is active, the discrete received signal at the secondary user can be represented as

$$H1{:}Y[n]=X[n]+W[n] \qquad (1)$$

Which is the output under hypothesis H1. When the primary user is inactive, the received signal is given by

$$H0 : Y[n] = W[n] \qquad (2)$$

And this case is referred as hypothesis H0.
Where Y[n] is received signal at the secondary user, X[n] is transmitted signal from the primary user with mean $\mu_x=0$ and variance σ_x^2, W[n] is AWGN with mean zero and variance σ_w^2. The test statistic using energy detection is given

$$T(Y)=1/M\sum_{n=1}^{M} |Y[n]|^2 \qquad (3)$$

For M sufficiently large, we can approximate the test statistic in 3 as Gaussian by central Limit Theorem (CLT)
$T|H0 \sim N(\sigma_W^2, 2\sigma_W^4)$

$$T|H1{\sim}N(\sigma_X^2+\sigma_W^2, 2(\sigma_X^2+\sigma_W^2)^2) \qquad (4)$$

Where $N(\mu,\sigma)$ denotes Gaussian distribution with mean μ and variance σ. Then false alarm probability P_{FA} and missed detection probability P_{MD} can be evaluated as

$$P_{FA} = Q\left(\frac{\beta-\sigma_W^2}{\sqrt{2\sigma_W^4}}\right)$$

$$P_{MD}=1-Q(\beta-(\sigma_X^2+\sigma_W^2)/\sqrt{2}(\sigma_X^2+\sigma_W^2)^2) \qquad (5)$$

Where β denotes the threshold (normalized). Given P_{FA} , β can be determined from (5.5) by

$$\beta=\sqrt{2\sigma_W^4}\,Q^{-1}(P_{FA})+\sigma_W^2 \qquad (6)$$

As we discussed earlier Let us assume that the received signal has the following simple form y(n) = x(n) + w(n) , where x(n) is the signal which is to be detected , w(n) is the additive white Gaussian noise (AWGN) sample, and n is the sample index. Note that x(n)=0 when there is no transmission by primary user. The decision metric for the energy detector can be written as

$$M = \sum_{n=0}^{N} |y(n)|^2 \qquad (7)$$

Where N is the size of the observation vector. The decision on the occupancy of a band can be obtained by comparing the decision metric M against a fixed threshold λ_E. This is equivalent to distinguish between hypothesis
The performance of the detection algorithm can be summarized with two probabilities: probability of detection P_D and the probability of false alarm P_F. P_D is the probability of detecting a signal on the considered frequency when its truly present. Thus, a large detection probability is desired [8]. It can be formulated as,

$$P_D = P_r(M > \lambda_E \mid H1) \qquad (8)$$

P_F is the probability that the test incorrectly decides that the considered frequency is occupied when it actually is not, and it can be written as

$$P_F = P_r(M > \lambda_E \mid H0) \qquad (9)$$

P_F should be kept as small as possible in order to prevent underutilization of transmission opportunities. The decision threshold λ_E can be selected for finding an optimum balance between P_D and P_F. However, this requires knowledge of noise and detected signal powers.

III. SIMULATION RESULTS

Results are implemented using Matlab R2013a version. Emphasis is on the performance of ED at low SNR and comparison of energy detection and ED at low SNR. Here, Fig (1) shows the practical and theoretical graph with reference of Probability of Detection versus Probability of False Alarm. From plot we can conclude that, as we increase the value of Probability of Detection, Probability False Alarm also gets increased. Probability of detection is directly proportional to probability of false alarm.

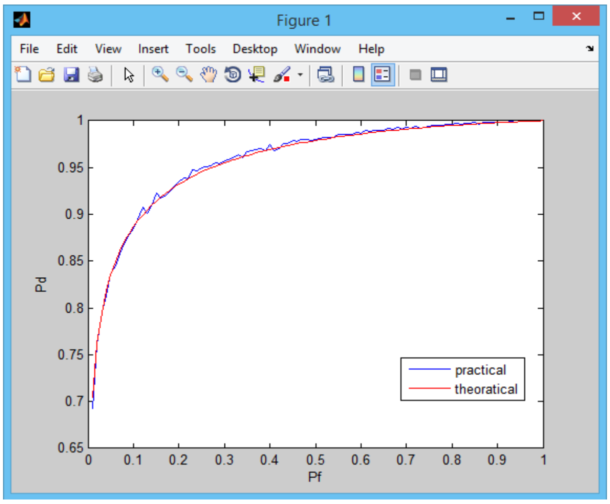

Fig 1. Plot for Energy Detection Method

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Fig (2) explains that the as we choose higher value of threshold probability of false alarm decreases. But we choose higher value of threshold upto certain limit after that limit we are not able to go for further value.

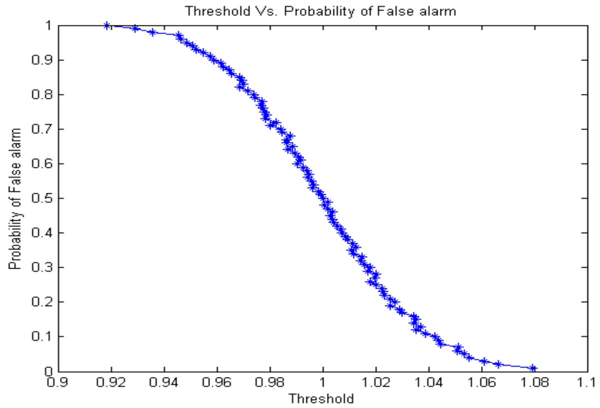

Fig 2. Threshold Vs. Probability of False Alarm

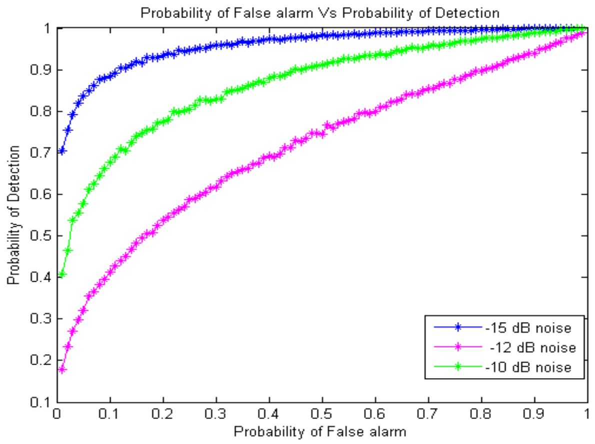

Fig 3. Probability of Detection vs. probability of False Alarm

Fig (3) Probability of false alarm versus Probability of Detection is plotted for the different values of SNR. We are able to study its characteristic from the above result.

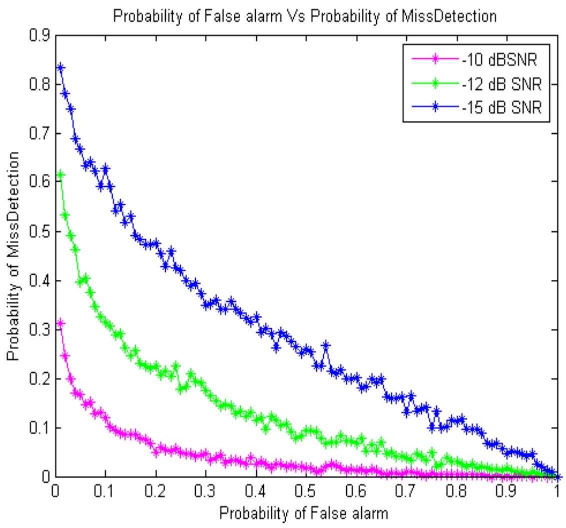

Fig 4. Probability of Miss Detection Vs. Probability of False Alarm

Fig (4) is the plot between the Probability of Miss Detection versus Probability of False Alarm. We have the characteristic for the different SNR values. And how performance changes in the case of low SNR is shown in below graph.

IV. CONCLUSION AND FUTURE WORK

Probability of Detection is directly proportional to the probability of False Alarm. As we increase the value of probability of detection the probability of false alarm also increases. From the different characteristic we can conclude that for the lower value of SNR its performance characteristic degrades.

In future, our aim should be reduced the probability of false alarm. That can be achieving by using MIMO technique. From that for a particular probability of false alarm we may get higher value of probability of detection.

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REFERENCES

[1] Pankaj Verma and Brahmjit Singh, “Simulation Study of Double Threshold Energy Detection Method for Cognitive Radios”, IEEE 2nd International Conference on Signal Processing and Integrated Networks (SPIN), 2015

[2] Guimin Li, Zaijiu Shang, Kehu Yang, “Detection of Joint Space And Spectrum Opportunities In Cognitive radio systems”, IEEE, 2015

[3] Iker Sobron, Paulo S. R. Diniz, Wallace A. Martins, Manuel Velez, “Energy Detection Technique for Adaptive Spectrum Sensing”, IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 63, NO. 3, MARCH 2015

[4] Udit Satija, Parthapratim De, “Compressed Sensing based Blind Spectrum Sensing in Cognitive Radio”, 2nd International Conference on Signal Processing and Integrated Networks (SPIN), IEEE,2015.

[5] Shashank Singh, Gowher Mushtaq, Neeraj Kumar Tiwari, Akhand Pratap Singh, “Cognitive Radio With Software Defined Radio and Mimo for Future Generation Wireless Communication”, Computer Science Systems Biology, 2015

[6] Hossam M. Farag, Ehab Mahmoud Mohamed, “Improved Cognitive Radio Energy Detection Algorithm Based upon Noise Uncertainty.