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Evaluation of Probability of Detection using Energy Detection for Secondary User in Cognitive Environment with Variable Threshold & Sample Values

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Abstract: In the current scenario, the conception of the Cognitive Radio (CR) and the cognitive radio networks are new areas of research, development, evolution and elaboration. The job of sensing the spectrum proves a very cumbersome process. In current times, in order to sense the spectrum which exists, we do have a number of techniques available. Some of these spectrum sensing techniques and methods are energy detection method, cyclo-stationary technique, feature detection technique, wavelet transform method etc. In this paper, the main area of concern will be the spectrum sensing using energy detection method with the enhancement of probability of detection by the adaptive nature of the threshold and the number of samples.

Keywords: Cognitive Radio, Probability of Detection, Energy Detection.

I. INTRODUCTION

Cognitive Radio (CR) is a system/model for wireless communication. It is built on software defined radio which is an emerging technology in 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 changes its transmission or reception parameters to communicate efficiently anywhere and anytime avoiding interference with licensed or unlicensed users for efficient utilization of the radio spectrum.Cognitive Radios may be defined as the model for the wireless communication where there is either a full network or simply a wireless node [10]. In order to communicate efficiently and without causing interference to the Primary Users or Secondary Users, these networks or nodes have to change their transmission or reception parameters.

The change in the value of the parameters depends on observing a number of factors in the internal as well as external environment where it is located. Some of these factors include radio-frequency spectrum, user behaviour, network state etc. In the current world, the main problem faced in the communication area is the spectrum shortage and this problem of spectrum shortage is solved by making a use of Cognitive Radio technology. It does so by allowing the Secondary Users to coexist along with the Primary Users in the same spectrum range without causing interference between their communications

According to the Dynamic Spectrum Access model, Cognitive Radio means the radio used by the Secondary Users to scan a particular section of the spectrum and wisely obtain a part of it for the transmission and reception purposes. From this definition the cognitive capability may be referred to as the potential to find and locate the unused spectrum, which is also called as the "spectrum hole" or "white space" and reconfigurability refers to the ability to dynamically change the various factors like modulation schemes, transmission power, time, frequency as well as other parameters The main aim of the Cognitive Radio is the maximum utilization of the available radio spectrum in the most efficient way. In order to do so, a number of conditions need to be satisfied by the Cognitive Radio [14]. Some of the basic requirements of a Primary Cognitive Radio are listed as below:

- Any Secondary User must have a negligible interference to the Primary User.
- It must be capable of adapting itself with a number of link properties.
- It must critical be capable of detecting and calculating the parameters about the surrounding, channel etc.
- It must have ability to exploit variety of spectral opportunity.

The goal of Cognitive Radio is to make use of the spectrum bands that are owned by the licensed users and hence the important requirement is the interference caused by Secondary User to Primary User must be kept at a negligible level. It should be noted that the main feature of the Cognitive Radio is the periodically scanning of the

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targeted frequency band in order to reveal its availability for the opportunistic use. Since the bands available for the cognitive communication are unused spectrum is static at different times and locations, therefore Cognitive Radio devices are expected to be highly flexible in nature. Since we know that the unused and idle frequency band of the spectrum are utilized by the Cognitive Radio user free of cost, therefore must be a number of users glad to make use of similar opportunity at the same time. Due to this, and various other parameters different changes used by the Cognitive Radio user may vary.

II. COGNITIVE CYCLE PRINCIPLE

A CR interacts with its environment in which it is working by means of a Cognitive Cycle. The basic cognition cycle is given in Figure 1. As soon as the interrupts are being sensed and then sent to the cognition cycle for some output responses, the activation signal enters into a CR. Such type of CR continuously observes its neighborhood, changes on its own, makes plans, takes decisions and finally takes some actions

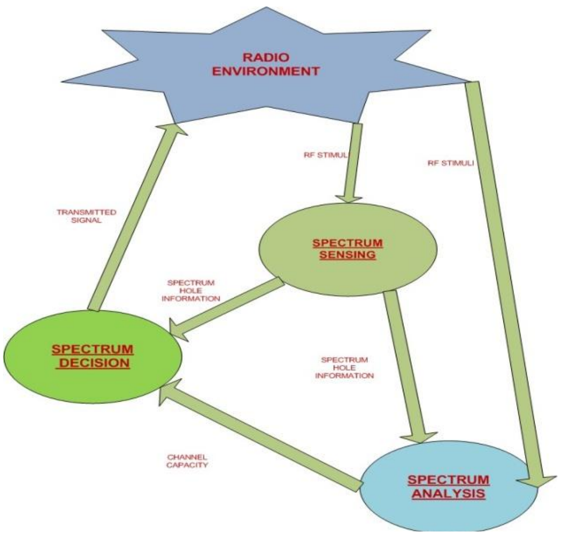

Figure 1 Cognitive Cycle

A simple cognition cycle consists of three simple stages. These include:

- Spectrum Sensing
- Spectrum Analysis
- Spectrum Decision Making

The CR can be categorized broadly into the following three types according to their capabilities:

Spectrum Sensing: - Spectrum Sensing may be defined as the capacity to calculate, detect and be known to the various elements which are related to the principal characters of the CR. These characters of the CR are spectrum availability, radio channel characteristics, power transmission, interference and noise, operating environment of the device, application and requirements of the user, available network structure and its nodes, local policies and other restrictions [14]. The process of spectrum sensing is done in various dimensions like time, frequency, space, phase, code, etc. a number of spectrum sensing techniques are available and we have used the energy based spectrum sensing method for this paper.

Spectrum Analysis: - The process of spectrum sensing is totally dependent on the previous step i.e. on the spectrum sensing. In the spectrum analysis the current and the latest status of a number of factors in its internal and external environment are analyzed. These factors include behavior of user, state of network, radio frequency used by the devices in the neighborhood [14]. After evaluating these factors, the job of the spectrum analysis is to find the most effective and best protocol for the communication, change in frequency, change in the channel as per the need and external conditions. Spectrum Analysis is also known as estimation of the channel.

Spectrum Decision Making: - Since the environment in which CR are working and functioning are always mobile, therefore the channel and the protocols keep on changing constantly. So spectrum decision making accounts and contributes to the reconfiguration of the above problems and it finally adjusts the output power [14]. Spectrum decision making is also used for the change in transmission parameters such as different formats of the modulation, changing symbol rates, different channel encoding schemes and various other characteristics of the CR devices.

III. SPECTRUM SENSING

Energy Detection Method

One of the most popular and frequently used methods for the spectrum sensing is the Energy Detection method [10]. The reason for this is that it is computational and implementation costs are very low. Besides this, the receiver s in the ED based spectrum sensing do not demand any sort of information or data regarding the signal that is received from the Primary User.

A signal is determined only when a comparison is made between the threshold values which is dependent on the noise floor and the output obtained at the energy detector.

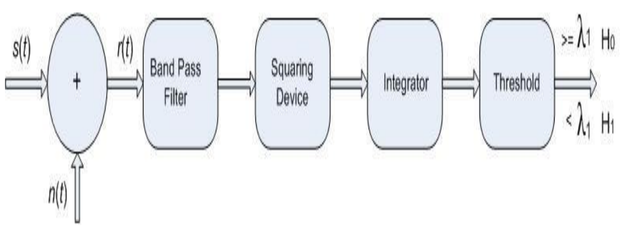

Figure 2 Energy Detection Method

However, a number of drawbacks and disadvantages are related with ED spectrum sensing method. Some of them are [3][5]:

1. Setting up the threshold value for the spotting and finding the signal of PUs

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2. Impotency to distinguish between the interference caused by the noise to the PU's signal
3. Low efficiency at the small values of SNR.

Besides this, this scheme does not work properly and efficiently for the purpose of detecting the spread spectrum signals. The received signal is assumed to have the following form:

$$Y(n) = S(n) + W(n)$$

Where Y(n) is the received signal,
S(n) is the signal to be detected,
W(n) is the AWGN noise.

For an ED, the decision metric value is determined by the following equation:

$$M = \sum_{n=0}^{N} |Y(n)|^2$$

where N is the number of samples of the received signal. The decision metric is then compared with the already fixed threshold value λ_E in order to make a decision regarding the occupancy of any band. This can be done by making a simple hypothesis test:

$$H_0 = Y(n) = W(n)$$

This means no signal is transferred from the PU and only noise is present in the spectrum.

$$H_1 = S(n) + W(n)$$

This means when both signal and noise are present in the spectrum.

The overall hypothesis is boiled down in to two probabilities. These are probability of detection Pd and probability of false alarm Pf which have been already discussed.

$$P_d = Pr\ (M > \lambda_E|H_1)$$

Which means P_d is equal to the probability when M is greater than λ_E at H_1 hypothesis and

$$P_f = Pr\ (M > \lambda_E|H_0)$$

Means P_f equals to the probability where M is greater than λ_E for the hypothesis H_0.

In order to use spectrum correctly the value of P_d should be as large as possible and the value of the Pf should be as small as possible [8].

IV. IMPLEMENTATION & RESULTS

The received signal is of the following form

$$y(n) = S(n) + N(n)$$

where S is the signal component, N is the noise component. The energy calculated by the ED is given as below:

$$\text{Energy} = \text{abs}(Y)^{\wedge 2}$$

This energy is then given to integrator to obtain the average values which are then compared with the threshold value and then a decision is made. The number of samples of the signal has been increased.

As a result of this the average value of signal to noise ratio increased, which in turn means that the signal power has increased, this decreases the probability of miss-detection, because:

$$Pm = 1 – Pd.$$

due to this the probability of detection increases.

For threshold Value Calculation: The received signal is of the form:

$$y(n) = w(n); \quad \text{for Ho}$$
$$= s(n) + w(n); \quad \text{for H1}$$

Where w (n) is the noise, s (n) is the signal from PU, Ho is the hypothesis corresponding to absence of Primary User, and H1 is the hypothesis corresponding to presence of Primary User.

The basis of calculation starts with the measurement of energy obtained over the band of interest which is given by:

$$T_N(y) = 1/N\ \{\ [\sum|Y(n)|^2]\ \}$$

and which lays the foundation for the hypothesis Ho and H_1.The equation for probability of false alarm is given as:

$$P_f = P\ [T_N(y)\ > \lambda;\ Ho]$$

This can be rewritten in terms of Q-function as

$$P_f = Q[(\lambda - 1)\ \sqrt{N}]$$

P_f , N are known and value of λ (threshold is obtained which is adaptive.

The equation for probability of detection is given as:

$$P_d = P[T_N(y)\ > \lambda;\ H1]$$

This can be rewritten in terms of Q-function as

$$P_d = Q[(\lambda - S - 1)\ \sqrt{(N/(2S + 1))}]$$

N and S are known and value of P_d is obtained

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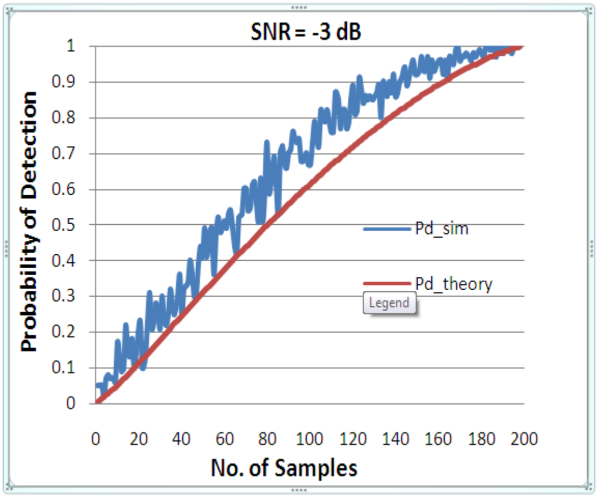

Figure 3.Probability of Detection Vs No. of Samples for SNR = -3 dB

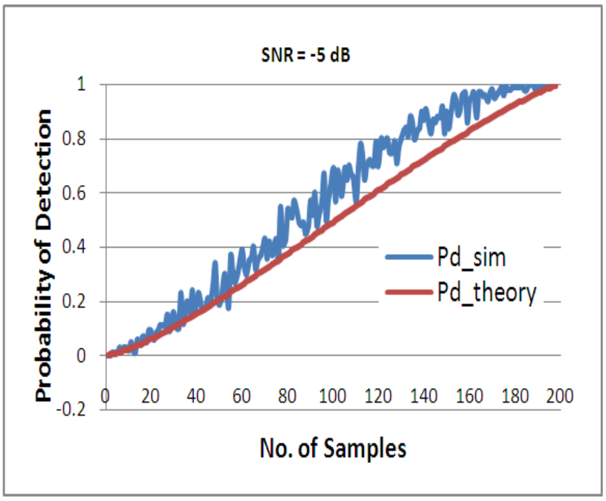

Figure4. Probability of Detection Vs No. of Samples for SNR = -5 dB

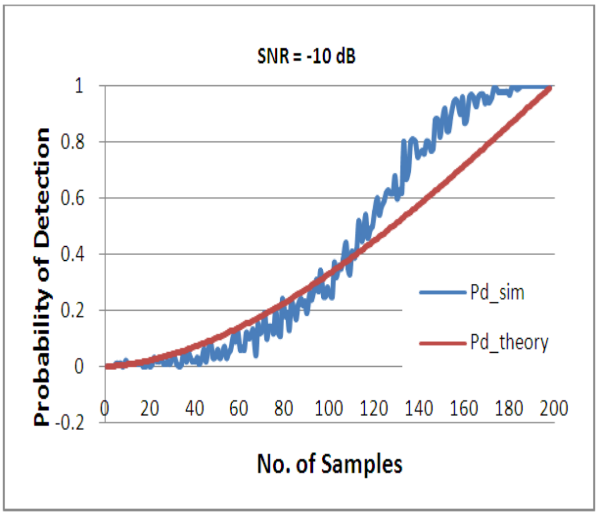

Figure 5: Probability of Detection Vs No. of Samples for SNR = -10 dB

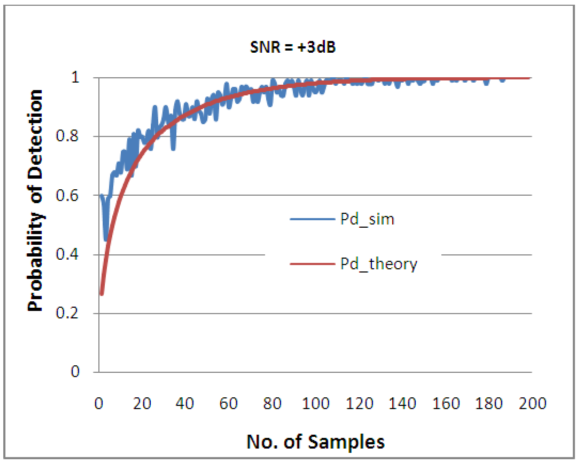

Figure 6: Probability of Detection Vs No. of Samples for SNR = 3dB

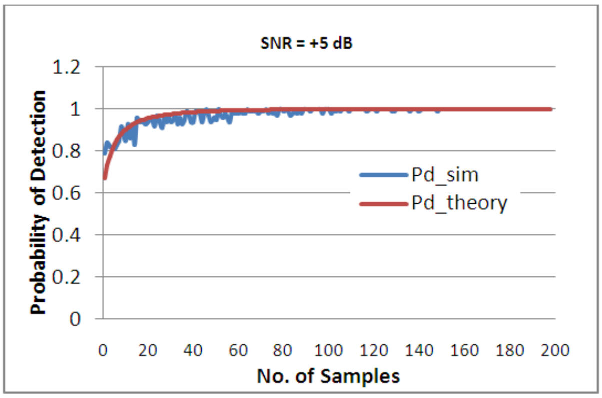

Figure7: Probability of Detection Vs No. of Samples for SNR = 5dB

From these above graphs we conclude that the probability of detection is increasing with the increase in the number of samples taken during the sensing period. The Pd_sim is more than the Pd_theory for most of the cases.

The small deviations in the curves shows the adaptive nature of the threshold value which makes the Pd_sim better for the low SNR values and detection is better.

The graphs shows that the probability of detection Pd_sim slowly increases with the increase in the number of samples but catches up fast when the number of samples are between 80 to 100.

It is also observed that for all SNR values there is an increase in the probability of Detection with the increase in the probability of false alarm which is an indicator of the spectrum availability. It is also observed that the probability of detection attains maximum value for low probability of false alarm.
The threshold which is made adaptive as it changes with the number of samples per cycle and are made variable. The samples for the above graphs were N=10. The number of samples when varied from N=8 and N= 12 the following graphs are obtained.

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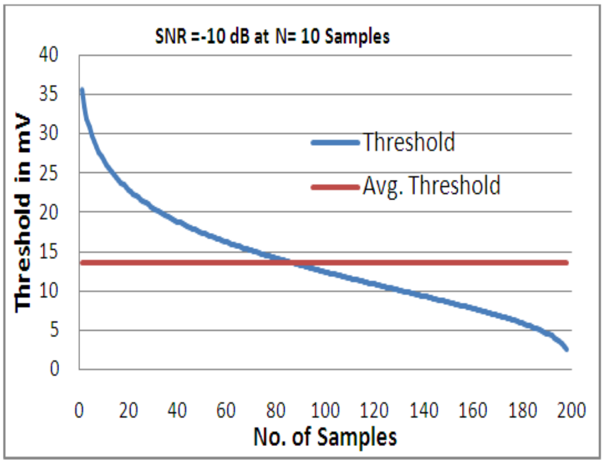

Figure 8: Threshold Vs No. of Samples for SNR = -10 dB for N=10 samples

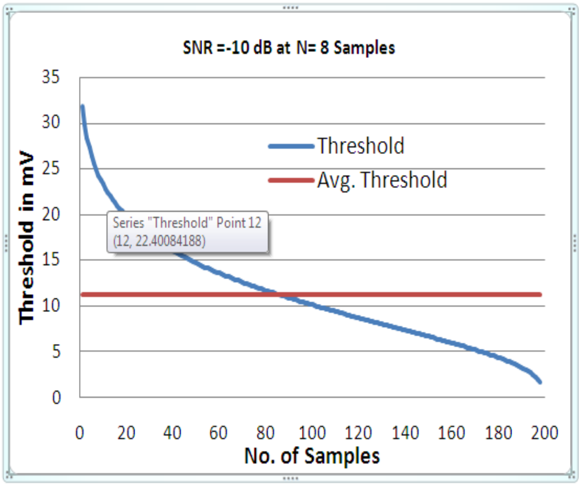

Figure 9: Threshold Vs No. of Samples for SNR = -10 dB for N=8 samples

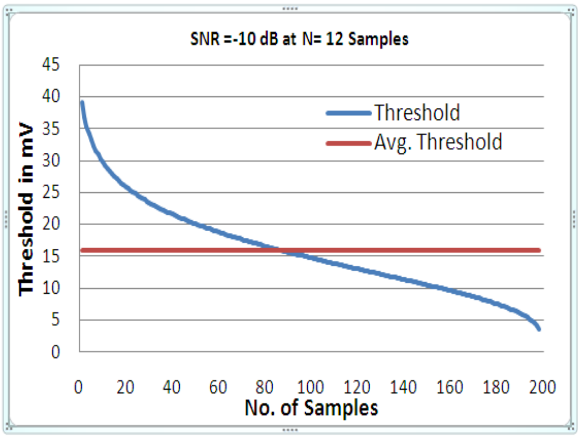

Figure 10: Threshold Vs No. of Samples for SNR = -10 dB for N=12 samples

The graphs clearly shows that the number of samples changes the threshold values and it decreases as the number of samples per cycle decreases and increases if the number of samples are increased.

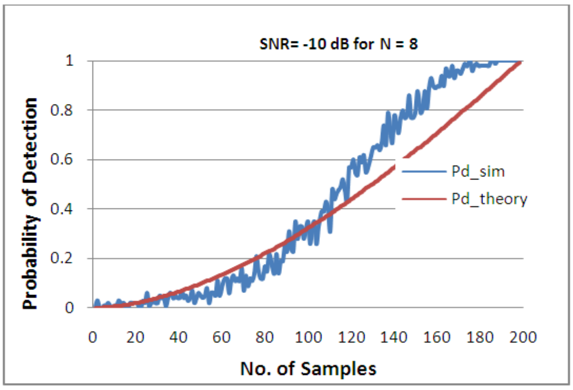

Figure 11: Probability of Detection Vs No. of Samples for SNR =-10dB for N=8 Samples per cycle

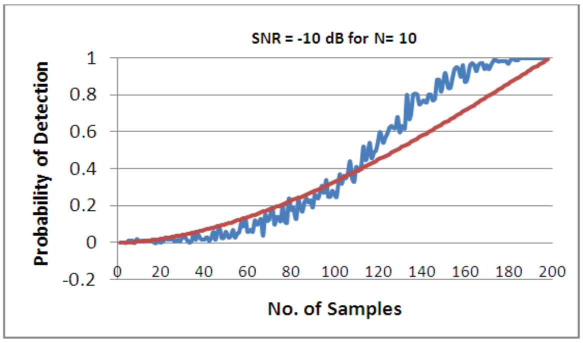

Figure 12: Probability of Detection Vs No. of Samples for SNR =-10dB for N=10 Samples per cycle

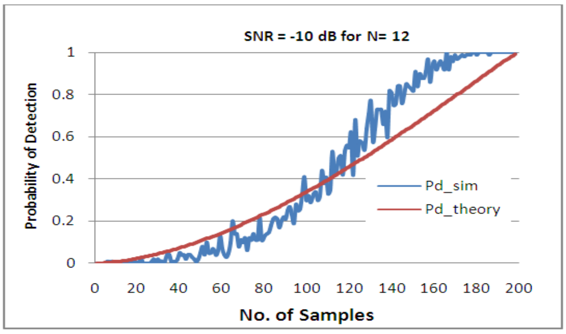

Figure 13: Probability of Detection Vs No. of Samples for SNR =-10dB for N=12 Samples per cycle.

The above graphs shows that for the fixed SNR values the Pd_sim shows better response then the Pd_theory for the less number of samples per cycle because the threshold levels have changed due to its adaptively.

V. CONCLUSION

In this paper, we have analysed the effect of adaptive threshold and variable samples on the probability of detection which is plotted for the different SNR values. The analysis clearly shows that the probability of detection increases with the number of samples for Low SNR values but its value attains maximum value for low samples values for higher SNR and at low level of probability of false alarm. The paper also investigates the change in the probability of detection with the number of samples. The paper also has discussed the effect of number of samples on the threshold value calculation and has been observed that its value increases with the increase in the number of samples.

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