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Spectrum Sensing and Spectrum Allocation using Double Threshold Energy Detection

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***Abstract*-The Cognitive Radio helps us in identifying the technology as not only a useful but also as a effective technology. This is proved as it helps us to not only identify or sense the frequency spectrum, but also helps us in allocation of the frequency spectrum. Generally, when we use the traditional energy detection method only spectrum sensing is done. Also, the traditional approach of spectrum sensing is done only with the help of a single threshold value This is also performed at a low Signal to Noise Ratio (SNR), here the performance degrades. So, to avoid this problem of deteriorating performances at low SNR we have brought the new approach of spectrum sensing using Double threshold.**

INTRODUCTION

Networking Engineering, there is a much need to increase the spectrum utilization of the available. In other words, the capacity of the network must be utilized more effectively. So, this entire spectrum is divided in to a number of frequency bands . This process of dividing the frequencies is termed as frequency allocation. The size of each individual cell is decreased in such a way that the entire frequency spectrum is utilized at its best. The Cognitive Radios has this ability to sense the spectrums and to provide the information about whether the frequency spectrum is available or occupied. This is done by taking a decision by comparing the thresholds with the input values.

This property of sensing the channel is a difficult task as the signals that are need sensing have less power and also less immune to noise too. The importance of any spectrum sensing is that it must be known whether the primary user is present or not. in a more efficient way. This tells the need for the technique to be able to perform sensing with a low figure. The primary thing that any technique desires to perform is to be able to sense the primary user in an accurate way. There are already a number of spectrum sensing techniques available. Matched Filter is one of those techniques that uses relationship with unknown signal to known signal. Here, signal which is unknown is the input where cognitive radio brings the input signal. after sensing the channel whereas the known signal is the primary users signal. This technique has a merit of being able to provide the decision in a quick time that indicates the presence or absence of the primary user signal.

This means each primary user must be allocated with a receiver, this increases the complexity of the circuitry. Apart from this, another technique called as cyclo-stationary detector has the merit that can even sense SNR signals and power signals which are low. But, it also requires large amounts of time and also multifaceted in circuitry.

LITERATURE SURVEY

Cognitive radio has emerging technology which has reliability and effective solution and it requires reliability to achieve Quality -of-Service(Q0S).with more QoS more improve of the SNR and give better performance [1].

Detection method is a simplest method compared to others in terms of detecting the presence of primary user whether the user is present or not. This technique in simple words detects the energy and Its functionality is explained as, when the total energy has less compared to threshold, then spectrum is vacant and it can be used. In the same way if threshold is less than the received energy signal then spectrum is occupied by primary user.

But this technique also has some of the limitations, it is difficult to set the threshold level that is to be compared with the signal to make the decision. This is due to the fact that the threshold is influenced by the noise levels and it varies rapidly with the change in noise levels. This scenario is termed as Noise Uncertainty. So, in order to avoid noise uncertainty the double threshold method ideology came to demand. In the Double threshold, by increasing the number of samples Re-sensing is performed Thus, It solves the problem of noise uncertainty. It employs “Neyman-Pearson” ideology for making any kind of decisions

In the Paper “Spectrum Sensing for Cognitive Radio” The phrase Cognitive radio can be attributed by Mitola and it involves the primary users and creates the incrementation of interference.[2]

In the paper ”Sensing-Throughput Trade-off for cognitive Radio Networks”, It explains that whenever the primary user is not present then the secondary user can use the frequency band. In cognitive radio spectrum sensing is important which is associated with spectrum sensing which is probability of detection and probability of false alarm.[3]

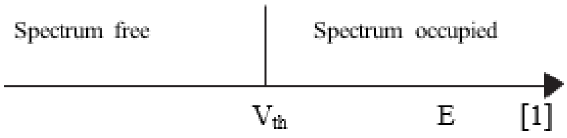

Figure 1. Single Threshold Method

The above figure explains that when the received energy (E) is higher than the threshold (V_{th}) then spectrum is said to be busy or is being used by some other primary user. But in the other case, i.e.. when It is less than the threshold then it indicates that the spectrum is free of user. The below figure shows how double threshold method uses two thresholds Vth0 and Vth1 for the sensing of the existence of the user . Now decision can be made such a way that When the value of energy received is larger than the value of Vth0, it is considered as presence of the primary user. But if the value of the energy is less than the value of Vth1 then primary user can be treated as absent. But ultimately, the value of the energy lies in the range between Vth0 and Vth1 then the value is said to be present in confusion region. Confusion region is the range of values over which we can't make an accurate prediction of whether user is available. So, to maintain accuracy, we perform Re-sensing. This means the sensing is performed again. But, this time the threshold values will be changed in such a way that the decision will be made. If still the value lies in the same range, then the re-sensing is performed again with some different threshold values. This is continued till a decision is made.

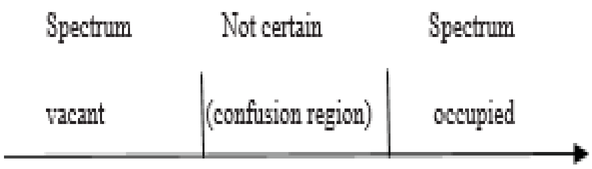

Figure 2. Double Threshold method

Now after performing the Sensing and when the decision indicates that the spectrum is free and available to use we perform the allocation of spectrum to that particular user. This is similar to single threshold method's spectrum allocation of spectrum to that particular user. This is similar to single threshold method's spectrum allocation. Whenever there is no prior knowledge about primary signals then energy detection can be used for spectrum sensing .while performing the energy detection we can use Bartlett's estimate as a test statistic.[4]

SYSTEM MODEL

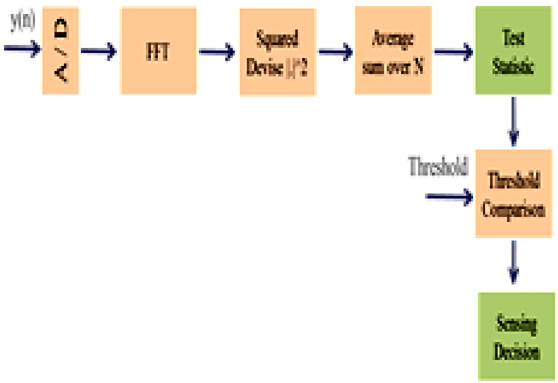

Figure: Block diagram of Spectrum sensing Techniques [6]

As observed in the above block diagram, we will be accomplishing spectrum sensing with the help of the algorithm, which is discussed later.

Methods involved in this process is explained as follows:

i) Spectrum Sensing

Under the following scenario H1, the signal received for the secondary user when primary user is present is given as

$Y(n) = s(n) + u(n)$

Under the following scenario H0, the signal received is given as

$Y(n) = u(n)$

Here u(n) is additive gaussian noise and has varience σ^2 , s(n) is primary signal with varience σ^2.[8]

ii) Single Threshold Detection

Detection of Energy is the simplest threshold and most popular technique known. Test statistic for sensing is given as

$$T(y) = \frac{1}{N}\sum_{n=1}^{N} |y(n)|^2$$

[10][11][8]

The possibility of false alarm is explained as follows

$$P_{fa} = \Pr\{T(y) > V_{th} \mid H_0\}$$

$$P_d = \Pr\{T(y) > V_{th} \mid H_1\}$$

The performance of detection is performed by the above two parameters. If the T(y) is greater compared to threshold, then it is assumed that primary user is present, otherwise the primary user is considered to be not present.

iii) Double Threshold Method

In the traditional detection model, the secondary users make their verdicts after performing the comparision between the test statistics and the thresholds, whose value is calculated by using following formula [14][15]

$$V_{th} = \left\{ Q^{-1}(P_f)\sqrt{\frac{2}{N}} + 1 \right\} \sigma_n^2$$

Where N represents the number of Samples, σn^2 represents noise varience and the function

$$Q(z) = \int_z^{\infty} \frac{1}{\sqrt{2\pi}} e^{\frac{-x^2}{2}} \text{[14][15]}$$

Here, two thresholds are considered to predict about the existence of primary user.

T (y) < Vth1 : decide H0

Vth0 < T(y) < Vth1 : re-sensing

T(y) > Vth0 : decide H1

Here Vth1, Vth0 are the two thresholds that help in making the decision. A decision is made in the favour of scenario H1 if it satisfies: [14][15]

$$p(H_1 | y_1, y_2, \dots y_m) = \frac{p(y_1, y_2, \dots y_m | H_1) p(H_1)}{p(y_1, y_2, \dots y_m) p(H_0) + p(y_1, y_2, \dots y_m) p(H_1)} > V_{th0}$$

$$T(y) = \frac{p(y_1, y_2, \dots y_m | H_1)}{p(y_1, y_2, \dots y_m | H_0)}$$

$$T(y) > \frac{V_{th0}}{1 - V_{th0}} \frac{p(H_0)}{p(H_1)}$$

$$T(y) < \frac{V_{th1}}{1 - V_{th1}} \frac{p(H_0)}{p(H_1)}$$

The thresholds can be independent of m in terms of finite horizon problem. Let upper threshold is defined as Vth0 and lower threshold is defined as Vth1. [14][15]

$$Pd = \int_A p(y|H1)dy = \int_A \frac{p(y|H1)}{p(y|H0)} p(y|H0)dy$$

$$= \int_A T(y)p(y|H0)dy$$

Over the interval A, the value of test statistic is more compared to that of the threshold Vth0.

Similarly, across the interval B, the test statistic is less than Vth1.

$$1 - \text{Pfa} = \int_B \frac{1}{\text{T(y)}} \text{p(y|H1) dy}$$

iv) Proposed Double Threshold Methodology

This process performs additional operation called as Re-sensing, which is not implemented by the other threshold techniques.

On comparison, if the value obtained after test lies in between the two thresholds then the region is said to be in confusion region.

Here, accurate decision cannot be made as it is difficult to conclude about the existence of primary user. In order to achieve accuracy, we conduct re-sensing. During Re-sensing, we rise the quantity of the number of samples. 2% above also below the confusion region two thresholds values are taken. Then the normal decision is made regarding the comparison between the received signal and the two thresholds. If still no decision can be made and still the value is present in the confusion region then the above step is repeated until the correct decision is made.

Algorithm used:

1.Consider initially P_{fa}=0.1 and N=500

2.Calculate the test statistic as

$$T(y) = \frac{1}{N} \sum_{n=1}^{N} |y(n)|^2 \qquad \text{[10][11][8]}$$

3.Calculate the two threshold values as Vth1 and Vth0

4.If test statistic is

i) > Vth0: Primary user is present

ii) Vth1<*T(y)*<Vth0 : Re-sensing is performed

iii) < Vth1 : Primary user is not present

5.For implementing re-sensing, increment the value of N and go to step 2

6.Re-Calculate the test statistic and continue the above process till a decision is made.

Thus here, we observe that re-sensing is done instead of conventional decision making , if the signal lies in the confusion region

RESULTS AND COMPARISIONS

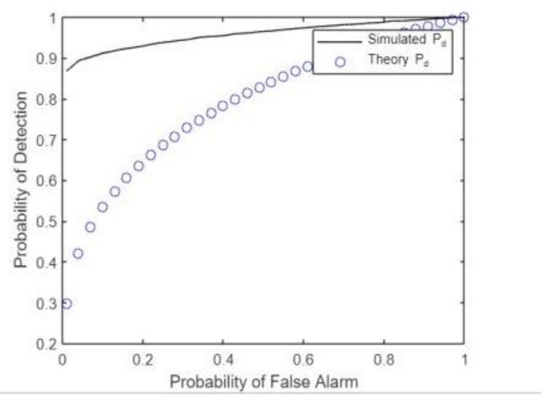

Figure 3 Spectrum Allocation by False alarm Probability

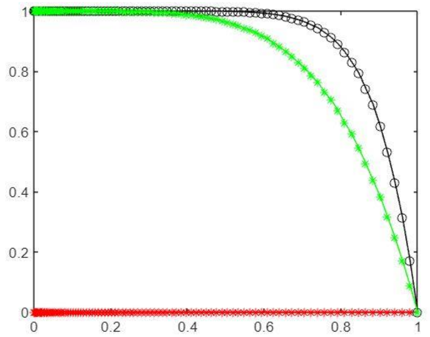

Figure 4: Simulation results

All the methods that perform detection of energy are distinguished based on the values of P_{fa} obtained, SNR and number of samples. Values of P_{fa} is taken as 0.1 and N= 500. The graph shows SNR vs Monte-Carlo Simulations. Observing graph it indicates, SNR of -12 dB, single threshold has a probability of detection as 0.2.Where, Double threshold has 0.2. While, the proposed version of Double threshold achieved a probability of 0.55 and it is observed as the best of the 3 methods.

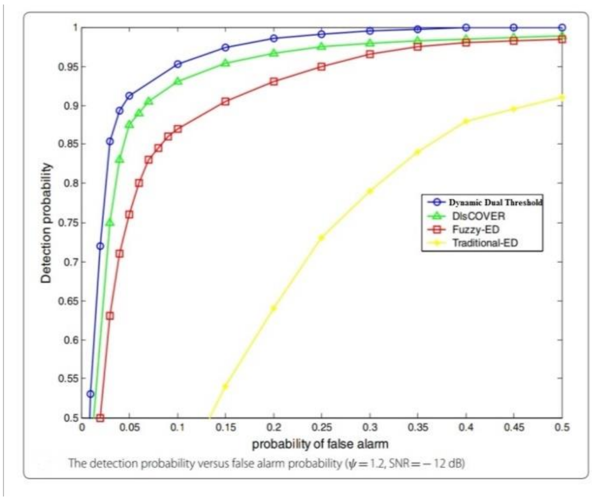

Figure 5 Spectrum allocation by other methods [6]

The above figure 5 [6] indicates the graph that explains about the results of various other sensing methods. By comparing both the graphs i.e.. the result of our proposed model and the results of other methods, it is clearly understood that the proposed method works efficiently at low SNR's compared to other methods.

The above graph indicates about the number of samples taken in threshold detection vs SNR. Thus , it gives an idea about the number of samples to be taken in order to deal with that particular amount of SNR

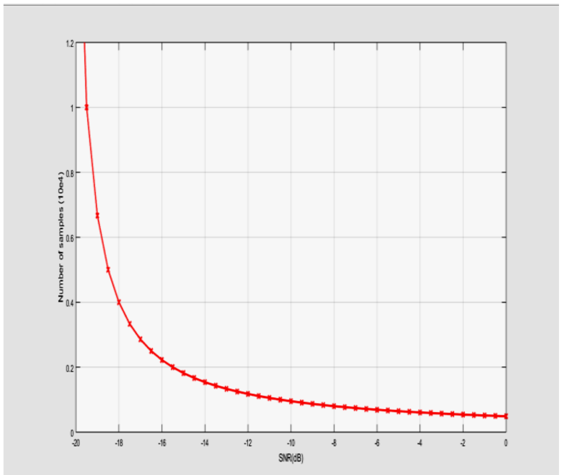

Fig: 6. Optimum numbers of samples versus SNR

The table of values that indicates Percentage of approximation of Threshold values for the respective SNR values of the proposed method is given as

Percentage of Approximation of threshold values → / SNR Values ↓	0.02	0.03	0.04	0.05
-20	1.0000	2.0000	2.000	2.000
-18	0.5000	0.5000	1.000	1.000
-16	0.2222	0.1818	0.2857	0.2857
-14	0.1429	0.1533	0.1538	0.1538
-12	0.1053	0.1333	0.1176	0.1176
-10	0.0769	0.0870	0.0870	0.0800
-8	0.0667	0.0833	0.0769	0.0667
-6	0.0588	0.0741	0.0714	0.0588
-4	0.0541	0.0645	0.0625	0.0571
-2	0.0526	0.0541	0.0526	0.0513
0	0.0513	0.0500	0.0488	0.0488

CONCLUSION

Spectrum sensing practices are accomplished to sense whether the spectrum is available or not and whether it is free to use. Detection of energy using single threshold technique is simple but it has its own disadvantages. In this work, we also studied the other two techniques that are considered to achieve spectrum sensing. The traditional energy detection of both single and double has limitations. The proposed double threshold method uses two thresholds that helps in maintaining the accuracy and also performs re-sensing, when the value is in confusion region (region between two thresholds). The methods are analyzed based on the performance depending on the parameters like Signal to Noise Ratio, possibility of detection (probability) and no of samples used. Simulations also indicate that the proposed double threshold method performs better at low SNR's compared to the other two methods.

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