ANALYSIS OF THE PERFORMANCE OF ENERGY DETECTION SPECTRUM SENSING TECHNIQUE

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ABSTRACT

Cognitive Radio (CR) technology is an ultimate approach to encounter spectrum scarceness issues arising in wireless communications system will have to face the problem of spectrum scarcity in near future. Spectrum sensing is the most important and basic need in cognitive radio. In spectrum sensing, the unused spectrum portions are detected and made them available for reuse by the other users. Spectrum sensing allows the secondary user to gather the data about the vacant band and identify the spectrum holes. Several spectrum sensing techniques have been proposed till now. In this paper, analysis of the performance of energy detection spectrum sensing technique is show.

KEYWORDS

Cognitive Radio, Primary User, Secondary User, Spectrum Sensing, Energy Detection. Matlab.

INTRODUCTION

Cognitive radio (CR) was proposed by Mitola in 1998 to use the radio spectrum more efficiently. The wireless systems are having conversion from just telephony very high speed communication employing a large amount of data. The data is not only limited to voice now, but can be audio-visual, live broadcast, large database of an organization or any other form of data also. As new systems are having wireless capabilities, the available spectra are. being reduced and the problem of spectrum scarcity arises. CR Technology Keep the ongoing communication smooth and allows new user to transmit on the existing spectra by means of dynamic spectrum access. The licensed users are referred to as the primary users and the unlicensed users as the secondary users or CR users. [1]. Spectrum sensing is the most important function in cognitive radio. New sensing methods are proposed based on the principal component values of the received signal at the secondary users. A Cognitive Radio is a perfect example of an intelligent wireless communication system. The most recent work focuses energy detection based on local observation of cognitive user. The spectrum sensing is the key issue. Spectrum sensing is the detection of the primary user (PU) signal and locates these white spaces available in the spectrum band allocated to the primary users.

COGNITIVE RADIO CYCLE:

1. **Spectrum sensing**
2. **Spectrum analysis**

3. **Spectrum decision**

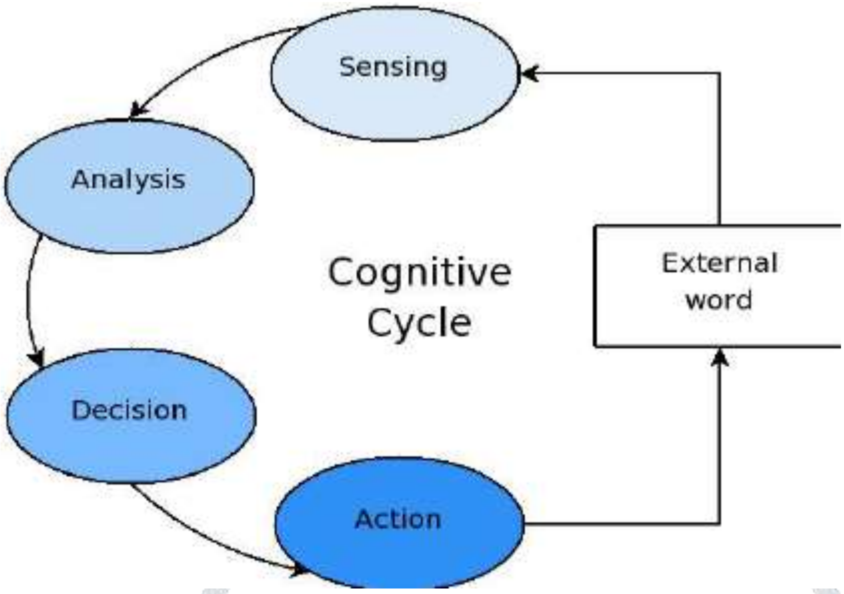

Fig: 1 Cognitive cycle

Spectrum Sensing: Detection of unused spectrum bands or estimation of the total interference in the radio environment.

Control Action: 1.Control on transmitter power level.

2. Control on transmission rate.

3. Setting the parameters.

OBJECTIVE

- To optimize the location of primary and secondary networks in Cognitive Radio Ad-hoc in spectrum sensing Networks.
- To enhance concurrent transmission in cognitive radio network.
- A primary user and secondary user in spectrum sensing.
- To exploiting spectrum sensing techniques for intelligent radio network.
- To compose a system model of a network having cognitive capabilities having CR transmitter and CR receiver, a primary transmitter or primary mobile station and a primary receiver or base station.
- To validate the proposed method, the system model of the network by implementing in QUALNET/MATLAB simulation tool.

SPECTRUM SENSING

The Secondary users utilize spectrum holes for transmission. The spectrum holes are the unused spectrum portions in between the spectrum bands allocated to the primary users. The primary users have the highest priority on the use of the spectrum and secondary users have lower priority. But the secondary users should not cause interference to the primary users while transmission. The secondary users scan for active primary devices within their range. If active primary users are found, then the secondary users cannot transmit the signal not causing unnecessary interference to the primary users.

The secondary users need to continuously scan the environment for finding spectrum holes. Spectrum holes and white spaces are same thing. This process of locating white spaces is called spectrum sensing.

Various spectrum sensing spectrum sensing methods have been proposed such as energy detection, matched filter detection, Cyclostationary detection etc. These methods are shown below in the diagram.

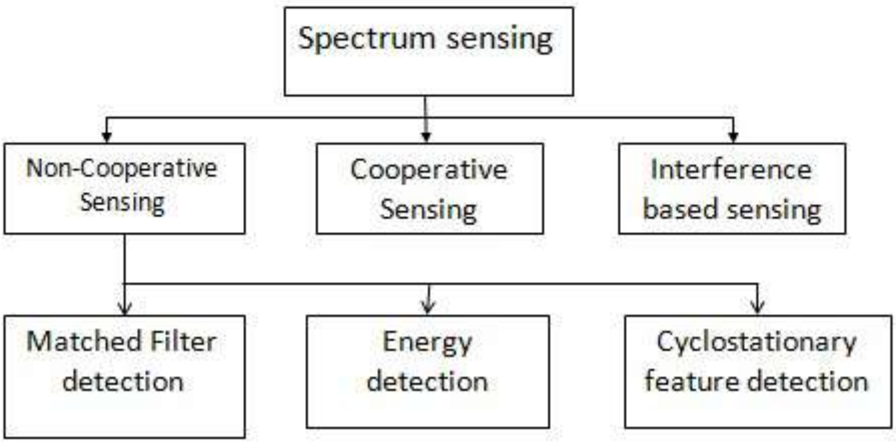

Fig. 3.1: Spectrum Sensing Techniques

ENERGY DETECTION :

Energy detection is the simplest sensing technique because it does not require any a priori knowledge of the primary user signal. In this detection the primary user is detected based on the sensed energy. The block diagram description of the same is given in figure 4. In this method, the received signal is passed through band pass filter and the band limited signal is then integrated over a time interval. The time integrated signal is then compared with the predefined threshold to determine the presence of primary signal. The hypothesis test for the signal identification can be expressed as [33]:

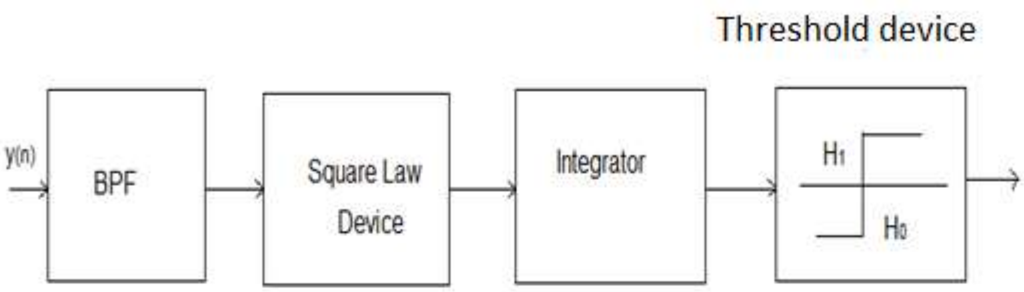

Fig. 3.2: Block diagram of Energy Detection

Hypothesis H0 represents the absence of primary user whereas H1 represents the presence of primary user. The mathematical expression for the calculation of energy is given as:

Let Y be the energy output from the integrator over the samples.

$$Y = \sum_{k=-\infty}^{\infty} |y(n)|^2$$

The decision of ED is made by comparing the energy Y with the threshold λ i.e.

Now the energy is compared to the threshold for checking which hypothesis is true using the following mentioned expressions.

$$D = \begin{cases} H_{1,} & if\ Y > \lambda \\ H_{0,} & if\ Y < \lambda \end{cases}$$

Where

H_1=hypothesis that the primary signal is present

H_0= hypothesis that the primary signal is not present

λ is threshold that depends on receiver noise.

As the power reduces with the distance, energy detection is dependent on the distance between the primary and the secondary node. The primary user power should be high enough to be detected but not very high as it may cause interference to the other nodes [34]

The threshold value should be proper. When it is very little, the noise signal may be detecteded as primary signal resulting in a false alarm. When it is set to high value, there may be missed detection due to comparatively weaker primary signal.

Advantages:

- Simple and less complex than other techniques
- No prior knowledge of the primary signal required
- Easy to implement

The selection of the threshold should be very appropriate, because if it is taken very low then the noise signal might be considered as primary signal i.e. it will be a false alarm. If threshold level is very high, the missed detection may occur because the primary signal may be weak.

PERFORMANCE ENERGY DETECTION SPECTRUM SENSING:

Being the simplest and the most economic spectrum sensing technique, we will move forward with Energy Detection. The hypothesis test of signal x(t) is taken and H_0 or H_1 output is obtained. H_1 indicates the presence of Primary user and H_0 indicates the absence

$$x(t) = \begin{cases} n(t), & H_0 \\ h * s(t) + n(t), & H_1 \end{cases} \quad (1)$$

Where,

x(t) = received signal,

n(t) = noise added,

h = channel gain between primary Tx and Rx,

s(t) = transmitted signal

Now, we take discrete samples of the channel to compute a test statistic

$$Y=\sum_{k=1}^{M} |x[n]|^2 \quad (2)$$

Where,

Y = Test statistic at the detector

M = Amount of samples

The energy of the obtained signal by equation (2) is given as

$$Y = \begin{cases} \chi_{2d}^2, & H_0 \\ \chi_{2d}^2(2\gamma), & H_1 \end{cases} \quad (3)$$

Where,

X^2_{2d} = Central chi-square distribution

$X^2_{2d}(2\gamma)$ = Non-central chi-square distribution.

d=the time bandwidth product at the detector

γ=The non-centrality parameter equal to the signal to noise ratio. i.e.

$$\gamma=\frac{E_s}{N} \quad (4)$$

The PDF for a chi-squared distribution is,

$$f_Y(y) = \begin{cases} \frac{1}{2^d\Gamma(d)} y^{d-1} e^{-\frac{y}{2}}, & H_0 \\ \frac{1}{2}\left(\frac{y}{2\gamma}\right)^{\frac{d-1}{2}} e^{-\frac{2\gamma+y}{2}} I_{d-1}(\sqrt{2\gamma y}), & H_1 \end{cases} \quad (5)$$

Where,

$\Gamma(.)$ is the gamma function,

$I_v(.)$=The v-th order modified Bessel function of the first kind

P_D is the probability that H_1 is chosen when the signal is there for threshold k.

P_D is given as,

$P_D = P(Y > k|H_1)$ (6)

Probability of false alarm is given as,

$P_{FA} = P(Y > k|H_0)$ (7)

Let us express P_D and P_{FA} in terms of PDF,

$P_{FA} = \int f_Y (y)\, dy$, (integration from k to ∞) (8)

From equation (4), we have

$$P_{FA} = \frac{1}{2^d \Gamma(d)} \int_k^{\infty} \left(\frac{y}{2}\right)^{d-1} e^{-\frac{y}{2}} dy \quad (9)$$

Substituting (y/2) = t with changed limits and showing the gamma function by equation (8); defined by

$\Gamma(d,x) = \int t^{d-1} e^{-t}\, dt$, (integration from x to ∞)

The probability of false alarm is given by,

$$P_{FA} = \frac{\Gamma(d, \frac{k}{2})}{\Gamma(d)} \quad (10)$$

It can be concluded by equation (10) that P_{FA} depends on two things; the threshold value, k and the time-bandwidth product, d. Therefore, it is independent of SNR.

P_D is attained from the (CDF) cumulative distribution function of equation (4) and it can be given as,

$P_D = 1 - f_y(y)$ (11)

Now the degrees of freedom (2d in this case) CDF of Y can be given by

$$F_Y(y) = 1 - Q_d(\sqrt{\psi}, \sqrt{y}) \quad (12)$$

By using equation (10) and (11), P_D for the AWGN channel can be computed as

$$P_D = Q_d(\sqrt{2\gamma}\sqrt{k}) \quad (13)$$

In practical transmission systems, the path between the Tx and Rx can be longer. We can use Rayleigh and Nakagami channels for fading models. The conditional AWGN P_D can be averaged over the SNR fading distribution.

P_D in Rayleigh channel can be shown as

$$P_{D_{Ray}} = e^{-\frac{k}{2}} \sum_{n=0}^{d-2} \frac{1}{n!} \left(\frac{k}{2}\right)^n + \left(\frac{1+\gamma}{\gamma}\right)^{d-1} \left[e^{\left(-\frac{k}{2(1+\gamma)}\right)} - e^{\left(-\frac{k}{2}\right)} \sum_{n=0}^{d-2} \frac{1}{n!} \left(\frac{k\gamma}{2(1+\gamma)}\right)\right] \quad (14)$$

The Rayleigh fading model is taken here because it takes urban multipath structures into its consideration. It also considers the impact of troposphere and ionosphere. Hence Rayleigh fading model is advantageous for us.

We have used Matlab for the simulation and obtaining the results for energy detection in Rayleigh Channel.

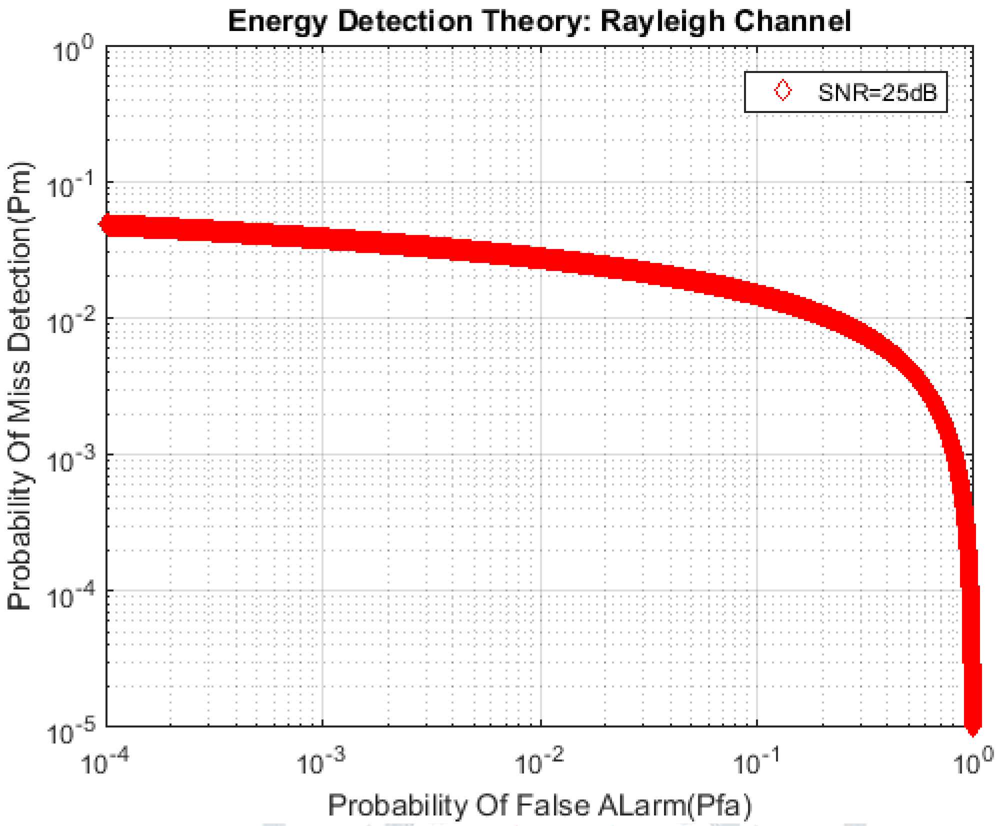

Fig. 4.1 P_{fa} vs P_m at SNR = 25dB and Number of Samples L = 15

We analyze presence of the primary user by variation in the probability of false alarm from 0 to 1 and obtaining the probability of miss-detection, which is shown in the below figures. We have taken different SNR values from 25dB to 45dB and the results are obtained.

The graph is drawn between probability of false alarm (P_{fa}) and probability of miss-detection (P_m) and is shown here in figure 4.1. The number of samples taken is 15 and the signal to noise is 25 dB.

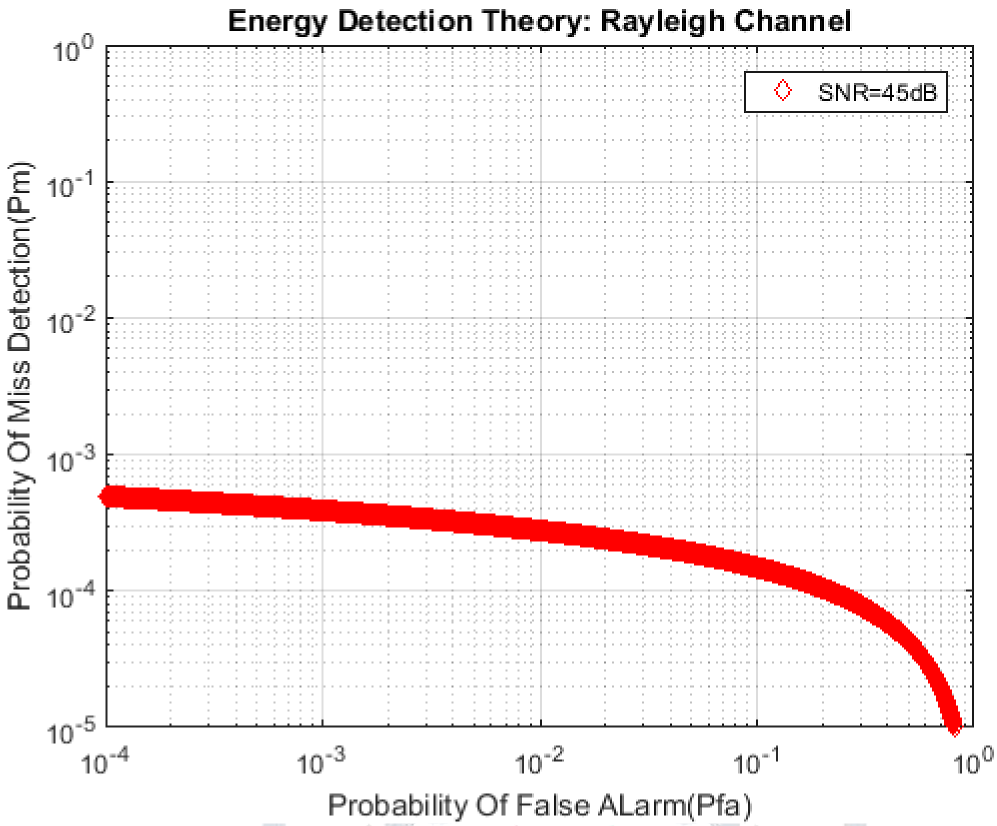

Fig. 4.2 P_{fa} vs P_m at SNR = 45dB and Number of Samples L = 15

We have drawn another graph between probability of false alarm (P_{fa}) and probability of miss-detection (P_m). This time we take the value of signal to noise ratio as 45 dB and number of samples = 15. We will get to see that the probability of the miss detection is reduced. Hence, the detection performance is better when higher signal to noise ratio is taken compared to the signal with low SNR. The graph is shown in fig. 4.2.

Now, we take various SNR values and obtain the results. The SNR values we have taken are 25 dB, 30 dB, 35 dB and 40dB in fig. 4.3. We clearly see that the probability of miss detection is minimum when the highest SNR value is taken, i. e. 40 dB in this case

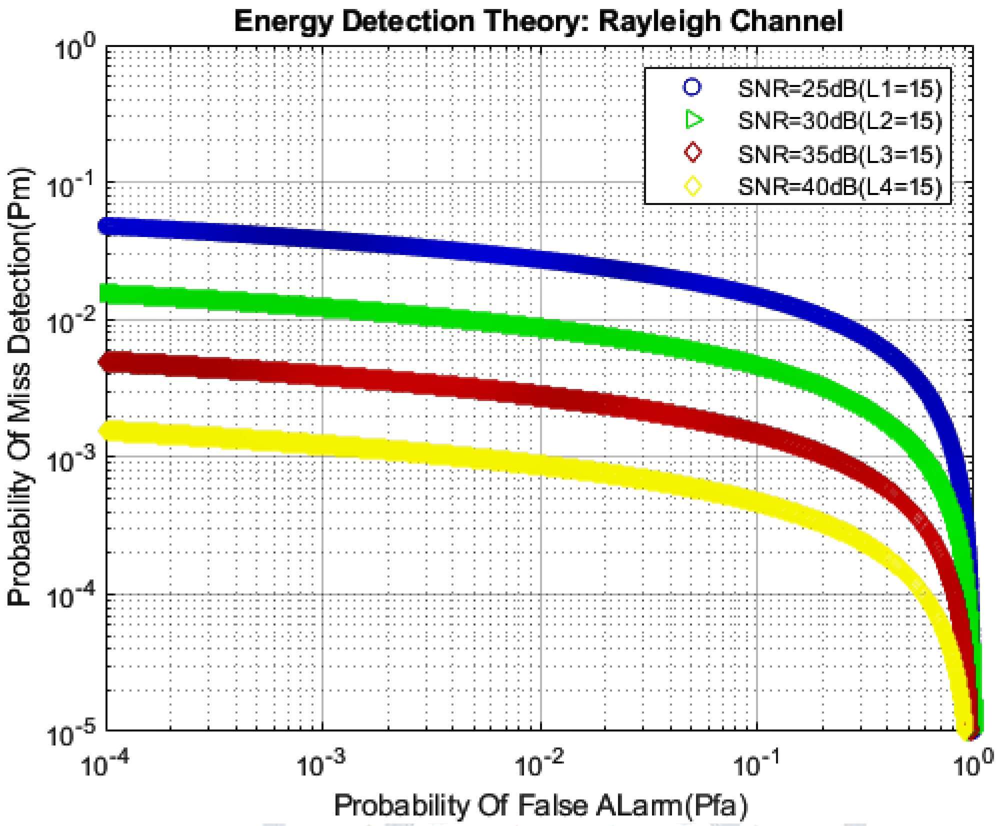

Fig. 4.3 P_{fa} vs P_m at varying values of SNR = 25dB and Number of Samples L = 15

Result and Conclusion

This paper studies the performance of the energy detection spectrum sensing technique and effect of the SNR value on the performance of the technique. It is clearly visible from the graphs obtained that the performance of the detector is nearly equal to the theoretical value of the energy detection and also the performance of the energy detection increases as the SNR value increases. So if the SNR value of the primary signal is higher than a certain value then it will be easy to detect them.

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