ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Performance and Analysis of Energy Spotting Method for Cognitive Radio Network Using AWGN Condition

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Abstract:

Cognitive Radio is an intelligent wireless communication technology in order to increase the spectrum efficiency. Increasing efficiency of an spectrum usage is an urgent need as an intrinsic result of the increasing demand for higher data rates, better quality of services and higher capacity. To sense existence of licensed user, Energy Spotting based spectrum sensing technique is used over different wireless fading channels. Performance metrics like probability of false alarm, probability of detection and signal to noise ratio are evaluated by analyzing receiver operating characteristics. In this paper we analyze the performance of energy Spotting technique to detect primary user (PU). Simulation results show that the probability of detection increases significantly when signal to noise ratio increases. It is also observed that the detection probability decreases when the bandwidth factor increases.

Keywords:

Cognitive Radio Network, Energy Spotting, Fading Channels, Receiver Operating Characteristics (ROC) Curve,Spectrum Sensing.

I. Introduction:

Today, by unprecedented growth of wireless applications, the problem of spectrum scarce is becoming more and more apparent. Most of the spectrum has been allocated to specific users, while other spectrum bands that haven't been assigned are overcrowded because of overuse. However, most of the allocated spectrum is idled in some times and locations. The Federal Communication Commission (FCC) research report reveals that, seventy percent of the allocated spectrum is underutilized.

So we need a technique to deal with the problem of spectrum underutilization, which makes the birth of cognitive radio. Cognitive radio can sense external radio environment and learn from past experiences. It can access to unused spectrum band dynamically without affecting the primary users, in such a way to improve the spectrum efficiency. Sensing external radio environment quickly and accurately plays a key role in cognitive radio. Spectrum sensing includes the detection of primary users and secondary users in other cognitive networks in the same region, but most of papers on spectrum sensing only consider the detection of primary users. In this paper, we consider the cyclic prefix, a special feature embedded in the OFDM (Orthogonal Frequency Division Multiplexing) signals; is used to detect the presence of primary user's signal and is considered to be better than energy detection and matched filter detection as it performs well even in the fading channels.In addition, cooperative detection is used among the secondary users to improve the performance of spectrum sensing. The existing spectrum sensing techniques can be broadly divided into three categories : energy detection, matched filter detection, and cyclostationary detection. Matched filter, energy detection and cyclostationary detection are widely used techniques as detection techniques. Among them, energy detection has been widely applied since it does not require any a priori knowledge of the primary signals and has much lower complexity than the other two schemes. In addition, it does not need any prior information about the PUs' signals. Therefore, it has been thoroughly studied both in local spectrum sensing. Energy detector based approach, also known as radiometry or periodogram, is one of the popular methods for spectrum sensing as it is of non-coherent type and has low implementation complexity. In addition, it is more generic as receivers do not require any prior knowledge about the primary use's signal.

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In this method, the received signal's energy is measured and compared against a pre-defined threshold to determine the presence or absence of primary user's signal. Moreover, energy detector is widely used in ultra wideband (UWB) communications to borrow an idle channel from licensed user. Detection probability ( ), False alarm probability ( ) and missed detection probability ( ) are the key measurement metrics that are used to analyze the performance of an energy detector. The performance of an energy detector is illustrated by the receiver operating characteristics (ROC) curve which is a plot of Pd versus Pf or Pm versus Pf.

II. System Model:

Throughout this letter, we assume that energy detection is applied at each CR user (fig.1). The energy detector consists of a square law device followed by a finite time integrator. The output of the integrator at any time is the energy of the input to the squaring device over the interval T. The noise prefilter serves to limit the noise bandwidth; the noise at the input to the squaring device has a band-limited, flat spectral density.

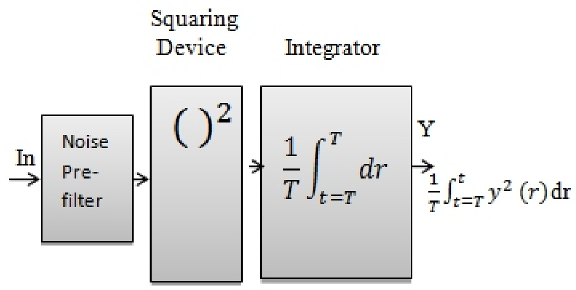

Figure 1: Energy Detection

The detection is a test of the following two hypotheses

H_0: The input $y^{(t)}$ is noise alone:

a) y (t)=n(t)
b) E[n(t)]=0
c) Noise spectral density = N_{02} , (two-sided)
d) Noise bandwidth = w cycles per second

H_1: Theinput $y^{(t)}$ is signal plus noise:

a) y(t) = n(t)+ s(t)
b) E[n(t) + s(t)] = s(t)

The received signal r^t takes the form

r(t) = h s(t) + n(t)...(1)

Where$h_{=0\,or\,1}$ under hypotheses H_0 or H_1, respectively. The received signal is first pre-filtered by an ideal band pass filter with transfer function.

$$H(f) = \begin{cases} \frac{2}{\sqrt{N_{01}}}, & |f-f_c| \le w \\ 0, & |f-f_c| > w \end{cases} \quad \text{.................................(2)}$$

To limit the average noise power and normalize the noise variance. The output of this filter is then squared and integrated over a time interval T to finally produce a measure of the energy of the received waveform. The output of the integrator denoted by Y will act as the test statistic to test the two hypotheses H_0 and H_1.

According to the sampling theorem, the noise process can be expressed as

n(t) = $\sum_{i=-\propto}^{\propto} n_i$Sinc (2$Wt$-$i$)................................(3)

Where

Sin c(x) = $\frac{Sin(\pi x)}{\pi x}$ and n_i = n $(\frac{1}{2W})$

One can easily check that $n_i \approx N(0, N_{01}W)$, for all i.$\int_{-\propto}^{\propto} \sin c(2Wt-k)dt = 1/2W,\ i = k$

$= 0, \quad i \ne k$ … … … … . . .(4)

We may write

$\int_{-\propto}^{\propto} n^2$(t)dt =
$\frac{1}{2W}\sum_{i=-\propto}^{\propto} n_i^2$..(5)

Over the time interval $(0,T)$, n(t) the noise energy can be approximated by a finite sum of $2TW$ terms as

n(t) = $\sum_{i=1}^{2TW} n_i$ Sin c(2Wt - i), 0< $t < T$ … … … … ….. (6)

Similarly, the energy in a sample of duration $T$is approximated by $2TW$ terms of the right-hand side:

$\int_0^T n^2$ (t)dt = $\frac{1}{2w}\sum_{i=1}^{2u} n_i^2$...............................(7)

Where u = TW . We assume that T and W are chosen to restrict u to integer values.

If we define

$n_i = \frac{n_i}{\sqrt{N_{01}\ w}}$.. (8)

Where N_{01} = one-sided noise power spectral density.

Then, the test or decision statistic Y can be written a

$Y = \sum_{i=I}^{2u} n_i^2$.. (9)

Y can be viewed as the sum of the squares of 2u standard Gaussian variants with zero mean and unit variance. Therefore, Y follows a central chi-square(χ^2) distribution with 2u degrees of freedom. The same approach is applied when the signal s(t) is present with the replacement of each $n_i + s_i$.

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Where .., $s_i = s(\frac{1}{2w})$. The decision statistic Y in this case will have a non-central χ^2 distribution with 2u degrees of freedom and a non-centrality parameter 2λ. Following the short-hand notations mentioned in the beginning of this section, we can describe the decision statistic as

$$Y=\begin{cases}\chi^2_{2u} & H_0 \\ \chi^2_{2u}(2\gamma), & H_1\end{cases} \quad \dots\dots (10)$$

The probability density function of Y can then be written as

$$f_r(y) = \begin{cases}\frac{1}{2^u \Gamma(u)} y^{u-1} e^{\frac{y}{2}}, & , H_0 \\ \frac{1}{2}\left(\frac{y}{2\gamma}\right)^{\frac{u-1}{2}} e^{\frac{2\gamma+y}{2}}\left(\sqrt{2\gamma y}\right), & H_1\end{cases} \quad \dots\dots (11)$$

Where Γ (.) is the gamma function. The probability of detection and false alarm can be generally computed by

$$P_{d}=\Pr(Y>\lambda|H_1) \quad \dots\dots (12)$$

$$P_{f}=\Pr(Y>\lambda|H_0) \quad \dots\dots (13)$$

Where λ is the final threshold of the local detector to decide whether there is a primary user present.

$$P_{f}=\frac{\Gamma(u,\frac{\lambda}{2})}{\Gamma(u)} \quad \dots\dots (14)$$

Hence

$$P_{d}=Q_{u}(\sqrt{2\gamma}\sqrt{\lambda}) \quad \dots\dots (15)$$

Where .., $\gamma = \frac{\sigma_x^2}{2\sigma_n^2} = \frac{\sigma_x^2}{2}$ denotes the signal to noise ratio (SNR), Q_u is the generalized Marcum.

III.Simulation Result and Analysis:

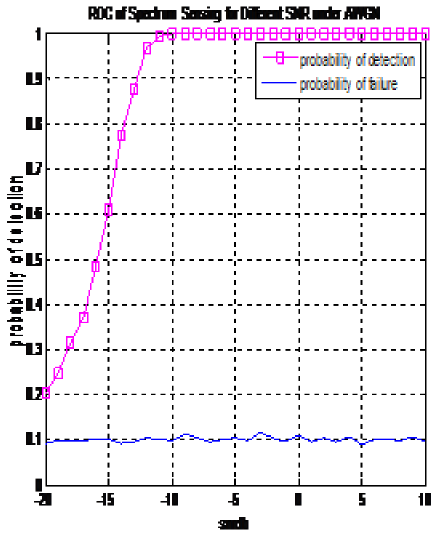

Figure 2: ROC of Spectrum Sensing of different SNR under AWGN

All simulation was done on MATLAB version R2011a under AWGN channel. We use receiver characteristics (ROC) analysis for the signal detection theory to study the performance of the energy detector. ROC has been widely used in the signal detection theory due to the fact that it is an ideal technique to quantify the tradeoff between the probability of detection (Pd) and the probability of false alarm (Pfa).Fig shows that ROC of spectrum sensing for different SNR under AWGN channel. The simulation was carried out for the analysis of detection probability under different number of SNR. Where Pfa=0.01 and time bandwidth factor u=100 were taken for this simulation. SNR was taken -20dB to 10dB and fig. shows that performance of detection varies based on SNR.The detection probability taken 0.2 to 10db, it significantly increases till -10db and then remains constant till 10db.

SNR	Pfa
1	0.0910
2	0.0975
3	0.0980
4	0.1010
5	0.1005
6	0.0930
7	0.0950
8	0.1050
9	0.1000
10	0.0990
11	0.1120
12	0.1035
13	0.0940
14	0.1020
15	0.1010
16	0.0990
17	0.1100
18	0.1030
19	0.0905
20	0.0150
21	0.0945
22	0.1010
23	0.0895
24	0.1020
25	0.1015
26	0.0980
27	0.0980
28	0.0895
29	0.1015
30	0.1080
31	0.0905

Table.1: Signal to noise ratio and detection probability

Table 1 show the measurement of based on SNR and detection probability.

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29	0.1015
30	0.1080
31	0.0905

Table.2: Detection probability based SNR

The false alarm probability also effects on detection probability. If false alarm increases, the detection probability increases. We also get the suitable SNR for the energy detector. So we almost get the final result of the spectrum sensing for cognitive radio based on Energy Detection as we expected.

IV. Conclusion:

In this paper, we have discussed spectrum sensing based on energy detection in CR networks. ROC curves are used to plots of the probability of detection vs. the probability of false alarm. The probability of detection varies based on SNR, false alarm probability and various time bandwidth factors. SNR influences on the detection probability. When SNR increases, the detection probability increases and we also get SNR=10dB is better where detection probability. Again the detection probability varies depend on time bandwidth factor.

If time bandwidth factor increases, the detection probability decreases. The false alarm probability also effects on detection probability. If false alarm increases, the detection probability increases. We also get the suitable SNR for the energy detector. So we almost get the final result of the spectrum sensing for cognitive radio based on Energy Detection as we expected.

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