ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2015

Enhanced Energy Detection Technique for Cognitive Radio

Swapnil Bengal, Sheetal D. Borde

P G Student, Dept. of Electronics & Tele-communication, Modern College of Engg, Pune University, Pune, India

Associate professor, Dept. of Electronics & Tele-communication, Modern College of Engg, Pune University, Pune, India

ABSTRACT: Spectrum sensing is regarded as a key technology in cognitive radio (CR). Cognitive radio is very useful to avoid spectrum scarcity problem and to use spectrum holes effectively by secondary users. Energy detector has been performed as an alternative spectrum sensing method because of its low computational complexity and not requiring a priori information of the primary signal. In cognitive radio systems, secondary users should determine correctly whether the primary user is absent or not in a certain spectrum within a short detection period. Traditional spectrum sensing schemes based on fixed threshold are sensitive to noise uncertainty, a fractional fluctuation in average noise power in a short time will result to the accuracy of spectrum detection will decrease seriously. In this paper we study a effect of noise uncertainty on energy detection algorithm in cognitive radio systems. In this paper we study a new spectrum detection algorithm based on noise uncertainty, to get a good performance of detection while without increasing the computer complexity. However, for schemes which are not sensitive to noise uncertainty, the proposed scheme, in essence, did not improve the detection performance

KEYWORDS: Cognitive radio, detection threshold, noise uncertainty, dynamic threshold detection, energy detection.

I. INTRODUCTION

Now a day's wireless systems are based on fixed spectrum allocations, allocated fixed spectral bandwidth to licensed user at any time. This leads to a wasteful use of scarce and expensive spectral resources and results in un-efficiency utilizing spectrum resource. Dynamic spectrum access techniques promise greater spectral-usage efficiency and enhanced access to frequency spectrum based on cognitive radio systems. Cognitive radio is a resource sharing strategy which allows the licensed owner to share part of his licensed spectrum with a rental system (RS), cognitive radio users quit until licensed users need it themselves. The goal of the cognitive radio is to improve spectral efficiency by overlaying new wireless radio systems on a licensed one (the licensed system, LS) without interfering to the LS, and without changing its operations. In order to keep co-existing and no harmful interference with LS, cognitive radios nodes must have the capability to detect unused spectrum, which is a very important process in cognitive radio systems. Spectrum detection is based on the detection of weak signals from primary users through the local observations of CR users. Three schemes are generally used, such as: Matched filter detection, Energy detection, Feature detection. In this report we are going to mainly investigate energy detection. A high spectrum detection probability must be achieved as the amount of interference that the LS encounter from the RS is directly linked to the detection probability. The detection process has to be repeated periodically at time intervals that are short enough to guarantee a more upper bound interference duration at the beginning of an LU’s access. At the same time, the detection duration and the false alarm probability should remain as low as possible for the sake of the RS’s efficiency.

The essential problem of spectrum sensing in cognitive radio is designing high quality spectrum sensing devices and algorithms for exchanging spectrum sensing data between nodes. Energy detection is a respected spectrum sensing scheme. Most papers discussed energy detection scheme based on a given invariant average noise power. However, the noise is an aggregation of various sources like thermal noise, leakage of signals, aliasing from imperfect front end filters, quantization noise, etc. Actually, “noise” is neither perfectly Gaussian nor white, nor stationary. Therefore, it is not practical that the average noise power keeps constant in detection duration, In fact,

The noise uncertainty is unavoidable. It has been shown that a simple energy detector cannot guarantee the accurate of signal detection, especially when the noise is uncertain. Hence, the conventional energy detection scheme is

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2015

sensitive to noise uncertainty. For those reason, a novel energy detection algorithm based on dynamic threshold is presented to deal with the noise uncertainty in this paper.

II. RELATED WORK

Urkowitz first proposed the original energy detector assuming an unknown deterministic signal over a flat band-limited Gaussian noise channel. This detector has been revisited recently by Kostylev for a random signal operating over a variety of fading channels. Then Digham et al. developed an alternative analytical approach to the one presented in and obtained closed-form expressions for the probability of detection over Rayleigh and Nakagami fading channels. After this, the comparison between different energy detector models and the exact solution both in additive white Gaussian noise (AWGN) and Rayleigh environments are derived. And an improved energy detector for random signals corrupted by Gaussian noise has been derived by Chen et al. In this paper, we propose an enhanced energy detector based on a simple modification to the traditional energy detector (TED).In the proposed detector, we have organized this study, our objective is to enhance energy detection scheme using noise uncertainty.

The rest of this paper is organised as follows:In Section II we studied work related to energy detection. In Section III, we formulate the problem of signal detection in additive noise. Then we investigate spectrum detection schemes in Section III. We discuss effect of noise uncertainty on spectrum detection performance of energy detection. Conclusions are drawn in section IV.

III. PROBLEMFORMULATION

where m is the number of hops in the route, TE = TE_{node} is the transmission energy between the nodes. The route having minimum total transmission energy i.e. min (TTE_R)will be selected as energy efficient route.

Given target variables: detection probability P_D, false alarmprobability P_{FA}, missing probability P_{MD} and sample numberN (detection duration), the relationship of these variables is deduced in terms of the signal-to-noise ratio (SNR)

In this objective, the signal is assumed to be independent of the noise. Random processes are also assumed to be stationaryand ergodic unless specified. The problem of signal detection in additive Gaussian snoise can be formulated as a binaryhypothesis testing problem with the following hypotheses.

$$\begin{cases} \mathcal{H}_0 : Y(n) = W(n) & , n = 1,2,\ldots\ldots, N \\ \mathcal{H}_1 : Y(n) = X(n) + W(n) & , n = 1,2,\ldots\ldots, N \end{cases}$$

Where $Y(n)$, $X(n)$ and $W(n)$ are the received signals at CR nodes, transmitted signals at primary nodes and white noisesamples, respectively; $\mathcal{H}_0$ and $\mathcal{H}_1$denote that the licensed user is present or not, respectively. Noise samples $W(n)$are fromAWGN process with power spectral densityσ_n^2, i.e.$W(n) \sim N(\,0, \sigma_n^2)$.If there is no deterministic knowledge about the signal $X(n)$, i.e., we only know the average power of the signal. In this casethe optimal detector is energy detector or radiometer; thetest statistic is given by,

$$D(Y) = \frac{1}{N}\sum_{n=0}^{N-1} Y^2(n) > \gamma \qquad \mathcal{H}_0$$

$$D(Y) = \frac{1}{N}\sum_{n=0}^{N-1} Y^2(n) < \gamma \qquad \mathcal{H}_1$$

Where $D(Y)$ is the decision variable and is the decision threshold, N is the number of samples. If the noise variance is known and without noise uncertainty, based on central limit theorem(CLT), it has:

$$\begin{cases} D(Y|\mathcal{H}_0) \sim N(\sigma_n^2, 2\sigma_n^4/N) \\ D(Y|\mathcal{H}_1) \sim N(P + \sigma_n^2, 2\,(P + \sigma_n^2)^2/N) \end{cases}$$

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2015

Where $P = \frac{1}{N}(\sum_{n=1}^{N}|X(n)|^2)$is the average signal power, σ_n^2 is the noise variance. Then, we can obtain the probability of detection, false alarm probability, and missing probability,respectively.

$$P_D = P_r(D(Y) > \gamma|\mathcal{H}_1) = Q\left(\frac{\gamma - (P + \sigma_n^2)}{\sqrt{2/N\,(P + \sigma_n^2)}}\right)$$

$$P_{FA} = P_r(D(Y) > \gamma|\mathcal{H}_0) = Q\left(\frac{\gamma - \sigma_n^2}{\sqrt{2/N\,\sigma_n^2}}\right)$$

$$P_{MD} = 1 - P_D = 1 - Q\left(\frac{\gamma - (P + \sigma_n^2)}{\sqrt{2/N\,(P + \sigma_n^2)}}\right)$$

Where Q(·) is the standard Gaussian complementary cumulative distribution function (CDF). P_D, P_{FA} and P_{MD} represent detection probability, false alarm probability and missing probability respectively.

To simplify the problem, energy detection algorithm basedon average noise power without uncertainty has been discussed. Eliminating the variable of decision threshold, and it has,

$$N = 2[Q^{-1}(P_{FA}) - Q^{-1}(P_D)(1 + SNR)]^2 SNR^{-2} \quad (1)$$

Where $Q^{-1}(\cdot)$ is the inverse standard Gaussian complementary cumulative distribution function (CDF), SNR = P/σ_n^2. Fig.1 is the numerical results of (1) given SNR = −10dB, P_{FA} € (0, 0.5). Fig.1 is the numerical results of (1) by varying SNR. Fig.2 is the numerical results of (1) by varying N. It shows that the performance is improved gradually with N's increasing, and an accurate detection probability can be obtained even if the SNR is much lower, as long as N is large enough without noise uncertainty.

IV. USING NOISE UNCERTAINTY

In previous section we have discussed the detection performance without noise uncertainty. In this section the noise uncertainty is taken into account. In order to discuss the effect on the detection performance as the noise power is uncertain, we set:$\sigma^2 \in [\sigma_n^2/\rho, \rho\sigma_n^2]$, where ρ is the noise uncertainty factor and the value of ρ is closer to 1, that is $\rho >$ 1 and $\rho \approx 1$. Thus (4) and (5) are modified to get.

$$P_D = \frac{min}{\sigma^2 \epsilon\left[\frac{\sigma^2}{\rho}.\rho\sigma_n^2\right]} Q\left(\frac{\gamma - (P + \sigma_n^2)}{\sqrt{2/N\,(P + \sigma_n^2)}}\right)$$

$$= Q\left(\frac{\gamma - (P + \sigma_n^2)}{\sqrt{2/N\,(P + \sigma_n^2/\rho)}}\right)$$

$$P_{FA} = \frac{max}{\sigma^2 \epsilon\left[\frac{\sigma^2}{\rho}.\rho\sigma_n^2\right]} Q\left(\frac{\gamma - \sigma_n^2}{\sqrt{2/N\,\sigma_n^2}}\right) \qquad = Q\left(\frac{\gamma - \sigma_n^2}{\sqrt{2/N\,\rho\sigma_n^2}}\right)$$

Eliminating γ and it has

$$N = 2[\rho Q^{-1}(P_{FA}) - (1/\rho + SNR)Q^{-1}(P_D)]^2 \times \left(SNR - (\rho - 1/\rho)\right)^{-2} \qquad (2)$$

Comparing (1) with (2), there is almost no contribution to the whole expression results if there is a tiny change of ρ; however, SNR^{-2} and $(SNR - (\rho - 1/\rho))^{-2}$ should be mainly discussed and compared. When $\rho \approx 1$, then $SNR^{-2} \approx (SNR - (\rho - 1/\rho))^{-2}$, the numerical value of (1) and (2) are almost the same; When ρ is larger and suppose $\rho = 1.05$, then $(\rho - 1/\rho) = 0.0976 \approx 0.1$, if SNR = 0.1, well then $(SNR - (\rho - 1/\rho))^{-2} \approx 0$, substituting into equation (2) to be

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2015

$N \rightarrow \infty$. In other words, only infinite detection duration can complete detection, which is impracticable. A tiny fluctuation of average noise power causes performance drop seriously, especially with a lower SNR.
Fig.3 is the numerical results of (2) given: SNR = −10dB, P_{FA} 2 (0, 0.5) and N = 1000. In Fig.3, ϱ=1.00 represents no noise uncertainty, namelythe average noise power keeps constant in short time. Wecan see that the performance gradually drops as the noise uncertainty factor increasing. When ρ=1.05, the performancedropped seriously. For example, if P_{FA} = 0.1, then P_D< 0.30,even when P_{FA}=0.5, the detection probability is still lessthan 40%.It means that cognitive users decide the spectrum is idle no matter whether there are primary users present. Consequently, cognitive users are harmful to licensed users when primary users are present. This situation often occurs in cognitive radio systems, particularly in lower signal-to-noise ratio environments. This indicates that Energy detector is very sensitive to noise uncertainty. In order to guarantee a good performance, choosing a suitable threshold is very important.

Traditionalenergy detection algorithms are based on a fixed threshold, and we have verified that the performance decreased under noiseuncertainty environments. This indicates that the choice of afixed threshold is no longer valid under noise uncertainty and threshold should be chosen flexible based on the necessary. Further we can propose an algorithm of energy detection with dynamic threshold.

IV.IDynamic Threshold:

Since performance declined sharply as noise uncertaintyand cognitive users' accessing will be serious interference tolicensed users, which should be avoided in dynamic spectrumaccess technology. For this reason, a new algorithm combatting the noise uncertainty is presented.Assuming ρ' is the dynamic threshold factor and $\rho' > 1$ and$\rho' \approx 1$, the value of dynamic threshold can be summarized in asingle interval$\gamma' \epsilon \left[\frac{\gamma}{\rho'} . \rho'\gamma\right]$. In this section, we will considerthe noise uncertainty and dynamic threshold respectively, it has:

$$P_D = \frac{\min}{\gamma' \epsilon \left[\frac{\gamma}{\rho'} . \rho'\gamma\right]} \frac{\min}{\sigma^2 \epsilon \left[\frac{\sigma^2}{\rho} . \rho\sigma_n^2\right]} Q\left(\frac{\gamma' - (P + \sigma_n^2)}{\sqrt{2/N\,(P + \sigma_n^2)}}\right)$$

$$= Q\left(\frac{\gamma\rho' - (P + \sigma_n^2/\rho)}{\sqrt{2/N (P + \sigma_n^2/\rho)}}\right)$$

$$P_D = \frac{\max}{\gamma' \epsilon \left[\frac{\gamma}{\rho'} . \rho'\gamma\right]} \frac{\max}{\sigma^2 \epsilon \left[\frac{\sigma^2}{\rho} . \rho\sigma_n^2\right]} Q\left(\frac{\gamma' - (P + \sigma_n^2)}{\sqrt{2/N\,(P + \sigma_n^2)}}\right)$$

$$= Q\left(\frac{\gamma\rho' - \rho\sigma_n^2}{\sqrt{2/N \rho\sigma_n^2}}\right)$$

Eliminating threshold and getting inter-relationship of PD, PFA, N, ρ, ρ' and SNR

$$N = 2[(\rho/\rho')Q^{-1}(P_{FA}) - \rho'(1/\rho + SNR)Q^{-1}(P_D)]^2 \times (\rho' SNR + \rho'/\rho - \rho/\rho')^{-2} \qquad (4)$$

In (4), when $\rho' \approx \rho$ and $\rho'/\rho \approx \rho/\rho' \approx 1$, $(\rho' SNR + \rho'/\rho - \rho/\rho')^{-2} \approx (SNR)^{-2}$and $\rho'(1/\rho + SNR) \approx (1 + SNR)$. We substitute (4) with the above approximate unequal expressions, and we can get that the numerical value of (4) is almost the same to (2). Therefore, dynamic threshold detection algorithm can overcome the noise uncertainty as long as a suitable dynamic threshold factor is chosen. Comparing (4) with (3), supposing SNR = 0.1 and ρ' and ρ both closer to 1, it is clear that$(\rho' SNR + \rho'/\rho - \rho/\rho')^{-2} \gg (SNR - (\rho - 1/\rho))^{-2}$. Consequently, detection duration N has been shortened largely with the same probability parameters PD and PFA. It can be concluded that as long as the dynamic threshold factor is suitable, even if there is noise uncertainty, we can get a better spectrum performance. To attaining the same performance, the detection time of dynamic threshold energy detection algorithm is less than the traditional version. Fig.3.3 is the numerical results of (2), (3) and (4).With the same parameters as before.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2015

V. SIMULATION RESULTS

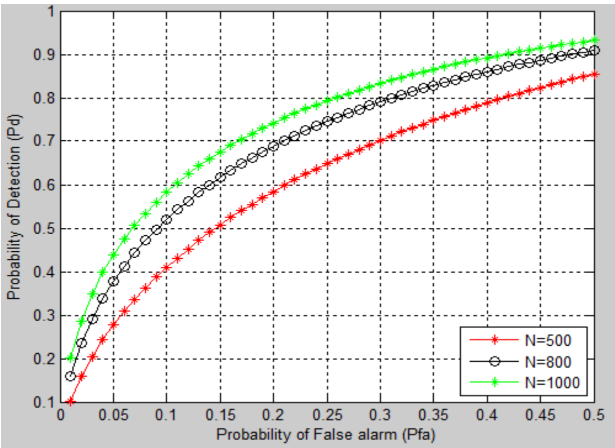

Fig.1: ROC Curves of ED schemewith different N

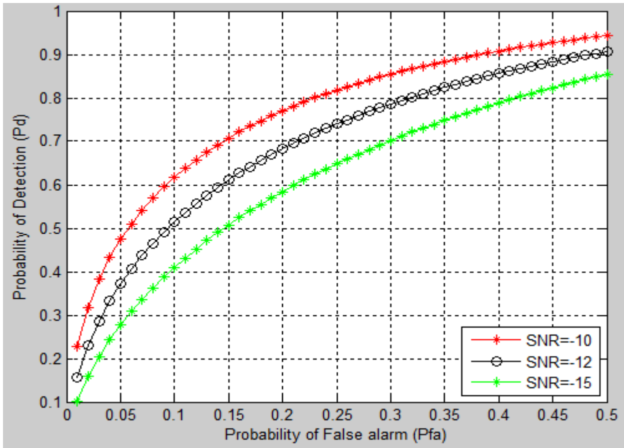

Fig.2: ROC Curves of ED scheme with different SNR.

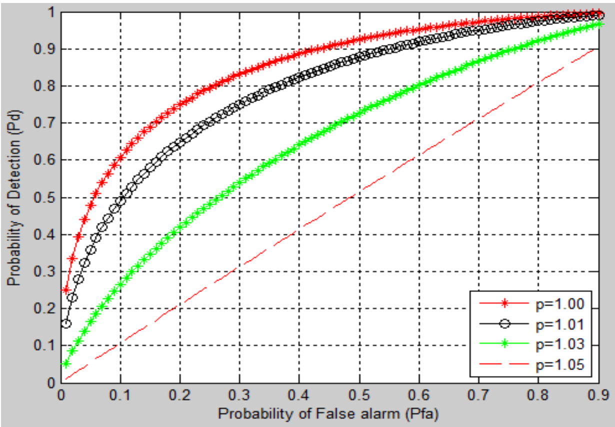

Fig.3: ROC Curves of ED scheme with different ρ

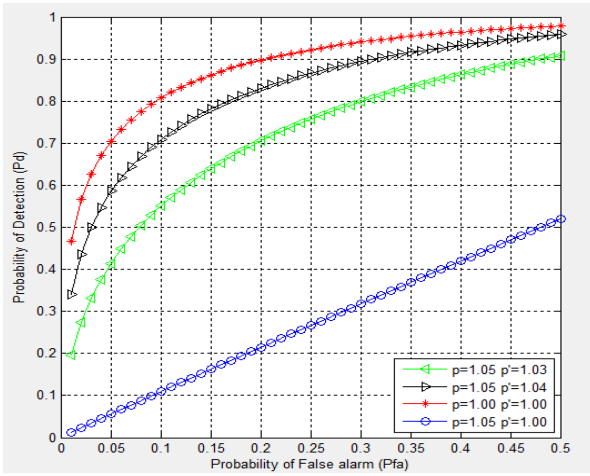

Fig.4: ROC Curves of ED scheme with different ρ,ρ′

VI. CONCLUSION AND FUTURE WORK

From above objective performance of energy detection can be enhanced by using different techniques, first one is to enhance energy detection scheme using noise uncertainty Energy detection schemes based on fixed threshold are sensitive to noise uncertainty, a fractional fluctuate of average noise power will lead to the detection performance dropping quickly. The simulation results show that: The proposed algorithm can have an accurate detection performance even if there is an evident noise uncertainty in the case of low signal-to-noise ratio, the algorithm enhanced the robustness of weak signal anti-noise uncertainty and improved the spectrum detection performance. Dynamic threshold spectrum detection algorithm is our future work.

From above three techniques performance of energy detection can be enhanced by using three different techniques, first one is to enhance energy detection scheme using dynamic threshold and noise uncertainty Energy detection schemes based on fixed threshold are sensitive to noise uncertainty, a fractional fluctuate of average noise power will lead to the detection performance dropping quickly. To overcome this drawback, dynamic threshold spectrum detection algorithm is presented in this thesis. This algorithm has an accurate detection performance even if there is an serious noise uncertainty in the case of low signal-to-noise ratio. Second technique is to enhance energy

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 10, October 2015

detector based on a simple modification to the traditional energy detector (TED). In this energy detector, the received signal amplitude is operated by an arbitrary positive power instead of the second power. Lastly we can improve the performance of the classical energy detector by SNR Enhancement. So as to improve the overall spectrum detection performance of TED scheme, SNR enhancement.

REFERENCES

1. V. I. Kostylev, "Energy detection of a signal with random amplitude," in Proc. IEEE Int. Conf. on Commun. (ICC'02), New York City, New York, pp. 1606–1610, May 2002.
2. H. Urkowitz, "Energy detection of unknown deterministic signals," Proc. IEEE, vol. 55, pp. 523–531, April 1967.
3. Mitola, J., Maguire, G.Q."Cognitive radios: making software radios more personal", IEEE Pers. Commun., 1999, 6, (4), pp. 13–18
4. Gui-cai YU, Yu-bin SHAO , Hua LONG and Guang-xinYue "Dynamic Threshold Based Spectrum Detection in Cognitive Radio Systems"
5. Jinbo Wu, Guicai Yu, Tao Luo and GuangxinYue "The Performance Merit of Dynamic Threshold Energy Detection Algorithm in Cognitive Radio Systems"
6. S. M. Kay, "Fundamentals of Statistical Signal Processing: Detection Theory", Englewood Cliffs: Prentice-Hall, 1998, vol. 2.
7. D.Cabric,S.M.Mishra,R.W.Brodersen, "Implementation issues in spec- trum sensing for cognitive radios", IEEE AsilomarConf.on Signals, Systems and Computers. Pacific Grove, USA, 2004. pp: 772-776.

BIOGRAPHY

Swapnil Namdevrao Bengalis a P G Student in the Electronics & Tele-Communication Department, Modern College of Engineering,PuneUniversity. He received Bachelor in Engineering (B.E) degree in 2012 from Pune University, Pune, MS, India. His research interests are CognitiveRadio.