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Spectrum Sensing in Cognitive Radio under Noise Uncertainty

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Abstract—*Sensing in cognitive radio (CR) is an essential thing. Without this we cannot predict the presence of primary user. In this paper we use two concepts to sense the primary user (PU). First is information theoretic criterion (ITC). In this sensing we can detect the single primary user. In this ITC based we can detect the single user target blindly. Second we can detect the target by energy detection method. There is no requirement of primary user information. In simulation we compare these two methods and deduce which sensing technique is better in performance. Performance can be analyzed on the basis of certain and uncertain noise.*

Keywords*: Spectrum sensing; information theoritic criteria; cognitive radio.*

1. INTRODUCTION

Cognitive radio is used to improve the utilization of spectrum. In this we sense the presence of PU. For this we use secondary user (SU) to determine whether we can get the channel or not. If it gets the channel then it can use the spectrum of primary user. Cognitive radio senses the primary user to use channel in time as well as frequency domain [1].

Many researchers have done a lot of work in cognitive radio for spectrum sensing. There are many spectrum sensing like energy detection [2], information theoretic criteria [9] and eigenvalue based [3]. Here energy detection is most used method due to the energy detection we can achieve high efficiency in sensing method. But this method is feasible for only certain noise and for uncertain noise this detection is robust with unknown interference. We all know that secondary user can't give accurate information about PU for sensing. We use eigenvalue method to detect the target blindly [3]. In this method we use two method MME and EME method and we get the covariance matrix. After the matrix we get the threshold value using this we can get the presence of PU.

Now we go to another method ITC [4]. In this method we perform sensing for PU by the single secondary user. Using this ITC sensing algorithm [5] we achieve performance that is better than other sensing method. Using the ITC method we can detect the primary user using secondary user in time and frequency domain. In this paper we use ITC in frequency domain for blindly detect the single user. In this paper we compare energy detection and MDL method. MDL method is based on ITC. Energy detection method is best than MDL method based on ITC in noise certain condition. But in case of noise uncertain condition we can find MDL method is best. Simulation result is used to compare between proposed methods to sense the target.

2. SYSTEM MODEL

In this a cognitive radio signal primary user that being sensed by signal secondary user. For the spectrum sensing we consider binary hypothesis.

$$H_0 : x_j(n) = w_j(n) \tag{1}$$

$$H_1 : x_j(n) = \sum_{m=1}^{M} \sum_{i=0}^{L-1} h_{m,j}(i) s_m(n-i) + w_i(n) \tag{2}$$

Here we consider the j antenna of secondary user. In this paper we consider single primary user and single secondary user for target detection. $x_j(n)$ is received signal sample of secondary user. $h_{m,j}(i)$ Channel gain $s_m(n)$ primary user signal. $w_i(n)$ is additive white Gaussian noise (AWGN).

Now we can find the matrix form of (1) and (2) as

$$H_0 : x_n = w_n \tag{3}$$

$$H_1 : x_n = s_n + w_n \tag{4}$$

When the signal is preset the hypothesis (4) is consider but in the absent of signal we consider the hypothesis (3).

Where

$$x_n = [x_1(n), \ldots\ldots\ldots\ldots, x_j(n)]^T ,$$

$$w_n = [w_1(n), \ldots\ldots\ldots\ldots, w_j(n)]^T$$

$$\bar{s}_n = [\bar{s}_1(n), \ldots\ldots\ldots\ldots, \bar{s}_j(n)]^T \text{ , and}$$

$$\bar{s}_j(n) = \sum_{m=1}^{M} \sum_{l=0}^{L-1} h_{m,j}(i) s_m(n-i)$$

In the real world different type of noise are present like thermal noise, shot noise. We never get the exact information of noise. This noise in the signal gives uncertainty in detection. This noise uncertainty represent as noise power in a interval

$$\rho^2 \in \left[\frac{1}{\rho} \sigma_n^2, \rho \sigma_n^2 \right]$$

σ_n^2 = noise power, ρ >1 represent quantifies of uncertainty.

Noise uncertainty comes under SNR wall phenomenon. If signal is detected below SNR than this is not feasible.

Now for energy detector

$$SNR_{wall}^{energy} = \frac{\rho^2 - 1}{\rho} \tag{5}$$

Now the covariance matrix of signal is as

$$R_x = E[x_n x_n^H]$$

$$x_n = s_n + w_n$$

$$R_x = E[s_n s_n^H] + E[w_n w_n^H]$$

$$R_x = H R_s H^+ + \sigma_n^2 I_{ML} \tag{6}$$

Where H is ML×(N+PL) is as

$$H_J \square \begin{bmatrix} h_j(0)\ldots\ldots\ldots\ldots\ldots\ldots h_j(N_j)\ldots\ldots\ldots\ldots\ldots\ldots 0 \\ \\ 0\ldots\ldots\ldots\ldots\ldots h_j(0)\ldots\ldots\ldots\ldots\ldots\ldots h_j(N_J) \end{bmatrix}$$

I_{ML} is Identity matrix

$$R_x = \frac{1}{N} \sum x_n x_n^H \tag{7}$$

This is sample covariance matrix of the received signal. Based on this two detection method i.e. maximum-minimum Eigen value (MME) or energy with Eigen value method is proposed.

We assume the eigenvalues of R_x is $\lambda_1 \geq \lambda_2 \geq \ldots\ldots\ldots\ldots \lambda_m$ if the signal is present. When the noise is present and $\lambda_1 = \lambda_2 = \ldots\ldots\ldots\ldots \lambda_m = \sigma_v^2$ no signal is present. So this method to calculate eigenvalue is done by covariance matrix. It is difficult to sense the PU.

3. ITC BASED FREQUENCY-DOMAIN SPECTRUM SENSING

ITC based method use to sense the primary user. In this paper we first sense the presence of primary user using ITC method. To sense the user first we determine the model (1-2). Actually in this paper we compare the blind detection method which is done by ITC method with the energy detection method. We use the condition that is with certain and uncertain noise.

$$x_j(f) = \overline{s_j}(f_n) + w_j(f_n) \tag{8}$$

$$x_j(n) = \overline{s_j}(n) + w_j(n) \tag{9}$$

Where the equation (8) is Fourier transforms of equation (9) and if we consider the entire secondary user antenna then

$$x(f_n) = [x_1(f_n), \ldots\ldots x_j(f_n)]^T ,$$

$$s(f_n) = [\overline{s_1}(f_n), \ldots\ldots, \overline{s_j}(f_n)]^T \text{ , and}$$

$$w(f_n) = [w_1(f_n), \ldots\ldots w_j(f_n)]^T$$

Based on [7] we find the likelihood function

$$L(\theta^{(k)}) = -N \log \det R^k - tr[R^{(k)}]^{-1} \hat{R} \tag{10}$$

Where $\hat{R} = \frac{1}{N} \sum x(t_n) x^H(t_n)$

ML of $\theta^{(k)}$ is maximize [7] and we find by Anderson [8]

$$\hat{\sigma}^2 = \frac{1}{J-q} \sum_{i=q+1}^{J} \lambda_i \tag{11}$$

$\lambda_1 > \ldots\ldots\ldots\ldots \lambda_M$ are eigenvalue of matrix $\hat{R}$. Now the log likelihood (12) is obtain by substituting the value of ML.

$$L(\hat{\theta}) = \log \left(\frac{\prod_{i=q+1}^{J} \lambda_i(f_n)^{\frac{1}{J-q}}}{\frac{1}{J-k} \sum_{i=q+1}^{J} \lambda_i(f_n)} \right)^{\frac{J-q}{N}} \tag{12}$$

The number of parameter is calculated as k*(2J–q)+1

Now we can write the MDL criteria [2].

$$MDL_K = -\log\left(\frac{\prod_{i=q+1}^{J} \lambda_i(f_n)^{\frac{1}{J-q}}}{\frac{1}{J-k}\sum_{i=q+1}^{J} \lambda_i(f_n)}\right)^{N(J-q)}$$

$$+\frac{1}{2}(q(2J-q)+1)\log N \quad (13)$$

As we can see that this method is varying of parameter i.e. q varies from 1 to J. now it can be simplified by taking only two value of MDL and determine $\hat{q}_{MDL}(f_n)$ and find that it is greater than zero or not. Now the calculation as

$$\Delta_{MDL}(f_n) = MDL_0(f_n) - MDL_1(f_n)$$

$$=$$

$$-JN\log\left(\frac{\prod_{i=1}^{J} \lambda_i(f_n)^{\frac{1}{J}}}{\frac{1}{J-1}\sum_{i=1}^{J} \lambda_i(f_n)}\right) - \frac{1}{2}(2J-1)\log N$$

$$+$$

$$(J-1)N\log\left(\frac{\prod_{i=1}^{J} \lambda_i(f_n)^{\frac{1}{J-1}}}{\frac{1}{J-1}\sum_{i=2}^{J} \lambda_i(f_n)}\right) \quad (14)$$

And

$$H_0 : \Delta_{MDL}(f_n) < 0$$
$$H_1 : \Delta_{MDL}(f_n) \geq 0 \quad (15)$$

So this hypothesis for single user with the single antenna primary and secondary user in cognitive radio.

4. SIMULATION RESULTS

This simulation result shows the method which is best for sensing in different condition. When we noise with certain condition than in graph (1) we can easily find that energy detection method is best than MDL method. As we change the condition i.e. in uncertain noise condition we find in graph (2) that MDL method is best in performance. MDL based formula in [6] which show the difference between two values of MDL to find the performance of ITC method.

Using these two graphs we can easily find we can't predict the noise certainty and uncertainty. According to this we can easily say that ITC based MDL is best in term of performance analysis. The performance comparison in these methods is show in graph (1) & (2) for 1000 samples.

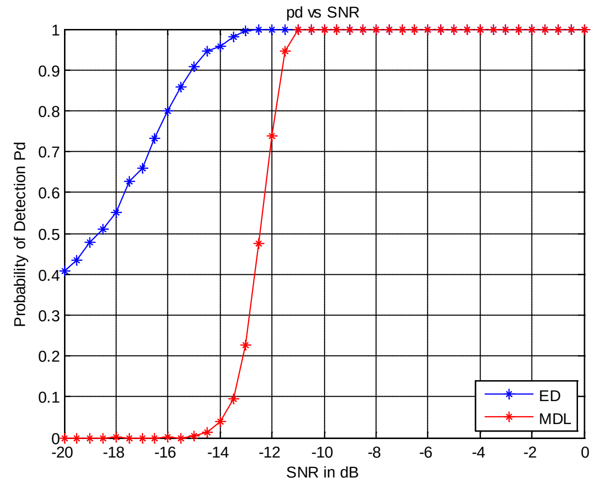

Fig. 1: Performance comparison with energy detection and MDL method with noise certainty (0dB) certainty

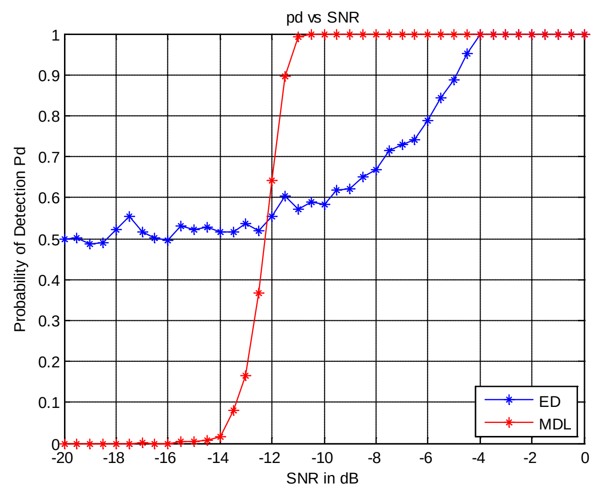

Fig. 2: performance comparison with energy detection and MDL method with noise uncertainty (-2dB) uncertainty

5. CONCLUSIONS

Method used in this i.e. energy detection have been proposed. According to threshold value we can determine the probability of detection of target without knowledge of signal. We also used ITC based method which is minimum description length (MDL) in frequency domain to detect the target. This method is far better than the energy detection method. Performance of these methods is show in graph. Which show than MDL has better performance in probability of detection of target with noise uncertainty.

REFERENCES

[1] S. Haykin, “cognitive radio: brain-empowered wireless communication,” IEEE J. Sel. Areas Commun., vol. 23, no. 2, pp. 201-220, Feb. 2005.

[2] F.F. Digham, M.S. Alouini, and M.K. Simon, “On the energy detection of unknown signals over fading channels,” IEEE trans. Commun., vol. 55, no. 1, pp. 21-24, Jan 2007.

[3] Y.Zeng and Y.chang Liang, “Eigenvalue-based spectrum sensing algorithms for cognitive radio,” IEEE Trans. Commun., vol. 57, no. 6, pp. 1784-1793, June 2009.

[4] M.Wax and T.Kailath, “Detection of signals by information theoritic criteria for cognitive radios,” Speech ans Signal Processing, vol. 33, no. 2, pp. 387-392, Apr. 1985.

[5] Rui Wang and Meixia Tao, “Blind spectrum sensing by information theoretic criteria for cognitive radios,” IEEE trans.on Vehicular Technology, vol. 59, no. 8, pp. 3806-3817, Oct. 2010.

[6] Yuan jing, Xiaofeng Yang, Li Ma Ji Ma and Bin Niu, “Blind MultiBand Spectrum Sensing in Cognitive Radio Network,” IEEE Trans. on Consumer Electronics, Communication and Network, pp. 2442-2445, 2012.

[7] “Estimation of arrival of Multiple Plane Wave,” IEEE Trans. Aerosp. Electron. Syst., vol. AES-19, pp. 123-133, 1983.

[8] T.W.Anderson, “Asymptotic Theory for Principal Component Anakysis,” Ann.J.Math.stat., vol. 34, pp. 122-148, 1963.