International Journal of Research in Advent Technology, Vol.5, No.4, April 2017
E-ISSN: 2321-9637
Available online at www.ijrat.org

Two stage Parzen window entropy based co-operative spectrum sensing

Sumathra T.[1] and Aparna N.S.[2]
Department of Electronics and Communication Engineering, Srinivas School of Engineering, Mukka, Mangalore - 574146, India[1,2]
rsumathra@gmail.com[1], *aparnansbhat@gmail.com*[2]

Abstract- Spectrum sensing is one of the key functions to detect the existence of the primary users in Cognitive Radio Networks (CRN). Sensitivity to noise uncertainty is the underlying curb of current spectrum sensing approaches in CR. The performance of conventional detectors decays quickly because of noise uncertainty, while signal-to-noise ratio (SNR) is low. A Parzen window entropy (PWE) based spectrum sensing algorithm enhances the primary user detection at lower SNR. This method detailed a single stage cooperative sensing strategy to improve the reliability of detection. The present article focusing on the improvement of reliability of detection of Parzen window entropy based co-operative spectrum sensing algorithm by implementing two-stage Parzen entropy-based cooperative spectrum sensing scheme using two-bit decision under low SNR condition. The proposed method relies on soft decision rather than the hard decision provided by the single stage Parzen window entropy based co-operative spectrum sensing approach.

Index Terms- Cognitive radio; Entropy; Co-operative spectrum sensing

1. INTRODUCTION

Wireless communication and its necessity have shown galloping growth today and which is the integral part of human life. It is unfeasible to meet the wide demand of data by utilizing the limited available spectrum and their utilization techniques because of fixed (exclusive) spectrum allocation which leads to underutilization or over utilization of allocated licensed spectrum. The internet usage will take major role in future for the communication which demands high speed data and robust connection. As per the prediction it is expected that the number of internet users will get almost tripled in next coming four years which intern increases the congestion in spectrum [1, 2].

Cognitive Radio (CR) gives novel approach to manage over crowded spectrum by utilizing unutilized licensed spectrum [3]. CR technique gives dynamic allocation of spectrum which involves four main functions namely spectrum sensing, management of spectrum, spectrum sharing and mobility of spectrum. CR spectrum sensing process is to identify availability of spectrum and its licensed primary user. Spectrum analysis involves analysis and estimation of characteristics of sensed spectrum. Spectrum management is to estimate the duration for secondary user to hold licensed spectrum. Spectrum sharing and mobility involves fair allocation of channel and provides transition to better frequency band, respectively.

In conventional spectral sensing of cognitive radio, techniques like matched filter detection, energy detection, cyclostationary detectors, centralized and decentralized spectrum sensing etc., are involved [4]. The detection through matched filter requires prior information of the channel to be sensed. However, the energy detector is highly sensitive to uncertainty in noise. The sensing through cyclostationay detectors are inefficient due to the complex computations involved and less robust and fails to meet requirement under low SNR conditions. Cognitive Radio entropy based spectrum sensing techniques can be implemented to mitigate the effect of noise uncertainty which resulted in considerable improvement in the robustness and SNR [5].

When the Gaussian noise and the interference levels are unknown in the region of interest the conventional spectrum detection techniques (energy detection and matched filtering) becomes infeasible. A simple carrier sensing technique based on entropy of the received signal [6] in presence of unknown noise and interference has shown favorable results when compared with conventional techniques, but the minimum SNR wall is considerably high. The entropy of the sensed signal is estimated in the frequency domain [6] to alleviate noise uncertainity in time domain entropy based detector [5]. The basic assumption in all the entropy based spectrum sensing strategies is the underlying primary signal is known to the spectrum sensing scheme, which limits the adaptability of the strategy. The white spaces in the frequency band of interest can be identified by the wavelet packet entropy based scheme [7] without requiring prior knowledge of the underlying primary signal and energy level of the noise. Recently, an entropy-based spectrum observing scheme [8] in frequency domain, based on spectrum power density is proposed. It is also robust to the noise uncertainty with better probability of detection and lower computational complexity but the SNR wall still needs improvement. The reliability of the detection was further improved by implementing a two-stage entropy-based spectrum observing scheme and a Cooperative spectrum sensing (CSS) scheme with two-bit decision, which has better performance than those one-stage ones.

In CSS [9-13], the information was sensed by the local sensors and the same were sent to the centre where the final decision is made. AND-rule-based CSS [9], OR-rule-based CSS [10], and VOTING-rule-based CSS are the three simple schemes of CSS. [11]. Even though these schemes are simple they pose lot of limitations on the performance. Recently weight based CSS schemes are dominating because of their outstanding performance. But the major drawback of these schemes are the SNR of each secondary user involved must be known accurately to estimate the fusion weight, which is merely a difficult task [13]. A PWE based spectrum sensing algorithm [14] elevated the SNR wall considerably in cognitive radio primary user detection, compared to the previous schemes. Further cooperative carrier sensing using the weighted gain combining (WGC) fusion method elevated the detection probability and reliability but still it has its own difficulty as stated in [13].

The single stage CR entropy based CSS techniques failed to provide a better reliability of detection and provide hard decision. However, the author Nan Zhao proved that the two stage CR entropy based CSS techniques improve the reliability even under low SNR and provide a soft decision. Also it alleviates the difficulty faced by weight based CSS schemes. Hence the present work focus to improve the reliability of detection of PWE based spectrum sensing algorithm under low SNR condition by incorporating a two-stage entropy-based cooperative spectrum sensing scheme instead of the WGC fusion method.

2. SYSTEM MODEL

Spectrum sensing is the fundamental method to determine whether or not the primary user signal exists in the carrier frequency of interest. This task can be formulated as follows [8]: Assume **s(z)** as primary user signal, **w(z)** as the additive white Gaussian noise signal and *h* as channel gain. Here $z = 0, 1, 2, \dots, N$-1, where *N* represents the number of discrete primary signal samples. The binary hypothesis for detecting the carrier frequency of interest is framed as,

$$H_0 : x(z) = w(z) \tag{1}$$

$$H_1 : x(z) = h.s(z) + w(z) \tag{2}$$

Where the hypothesis H_0 called as null hypothesis indicates the absence of primary user signal, has the noise component alone and the hypothesis H_1 called as true hypothesis indicates the presence of primary user signal, has signal component plus noise component. The noise signal **w(z)** has Gaussian distribution with zero mean and variance σ_w^2 and the signal in hypothesis H_1 also exhibits Gaussian distribution with zero mean and variance $\sigma_w^2 + \sigma_s^2$.

2.1. Parzen window entropy (PWE) based scheme

In statistics, pdf p(x) of a finite set of discrete samples can be estimated by a non-parametric method called as kernel density estimation (KDE) without prior knowledge of the fundamental distribution. Assume, the discrete samples of the random variable **X** as $[x_1, x_2, \dots, x_n]$. The Parzen window estimator of discrete samples of the random variable **X** having a pdf (probability density function) 'f' which is unknown is [14]

$$f_X(x) = \frac{1}{n}\sum_{i=1}^{n} \mathrm{K_h}(\mathrm{x_k} - \mathrm{x_i}) \tag{3}$$

where *n* represents the number of discrete Gaussian samples, '*h*' is the kernel width, $K_h(.)$ represents the scaled kernel which is defined as,

$$K_h(x) = \frac{1}{h} K\left(\frac{x}{h}\right) \tag{4}$$

Here '*h*' is the data smoothing parameter. By assuming Gaussian kernel the Gaussian kernel width can be stated as [14],

$$h = \left(\frac{4\sigma^5}{3n}\right)^{\frac{1}{5}} = 1.06\sigma n^{-\frac{1}{5}} \tag{5}$$

where σ represents standard deviation of samples.
The Parzen window entropy of the received signal **x(z)** with random variable **X** can be stated as [14],

$$H_R(X) = \frac{1}{1-\propto} log\left[\frac{1}{n^{\propto}}\sum_{k=1}^{n}\left(\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{K_h}(\mathrm{x_k} - \mathrm{x_i})\right)^{\alpha-1}\right] \tag{6}$$

The test statistics for the Parzen window entropy estimator which are calculated from the hypothesis test of samples of random variable **X**, $[x_1, x_2, \dots, x_n]$ is stated as,

$$H_R(X) \underset{H_0}{\overset{H_1}{\lessgtr}} \lambda \tag{7}$$

where λ indicates detection threshold, which can be calculated based on the false alarm probability (p_{fa}) and is represented as,

$$\lambda = H_n + Q^{-1}(1 - P_{fa})\sigma_w \quad (8)$$

2.2 Cooperative spectrum sensing

In cooperative spectrum sensing scheme a cluster of secondary users share the knowledge gained about the spectrum of interest to boost the reliability of decision. By the use of 2-stage CSS the reliability of the decision about the presence of primary user is further boosted greatly [8]. In this 2-stage CSS scheme each secondary user sends a 2-bit decision about the spectrum of interest to the common receiver, which further fuse the individual secondary user decisions to determine whether the primary user spectrum of interest is vacant or not.

The proposed cooperative spectrum sensing scenario is framed as follows: Assume there are *M* secondary users are in cooperation. The binary hypothesis framed as,

$$H_0: x_m(z) = w_m(z) \quad (9)$$

$$H_1: x(z) = h_m.s_m(z) + w_m(z), \quad z = 0,1,2,\dots N-1 \quad (10)$$

where m = 0, 1, 2, . . . , M-1 and h_m is the channel gain of M^{th} secondary user.

1. Determine the Parzen window entropy using equation 6 at the m^{th} secondary user and denote it as H_{R1}.
2. The first stage of detection with a positive parameter Δ_0 and detection threshold λ [8] is organized as

$$H_{R1}(X): \begin{cases} \le \lambda - \Delta_0: The\ final\ decision\ d_m is\ made\ equal\ to\ 11, and\ jump\ to\ step\ 5 \\ > \lambda + \Delta_0: The\ final\ decision\ d_m is\ made\ equal\ to\ 00, and\ jump\ to\ step\ 5 \\ else, jump\ to\ step\ 3\ to\ carry\ out\ the\ second\ stage\ detection \end{cases} \quad (11)$$

If H_{R1} is less than or equal to the threshold $\lambda - \Delta_0$ then with full confidence a 2-bit decision d_m = 11 is made at the m^{th} secondary user and if H_{R1} is greater than the threshold $\lambda + \Delta_0$ then with full confidence a 2-bit decision d_m = 00 is made at the m^{th} secondary user and the detection process jump to step 5. If H_{R1} is in the region $(\lambda - \Delta_0, \lambda + \Delta_0)$ then it is required to perform the second stage of detection and the detection process jump to step 3.

3. Determine the Parzen window entropy using equation 6 again at the m^{th} secondary user and denote it as H_{R2}.
4. Based on H_{R2} the following decision is made,

$$H_{R2}(X): \frac{H_{R1}(X)+H_{R2}(X)}{2} \begin{cases} \le \lambda: The\ final\ decision\ d_m is\ made\ equal\ to\ 10 \\ > \lambda: The\ final\ decision\ d_m is\ made\ equal\ to\ 01 \end{cases} \quad (12)$$

After making the final soft decisions about the spectrum of interest in all the secondary users the decisions are send to the common receiver for fusing.

5. The common receiver fuses the information received from all the secondary users. For convenience in processing, the decisions d_m from different secondary users are assigned to signed integer F_m as given below:

$$F_m = \begin{cases} 2, when\ d_m = 11 \\ 1, When\ d_m = 10 \\ -1, When\ d_m = 01 \\ -2, when\ d_m = 00 \end{cases} \quad (13)$$

Using equation (13) the fused final decision of the common receiver in co-operative spectrum sensing scheme is,

$$Z = \sum_{m=1}^{K} F_m \begin{cases} > 0, H_1 \\ < 0, H_0 \\ = 0 \begin{cases} H_1, The\ number of positive\ F_m\ is\ larger\ than\ K/2 \\ H_0, else \end{cases} \end{cases} \quad (14)$$

6. End of current detection process.

3. DISCUSSION

Through simulation Swetha et al. [14] showed that a PWE based spectrum sensing algorithm enhances primary user detection when SNR is low in comparison with the underlying spectrum sensing algorithms. But along with this algorithm a single stage entropy-based CSS algorithm is used to improvise the reliability of detection. However, Nan Zhao [8] proposed a novel two stage entropy-based CSS algorithm to further improve the reliability of detection and proved the same through simulation. But the entropy was calculated based on the power spectral density of the received signal in frequency domain. In our proposed scheme we have suggested a two stage entropy-based CSS algorithm based on Parzen window entropy (PWE). Swetha et. al [14] showed that PWE based spectrum sensing algorithm performs well compared with other schemes and Nan Zhao [8] showed that two stage entropy-based CSS algorithm improves the reliability of detection compared with single stage entropy-based CSS. Hence the proposed scheme is expected to improve the reliability of detection compared to parzen window entropy based single stage CSS algorithm under low SNR condition with less computational complexity.

4. CONCLUSION

A 2-stage PWE based co-operative spectrum sensing scheme for cognitive radio networks has been proposed in this paper. Spectrum sensing based on PWE outperformed all the existing energy and entropy detection techniques. Co-operative carrier sensing using the weighted gain combining (WGC) fusion method lifted the Parzen window detection probability and reliability. But the major setback is the weight calculation, which is purely depending on the characteristics of the received signal. A 2-stage entropy based co-operative spectrum sensing scheme uplifted the reliability of co-operative carrier sensing even under low SNR which eliminates the limitations of WGC fusion techniques. In this work PWE is combined with 2-stage entropy based co-operative spectrum sensing scheme is proposed which is expected to improve the reliability of detection further.

REFERENCES:

[1] http://www.dospeedtest.com/blog/the-future-of-the-internet-7-big-predictions-of-2020/
[2] FCC, ET Docket No 03-222 notice of proposed rulemaking and order, December 2003.
[3] Mitola, J; Maquire, G. Q. (1999): Cognitive radio: making software radios more personal. IEEE Personal Communications, **6**, 13.
[4] Muchandi, N; Khanai, R; Sheshgiri, M. S. (2016): Cognitive Radio Spectrum Sensing: A Survey. International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), 3233.
[5] Nagaraj, S. V. (2009): Entropy based spectrum sensing in cognitive radio. Signal Processing, **89**, 174.
[6] Zhang, Y; Zhang, Q; Wu, S. (2010): Entropy-based robust spectrum sensing in cognitive radio. IET communications, **4**, 428.
[7] Jiang, Z; Zhang, Q; Wang Y; Shang, X. (2011): Wavelet Packet Entropy Based Spectrum Sensing in Cognitive Radio. IEEE 3rd International conference on Communication Software and Networks (ICCSN).
[8] Nan Zhao. (2013): A Novel Two-stage Entropy-based Robust Cooperative Spectrum Sensing Scheme with Two-bit Decision in Cognitive Radio. Wireless Personal Communications, 69, 1551.
[9] Visotsky, E; Kuffner, S; Peterson, R. (2005): On collaborative detection of TV transmissions in support of dynamic spectrum sharing. Proc. First IEEE Symposium on Dynamic SpectrumAccess Networks, 131.
[10] Cabric, D; Tkachenko, A; Brodersen, R. W. (2006): Experimental study of spectrum sensing based energy detection and network cooperation. The 1st International Workshop on Technology and Policy for Accessing Spectrum.
[11] Varshney, P. R. (1996): Distributed Detection and Data Fusion. Springer-Verlag, New York.
[12] Zheng, Y; Xie, X. Z; Yang, L. L. (2009): Cooperative spectrum sensing based on SNR comparison in fusion centre for cognitive radio. Proc. International Conference on Advanced Computer Control, 212.
[13] Kieu-Xuan, T; Koo, I. (2010): An efficient weight-based cooperative spectrum sensing scheme in cognitive radio systems. IEICE Transactions on Communications, **E93-B**, 2191.
[14] Swetha, N; Sastry, P. N; Rajasree Rao, Y; Sabat, S.L. (2016): Parzen window entropy based spectrum sensing in cognitive radio. Computers & Electrical Engineering, **52**, 379.