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Multiple Detectors Based Analytical Performance of Spectrum Sensing

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Abstract

A key challenge in operating cognitive radios (CRs) in a self-organizing (ad hoc) network is how to adaptively and efficiently utilize spectrum resources keeping in mind that no interference is caused to primary users and also that no spectrum is rendered unused when a secondary user is waiting for access. Detecting the spectrum holes using one detector can be insufficient for increasing secondary users. In the proposed paper, an attempt has been made to implement multiple detectors to improve the probability of detection by increasing the SNR. Multiple detector technique has been implemented using various methods like Selection Combining (SC), Equal Gain Combining (EGC), and Maximum Ratio Combining (MRC), to discover which of these methods provide better increase in SNR as the numbers of detectors are increased.

Keywords

Spectrum sensing, multiple ratio combining, equal gain combining, selection combination, spectrum holes.

1. Introduction

A limited resource in wireless communication is frequency spectrum. Furthermore, because of pre-determined spectrum allocation scheme, utilization of the frequency spectrum is very meagre, which makes the shortage of spectrum even more severe. According to the FCC, the under utilization of spectrum is not due to scarcity but major reason is static allocation of the spectrum [1-3].

It is necessary to introduce a new communication model to overcome the spectrum inefficient utilization [4]; with which frequency spectrum can be properly utilized whenever any spectrum hole is available.

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A spectrum hole is a band of frequencies assigned to a primary user, but, at a particular time and specific geographic location, the band is not being utilized by that user.

Cognitive radio is coming up as an enabling technology, which, with the help of a technique called spectrum sensing (SS), determines whether the given frequency band is vacant to be used by an unauthorized/ secondary user (SU).

Whenever a Primary user (PU) is absent or not using the frequency band licensed to the frequency band is free or we can say unutilized, this seems as an opportunity for the SU to use the vacant frequency band. The major point to be considered here is that the SU should not cause any kind of interference to the PU.

During their communication, SUs do not sense the channel, so they must periodically suspend their transmission and enter a sensing period so as to determine whether the PU has emerged or not.

The main task of spectrum sensing is to detect the presence of PU correctly, i.e. to show the presence when PU is actually present and to show the vacant band when PU is actually not operating. This is called probability of detection. Previous research has shown that Probability of detection increases with increase in Signal-to-Noise ratio[5]. There are 3 major techniques for spectrum sensing, namely Energy Detection, Matched-Filter Detection and Cyclostationary detection. Energy detection is of particular interest because it does not require any prior knowledge about the signal [6]. A major challenge here is that when a single energy detector is used in cognitive radio, it raises a question over the reliability of cognitive radio and its performance. The motivation of this paper is to provide an unfailing system with improved spectrum sensing performance.

A key challenge in cognitive radio networks is the unreliability of CR which affects its performance also. In this paper the proposed technique uses multiple detectors that work cooperatively to detect the presence of PU.

2. Spectrum Sensing

CRs utilize unused channel of PU's signal and spectrum sensing mechanism allows them to determine the presence and absence of a primary user.

2.1 Energy detection spectrum sensing

Energy detection spectrum sensing is known as the most favourable method when the signal information is not available. Major challenges of energy detector based sensing are the selection of threshold to detect the primary users, the inability to differentiate whether the interference being caused is from primary users or noise, and its poor performance when the Signal-to-Noise ratio is low.

To determine the energy of the received signal, output signal from band-pass filter with bandwidth W is squared and integrated over the observation interval T.

Now finally, Y, the output of the integrator is compared with a threshold λ to decide if a licensed user is present or not [7].

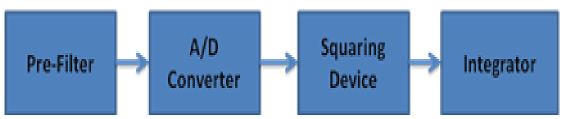

Figure 1: Block diagram of energy detector spectrum sensing

Energy Detector is composed of four main components:

1) Pre-filter.
2) A/D Converter (Analog to Digital Converter).
3) Squaring Device.
4) Integrator.

Output of the integrator is the energy of the filtered received signal over the time interval T and this output is considered the test statistic to test the two Hypotheses H_0 and H_1[8].
H_0 : corresponds to the absence of the signal and only presence of noise.
H_1 : corresponds to the presence of both signal and noise.
To detect the PU signal, a binary hypothesis testing problem is used where, hypothesis (H_0) corresponds to the case where signal is not present, and the hypothesis (H_1) corresponds to the case where primary signal is present.

$$H_o : x_i(n) = w_i(n) \quad (1)$$

$$H_1 : x_i(n) = h_i s(n) + w_i(n) \quad (2)$$

n=1,2,3,...N ; p=1,2,3....M

Where, s(n) represents the samples of a primary signal with received power P, $w_i(n)$ represents the Additive White Gaussian Noise, and h_i is a scaling factor representing the channel fading experienced by the primary signal for user *i*.
The detection performance of the detecting node can be calculated according to:

$$p_d = p(H_1 / H_1) \quad (3)$$

2.2 Cooperative spectrum sensing

Cooperative spectrum sensing is a technique where various cooperating cognitive radios together decide if a particular band is free for secondary access.
The main idea of cooperation is to improve the detection performance by taking advantage of the different techniques that can be used to combine the results from different nodes, in order to better protect a primary user, and reduce false alarm to utilize the idle spectrum more efficiently.

In this paper, multiple energy detectors are used in combination to cooperatively decide the presence or absence of primary users.

The reason behind using multiple detectors is to enhance the performance of cognitive radio and reduce the chances of miss-detecting the spectrum.

3. Proposed methods

In this approach 20 detectors have been used that use energy detectors to conclude a result and all their results are fused together using different methods like Selection Combination (SC), Equal Gain Combining (EGC), and Maximal Ratio Combining (MRC).
The basic Idea behind this is to increase the SNR, to improve the detection probability [3].

3.1 Selection Combination

Selection Combination is one of the simplest combination techniques. The receiver simply picks the signal with the largest SNR as given in figure (2).
Mathematically, output SNR in case of Selection Combination, γ_{SC}, can be written as[9]:

$$\gamma_{SC} = \max\{\gamma_1, \ldots\ldots\ldots\ldots\ldots\gamma_L\} \quad (4)$$

Where, L is the number of detectors used and γ is the SNR.

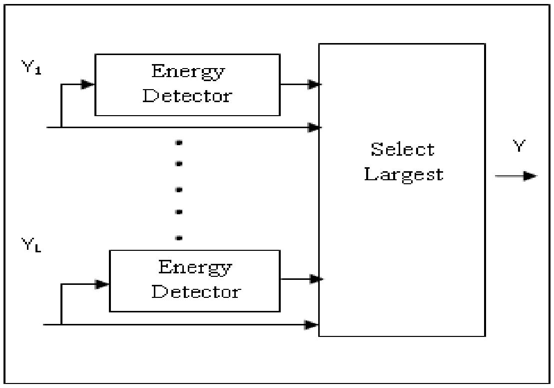

Figure 2: Selection Combination

3.2. Equal Gain Combining

In Equal Gain Combining (EGC), all the received signals are co-phased at the receiver and added together without any weighting.

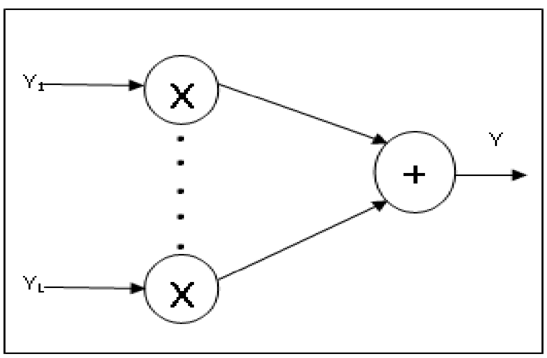

Figure 3: Equal Gain Combining

3.3 Maximal Ratio Combining

In Maximal Ratio Combining (MRC), the signal all the branches are co-phased and individually weighed to provide the optimal SNR at the output. It can be shown that [10] the output SNR is maximized when the signals in each of the diversity branches are weighed by their own envelopes. γ_{MRC} can be written as a sum of individual branch SNR values,[9]

$$\gamma_{MRC} = \sum_{i=1}^{L} \gamma_i \qquad (5)$$

Where, L is the number of detectors.

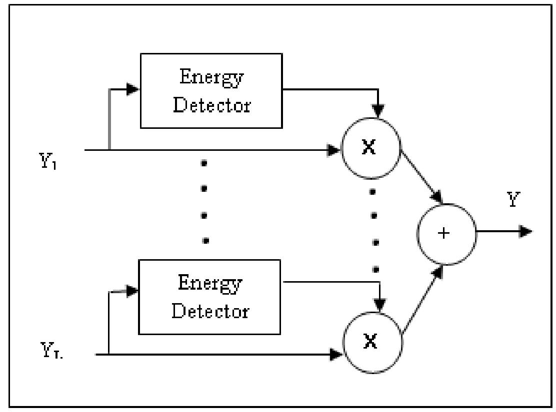

Figure 4: Maximal Ratio Combining

4. Simulation and result

C In the simulation, multiple detectors have been used to cooperatively sense the spectrum for presence of primary users. Each detector implements energy detector in the background. This simulation is done to find the improvement in SNR as the number of detectors change. Here the maximum no of detectors used are 20. As we are aware the Increase in SNR is directly proportional to probability of detection.

The graph below shows that SNR improvement is very minimal with the increase in the number of detectors.

4.1. Selection Combination

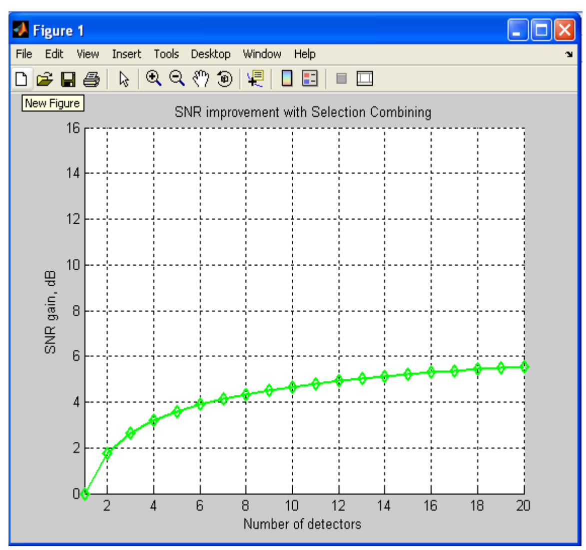

Figure 5: ROC for SNR improvement with Selection Combination

4.2 Equal Gain Combining

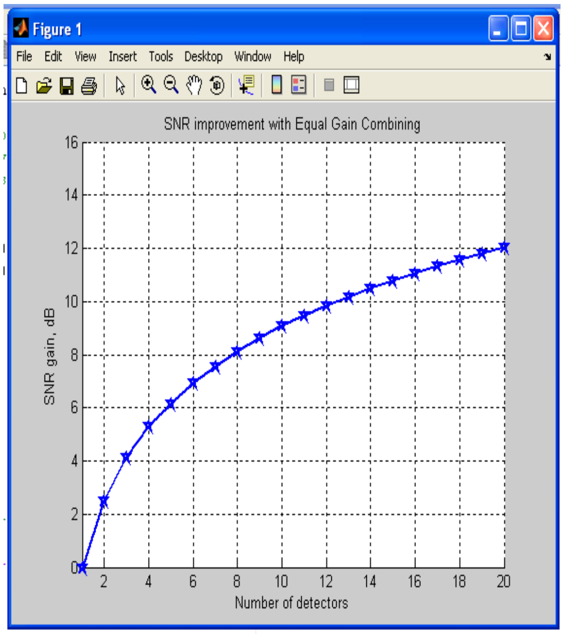

Figure 6: ROC for SNR improvement with Equal Gain Combining

The above figure shows that SNR improvement has increased as compared to selection combination.

4.3 Maximal Ratio Combining

The graph below shows that the improvement in SNR is maximal as compared to SC and EGC.

The reason for such a drastic increase in SNR is because, in MRC, the branches with strong signal are further amplified, while weak signals are attenuated [11]. Although as compared to MRC, EGC is simple to implement as it does not need any amplifier /attenuator unlike MRC, but EGC is difficult to analyze.

MRC requires perfect knowledge of the branch amplitudes and phases, MRC diversity combining provides the optimal diversity that offers the maximal capacity improvement relative to other combining techniques, for example selective combination and equal-gain combination.[12][13][14].

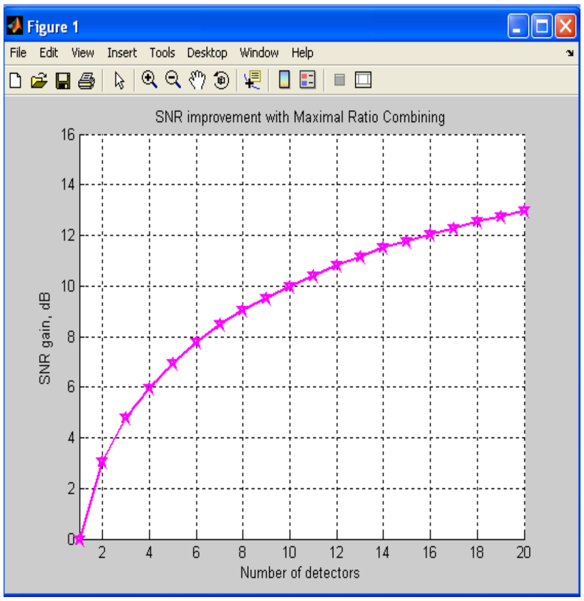

Figure 7: ROC for SNR improvement with Maximal Ratio Combining

4.4 Comparison to the traditional energy detector.

Using a single detector for analyzing the spectrum always left a large window for mistakes, while including multiple detectors to work cooperatively would help in reducing that window for mistakes. Furthermore, using SC, EGC and MRC for cooperative sensing helped in finding out which technique works better if multiple detectors are used. Clearly, cooperative sensing is better than single detector based sensing and this analysis shows that MRC is the best technique to use for cooperative spectrum sensing as it is much better than EGC and SC.

5. Conclusion and future work

The simulations above show that with the increase in the number of detectors, Multiple Ratio Combination technique shows a very noteworthy increase in the SNR as compared to Selection combination and Equal gain combining.

The gain in SNR when Maximal Ratio Combining is used is 62% more when compared to Selection Combination, while Equal Gain Combination shows 55% gain in SNR when compared to Selection Combination. Performances of Equal Gain Combination and Maximal Ratio Combining differ by almost 7%, with Maximal Ratio Combination showing the higher improvement in comparison with

Equal Gain Combination. Future work may involve working on Maximal Ratio Combination for even higher number of detectors to find the optimal number of detectors that can guarantee perfect probability of detection, as it is the best among the three techniques defined in this paper.

References

[1] Federal Communications Commission, "Notice of proposed rulemaking and order: Facilitating opportunities for flexible, efficient, and reliable spectrum use employing cognitive radio technologies," ET Docket No. 03-108, Feb. 2005.
[2] Federal Communications Commission (FCC), 2002. "Spectrum Policy Task Force," Report, pp: 2-37.
[3] Federal Communications Commission (FCC), 2003. "FCC 03-322".
[4] Haykin, S. 2005, "Cognitive radio: brain-empowered wireless communications", IEEE Journal on Selected Areas in Communications 23(2): 201 - 220.
[5] S.Taruna, Bhumika Pahwa, "Simulation of cognitive radio using Periodogram", International Journal of Engineering and Research, Vol. 2 Issue 9, September – 2013.
[6] Ganesan, G., & Li, Y. (2007a, June). Cooperative spectrum sensing in cognitive radio, part II: Multiuser networks. IEEE Trans. Wireless Commun., 6, 2214-2222.
[7] T. Yucek and H. Arslan "A Survey of Spectrum Sensing Algorithms for Cognitive Radio Applications", IEEE Communications Surveys & Tutorials, Vol. 11, No. 1, pp. 116-130, 2009.
[8] H. Urkowitz, "Energy detection of unknown deterministic signals," Proceedings of the IEEE, Vol. 55, No.4, pp. 523–531, 1967.
[9] Sanjeewa Priyadarshana Herath, "spectrum sensing in cognitive radio - fading, Diversity and user cooperation", may 2009.
[10] Erfan Soltanmohammadi, Mahdi Orooji, "Improving the Sensing-Throughput Tradeoff for Cognitive Radios in Rayleigh Fading Channels", IEEE 2012.
[11] S. Haykin, D. J. Thomson And J. H. Reed, "Spectrum Sensing For Cognitive Radio", 3rd International Symposium On Intelligent Information Technology Application Workshop, Vol. 97, No.5, Pp.410-412, 2009.
[12] W. C. Jakes, Microwave Mobile Communications, W. C. Jakes, Ed. Wiley IEEE Press, 1994.
[13] D. Brennan, "Linear diversity combining techniques," Proceedings of the IEEE, vol. 91, no. 2, pp. 331 – 356, Feb 2003.
[14] L. Dong, "Performance analysis of MRC diversity for cognitive radio systems," IEEE Transactions on Vehicular Technology, vol. 61, no. 2, pp. 849–853, 2012.

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