Cognitive Radio Network based on Energy Spotting Method with Enhanced Sensing Accuracy

M. Ajay Kumar, N. Rajesha, Anupama Deshpande

***Abstract:** This paper represents the unique system model for cognitive radio based on the energy spotting method to enhance the performance of the accuracy by managing the queue regarding energy-samples and also estimating their average in order to characterize the decision-threshold. Consequently, these typical values summed and estimated over the sum of the samples are repeatedly correlated and analyzed with the recent energy values to determine whether the frequency band is vacant or occupied most accurately. The energy spotting technique's performance is analyzed and estimated analytically for distinct decision-thresholds. Conventionally Such evaluations interprets that; the advances made to energy spotting algorithm which have enhanced the sensing accuracy in spectrum under the differing signal-to-noise ratio values. Consequently, we shown the utilities and advantages of proposed model that increases the cognitive radio ability. The performance has measured by utilizing the AWGN (Additive White Gaussian Noise) channel and receiver operating-characteristics curves varying under various SNR values alike as: -20 dB, -15 dB, -5 dB, 0 dB, 5db and 10db. With small-tradeoffs among the detection and false-alarm probabilities, the model increases and enhances the ability of spectrum sensing mechanism greatly in the lower SNR situations while tested with number of samples. By that, improving the conventional performance by increasing the sensing accuracy of cognitive radio networks under the low SNR have been the promising achievement of this research work.*

***Keywords:** Cognitive Radio, False alarm and detection probability, spectrum sensing, Threshold.*

I. INTRODUCTION

Radio frequency spectrum is compelling gift and frequency bands unable be increased above the certain-limit. Furthermore, it is going to be utilized effectively to reduce the issues of the spectrum-scarcity. For this context, the CR users are segregated into two types conventionally; they are primary users (licensed users) and secondary users (unlicensed users) in virtue to use the spectrum bands efficiently. The spectrum bands which are heavily underutilized i.e., 60% of frequency bands are vacant CR offers the significant future for spectrum scarcity and resolves the dilemma of the spectrum and also widely addressed by researchers academics. The spectrum sensing mechanism is fundamental step of the CR networks, that spots the spectrum holes effectively rely considerably on the dynamic spectrum sensing and the noticeable point is that the interference constraint as also an vital factor; Although opportunistic accessing typical licensed-channel empowered to the primary users [5]. Cognitive Radio some specific characteristics rather than radio spectrum sensing such as power control, software-defined radio and frequency agility to attain the needy target for effective utilization of radio spectrum. The CR's most crucial mechanism is its sensing capacity to assess the spectrum accurately and detects vacant/idle spectrum bands which are known has the white spaces. The radio spectrum sensing detects weak primary-users signal and thence avoids the harmful interference. Energy spotting method is one noted for its lower complexity implementations but as limitation and restraints in spotting the weaker signals [6]. In this particular paper we propose a proper detection procedure to increase the sensing accuracy that provides fair detection capacity with the low complexity.

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II. SYSTEM MODEL

We consider the primary-secondary model in that the cognitive PU occupies the allocated radio spectrum band for specific time. The cognitive SU (secondary user) needs to use the spectrum band in practical manner after the sensing of radio frequency conditions and also ensure that the RF band is vacant not occupied by primary user. In virtue to accomplish the detection of signal, no priori information about primary-signal is premeditated. In the conventional continuous time-domain, the typical *received/acknowledged signal* is interpreted has

$$p(t) = j(t) + u(t)$$

Here, $j(t)$ is the primary-signal with the bandwidth Bj and the $u(t)$ is the noise. Moreover, we presume $r(t)$ is stationary during the period of sensing.

III. SPECTRUM SENSING

Spectrum-sensing mechanism is action of estimating the RF conditions in virtue to sense the certain characteristics of signal for example its energy. The detection of signal, in common words, may be effected neither through the optimal detection nor sub-optimal detection. Optimal detection needs coherent reception through the matched filtering.

This is not the appropriate method for RF-sensing in the cognitive radio by considering the distinct primary-user signal needs equivalent matched filter. The non-coherent detection approaches, i.e., energy spotting dependent systems, are effective because they are utilized to sense the signals indifferent of their inherent and internal nature. In this specific paper; we focused on the efficiency of energy spotting method to improve the accuracy of sensing.

A. Energy Spotting Method

Energy spotting method is one of dynamic spectrum sensing methods, the essential serviceable block includes a band pass filter, squaring-law device and integrator.

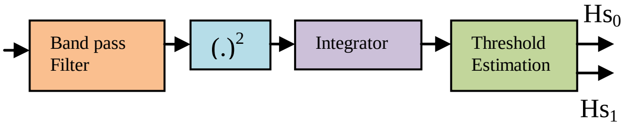

Fig 1: System model of Energy Spotting Method

The band pass filter allows only certain range of frequencies and the a squaring device averages the received signals energy and this method can implemented either in frequency domain or time domain. Time domain operation would need of primary signal front-end filtering. In scenario of multiple-filters are essential; if the more than likewise one primary-user signal with the distinct spectrum bands is expected [8]. Here in the frequency-domain operation, the conventional broad-band front-end filtering process is enough and adequate and samples of received signal are first converted and transformed to the frequency-domain samples before and ahead of squaring device operation. The detection of signal commonly affected by correlating the squared-signal outcome with which of the conventional threshold value. Typical threshold-value as fundamentally the power of ambient-noise emergent from receiver and the RF intervention/interference in surrounding. Even though we consider a static RF conditions for the simplicity, but in real time the RF condition is not static and there is need to determine the threshold-flexibly.

The operation of squaring device of energy spotting method is as follows

$$q[s]= j[s]^2 + j[s]\, u[s]+ u[s]^2$$

To sense the primary users signal by energy spotting approach in the AWGN-channel is to determine among the sub sequential hypotheses:

$$Hs_0\text{: } G(n) = K(n) \qquad n = 1\ldots.F$$

$$Hs_1\text{: } G(n) = H(n) + K(n) \qquad n = 1\ldots.F$$

Whereas F denotes the number of the samples, *G* is signal received, H is the signal transmitted from primary-transmitter and K is noise variance σ_K^2

Here n = 1……F; represents the samples that to proceed. If above outcome is measured with the F_{av} times and also averaged with presumption that of noise is typically Gaussian distributed and zero mean, the conventional decision -statistic is interpreted by the distribution of Chi-square. Based on the absence and presence of the signal, these distributions will be neither central nor non-central conventional Chi-squared and also for detection of signal, the discrete binary hypothesis testing is specified as following

Further, the statistic decision of energy spotting method is

$$D = \sum_F (G[n])^2$$

The detection performance is measured by probability of false-alarm and detection (Pr_{dt}, Pr_{fa}) and those probabilities are correlated with the threshold δ statistic-decision

B. Performance Metrics

To assess the energy spotting method performance, a sum of metrics has been recommended, comprise of false alarm P_{fa}, detection probability P_{dt} and miss detection probability P_{md}. P_{dt} is probability declares the PU signal presence; in case the spectrum is conventionally occupied. The detection probability is characterized as the:

$$P_{dt} = Prob(Hs_1 / Hs_1)$$

Whereas Hs_1 and Hs_0 denotes the PU signal presence and absence. The greater the detection possibility, the better that of the primary-user protection.

$$Pfa = Prob(Hs1 / Hs0)$$

The low the false alarm probability, the better the spectrum band access the cognitive secondary users will obtain.
The miss-detection probability, P_{mdt} is possibility that declares the PU signal absence when in case the spectrum band is conventionally occupied and it is represented by

$$Pmdt = Prob(Hs0 / Hs1)$$

These specific three-metrics estimates the effectiveness of spectrum-sensing methods and that can be written as:

$$Pdt+ Pfa+ Pmdt = 1$$

There is trade-off among false alarm probability and miss-detection probability. The false and uncertain detection of CR primary user activities causes the intervention/ interference to cognitive PU as well as the miss-detection of activities of PU misses' the spectrum-opportunities. Typically the trade-off can indicated as conservative with aggressive with P_{mdt} and conservative with P_{fa} .
Moreover, this spectrum-sensing techniques need to accomplish the conventional constraints on both of the probabilities [2].

IV. COGNITIVE RADIO CHALLENGES

Considerable challenges in spectrum sensing regarding cognitive radio. The Spectrum-sensing is determined as following. To sense the presence of cognitive primary users in the licensed-spectrum as well as leave the spectrum band probably to prevent the interference with the primary users. Distinct methods are utilized to analyze the primary signal presence. Conventionally spectrum-sensing approach can outlined as majorly two. Direct and indirect techniques.

Direct Technique: The signal's approach can utilize for estimation and also it refereed as the frequency-domain approach.

Indirect Technique: The signal's autocorrelation is utilized for the estimation; moreover it referred as the time-domain approach.

A. Challenges in Spectrum-Sensing

1. Primary User's Hidden Issue

Many effective factors alike as shadowing and multipath-fading cause the hidden-node issue. By using the co-operative spectrum sensing hidden PU problem can be managed.

2. Sensing Duration and Frequency

In virtue to prevent interference with the cognitive PUs, the sensing approaches have the capability to sense the primary user's presence within the certain-time. The sensing parameters alike as channel detection time and sensing frequency are vital to provide the synchronization among sensing reliability and sensing time.

V. ENABLING TECHNIQUES

The cognitive radio's main tasks includes
(1) Radio-scene analysis
(2) Identification of channel and
(3) Effective spectrum management.

The conventional radio-scene analysis encompasses the spectrum holes detection; for instance sensing the RF spectrum. The Identification of channel comprises of channel state data estimation that is essential at receiver for the conventional coherent detection.

The effective spectrum management and transmit power control selects the power transmission levels and the frequency holes for transmission dependent on results of channel identification and radio scene analysis.

The Effective spectrum management is carried out and accomplished in the transmitter (TX) and identification of channel and radio scene analysis tasks is carried out in receiver (RX). The CR is inclined and susceptible to the emergence behavior due to nature of time-varying in operating conditions. *Emergence* referred as occurrence properties at the high hierarchy levels that are not anticipated and predictable from the properties found at the lower level. In the CR scheme the positive eminent property is the improved area's spectral efficiency. Moreover the negative eminent properties comprise possibility to the chaotic behavior.

A CR network is smart multiuser communication system which perceives the conventional radio-scene, adapts and acclimates to variations in environment and also facilitates the communication among users by the co-operation, as well as systematically controls and commands the communication through the proper resource allocation. The CRNs encompasses the intelligent process which can perceives the network environments, and then plans, decides, and acts on those typical conditions. Cognitive networks essential of software flexible and adaptable network for implementation of actual network capability, functionality and to allow the process to adapt the CR network.

VI. SIMULATION ANALYSIS

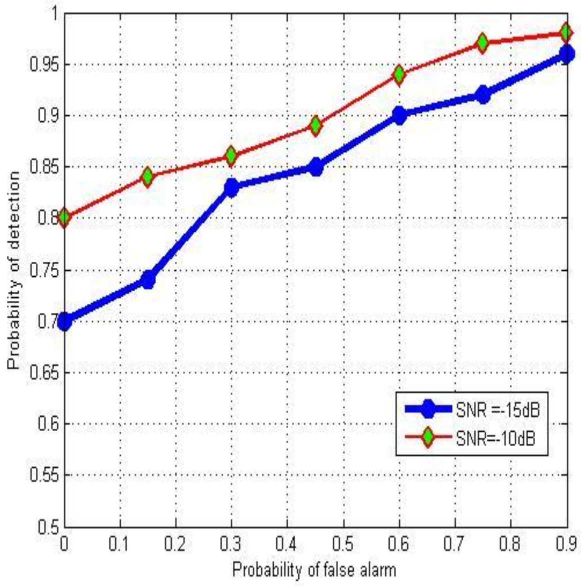

Fig 2: Detection vs False alarm probabilities at specific SNR

The simulation outputs were done in MATLAB 2018b; the fig 2 shows that false alarm and detection possibilities at the SNR = -15dB and -10 dB and the detection probability is 0.85 at false alarm probability 0.3 at SNR =-10dB; if the false alarm possibility increases the detection possibility improves at higher which results in increasing the sensing accuracy in energy spotting method and by utilizing the optimum threshold we have possibility to produce fair detection probability.

Table 1: Probability of detection vs Probability of false alarm at SNR= -10dB

S.No	Probability of detection	Probability of false alarm
1	0.83	0.1
2	0.84	0.2
3	0.86	0.3
4	0.88	0.4
5	0.91	0.5
6	0.94	0.6
7	0.96	0.7
8	0.97	0.8
9	0.98	0.9

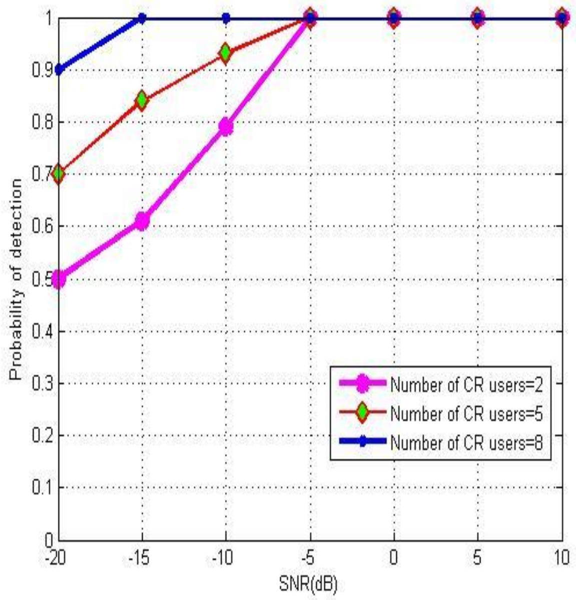

Fig 3: Probability of detection at Different SNR

In above figure we plotted the detection possibility for distinct SNR for different cognitive users. The result is plotted for sum of users k=2,5 and 8; as we can observe for sum of users k=5 the detection probability is 0.92 at SNR= -10dB and at SNR=-5dB the probability of detection reaches the maximal value of 1; for k=8, the detection possibility reaches 1 at SNR=-5dB;b y this we can observe that when the sum of users increases the detection possibility increases.

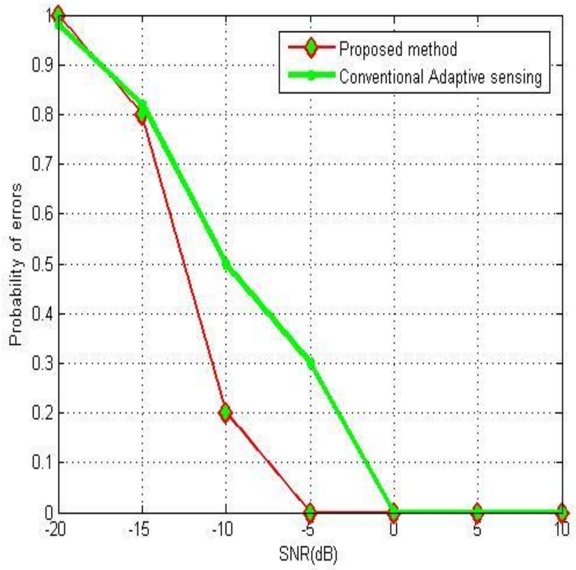

Fig 4: Comparison of error possibility of conventional adaptive scheme with proposed scheme

The fig 4 represents the error probability decreases with in SNR range, in proposed model the possibility of error decreases to 0.2 at SNR=-10dB and error possibility is 0 at SNR=-5 dB. By comparing with conventional model the proposed model as better detection which may lead to decline sensing errors that increases the accuracy of sensing.

VII. CONCLUSION

The energy spotting approach is conferred to improve the detection accuracy that can lead to decrease the error possibility. For the local sensing the design is suitable that enhances the detection to increase the accuracy, in proposed method it is conventionally proved that the suggested scheme of detection mechanism improves the detection performance and also declines the interference among the CR primary and secondary users, and this approaches were carried out in different environments of fading.

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