Enhanced energy Detection based spectrum sensing for Cognitive Radios

T V N L Aswini, Padma Raju. K, Leela Kumari. B

Abstract*: *Wireless communications play an important role in present days growth of wireless networks which shows the association of mobile systems and internet technologies like IoT in the future which offers various number of services. Different networks with different qualities of networks are available for various areas. In some areas, there will be no connectivity whereas some areas deliver poor connectivity to the network. Hence the spectrum may not be always in use which results in spectral inefficiency. Radio spectrum in the advancement of technology gave an effective solution in terms as Cognitive Radio which manages the spectrum by sensing and sharing effectively. Of all these, sensing plays an important role which detects the vacant band within less time. Energy Detector is one of the sensing methods became more popular because of its low complexity and moderate sensing time. The proposed method is an improvement of Energy Detector with an arbitrary power operation. This reduces the sensing time and improves the recovery performance even at low SNR. The simulation results have proved this for different SNRs ranging from -15db to 5db. The probability of detection was also increased.

Keywords*: *Spectrum Sensing, Cognitive Radio, Threshold, Sensing Gain.

I. INTRODUCTION

Now a day wireless communications became more important and well known even to a lame man.

A. Urge of Spectrum

The transmission of data between one to another network that are not linked by any type of cables is called Wireless communication. Radio Waves are mostly used in these wireless technologies. It is used in applications such as mobiles, including two- way radios, personal digital assistants (PDAs) and wireless networking. The optimized use of spectrum is called Spectrum efficiency. By this, the maximum data can be transmitted with few errors in transmission. Increase in spectrum users leads to trouble in spectrum management. The spectrum consists of different frequency bands, each has a specific application. Based on the application characteristics and its users each frequency band is assigned [1]. Some applications uses wider band than others. In addition to these, "guard bands" are required to maintain the interference between applications to a minimum.

Cognitive Radio (CR) is an adaptive, intelligent radio and network technology which detects the available channels automatically. It also changes transmission parameters like modulation, output power etc., to improve operating behavior of a radio and to run concurrently. In radio receiver and communications technology Cognitive radio (CR) is one of the new developments that is emerging. CR is followed by the Software Defined Radio (SDR) that slowly becoming useful, and it shows a great development in radio communications systems [2]. Communities in rural and under privilege, there is an immediate need to supply broadband Internet services. TV white space (TVWS) is a frequency band used to observed ample quantity of white spaces available and also it is also called as TV band, In order to assure quality services and spectrum availability to authorized users of the spectrum, the unauthorized users who had occupied left out frequency bands have to leave as soon as main users return. The arena of cognitive radio handles this through perception of channels and by geo-location databases which stores the actual information about handiness of channel and its utilization. Cognitive radio is an instrument that is known of its radio environments such as spectrum accessibility, signal capability, channel evaluate methods, transfer of protocols and spectrum principals and is capable of choosing the right parameters at right time to take part in radio communication.

B. Spectrum sensing

Cognitive Radio is an emerging technology which overcomes the spectrum congestion and low usage of licensed spectrum. It senses the spectrum and takes decision intelligently to allot the secondary user [8],[9]. As depicted in Fig. 1, the unused spectrum or spectrum hole is detected by cognitive radio transceiver, and it will also determine the computing method of it (i.e. power transmission and time of approach) without disturbing the transmission of authorized user's band. Spectrum sensing determines spectrum status and the activity of authorized users by recognizing the target frequency band time to time [4]. Spectrum management holds the finest accessible frequencies to meet the necessities of users for communication. To meet the parameters like QoS, the CRs select the empty band of total spectrum. So the purpose of spectrum management is significant for the CRs. Spectrum mobility is similar to the distinction of band of operating frequency of CR users. If an authorized user accesses a radio channel which is not free i.e., presently under an unauthorized user,

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then the idle spectrum can be changed to active spectrum by an unlicensed user. In order to fit the original operating frequency band, a special protocol stacks are aligned during spectrum hand-off. Since the available spectrum holes are used by number of secondary users, cognitive radio transfers data efficiently [3] and also distribute the accessible spectrum with different primary and secondary users.

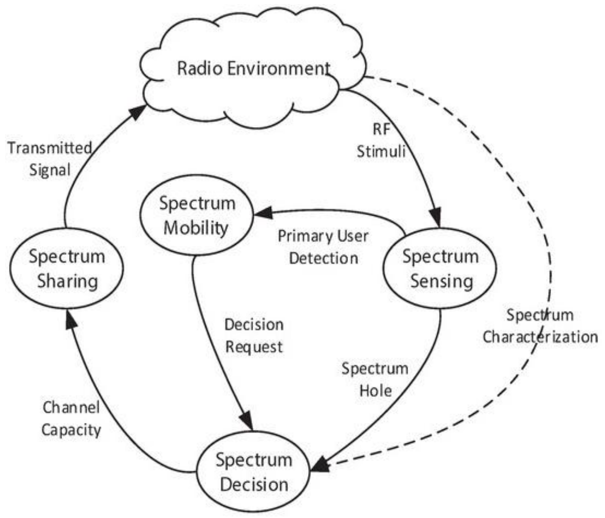

Fig. 1.Cognitive Radio Cycle.

II. SENSING TECHNIQUES

In order to use licensed spectrum effectively, CR is fixed in a wireless sensor. Sensing accuracy of SUs gives the intervention of unauthorized users to authorized users. If SUs can signifies the channels with high veracity, disturbance with the PU decreases. The tradeoff between the perception delay and sensing accuracy depends on sensing technique. Fig. 2 shows the comparison of spectrum sensing techniques.

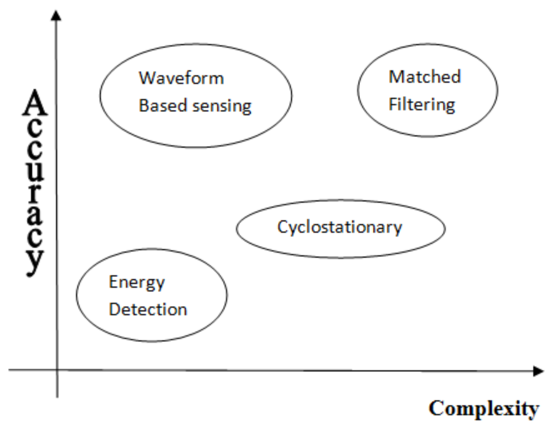

Fig. 2. Comparison of Spectrum Sensing Techniques

In order to use licensed spectrum effectively, CR is fixed in a wireless sensor. Sensing accuracy of SUs gives the intervention of unauthorized users to authorized users. If SUs can signifies the channels with high veracity, disturbance with the PU decreases. The tradeoff between the perception delay and sensing accuracy depends on sensing technique. Figure 2 shows the comparison of spectrum sensing techniques.

- *Positioning Figures and Tables:* It is the usual way for spectrum identification because of its few mathematical calculations and less difficulty in execution. This method is also known as radiometry or periodogram [5].
- *Matched Filtering Method*: In a short duration matched filter method probably achieves higher detection, compared to other methods that are similarly based on prior information. Hence, this method is considered as the best sensing method.
- *Cyclostationary Feature Detection Method*: In this method the detection algorithms can separate the noise from main user's signals and this method is used to detect transmission of data by primary users making use of the received signals given by cyclostationarity features [7].
- *Waveform Based Sensing Method*: In wireless systems, to serve the synchronization for different uses known patterns are usually utilized which includes preambles, regularly transmitted pilot patterns, midambles spreading sequences etc. It requires short duration for measuring.

If the information about the PU is unknown in the cognitive radio, a commonly used method for detecting the PUs is energy detection. The signal is recovered and controlled by signals from the upper layers to detect a specific data transmission B. Firstly, the noise is rejected by filtering the received signal $x(t)$ with the unwanted signals. Next, by sampling and quantizing the required signal by means of A/D converter, the required signal is converted to digital form. Then, the energy of the signal is measured by square-law device followed by an integrator. The presence/absence of the primary user is determined by comparing the prefixed threshold value with the integrator output.

III. METHODOLOGY

Let the input signal $x(t)$ is a multiband signal which is amplitude modulated and transmitted through the channel. The noise like additive white Gaussian noise (awgn) is combined with the signal in the channel. Now the received signal from the detector is noisy.

Energy Detector is a general method of spectrum sensing techniques used at the receiver. It is popularly used because of its low cost and low complexity performance. Another advantage is prior information of the primary user is not necessary [3]. The energy detector provides PSD for the received signal which is compared with the fixed threshold value to detect the primary signal. This is a familiar method due to its simplistic nature. The main disadvantage is it does not give exact values i.e., veracity is low. It cannot differentiate the main signal from the secondary signal. Under low SNR this technique cannot be used to discover spread spectrum signals and has poor execution.

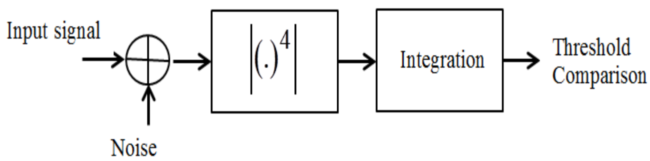

Fig. 3. Proposed Enhanced Energy Detector

The system is improved by using an alternative form of fourth power of magnitude in place of squaring the power which provides the energy enhancement was achieved as shown in Fig. 3. The energy detector provides PSD for the received signal which is compared with the threshold value to detect the primary signal.

The test statistic of the analog energy detector is given in (1) as

$$Y = \frac{1}{N}\sum_{n=0}^{N} \left| s(n) \right|^2 \quad (1)$$

The detected energy is compared with prefixed threshold value to check the true hypothesis as given in Eq. 2.

$$Y > \lambda : H_1 ; Y < \lambda : H_0 \quad (2)$$

H_0 =Absence of the user; H_1 = Availability of user

The presence or the absence of the PU is analyzed by different performance metrics such as probability of detection (*Pd*), [6]. [10] probability of false alarm (*Pf*) and Probability of missing detection (*Pm*). These probabilities show the recovery performance of the detector and are given as:

- False alarm probability(P_f):The probability of presence of the signal for H_0 =1, i.e., P_f . Equation 3 achieves false alarm gives unnoticed spectrum holes [4]. Hence, it indicates that the spectrum is less used for increase in P_f .

$$P_f \approx Q\left(\frac{\lambda - N\left(2\sigma_w^2\right)}{\sqrt{N}\left(2\sigma_w^2\right)} \right) \quad (3)$$

- *Detection probability* (P_d):The probability of presence of the signal for H_1 =1, i.e., P_d as given in (3). This shows the usage of spectrum. A higher P_d (or lower P_{md}) and lower P_f are desired for achieving dependability and efficiency of spectrum sensing technique used in cognitive radio.

$$P_d \approx Q\left(\frac{\lambda - N\left(2\sigma_w^2\right)(1+\gamma)}{\sqrt{N(1+2\gamma)}\left(2\sigma_w^2\right)} \right) \quad (4)$$

where λ, the threshold and γ is the SNR ranging from -20 dB to 15dB. Also N indicates number of samples with variance $2\sigma_w^2$=1.

- *Missed-detection probability* (P_{md}): The probability of absence of the signal when H_1=1, i.e., $P_{md} = 1 - P_d$. This is almost equal to detecting the spectrum holes when there are no holes. In this context, increase in P_{md} produces an unexpected interference to primary users.

The proposed enhanced energy detector is evaluated with the above performance metrics and compared with conventional detector. Enhanced energy detector proved its performance which is described in the next section.

IV. SIMULATION RESULTS

Most of electromagnetic spectrum is unused. In this context a primary signal of 200 KHz is detected using Energy detector method. The Power spectral density of the received signal is found and compared with the threshold value to sense the primary signal. This is shown using simulation results in Fig.4.

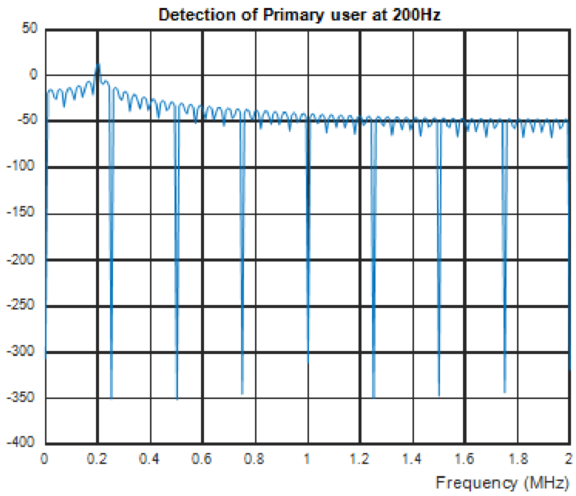

Fig. 4. Power spectral Density of Energy Detector

The performance of the Enhanced Energy Detector is compared with the conventional detector as depicted in Fig.5. The probability of detection of enhanced ED is improved even at low SNR. 80% of the recovery is possible at SNR of -1dB for enhanced ED but it is only 40% recovery for conventional ED.

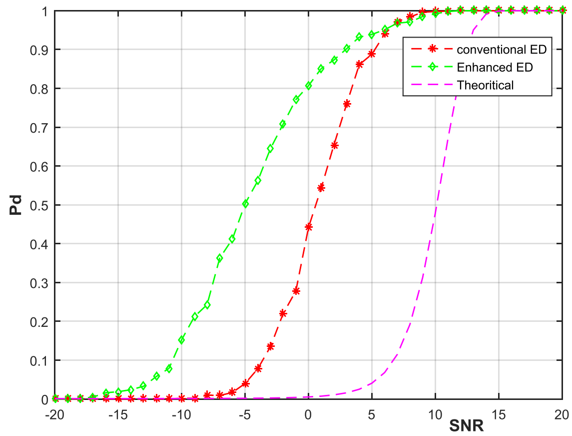

Fig. 5. Comparision of proposed method in terms of pd vs SNR

If the probability of missed-detection (*Pm*) decreases as SNR increases, it is referred as sensing gain. Fig.6 depicts the high sensing gain for enhanced ED. Also it can be observed that there is a large slope at high SNR. This indicates that only the actual spectrum holes are detected.

Channel gain depends on the received SNR. In cognitive radio, the gain almost depends on probability of detection P_d . Fig.7 shows the exact P_f and P_d of the test statistic for the input signal. This ROC curves depicts the recovery performance of both the energy detectors.

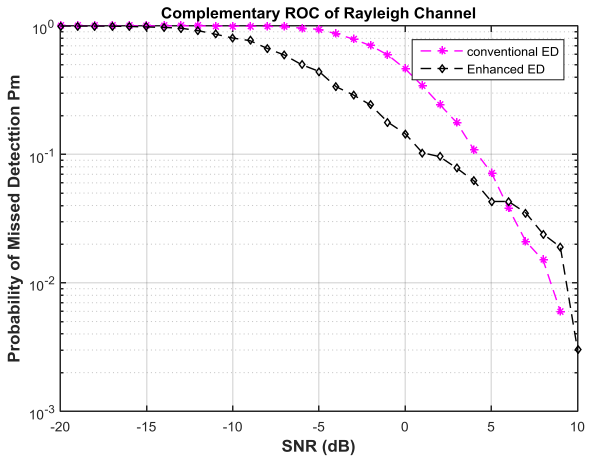

Fig. 6. Probability of Miss Detection (Pm) vs SNR showing high Sensing Gain

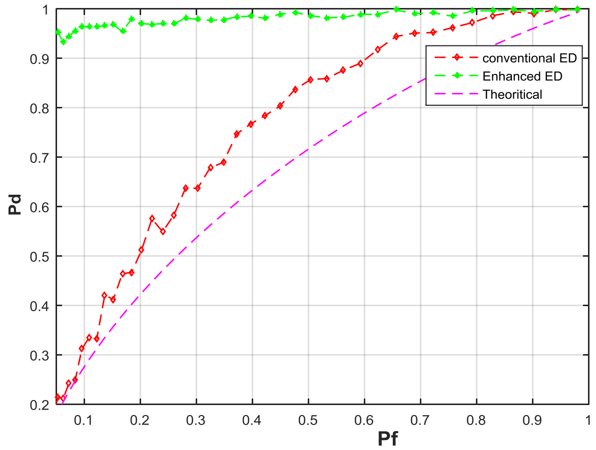

Fig. 7. Probability of Detection (Pd) vs Probability of False Alarm(Pf)

We can say that the probability of detection for Enhanced ED is best as 90% of recovery is performed for $P_f > 0.01$ indicates good probability. As P_m is less for Enhanced ED shown in Fig.8 indicates improvement in detection.

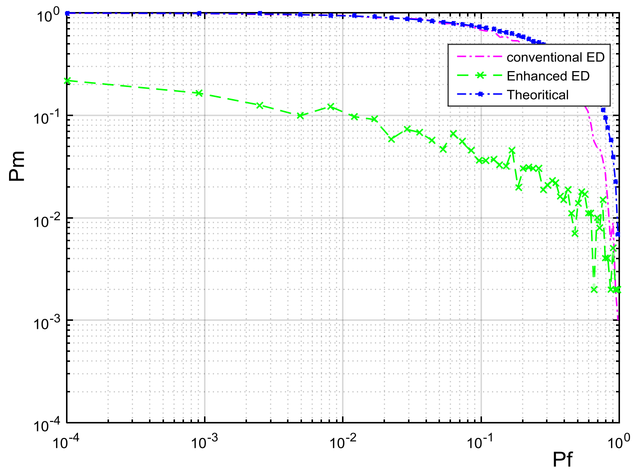

Fig. 8. Probability of Miss Detection (Pm) vs Probability of False Alarm(Pf)

The plot between probability of detection and signal to noise ratio at different threshold (pf) indicates sensing of the spectrum. Another way of calculating sensing gain is shown using Fig.9 and Fig.10. From these figures, it is clear that probability of miss detection has a good fall for enhanced ED with that of conventional ED and shown for various SNRs. Particularly at low SNR enhanced ED proved its performance.

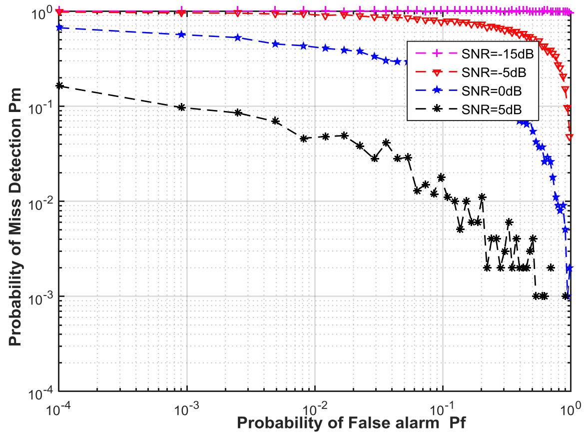

Fig. 9. The average missed-detection probability with average SNR for conventional ED

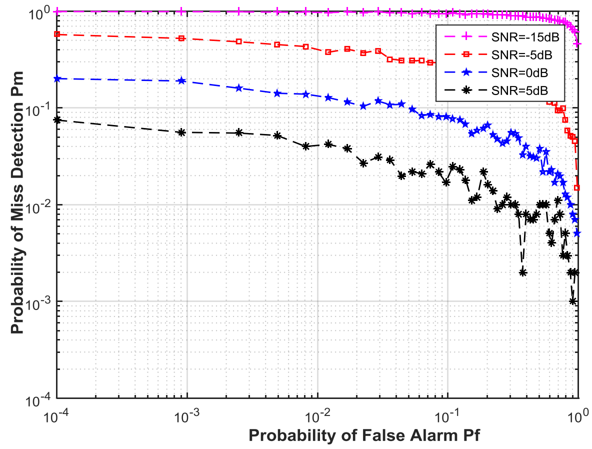

Fig. 10. The average missed-detection probability with average SNR for Enhanced ED

V. CONCLUSION

Cognitive radio is promising technology for improving the spectrum scarcity for wireless applications. It has its services extended to rural applications as well. Of all the duties of CR, sensing plays an important role. Energy detection is the well – known technique for narrow band spectrum sensing. It is used for any applications which provide the Probability of false alarm is inversely proportional to the SNR. PFA is high for low SNR rates and vice versa. The proposed enhanced energy detector proved its performance than conventional detector. The recovery performance of energy detector is improved by fourth power of arbitrary operation. Simulation results has proved the improvement in the detection performance and sensing gain at different SNRs. Even at low SNR, it proved its recovery performance.

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