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Analysis of Hybrid Model based on Energy and Cyclostationary Spectrum Sensing Techniques

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Abstract- Spectrum sensing is the essential requirement of Cognitive Radio (CR) which enables to find the spectrum which is free to be used by the secondary users when the primary users are not using it. Cognitive Radio is a technology which is designed to help the unlicensed users for utilizing available certified bandwidth. It is the solution for solving the inefficiency problem of the radio spectrum. There are some techniques such as the matched filter detection , energy detection , cyclostationary feature detection for sensing spectrum in case of Cognitive Radio.

In this paper the analysis of the two sensing techniques - Energy detection and Cyclostationary feature detection has been done and from this Hybrid model is purposed to make the proper utilization of spectrum . The efficiency of the network is enhanced with the hybrid technique. The output obtained from the proposed methodology has been compared with previous techniques for the improved performance of energy consumption and throughput of the network. The results are implemented by simulating the graphs using MATLAB on the basis of probability of false detection and probability of correct detection.

Keywords - Cognitive Radio (CR), Cyclostationary feature detection, Energy feature detection , Hybrid model, Primary User(PU), Secondary User(SU), Spectrum Sensing , Transmitter detection techniques.

1 INTRODUCTION

With the increasing demand of wireless users in personal, commercial, and governmental sectors efficient spectrum utilization has become a prime key. High data rates are potential requirement for the wireless communication system. In order to increase data rate more spectrum is required. Cognitive radio is a technology of the wireless communication for solving the problems occurring while sensing for the radio spectrum system .

To make the wireless communication system intelligent, cognitive radio is defined as a radio that is aware of its environment and it selects parameters like free channels, type of data to be transmitted and the type of modulation scheme that may be used and implement decisions about its behavior.[1][16].

Utilization of the frequency band can be improved by introducing secondary user (SU) which will continuously detect the presence of PU called spectrum sensing, and utilize licensed band when PU is absent. Secondary user (SU) will transmit their information without disrupting licensed user (PU), such an opportunity is called spectrum hole and the device that detect these holes are called Cognitive Radio (CR).

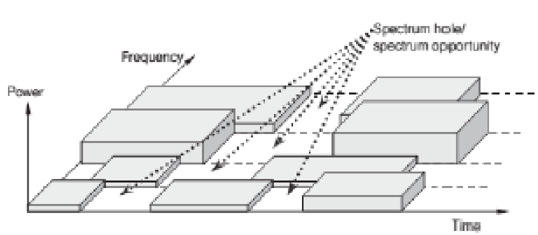

Fig1: Spectrum utilization[17]

Following are the operations of CR – to identify the spectrum, detection of the spectrum , tracking and the spectrum exploitation. By sensing to the environment, a cognitive radio is able to recognize free spectrum that can be used by secondary users without causing interference to the primary users[2].

There are many techniques to sense the spectrum the common sensing algorithms are the energy feature detection, the coherent based detection, cyclostationary feature detection, matched filter detection.

The purpose of this paper is to compare the results of different research papers based on variety of the performance metrics like error, accuracy, complication, the robustness and the design choices[3]. In this paper the analysis of the two spectrum sensing techniques – the energy detection and the cyclostationary feature detection has been done and a hybrid model for transmitter based spectrum sensing is investigated and analysed .

2. SPECTRUM SENSING

Spectrum Sensing is defined as the ability of the Cognitive Radio to allocate the unused licensed spectrum to the secondary users without causing interference to the primary users(PU)[4].Cognitive Radio users must be able to identify spectrum bands free for the transmission of signal. Detection of the spectrum is categorized into two types**:** Cooperative and Non Cooperative Dectection

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A.Cooperative Detection :

Within cooperative spectrum sensing system the sensing will be undertaken by the number of different radios within the network and the information of signal will be received by central station from different radios in network.

B.Non Cooperative Detection:

In case of Non cooperative spectrum sensing each cognitive radio acts at its own , to carry detection of unused frequency band and for the occupancy of spectrum. It is based on the detection of signal from the primary user. For this detection, three methods are explained for the efficient utilization of the spectrum in the subsections.

Analytical Model : Spectrum sensing can be thought of an identification problem, popularly known as the hypothesis test.[5] The sensing algorithm has to select one of the following two hypotheses:-

H1: x(t)= s (t) + n(t) (i)

H0 : x(t) = n(t) (ii)

H0 hypothesis tells absence of primary signals in the spectrum and presence of only noise . So it can be allotted to the secondary users (SUs).

H1 hypothesis tells that primary signals are present in spectrum along with presence of noise .So it cannot be allotted to the secondary users because it will cause harmful interference to the PUs.

S(t) is the signal transmitted by the PUs.

X(t) is the signal received by the SUs.

N (t) is known as the AWGN (Additive White Gaussian noise).

3. SPECTRUM SENSING ALGORITHMS

Based upon the cooperative and non cooperative detection methods spectrum sensing algorithms are classified into subsections .Here we will discuss three methods of Non cooperative detection .

- Energy Detection
- Cyclostationary Detection
- Matched filter Detection

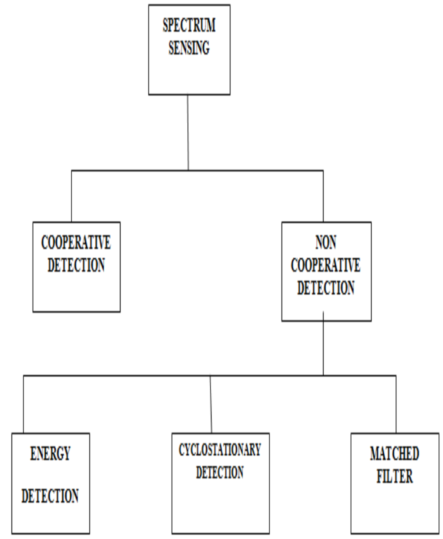

Fig2: Spectrum Sensing Techniques

A.Energy Detection: Energy detection is a non-coherent method of spectrum sensing used in detecting the presence of primary signal in the spectrum that is being sensed[7]. Energy detection is a mechanism that uses energy detector to detect the signal to specify the absence or presence of the signal in the band. In this method the received signal energy is compared with predetermined threshold to make decision about the spectrum . It is detection method which does not require knowledge of input signal therefore it is commonly used and this detection is not much complicated.

B.Cyclostationary Detection: Cyclostationary detection technique is best used when we have no prior knowledge about licensed signal . A signal is said to be a cyclostationary if the mean and autocorrelation of a cyclostationary are a periodic function [8]. It performs better than energy detector because of its ability of rejectance of noise.It can be used for the detection of weak signal at low SNR.

C.Matched Filter Detection : Matched Filter is an optimal detection scheme but it requires prior information about PU the signal. It is designed to maximize the output SNR for given input signal.

In this method ,the operation convolution of the unknown signal is done by using the filter whose impulse response is time shifted and mirrored with respect to the desired signal. Advantage of matched filter is that it requires less sensing time to achieve a good detection due to coherent detection and even work with very low SNR[9].

Table1:Comparison of Advantages and Disadvantages of Sensing Algorithm

Algorithm	Advantages	Disadvantages
Energy detection	• No priori information is required. • Computational complexity is low. • It is easy to implement.	• It does not clearly distinguish between primary signal and noise. • The require time to achieve the desire probability of the detection may be higher.
Cyclostationary detection	• Valid in slow SNR region. • Robust against interference.	• It requires partial priori information. • High computational complexity. • Long Sensing Time.

Table2: Metric comparison of the various spectrum sensing techniques[19]

Metric	Energy Detector	Matched Filter	Cyclostationary	Hybrid
Sensing Time	Low	High	High	Less
Detection and Accuracy	Good performance at only high SNRs	Best performance at all SNRs if Rx have sufficient knowledge of Tx	Good performance at all SNRs	Good performance at all SNRs
Robustness	Does not require any prior information of TX signal	Requires near perfect Tx information at Rx	Rx must know Tx signal fundamental frequency	Requires Tx signal to contain pilot symbols
Compexity	Low computation and implementation complexity	High complexity	Medium complexity	Medium complexity
Prior information required	Low	High	Low	Low
Design choices	Difficult to choose decision threshold	Tx characteristics can be chosen to improve accuracy	Cyclostationary can be intentionally induced to improve accuracy	Pilot symbols can be increased to improve the accuracy

4 . RELATED WORK

In this section work that has been done over the past years in the field of cognitive radios for spectrum sensing has been discussed [10] [11][12][13].

Table3: Related work done

Name of Author/year	Paper Title	Remarks
Minho Jo et al. [2013]	Selfish Attacks and Detection in Cognitive Radio Ad-Hoc Networks	efficient selfish cognitive radio attack detection technique,which is known COOPON identified . COOPON may be less reliable in case of more than one neighbouring selfish node .
YTawk et al. [2014]	Performance Analysis of a Cognitive Radio Network with a Buffered Relay	The operation of CR is mainly divided into two main tasks - spectrum identification , spectrum decision. A cognitive-radio engine manages all functions intoasingle cognitive radio device.
Yuli Yang, Aissa, et al.[2014]	Spectrum Band Selection in Delay-QoS Constrained Cognitive Radio Networks	CR network with the multiple spectrum bands available for SUs. Active spectrum band selection which depends on the highest and the lowest secondary channel power gain.
Nhan Nguyen Thanh et al.[2015]	Surveillance Strategies against Primary User Emulation Attack in Cognitive Radio Networks	PUE attack is a serious security problem which is investigated in CR. PUE attackers: selfish one, malicious , mixed one exists.

5. PROPOSED WORK DONE

From our literature review we conclude that out of the various spectrum sensing techniques available in Cognitive Radio, important ones are Energy based detection and the Cyclostationary based detection.[14] But there are a several limitations of this techniques. The performance of the Energy detection method is poor at low SNR which causes chances of the false detection. The drawback of cyclostationary method is the complexity of the calculations and more sensing time required.To overcome flaws of the energy and the cyclostationary detection techniques, a new Hybrid spectrum sensing technique is proposed for the transmitter based spectrum sensing to reduce the power consumption and sensing time[15]

6. METHODOLOGY

Hybrid model is a fusion of two techniques (energy detection method and the cyclostationary detection)[16]

Step1: Initialisation of the system network .
Step2: First of all energy detection is done
Step3: In energy based detection the number of nodes are deployed and source and sink nodes are generated.
Step4: The energy feature and energy status are checked **.**
If both energy feature and energy status are in favour slot is free it is true detection.

If energy feature is in favor but energy status is not in favor then it is called false detection, so check status on basis of cyclostationary detection .

If cyclostationary feature and cyclostationary status both are in favor band is free. If cyclostationary feature is in favour and cyclostationary status not in favour . Hence we cannot shift band because there is no availability of the free band .

Step 5: if Distance>200 and SNR<0.50 then SNR and Distance Value are not in favour then it will move to the case of cyclostationary detector.

Step 6: In cyclostationary based detection number of nodes are deployed and source and sink nodes generated.

Step7: If Distance<200 and SNR>0.50 or if Distance>200 and SNR>0.50 or if Distance<200 and SNR<0.50 then we use previous method of shifting and check conditions for the various number of rounds and wait for next round if satisfactory conditions are not met.

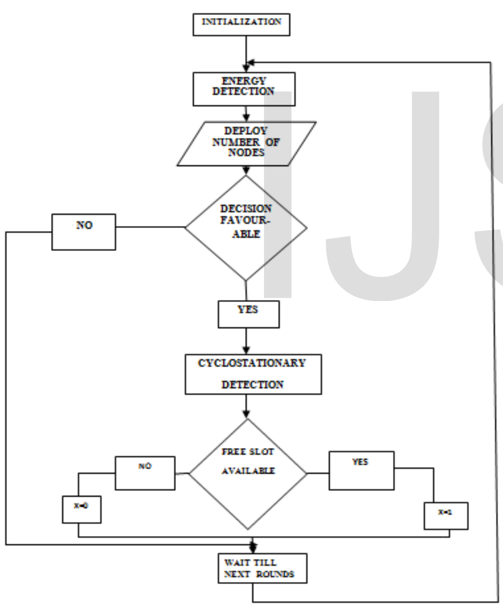

Fig3: Flowchart of Methodology[16]

Table4: Simulation Parameters

No. Item	Item Description Parameter	Item Description Value
1	Simulation Tool	Matlab
2	Technology	Cognitive Radio
3	Spectrum Sensing Type	Non cooperative detection
4	Methodology used	Energy and Cyclostationary feature
5	Proposed method	Hybrid Model
6	Rounds of communicatio	100
7	Number of bands	2
8	No. of nodes	300
9	Users	Primary and Secondary users
10	Probability status	False detection and correct detection

7. RESULTS AND SIMULATIONS

The proposed methodology outputs has been compared with previous techniques. Graphs are shown on the bases of two parameters probability of the false detection and probability of correct detection.

The graphs plotted using the Probability of a False detection technique shows us the probability which is dependent on the "FDet"value and for the correct detection "Det"value.The values are calculated during simulation for 100 number of rounds of communication.

Probability of false and the correct detection using previous technique: In previous technique of cognitive radio the detection of the free band is done on the basis of the energy feature only.

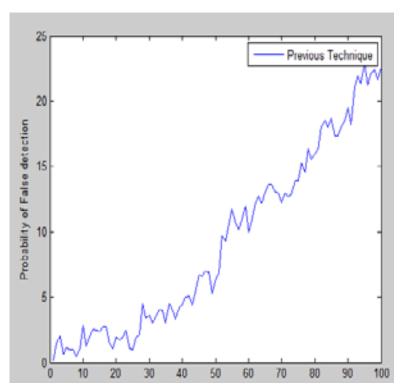

Fig4: Probability of False detection versus Rounds for previous technique

From the graph obtained , for the Rounds 1 to 10 the value of the probability for false detection is 1.4594 1.9931 1.8435 2.9345 2.5211 2.5908 3.5942 2.1108 3.6032 3.5969

For the Rounds 91 to 100 the value of probability for false detection is 11.3965 11.7933 11.9365 13.5551 14.1310 15.4946 15.5502 15.9342 16.4166 15.2049

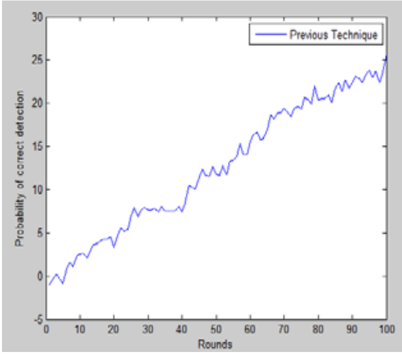

Fig5: Probability of correct detection versus Rounds for previous technique

From the graph obtained , for the Rounds 1 to10 the value of probability for correct detection is -0.2279 -0.6179 -0.8226 -1.9414 0.8304 0.9031 0.4296 0.3611 2.1872 2.9199

For the Rounds 91 to 100 the value of probability for correct detection is 26.8339 27.1014 27.6381 26.2544 27.2909 26.3845 26.8282 27.6577 27.4206 26.8286

Probability of false and the correct detection using hybrid technique : In hybrid technique of cognitive radio the detection of free band is done on the basis of the energy feature as well as the cyclostationary feature.

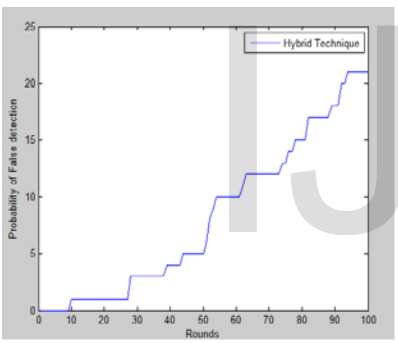

Fig6: Probability of False detection versus Rounds for hybrid technique

From the graph obtained , for the Rounds 1 to 10 the value of probability for the false detection is 1 1 1 2 2 2 2 2 2 2

For the Rounds 91 to 100 the value of probability for false detection is 11 11 11 12 14 14 14 15 15 15

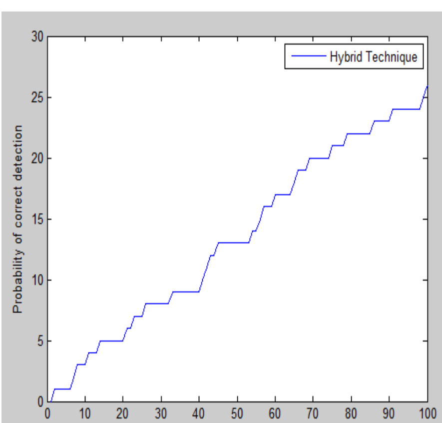

Fig 7: Probability of correct detection versus Rounds for hybrid technique

From the graph obtained ,for the Rounds 1 to 10 the value of probability for correct detection is 0 0 0 0 1 1 1 2 3 3

For the Rounds 91 to100 the value of probability for correct detection is 28 28 28 28 28 28 28 28 28 28

Probability of false detection and the correct detection the hybrid technique and the previous technique: In these two graphs comparison of both technique previous and hybrid is shown for false detection as well as correct detection.

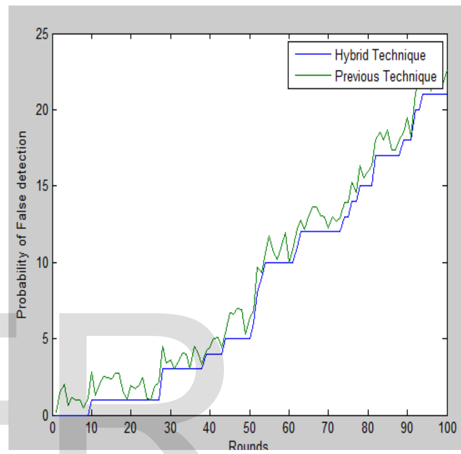

Fig8: Comparison of Probability of false detection versus Rounds for hybrid and previous technique

The Fig8. shows the plot between previous and hybrid technique on the bases of probability of False detection. In this graph we can clearly see the curve of hybrid technique lies below previous technique.

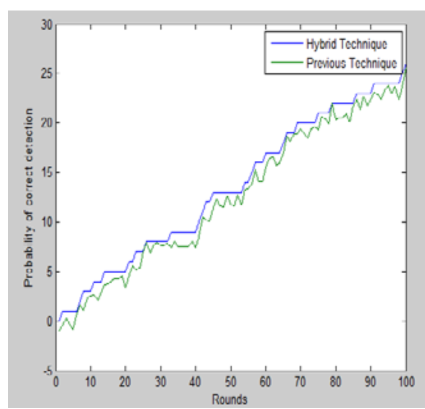

Fig9. Comparison of probability of correct detection versus Rounds for hybrid and previous technique.

The Fig 9.shows plot between hybrid and previous techniques on the bases of Probability of correct detection. In this graph we can clearly see curve of hybrid lies above the previous techniques curve which proves the robustness of the system in terms of correct detection. While correct detection the hybrid system performs better than the previous techniques . Also if we look at the stability in the curve, although for short periods is better in case of hybrid.

Energy and Throughput Graphs:

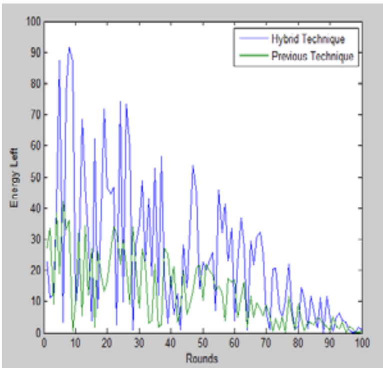

Fig10: Energy Graph

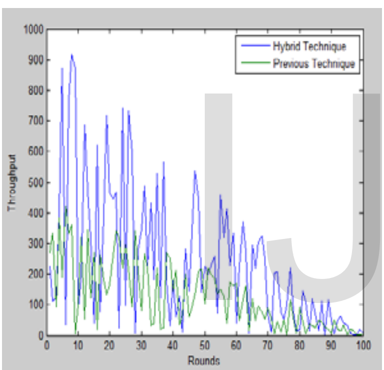

Fig.11:Throughput Graph

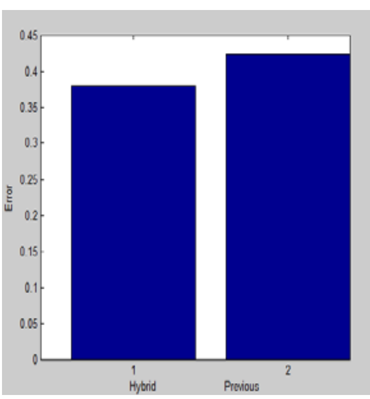

Fig.12:Error

8. CALCULATIONS:

Variables for Calculation:
Det= 0; correct detection
FDet= 0; false detection

On the basis of cases formed before , the variables of the True detection and the False detection are incremented and graphs are plotted.
Det=Det+1
FDet=FDet+1

ENERGY
E1(i)=energy(i)*rand(1)
E2(i)=energy(i)*rand(1)/2

THROUGHPUT
Throughput1=(E1)*10
Throughput2=(E2)*10

Table5: Comparison of Result Analysis

Parameter	Previous	Proposed
Probability of false detection	15.2	15
Probability of correct detection	26.8286	28
Energy	0.3769	0.9914
Throughput	3.7691	9.9135
Error	0.4227	0.3791

9. CONCLUSION

Cognitive Radio technology can intelligently sense an unused spectrum that can be used by secondary users without creating any harmful interference to licenced users.The analysis of the two sensing techniques – energy detection and cyclostationary feature detection has been done.But in Energy detection method the accuracy of correct detection is less and the decreased SNR causes a lot of problems. From these observations ,Hybrid model is purposed to solve the inefficiency problem of spectrum .In this paper we have formulated the results on the basis of the probability of false detection and probability of the correct detection .With this strategy we can reduce computational power consumption , sensing time and improvement in Throughput and Error .

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