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Hybrid Spectrum Sensing Method for Cognitive Radio

A. S. Khobragade[1], R. D. Raut[2]
[1]Department of Electronics Engineering, Nagpur University, India
[2]Shri Ramdeobaba College of Engineering and Management Nagpur University, India

Article Info	ABSTRACT
	With exponential rise in the internet applications and wireless communications, higher and efficient data transfer rates are required. Hence proper and effective spectrum is the need of the hour, As spectrum demand increases there are limited number of bands available to send and receive the data. Optimizing the use of these bands efficiently is one of the tedious tasks. Various techniques are used to send the data at same time, but for that we have to know which bands are free before sending the data. For this purpose various spectrum sensing approaches came with variety of solutions. In this paper the sensing problem is tackled with the use of hybrid spectrum sensing method, This new networking paradox uses the Centralized concept of spectrum sensing and creates one of the most trusted spectrums sensing mechanism. This proposed technique is simulated using MATLAB software.This paper also provides comparative study of various spectrum sensing methodologies.

Corresponding Author:

Awani S. Khobragade,
Department of Electronics Engineering,
Nagpur University,
42 Shukhsawarup Apartment, Nelco society, Subhashnagar, Nagpur,
Maharashtra 440022, India.
Email: awanigaidhane@yahoo.co.in

1.   INTRODUCTION

Due to increase in wireless devices and applications, the available electromagnetic radio spectrum is getting crowded day by day. It has been also noticed that, because of the static allocation policy of the spectrum, the allocated spectrum is under-utilized. The unutilized part of the spectrum results in 'Spectrum holes' or 'White Spaces'.The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically[1]-[4]. To deploy new services or to enhance existing ones ie. Dynamic spectrum access is proposed to solve these current spectrum inefficiency problems as shown in Figure 1.

Cognitive Radio (CR) using spectrum sensing technique can be used to solve the issues of spectrum underutilization. In order to supply extremely reliable communication for all secondary users of the network. CR is defined as "An intelligent wireless communication system that provides more efficient communication by allowing secondary users to utilize the unused spectrum segments". From the definition, the main functionalities required for the cognitive radio systems can be summarised as follows:

1. Spectrum Sensing: Sensing and monitoring the available spectrum bands reliably to detect the unused portion of the primary user spectrum.
2. Spectrum Decision: The cognitive radio can allocate a channel based on the regularly policies and spectrum sensing results.

3. Spectrum Sharing: Coordination among multiple cognitive radio users is needed to prevent the colliding in the available portion of the spectrum.
4. Spectrum Mobility: The cognitive radio user is regarded as visitor to the primary user spectrum, and a reliable communication cannot be sustained for a long time if the primary user uses the licensed spectrum frequently. Therefore, the cognitive radio system should support mobility to continue the communication in other vacant bands.
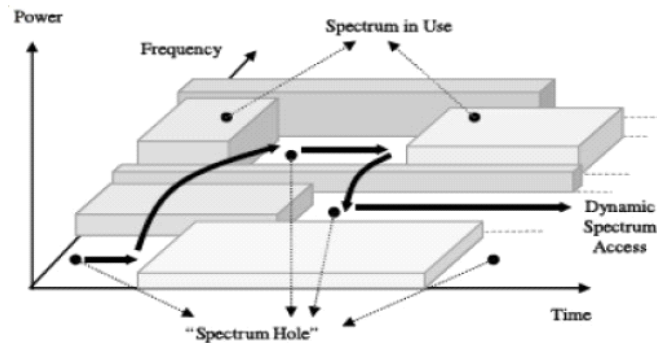

Figure 1. Illustration of spectrum white space

Figure 2.shows cognitive radio cycle consists of all the above functions, the most crucial task is to establish cognitive radio network using spectrum sensing method. The various spectrum sensing techniques broadly classified as:
a. Transmitter based detection
b. Cooperative based detection
c. Interference based detection.In this paper we discussed about hybrid spectrum sensing method which blend five different detecting methods of spectrum sensing.
To view its performance in hybrid manner. This paper is organized as follows: Section 2 Describes the hypothesis test on analytical model and system parameters Section 3 Explains Proposed system, Section 4 Implementation of Hybrid Spectrum Sensing, Section 5 Simulation Result and Discussion, Section 6 Final Conclusion, Section 7 references.
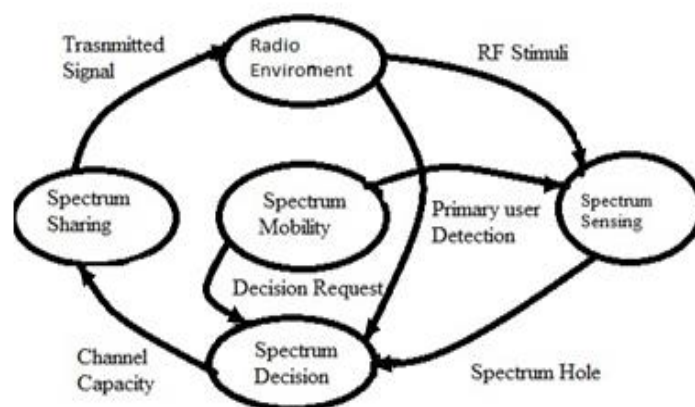

Figure 2. Cognitive Radio cycle

2. LITERATURE REVIEW
Spectrum sensing is the capability of the CR to allocate the best available ideal licensed spectrum to the secondary users (SUs) keeping in mind their Quality of services (QoS) but without disturbing the primary

or licensed users.One of the most challenging tasks in CR systems is spectrum sensing as it requires high accuracy and low complexity for dynamic spectrum access. In figure3 we observe that the spectrum sensing field, the spectrum sensing performance metric is measured between selectivity and sensitivity which are expressed in terms of levels of detection and false alarm probability. Higher detection probability ensures better primary users (PUs) protection and lower false alarm probability ensures more chances of channel utilization by secondary users(SUs). A false alarm probability of 10% and a detection probability of 90% have been regarded as the target requirements for all the sensing algorithms.
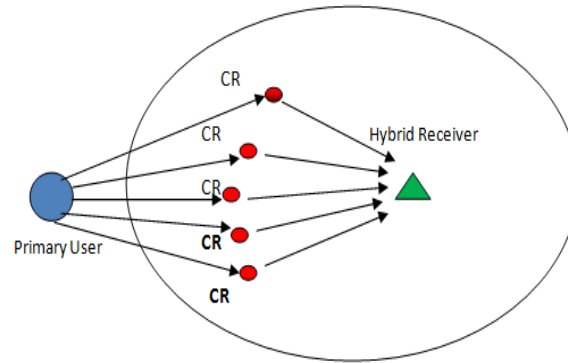

Figure 3. Hybrid Spectrum sensing structure in a cognitive radio network

2.1. Analytical Model (Two hypothesis)

Spectrum sensing is one of the most important task in the cognitive radio network. It is the first step for communication to take place that needs to be performed. Spectrum sensing is popularly known as the hypothesis test because it is thought as an identification processes. The Spectrum sensing is a test of the following two hypotheses:

H0:x(t)=n(t)

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

s (t)-The signal that is transmitted by the PUs.
x (t)-The signal which is received by the SUs.
n(t)-Known as the AWGN (Additive White Gaussian noise).

H0 hypothesis is used to tell that no primary signals are present in the spectrum and only noise is present. And hence it is allotted to the secondary users. H1 hypothesis is used to tell that primary signals are present in the spectrum along with the noise. And hence it is not allotted to the secondary users else there will be harmful interference to the primary users.

2.2. System Parameters

Our fundamental objective of spectrum sensing is to use the system for decision making process to check the availability of the spectrum holes, record the data and then carry out simulation to analyze the stored data:

2.2.1. Probability of false alarm (P_{fa}):

Probability of false alarm occurs when no primary signals are present in the spectrum but we get the idea that they are present and hence do not allocate bands to the SUs. It occurs when only noise is present in the channel and energy of noise level exceed the predefined threshold value and hence the presence of primary user is detected by the decision making device. This is false representation and should be minimized.

$$P_{FA} = \int_{V_{TH}}^{\infty} \frac{1}{\sqrt{2\pi\sigma_n^2}} exp\left(-\frac{v^2}{2\sigma_n^2}\right) dv$$

(1)

2.2.2. Probability of missed detection (P$_m$):
　　　　Probability of missed detection occurs when primary signals are present in the spectrum but we get the idea that they are not present and hence spectrum is allocated to other SUs. This causes interference to the primary users. It happens when a signal is present in the channel and energy of signal present do not exceed the predefined threshold value and hence the presence of primary users is not detected by the decision making device. This is miss condition　　and hence should be minimized. Figure 4 shows the trade-off between P$_m$ and P$_{fa}$ with respect to the threshold value:

PM= 1 – PD   (2)

$$P_D = \int_{V_{TH}}^{\infty} \frac{1}{\sqrt{2\pi\sigma_n^2}} exp\left(-\frac{v^2 + V_0^2}{2\sigma_n^2}\right) dv$$
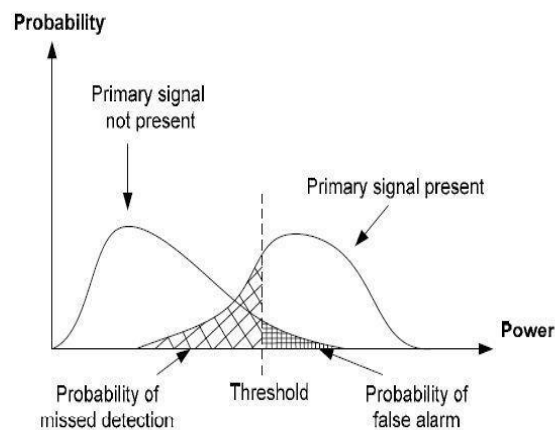
(3)

Figure 4. PDFs for Hypothesis Test Model

In the above Figure 4, we observe that threshold value decrease with the decrease probability of missed detection would increase the probability of false alarm and increasing the threshold value to decrease the probability of false alarm would increase the probability of missed detection. Since both are unwanted and both can't be decreased simultaneously, hence trade-off between these two parameters is done and the threshold is set accordingly.

3. PROPOSED SYSTEM
　　　　To efficiently sense the spectrum, authors uses five spectrum sensing techniques and club them together to create a hybrid spectrum sensing method. This hybrid method is summarized as follows: Hybrid spectrum sensing method is based upon Centralized Coordination concept in which, an infrastructure deployment is thought for the CR users. Once CR detects the presence of a primary transmitter, it informs CR controller which can be a wired immobile device. The CR controller informs all the CR users in its range using broadcast control message.

3.1. Centralized schemes can be further classified according to their level of cooperation as:
　　a.　Partially Cooperative Scheme where network nodes cooperate only in sensing the channel. CR users independently detect the channel and inform the CR controller about it.
　　b.　Totally Cooperative Schemes where nodes cooperate in relaying each other's information in addition to cooperative sensing channel.
　　　　The proposed system consists of five spectrum sensing methods :
　　a.　Match Filter detector,
　　b.　Energy detector,
　　c.　GLRT,
　　d.　Robust Estimator Correlator and
　　e.　Temperature based detector.

These methods are explained in brief below the hybrid sensing algorithm. All these methods have their special functions to detect the spectrum whether it is free or occupied. To perform the hybrid spectrum sensing method the system will take the input as the received signal and will test this received signal on all the five detector methods , then compared the outputs with the threshold value and then finally output is declared whether the band is free or occupied.

The Algorithm is as follows:

Step 1: Take input signal.
Step 2: Give input to the Match Filter method.
Step 3: record the output.
Step 4: Repeat step 2 and step 3 for all the other 4 methods.
Step 5: if number of true results recorded divide by 5 is greater than 0.66.
Then return true
Else return False.

3.2.   The implemented sub-methods are explained as follows:
3.2.1. Match Filter

The MFB (Matched Filter Bound) is a versatile method to analysis the theoretically optimal performance of a wireless transmission system in a time-frequency variant fading channel. The effectiveness of a digital communication systems in the presence of interference is measured by the rate at which errors in the reception of the information bits are made. This is referred to as the bit error rate (BER). If the interference is assumed to be Gaussian noise, then BER is a minimum in any system in which the signal-to-noise ratio of the individual bits is a maximum. Theoretical analysis has shown that if the signal-to-noise ratio is optimized for white Gaussian noise interference, then the receiver is implemented as a "matched filter" [7]. The characteristics of matched filters can be designated by either a frequency response function or a time response function, both are related to each other by a Fourier transform operation.

In the frequency domain, the matched-filter transfer function H(f) is the complex conjugate function of the spectrum of the signal Td be processed in an optimum fashion. Thus, in general terms:

$$H(f) = 2K/NoS*(f)e^{-jwTb} \qquad (4)$$

where S*(f) is the spectrum of the input signal s(t), and Td is a delay constant required to matched filter physically realizable. The normalizing factor, 'K' and the delay constant are generally ignored in formulating the underlying significant relationship, usually expressed as :

$$H(f) = S*(f). \qquad (5)$$

The corresponding time domain relationship between the signal to be operated upon and the matched filter is obtained from the inverse Fourier transform of H(f). This leads to the result that the impulse response of the matched filter is a replica of the time inverse of the known signal function.

$$h(t) = KS(Tb-T) \qquad (6)$$

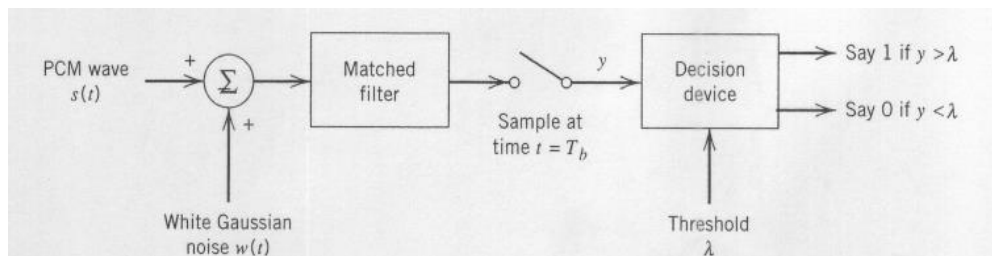

Figure 5. Matched Filter Detector

A general representation for a matched filter is illustrated in Figure 5 The filter input x(t) consists of a pulse signal s(t) corrupted by additive channel noise w(t), as shown in Figure .where Tb is an arbitrary observation interval. The pulse signal s(t) may represent a binary symbol 1 or 0 in a digital communication system. The w(t) is the sample function of a white noise of zero mean and power spectral density No/2. The

source of uncertainty lies in the noise w(t). The function of the receiver is to detect the pulse signal s(t) in an optimum manner, gives the received signal x(t).To satisfy this requirement, we have to optimize the design of the filter so as to minimize the effects of noise at the filter output in some statistical sense, and thereby enhance the detection of the pulse signal s(t).Since the filter is linear, the resulting output *y(t)* may be expressed as:

$$y(t)=s(t)+w(t) \tag{7}$$

where s(t) and w(t) are produced by the signal and noise components of the input x(t), respectively.

A simple way of describing the requirement that the output signal component s(t) be considerably greater than the output noise component w*(t)* is to have the filter make the instantaneous power in the output signal s(t), measured at time $t = Tb,$ as large as possible compared with the average power of the output noise n(t). This is equivalent to maximizing the peak pulse signal-to-noise ratio, defined as

$$\eta=|s(t)|^2/E|w(t)| \tag{8}$$

Finally, the structure of the receiver used to perform decision-making process is shown in Figure 5. It consists of a match filter followed by a sampler, and then finally a decision device. The filter is matched to a Triangular pulse of amplitude A and duration T*b,* exploiting the bit-timing information available to the receiver. The resulting matched filter output is sampled at the end of each signaling interval. The presence of channel noise w(t) adds randomness to the matched filter output. The sample value y is compared to a preset threshold A in the decision device. If the threshold is exceeded, the receiver makes a decision in favor of symbol 1; if not, a decision is made in favor of symbol 0.

3.2.2. Energy Detector

Conventional Energy detector is a simple detector. The detector computes the energy of the received signal and compares it to certain threshold value to decide whether the desired signal is present or not. When the primary user signal is unknown or the receiver cannot gather sufficient information about the primary user signal, the energy detection method is used. This method is optimal for detecting any unknown zero-mean constellation signals and can be applied to CR (Cognitive Radio) is the new intelligent wireless communication technology to solve the inefficiency of a fixed spectrum assignment policy [6].

Generally, the performance of spectrum sensing depends majorly on the settings of the detection threshold. Adopting a fixed threshold to distinguish the primary user from noise is one of the most conventional spectrum sensing methods [9]. But with the fixed threshold setting method, it is difficult to guarantee the detection probability and false alarm probability, especially with the Fluctuating noise power. Unlike the conventional method of fixed threshold sensing algorithm, recent work considers an adaptive threshold. According to the SNR, sensing time or transmit power the adaptive threshold dynamically adjust the SU. Study shows the design of sensing duration to maximize the energy efficiency for SUs with cooperative sensing in cognitive radio networks.
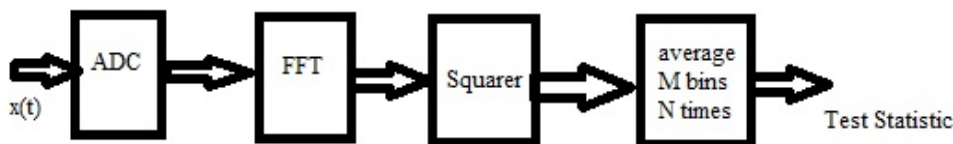

Figure 6.Frequency domain representation of Energy Detector

The energy detection method calculates the energy of the input signal and compares it with a Threshold energy value. The signal is said to be present at a particular frequency if the energy of the signal exceeds the Energy level of the threshold. The threshold value is chosen so as to control the parameters such as probability of false alarm and probability of detection. The threshold voltage can be calculated from:

$$V_{TH} = \sqrt{2\sigma_n^2 \ln\left(\frac{1}{P_{FA}}\right)}$$

                                                          (9)

3.2.3. GLRT (Generalized Likelihood Ratio Test):

The model of GLRT based spectrum sensing shows reduction in probability of false alarm versus the probability of detection for different input energy levels and hence the energy shall also be a parameter in deciding the effectiveness of cognitive systems besides their optimization techniques for energy efficiency. For multipath fading the GLRT is considered as the best method in demodulator domain for channel estimation and data detection. It is regarded as blind because the channel fading coefficients are unknown to both the receiver and transmitter. The GLRT that is the generalized likelihood ratio test is considered the best decision maker for this work. The GLRT Criterion is as follows: Firstly we give two assumptions. Both transmitter and receiver knows the memory order of the channel v. Secondly none of them has the knowledge about channel fading λ.
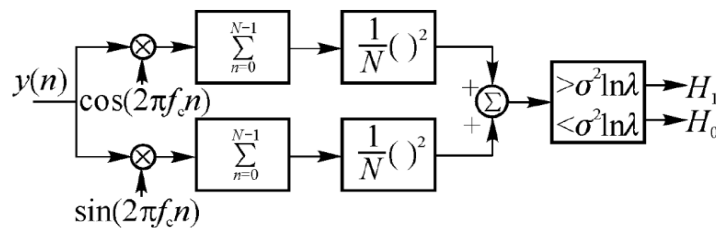

Figure 7. Principle of the GLRT Detector

The received signal can be expressed in the form

y(n) =θ Acos (2π fc n +φ)+ w(n);

n = 0,1,..., N −1, θ = 0 or 1

where A is the amplitude,
        φ is the phase, and
        fc is the carrier frequency.
        θ = 0 or1, represents the primary signal is absent or present respectively, the test statistic as follows

        T(y)=P(y(n);A,φ,H1)/P(y(n);H0)=λ   (10)

where p(y(n);H1) and p(y(n);H0) are the PDF of the received signal under each hypothesis.
While A and φ represent the maximum likelihood estimation (MLE) of the amplitude and the phase respectively.The likelihood function under H0 in the condition of the unknown parameter A and φ is

        P(y(n);H$_0$)=1/(2Πσ^2_w)$^{N/2}$exp[-1/2σ^2_wΣ$^{N-1}_{n=0}$y^2(n)]   (11)

If the signal is present, the likelihood function under H1 can be expressed as

        P(y(n);A,φ,H$_1$)=1//(2Πσ^2_w)$^{N/2}$exp(-1//(2Πσ^2_w)Σ$^{N-1}_{=0}$(y(n)-Acos(2Πf$_c$n+φ))^2)   (12)

Putting above two Equations in test statistics ,we get

        T$_G$(y)=1/N[[Σ$^{N-1}_{n=0}$y(n)cos2Πf$_c$n]^2+[Σ$^{N-1}_{n=0}$y(n)sin2Πf$_c$n]^2]><H1H0λG   (13)

3.2.4. Robust Estimator Correlator:

The more we know a priori how a system behaves, the better we can optimize the performance. Exploiting prior knowledge of a system has proven to be a source of performance improvement in many

scenarios. However, if this knowledge is relied upon without taking into consideration the possibility of errors or deviations the result can be degraded. In this method , we provide robust designs for the signals to be emitted from a multi-antenna array by taking into account uncertainties in the system parameters. By characterizing the possible parameter uncertainties or errors, the design can combat against severe performance degradation. In general design problems, there exists an objective function $f(Dv, Sp)$ where design variables Dv should be chosen such that $f(Dv, Sp)$, for given system parameters Sp, is optimized; Moreover a set of constraints over Dv, described by the set Dv, is also satisfied. Mathematically, $1\min Dv$ $f(Dv, Sp)$ s.t. $Dv \in Dv$. (1.1) The performance degradation occurs when a physical phenomenon is described by an erroneous model with (possibly)) uncertain system parameters. Time variations are also important causes of errors. Even if one estimates system characteristics perfectly, these characteristics will change over time which make the estimates unreliable. As a result, signal processing or control schemes are devised under incorporating such uncertainties. In practice, some levels of loss are inevitable, where the performance of a system is evaluated under real-world assumptions, that is using real parameters which essentially fall away from prior knowledge based on which the whole processes and designs have taken place [10]-[12]. Let the MIMO base-band system model between the primary user base-station and the secondary user, corresponding to the kth symbol transmission, be represented as,

$$y(k)=Hx(k)+\eta(k) \tag{14}$$

where $y(k) \in C^{Nr*1}$, $x(k) \in C^{Nr*1}$ are the received and transmitted temporally independent and identically distributed (IID) zero-mean Gaussian signal vectors respectively, with the Gaussian signal covariance matrix defined as:

$$R_S \in C^{Nr*Nr} \tag{15}$$

$$R_s=E\{s(k)s^H(k)\}=H.E\{x(k)x^H(k)\}H^H \tag{16}$$

3.3. Robust Test Static Detector

The test statistic corresponding to RTSD for spectrum sensing in MIMO cognitive radio scenarios can be equivalently given as,

$$T_{RTSD}=\Sigma_{k=1}y^H(k)R^{-1}_\eta y(k)-f_{RTSD}* \tag{17}$$

Where denote the optimal value of the objective function for the optimization framework.

3.4. Robust Estimator Correlator Detector:

The optimization framework in, the test statistic in can be equivalently formulated as,

$$T_{RECD}=\Sigma^K_{k=1}y^H(k)R^{-1}_\eta y(k)-f*_{RECD} \tag{18}$$

Where $f*_{RECD}$ denote the optimal value of the objective Function The above test statistic yields a robust decision rule for primary user detection in MIMO cognitive radio networks.

3.5. Interference Based Detection:

Unlike the primary receiver detection, the basic idea behind the interference temperature management is to set up an upper interference limit for given frequency band in specific geographic location such that the CR users are not allowed to cause harmful interference while using the specific band in specific area. Typically, CR user transmitters control their interference by regulating their transmission power (their out of band emissions) based on their locations with respect to primary users. This method basically concentrates on measuring interference at the receiver .The operating principle of this method is like an UWB technology where the CR users are allowed to coexist and transmit simultaneously with primary users using low transmit power that is restricted by the interference temperature level so as not to cause harmful interference to primary users.
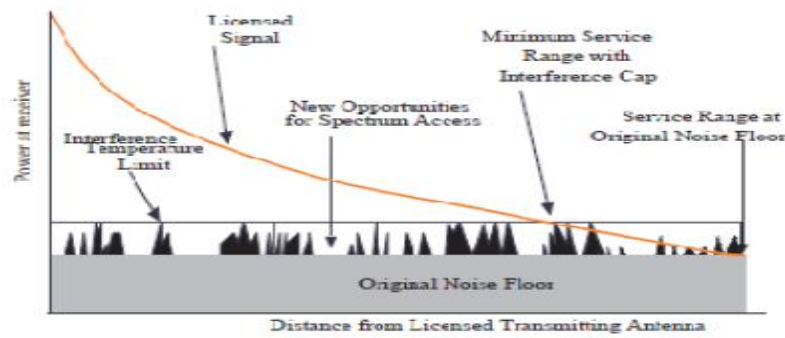
Figure 8. Interference temperature model

Here CR users do not perform spectrum sensing for spectrum opportunities and can transmit right way with specified preset power mask. However, the CR users can not transmit their data with higher power even if the licensed system is completely idle since they are not allowed to transmit with higher than the preset power to limit the interference at primary users. [13]-[14] It is noted that the CR users in this method are required to know the location and corresponding upper level of allowed transmit power levels. Otherwise they will interfere with the primary user transmissions .The next section will show the implementation of the proposed system.

4.   IMPLEMENTATION

To enhance the spectrum sensing efficiency a hybrid spectrum sensing technique is implemented [15]-[16]. In this proposed technique all five detectors are arranged in a cooperative manner.
  a.   Match Filter Detector.
  b.   Energy Detector
  c.   GLRT.
  d.   Robust Estimator Correlator.
  e.   Temperature Based Detector.

To detect whether band is vacant or occupied single frequency band is sensed by all the above methods and the result of each method is then sent to the function block where the results are compare with the fixed threshold value and a final output is determine. The flow of the system is as follows:
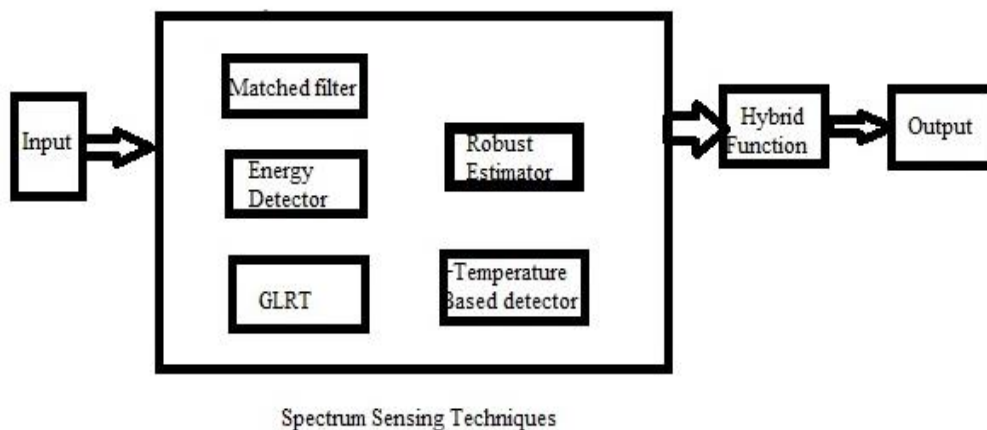

Figure 9. Flow of Proposed System

In the above Figure9, the system is provided with a spectrum band as the input, to check whether it is free or occupied [17]-[18]. The input module sends the information of the band to the spectrum sensing module. In this module the system will test the individual bands of the spectrum. The same   input is provided

to all the five methods of the spectrum sensing block. That is if the channel 2 is to be checked all the sub-block will receive the channel 2 credentials only. Once all the sub-blocks process the channel status and provide the output, then this output is then taken to the functional block. In the functional block the output is checked. If the output of majority of sub-blocks takes either of the side that the channel is free or not then the final output will be displayed [19][24].

For example: Let us assume that the outputs from the sub blocks are as follows: M=1, E=1, G=1, R=0, T=1. From the output we observed that 4 detectors say that the band is free out of the 5 detectors taken. This result is then sent to the Hybrid function block. In the function module the system will check for the majority, if the majority of the output is true and is greater than the threshold of 66%, in our case the channel is free with a chance of 80% since 4 methods say channel is free out of five methods. Therefore the final output is say's that band is vacant. In this way multiple bands can be tested. Further in the next section results of the proposed technique are shown.

5. SIMULATION RESULTS

In order to compare the performance of different spectrum sensing methods two basic tasks are considered a. To determine which bands are unoccupied and b. Best method can be determine for assigning secondary users to the unoccupied spectrum without interfering with the primary users [21]-[22]. Using MATLAB simulation of above detectors we have experimentally check the unoccupied band. The purpose of this paper is to aggregate different spectrum sensing methods and compares these methods based on a variety of performance metrics. Such performance metrics include detection accuracy, complexity, robustness, flexibility of design choices, RF spectrum used and execution time of each system. In the below table spectrum sensing algorithms such as energy detector, matched filtering, GLRT, robust Estimator correlator and a hybrid technique are analyzed and compared.

As with experimental practices, the best spectrum decision method depends on the application. Some variables to be considered are:
a. Expected SNR values.
b. Computational and implementation complexity.
c. Required reliability (express in terms of probability of detection, probability of false alarm).
d. Amount of information that the receiver knows about the primary user's transmitted signal.
e. Execution time.
f. Flexibility in primary user's transmitted signal.

Table 1. Performance comparison summary of various spectrum sensing techniques. The choice of a particular method purely depends on the application and environment in which it will be used. From the Figure 10(a), we observed that the output from the sub blocks are as follows: M=1, E=1, G=1, R=1, T=1. Hence, the analysis concludes that all 5 detectors say that the band is free. This result is then sent to the function block. In the function module the system will check for the majority, if the majority of the output is true and is greater than the threshold of 66% then, the channel is free with a chance of 100%.Since 5 methods say's that band is vacant. Therefore the final output is displayed as Band is free. In this way multiple channels can be tested. After certain time interval if we again check the same channel we observe that the result of the proposed technique is different which depends on the status of primary user.
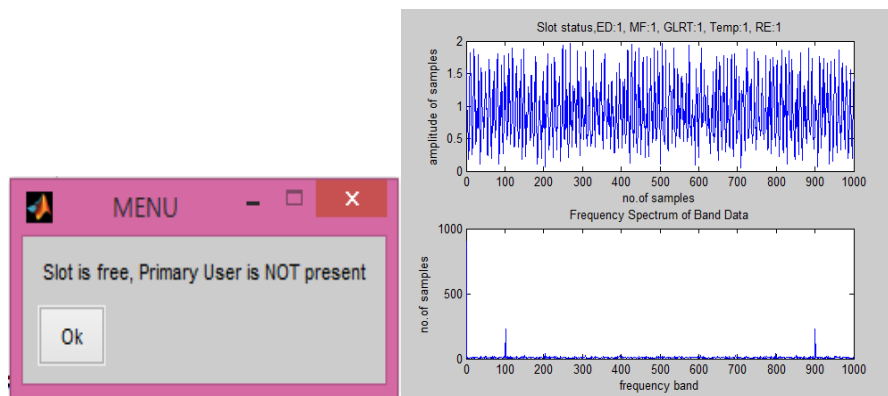

Figure 10(a).Output of Hybrid System in terms of slot status.

Table 1. Summarizes all of the results presented throughout research

|	Energy Detector	Matched-Filter	GLRT	Robust Estimator	Interference Based	Hybrid Method
Detection Accuracy	Good performance at high rate & Poor performance at low SNR, High noise could show false detection.	Best performance at all SNRs (if receiver has sufficient knowledge of transmitter) & poor performance if insufficient data is known	Best performance at all SNRs (It needs no knowledge of noise varience).	Good performance at all SNRs.	Measuring interference at the receiver.	Good performance at all SNRs .
Complexity	Low computations and Implementation complexity,requires higher no. Of samples to converge.	High complexity (requires a dedicated receiver for each primary signal class),requires fewest no. Of samples to converge.	Optimal when the sample size goes to infinity+.	Robust designs (the signals to be emitted from a multi-antenna array).	Medium complexity (transmitters control totally depends on transmission power).	Medium complexity ,if channel symbol positions are unknown ,must estimate positions.
Robustness	Does not require any priror information of transmitted signal.	Requires perfect transmitter information at receiver. It need a dedicated receiver for every type of primary user.	received signal samples at different antennas/receivers are usually	Prior knowledge of a system has proven to be a source of performance improvement.	Regulating their transmission power.	Requires perfect channel symbol positions for dedicated receives .
Design Parameters	Difficult to choose decision threshold.	Transmitter characteristics can be choosen to improve accuracy.	Statistical Covariance Matrix of the primary signals is required.	The design performance depends on erroneous model with uncertain system parameters.	Specific geographic location	Fixed threshold , Cooperative Concept and dedicated channel symbols are used to improve accuracy.
Types of RF Spectrum	Does not work for spread spectrum signals.	RF spectrum	TV band	MIMO base-band system model .	UWB technology	Spectrum Diversity concept is used.
Execution Time	Sensing time taken to achieve a given probability of detection may be high.	Matched filter detection needs less detection time because it requires only O/1 samples to meet a given probability of detection constraint.	Execution time depends on propagation channel dispersive time.	Time variations are also important causes of errors.	Execution is totally depends on restricted by the interference temperature level .	It perform sensing at periodic time intervals as sensed information become fast due to factors like mobility, channel impairments etc. Hence execution time is very small.(no delay)
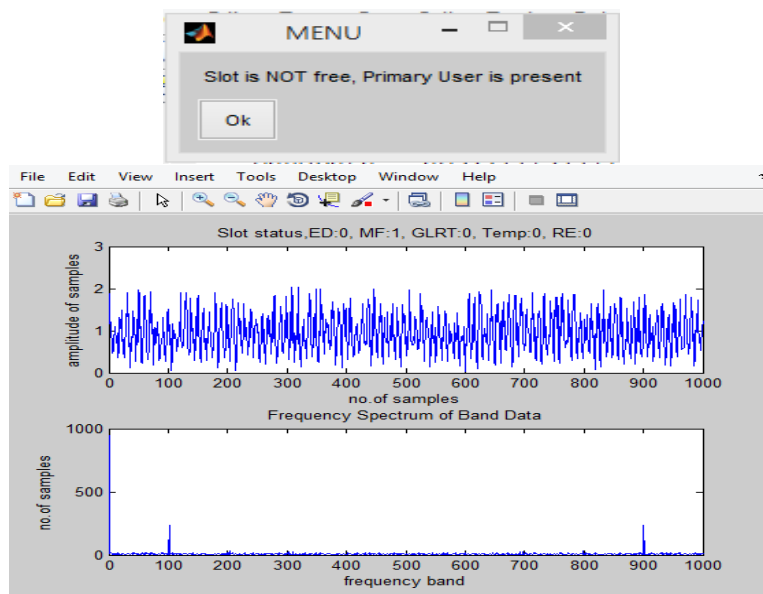
Figure 10(b).Output of Hybrid System in terms of slot status.

From the Figure 10(b), we observed that the output from the sub blocks are as follows: M=1, E=0, G=0, R=0, T=0. Hence, we observed that only 1 detector say that the band is free out of the 5 detectors. This result is then sent to the function block. In the function module the system will check for the majority, if the majority of the output is true and is greater than the threshold of 66%, then the band is free with a chance of 20 % since only 1 method say that channel is free out of five methods. Therefore the final output is that the slot is occupied by the primary user. In this way multiple channels can be tested. Further the final conclusion is drawn in the next section.

6.   CONCLUSION

Spectrum utilization can be improved significantly by allowing secondary users to utilize a licensed bands when the primary users (PU) are absent. Cognitive radio (CR), as an agile radio technology, has been proposed to promote the efficient use of the spectrum. Considering the challenges raised by cognitive radios, the use of spectrum sensing method appears as a crucial need to achieve satisfactory results in terms of efficient use of available spectrum and limited interference with the licensed primary users. To overcome these challenges we have implemented hybrid spectrum sensing method.

As we have already described in this paper, the implementation of the hybrid spectrum sensing algorithm for cognitive radio network (CRN). It requires the involvement and interaction of many advanced techniques, which includes cooperative spectrum sensing, interference management, cognitive radio reconfiguration management, and distributed spectrum sensing communications. Further for efficient utilization of limited radio frequency spectrum, the method used should identify the interference, So that the primary user will not suffer from CR system to utilize their licensed spectrum. Agility improvement of cooperative networks reduces detection time compared to uncoordinated networks. It also provides fast, reliable operation with proper identification of the system interferences. The throughput of secondary nodes can be improved by increasing the spatial diversity and spectrum diversity. To demonstrate the feasibility and performance of hybrid method, simulation is done using MATLAB Software. It is a totally new research direction for CRNs and interesting future research topics for discussed.

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BIOGRAPHIES OF AUTHORS

Awani S. Khobragade has completed her bachelor's degree in Electronics Engineering, from Shri Ramdeobaba Kamla Nehru Engineering College, Maharashtra, India. She Completed her Masters in Electronics Engineering from G.H.Raisoni College of Engineering Maharashtra, India in 2009. Presently Pursuing Ph.D in Electronics. Having an experience of 12 years, she is currently working as a Assistant Professor in Electronics Department of Priyadarshini college of Engineering Maharashtra, India. Her research interests include wireless communication, mobile communication and cognitive radio.

Dr. Rajeshree D. Raut, a young and dynamic Academician is Ph. D in Electronics and her research has made significant contribution in the field of Error Control Coding in Cognitive Environment. Having an experience of 16 years, she currently is actively associated with Research & Development Cell at Shri Ramdeobaba College of Engineering & Management and has worked as the Associate Dean R & D. Dr Raut has been conferred the Prestigious **National Award for Best Engineering Teacher**, by ISTE. She was awarded the IDEAL TEACHER of RTM, Nagpur University, in the year 2011. Her work as a resource person includes **Book on 'Error Control Coding; For Performance Improvement in Cognitive Radio', published by Verlag Academic Publishing,** Chaired the Session for National & International Conferences in India & abroad, Reviewer, Advisory & Editorial Board Member for many International Journals including IEEE Communication Letters, Elesvier, InderScience & Hindawi Publications. She has on her accord more than 50 International Journal and conference papers, organized by countries like USA, Italy, Mexico, UK and Malaysia. She has delivered more than 30 expert talks in the field, including one at Mexico. At this young age she has worked as LEC committee expert and an RTMNU appointed expert in Selection Committees constituted for the appointment of Ass. Prof/ Lecturer. She is a registered guide at Nagpur , Amravati & Vignan University , Guntur, with a total of 8 research scholars working under her guidance.