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A LITERATURE SURVEY ON COGNITIVE RADIO NETWORK – REVIEW OF SPECTRUM SENSING

Preeti Gadekar [1], Prof.Vinay Gupta[2]
[1]M.Tech Scholar, [2]Assistant Professor
[1,2]Department of Electronics & Communication Engineering
[1,2]Bhopal Institute of Technology (BITS)., Bhopal (M.P), INDIA
[1] gadekarpreeti@gmail.com, [2]Vinaygupta11121986@gmail.com

***Abstract*— In this survey paper discuss on Reliable detection of the existence of primary users is a primary requirement for the minimization of interference to existing primary networks. In a real communication environment the local sensing performance of individual users may severely degrade due to deep fading/shadowing. Therefore, individual spectrum sensing is unreliable and prone to errors. However, spectrum sensing can be significantly improved by allowing different users to share their local sensing observations and to cooperatively decide on the licensed spectrum occupancy. CR is an advanced technique which lessens the issue of spectrum scarcity in electromagnetic spectrum. Spectrum sensing is one of the systems which checks the vacancy of primary user designated to particular frequency spectrum. There are a several methods for spectrum sensing for non-cooperative and cooperative CR users. There are few techniques for non-cooperative CR users such as energy detection, matched filter detection, feature detection. Energy detection technique is less complex than matched filter and cyclostationary methods. The energy detection technique does not require any data about the signal structure present in the permitted band to detect the occupancy of user in that band. Energy detection works in high signal – to – noise ratio values compared to other methods.**

***Keywords*—Cognitive radio; Spectrum Sensing; SNR; radio-frequency spectra; Energy detection etc.**

I. INTRODUCTION

The radio frequency spectrum is a limited characteristic asset that is divided into spectrum bands. In the course of the most recent century, spectrum bands have been apportioned to diverse services, for example, mobile, fixed, broadcast, fixed satellite, and mobile satellite services. As all the spectrum bands are as of now dispensed to diverse services, most often requiring licenses for operation, a crucial issue confronting future wireless systems is to discover suitable carrier frequencies and bandwidths to take care of the anticipated demand for future services.

With Cognitive Radio being utilized as a part of various applications, the territory of spectrum sensing has become progressively vital. As Cognitive Radio technology is being utilized to provide a method for utilizing the spectrum all the more productively, spectrum sensing is key to this application. The ability of Cognitive Radio frameworks to get to spare sections of the radio spectrum, and to continue observing the spectrum to guarantee that the Cognitive Radio framework does not create any undue interference depends totally on the spectrum sensing components of the framework. For the overall framework to work viable and to provide the required change in spectrum efficiency, the Cognitive Radio spectrum sensing framework must have the capacity to adequately recognize some other transmissions, distinguish what they are and inform the central preparing unit inside the Cognitive Radio so that the required actions can be taken.

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II.COGNITIVE RADIO

Cognitive radio is a type of wireless communication where a transceiver can intelligently distinguish the channels for communication which are being used and which are not being used, and move into unused channels while maintaining a strategic distance from occupied ones. This enhances the utilization of available radio-frequency spectra while interference is minimized to other users. This is an ideal model for wireless communication where transmission or reception parameters of system or node are changed for communication dodging interference with licensed or unlicensed clients.

Types of Cognitive Radio

There are two types of Cognitive Radios:

- **Full Cognitive Radio:** Full Cognitive Radio (CR) adapts all transmission parameters to the environment, i.e., modulation format, multiple-access method, coding, as well as centre frequency, bandwidth, transmission times, and so on. A wireless node or network can be conscious of every possible parameter observable. While a fully cognitive radio is interesting from a scientific point of view, it currently seems too complicated for practical purposes.

- **Spectrum Sensing Cognitive Radio:** It only adapts the transmission frequency, bandwidth, and time according to the environment. Detects channels in the radio frequency spectrum. Fundamental requirement in cognitive radio network is spectrum sensing. Such cognitive radio is also often called Dynamic Spectrum Access (DSA).

Characteristics of Cognitive Radio

There are two main characteristics of the cognitive radio and can be defined as:

- **Cognitive ability:** Cognitive Capability characterizes the capacity to catch or sense the data from its radio surroundings of the radio technology. Joseph Mitola initially clarified the cognitive capability in term of the cognitive cycle "a cognitive radio constantly observes nature, orients itself, makes plans, decides, and then acts."
- **Reconfigurability:** Cognitive capacity offers the spectrum awareness, Reconfigurability refers to radio capability to change the functions, empowers the cognitive radio to be programmed dynamically as per radio environment (frequency, transmission power, modulation scheme, communication protocol).

Functions of Cognitive Radio

There are four major functions of Cognitive Radio. Figure shows the basic cognitive cycle**:**

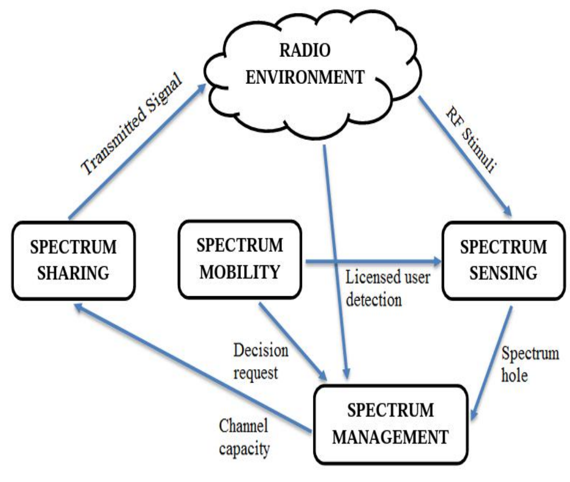

Fig.1. Basic cognitive cycle

- **Spectrum Sensing**
  The principal step of spectrum sensing is that it decides the presence of primary user on a band. The cognitive radio has the capacity to impart the result of its detection with other cognitive radios in the wake of sensing the spectrum. The main objective of spectrum sensing is to discover the spectrum status and activity by periodically sensing the target frequency band.
- **Spectrum Management**
  Provides the reasonable spectrum scheduling technique among coexisting users. The available white space or channel is quickly chosen by cognitive radio if once found. This property of cognitive radio is described as spectrum management.

- **Spectrum Sharing**
  Cognitive Radio doles out the unused (spectrum hole) to the secondary user (SU) as long as primary user (PU) does not utilize it. This property of cognitive radio is described as spectrum sharing.
- **Spectrum Mobility**
  When an authorized (Primary) user is detected, the Cognitive Radio (CR) empties the channel. This property of cognitive radio is depicted as the spectrum mobility, also called handoff.

Applications and Advantages of Cognitive Radio

Applications:

- Improving reliability in wireless communication system.
- Less expensive radio.
- Advanced network topologies.
- Enhancing SDR techniques.
- Automatic radio resources management.

Advantages:

- Mitigate and solving spectrum access issues.
- Spectrum utilization improves.
- Improves wireless networks performance through increased user throughput and system reliability.
- More adaptability and less co-ordination.

III.SYSTEM MODEL

A.General Model

The general model for spectrum sensing is defined as:

$$y_i(n) = f(x) = \begin{cases} H_0: & u_i(n) \\ H_1: & h * s(n) + u_i(n) \end{cases} \quad 1$$

Where $y_i(n)$ is the signal received by the cognitive user, $s(n)$ with variance of σ_s^2 denotes the received PU and, $\sigma_{u,i}^2$ with variance of $y_i(n)$ represent the circularly symmetric complex Gaussian noise (CSCGN) and h denotes the gain of the channel. In eq. (1), H_0 is the null hypothesis, which states that there is not any PU signal. H_1 is the alternative hypothesis, which implies that PU signal is present.

B. Energy Detection

The test statistic for energy detector is given by:

$$T_i(y) = \frac{1}{N}\sum_{n=1}^{N} |y_i(n)|^2 \quad 2$$

Where *N* is the number of samples, $N = \tau f_s$ where τ and f_s are the available sensing time and signal bandwidth. For hypothesisH_0, the probability of false alarm given by:

$$P_f^i(\epsilon_i, \tau) = P_\tau(T_i(y) > \epsilon_i \setminus H_0) = \int_{\epsilon}^{\infty} p_0(x)dx \quad 3$$

Where, $p_0(x)$ is the probability density function (PDF) of test static $T_i(y)$.

IV.LITERATURE SURVEY

A. ***Lorincz, Josip, Ivana et.al.* "Algorithm for Evaluating Energy Detection Spectrum Sensing Performance of Cognitive Radio MIMO-OFDM Systems." Sensors,**

Cognitive radio technology enables spectrum sensing (SS), which allows the secondary user (SU) to access vacant frequency bands in the periods when the primary user (PU) is not active. Due to its minute implementation complexity, the SS approach based on energy detection (ED) of the PU signal has been analyzed in this paper. Analyses were performed for detecting PU signals by the SU in communication systems exploiting multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) transmission technology. To perform the analyses, a new algorithm for simulating the ED process based on a square-law combining (SLC) technique was developed. The main contribution of the proposed algorithm is enabling comprehensive simulation analyses of ED performance based on the SLC method for versatile combinations of operating parameter characteristics for different working environments of MIMO-OFDM systems. The influence of a false alarm on the detection probability of PU signals impacted by operating parameters such as the signal-to-noise ratios, the number of samples, the PU transmit powers, the modulation types and the number of the PU transmit and SU receive branches of the MIMO-OFDM systems have been analyzed in the paper. Simulation analyses are performed by running the proposed algorithm, which enables precise selection of and variation in the operating parameters, the level of noise uncertainty and the detection threshold in different simulation scenarios. The presented analysis of the obtained simulation results indicates how the considered operating parameters impact the ED efficiency of symmetric and asymmetric MIMO-OFDM systems **[1]**.

B. **Bhaskar, Kommula et.al.. "Spectrum Sensing in OFDM using Energy Detection: A Comparative Study in AWGN and Rayleigh Channels."** ***2020*** **IEEE,**

An ED system for OFDM in two different channel conditions is analyzed in this work. ED is the simplest and low-cost spectrum sensing method, since it does not need any information regarding PU, channel gain or any other parameter estimates. The simulation under different channel conditions showed that OFDM with QAM symbol mapping under AWGN environment exhibited better performance with highest AUC value of 0.9897[**2].**

C. **Kumar Alok et.al.,"Analysis of optimal threshold selection for spectrum sensing in a cognitive radio network: an energy detection approach."** ***Wireless Networks*** **25, no. 7 (2019): 3917-3931.**

The spectrum sensing is a key process of the cognitive radio technology in which the cognitive users identify the unutilized/underutilized primary users (PUs)/licensed users spectrum for its efficient utilization. The sensing performance of cognitive radio (CR) is generally measured in terms of false-alarm probability (Pf) and detection probability (Pd). IEEE 802.22 wireless regional area network is one of the typical cognitive radio standards to access unused licensed frequencies of TV band and according to this standard, the false-alarm probability of CR should be B 0.1 and the detection probability must be C 0.9. Further, the detection and false-alarm probabilities are greatly affected by the selected threshold value in the spectrum sensing approach and selection of threshold is a crucial step to yield the status (presence/absence) of PU. In most of the available literatures, the threshold is decided by fixing one parameter (Pf or Pd) and optimizing the other parameter (Pd or Pf). Moreover, at low SNR, while achieving one of the targeted sensing parameter, there is significant degradation in the other sensing parameter. Therefore, in this paper, we are motivated to decide the optimal threshold at low SNR (signal-to-noise ratio) in such a way where we can jointly achieve both sensing matrices (Pf B 0.1 and Pd 0:9) and provided better sensing performance in comparison to that of the traditional constant false-alarm rate and constant detection rate (CDR) threshold selection approaches. Further, we have illustrated that at low SNR, the proposed optimal threshold selection approach has provided better throughput as compare to that of the threshold selected by traditional CDR approach. The proposed approach has improved throughput approximately 24.63% when compared with CDR at chosen SNR **[3].**

D. Arjoune, Youness, et.al."Spectrum sensing: Enhanced energy detection technique based on noise measurement." ***2018*** **IEEE,**

In this paper, we described an enhanced energy detection based technique to increase the probability of detection and decrease the probability of false alarm using a dynamic threshold selection based on measuring the noise level present in the received signal. The level of noise is measured using a blind technique based on sample covariance matrix eigenvalues of the received signal. The proposed approach was implemented using the GNU Radio software and USRP units. The results show that the dynamic selection of the sensing threshold proposed in this workincreases the probability of detection and decreases the probability of false alarm **[4].**

E. Md. Zulfikar Alom, Dr. Tapan Kumar Godder, Mohammad Nayeem Morshed, Asmaa Maali, "Enhanced Spectrum Sensing Based on Energy Detection in Cognitive Radio Network using Adaptive Threshold", IEEE 2017

There's a huge demand for spectrum, but in conventional system radio spectrum is inefficiently used. To overcome this problem and increase array use of spectrum, cognitive radio (CR) technology concept was proposed.CR is the greatest mechanism for use spectrum efficiently. The main objective of CR is to use scarce and limited natural resources efficiently without any interference to the primary users (PUs).Among most challenging problems in cognitive radio systems is spectrum sensing concepts. Energy detection, Matched filter detection and Cyclostationary detections are most common strategies for spectrum sensing. This study has been performed based on Energy detection spectrum method. The reason for choosing Energy detection technique, it doesn't need any earlier information from the PU transmission. Also, the particular result of energy detection method degrades with lower sign to noises ratio (SNR) level signal location. General detection performance of Energy detection is highly dependent upon noise, especially while the SNR is very low for PU. Considering this issue, this paper presents an adaptive threshold model for efficient Energy detection technique to enhance the detection performance at low SNR level. Simulation outcomes show, the detection performance using offered system model is more preferable than fixed threshold at low SNR signal locations. This paper proposed adaptive threshold detection model of energy detection based spectrum sensing. Through maximized the probability of detection with respect to a false alarm rate constraint in order to find the detector thresholds for each stage. Derivation and simulation outcomes show that our offered system can effectively enhanced the detecting probability and the utilization of spectrum holes at low SNR region [5].

F. Kirubakaran.S, et.al."Performance analysis of MRC and EGC based Cooperative Diversity System using Incremental Relaying", IEEE 2016

Cooperative diversity decreases the fading in communication system. It comprises of a source, a destination and a relay to do the error analyses. Analysis is done using Equal Gain Combining (EGC) and Maximal Ratio Combining (MRC) technique with Incremental Relaying. For a cooperative diversity system employing incremental relaying, it is assumed feedback channel is present to relay from the destination. Receiver sends the feedback to the relay then Incremental relaying works. When the receiver SNR value is below the threshold, the relay forwards source signal to the destination. This achieves better performance than other relaying protocols. The Symbol Error Probability (SEP) with incremental relaying for MRC and EGC Technique is analyzed in closed form. Authors proposed Equal Gain Combining and Maximal Ratio combining Schemes and analyzed with DF relaying of cooperative diversity system. Feedback signal is considered in Incremental relaying and it boosted up the bandwidth efficiency. Authors derived the equation of end to end Symbol Error Probability with the Raleigh fading channel. Authors have compared the proposed technique of EGC, MRC and Non-cooperative with value functions. It has been shown that the EGC with Incremental relaying done good than the MRC and non-coop modes of communication [6].

Sitadevi Bharatula, Meenakshi Murugappan, "An Intelligent Fuzzy Based Energy Detection Approach for Cooperative Spectrum Sensing", 2016 Cognitive radio systems are helpful to access the unused spectrum using the popular technique, referred to as spectrum sensing. Spectrum sensing involves the detection of primary user (PU) signal using dynamic spectrum access. Cooperative spectrum sensing takes advantage of the spatial diversity in multiple cognitive radio user networks to improve the sensing accuracy. Though the cooperative spectrum sensing schemes significantly improve the sensing accuracy, it requires the noise variance and channel state information which may lead to transmission overhead. To overcome the drawbacks in conventional cooperative spectrum sensing, this paper proposes a fuzzy system based cooperative spectrum sensing. Selection combining (SC) and maximum ratio combining (MRC) are used at fuzzy based fusion center to obtain the value of the sensing energy. These energy values are utilized in finding the presence of PU, results in improved sensing accuracy. In

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addition, an intelligent fuzzy fusion algorithm determines the PU presence without the channel state information based on multiple threshold values. Simulation results show that the proposed scheme outperforms the existing schemes in terms of sensing accuracy [7].

G. Priyanka Pandya, Aslam Durvesh, Najuk Parekh, "Energy Detection based Spectrum Sensing for Cognitive Radio Network", IEEE 2015

Cognitive radio is an intelligent radio wireless communication technology in order to increase the spectrum efficiency. In this paper one of the most important cognitive radio task i.e. spectrum sensing is explained in detail. Spectrum sensing used to detect the presence of the primary users in a licensed spectrum, which is a fundamental problem for cognitive radio. Increasing efficiency of the spectrum usage is an urgent due to increasing demand for higher data rates, better quality of services and higher capacity. In this paper Energy Detection Technique is discussed in detail.

This study provides useful insight to the behaviour of the energy detection technique, as it relates to detecting signals in a band for opportunistic access. In this work, the performance of an energy detector in detecting unused (vacant) spectrum was evaluated. The study includes a theoretical background; expressions for the detection probability and false alarm probabilities for a sensing node over both a non-fading (AWGN).

Simulation results indicate that depending on the threshold of a single user energy detector, performance improves over a non-fading channel (AWGN), as SNR increases, detection probability increases for a single user detector node in a channel with no fading. Fewer samples produce better performance for non-fading channels for the case of a single secondary user. To improve performance of system we apply MIMO-STBC coding to provide spatial diversity which provide efficiency and reliability to system [8].

H. Ireyuwa E. Igbinosa, Olutayo O. Oyerinde, Viranjay M. Srivastava, Stanley H. Mneney, "Energy Detection Based Spectrum Sensing Performance Evaluations in Cooperating Cognitive Radio Networks", 2015

The ever growing wireless technologies has put a lot of demand on the usage of available spectrum, thus leading to spectrum underutilization and scarcity. To address this issue and improve spectrum utilization gave rise to the concept of the cognitive radio. The cognitive radio is known to enhance the utilization of spectrum of where a secondary user can utilize the spectrum of the primary user without causing harmful interference to the incumbent primary user. In this paper, we evaluated the performance of the energy detection based spectrum sensing in a fading and non-fading environments. Also we presented results on the single user detection and cooperative detection applying the energy detector. The performance of the energy detection technique was assessed by the use of the receiver operating characteristics (ROC) curves over additive white Gaussian noise (AWGN), Rayleigh and Nakagami channels. The cooperative detection shows better performance to the single user in the fading environments.

In this work, we have considered the performance analysis of energy detection based spectrum sensing in a cooperative scheme, we evaluated the performance of energy detection in detecting unused spectrum in fading and non-fading channels models. The effects of cooperating nodes using energy detection over various fading channels are assessed by using complementary ROC curves. In conclusion, simulation results show that the cooperating spectrum sensing is a viable technique in combating the inherent performance degradation of the energy detectors in a severe fading and shadowing environments [9].

I. Doha Hamza, Sonia Aïssa, Ghassane Aniba, "Equal Gain Combining for Cooperative Spectrum Sensing in Cognitive Radio Networks", IEEE 2014

Sensing with equal gain combining (SEGC), a novel cooperative spectrum sensing technique for cognitive radio networks, is proposed. Cognitive radios simultaneously transmit their sensing results to the fusion center (FC) over multipath fading reporting channels. The cognitive radios estimate the phases of the reporting channels and use those estimates for coherent combining of the sensing results at the FC. A global decision is made at the FC by comparing the received signal with a threshold. We obtain the global detection probabilities and secondary throughput exactly through a moment generating function approach. We verify our solution via system simulation and demonstrate that the Chernoff bound and central limit theory approximation are not tight. The cases of hard sensing and soft sensing are considered and we provide examples in which hard sensing is advantageous to soft sensing. We contrast the performance of SEGC with maximum ratio combining of the sensors' results and provide examples where the former is superior. Furthermore, we evaluate the performance of SEGC against existing orthogonal reporting techniques such as time division multiple access (TDMA). SEGC performance always dominates that of TDMA in terms of secondary throughput. We also study the impact of phase and synchronization errors and demonstrate the robustness of the SEGC technique against such imperfections. [10]

J. Sanjeewa P. Herath, Nandana Rajatheva, "Analysis of Equal Gain Combining in Energy Detection for Cognitive Radio over Nakagami Channels", IEEE 2008

This paper addresses the problem of energy detection of unknown deterministic signal of a primary user in a cognitive radio environment. As an extension to the previous works, we focus on equal gain combining technique when the wireless channel is modeled as Nakagami-m. We derive series form exact expressions for probability of detection and false alarm when the number of diversity branches are 1, 2, 3 and $L \geq 4$. Finally, performance variation is shown against the number of diversity branches and the time bandwidth product in decision statistic with the aid of numerical results.

We consider the problem of primary user detection in cognitive radio over the Nakagami-*m* fading channel with the equal gain combining diversity receiver. Expressions are derived for exact probability of detection when the number of diversity branches are 1, 2, 3 and $L \geq 4$. Interestingly, all the expressions could be expressed in terms of confluent hypergeometric function of the first kind $1F1(.; .; .)$. These results could be readily used in deciding the number of diversity branches and the energy threshold value to achieve a specified false alarm rate of equal gain combiner energy detector receiver in cognitive radio. [16]

CONCLUSION

In this survey paper analysis of different survey spectrum sensing techniques. There are different techniques types of techniques are discussed in this paper. Also discuss the basics of cognitive radio network (CRN) and its type. In the last decade requirement of spectrum is increases rapidly that's why researches are mainly focus – "How to utilize spectrum more effectively at primary as well as second end users" in Cognitive radio network (CRN). In future try to design an improve cognitive radio network system which is effective as compare to previous method and give higher spectrum for better channel allocation in next generation communication systems.

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