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Cooperative Sensing Approach in Cognitive Radio Network-A Review Paper

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ABSTRACT: Radio Spectrum is considered as a base line in Wireless communication network, due to its important role as a transmission medium; and according to the rapid improvement in the technologies which deal with radio spectrum; cognitive radio raised as a promising solution for solving the problem of radio spectrum scarcity. Cognitive radio is based on spectrum sensing as appropriate tool to study surrounding environment in order to illustrate the suitable scenario for sharing spectrum between users. Cooperative sensing is the most sophisticated approach in spectrum sensing depends on base of sharing information to eliminate error in spectrum sensing mechanism. This paper is a review paper. It discusses Cooperative sensing approach features in cognitive radio.

KEYWORDS*:* PU, SU, cognitive radio.

I. INTRODUCTION

Free spaces radio spectrum had been limited in recent years, according to the increasing of the wireless technologies. Radio spectrum is controlled and allocated by government agencies in every country avoiding the problems come from interference or sharing the same band between different users. With wide spread of wireless devices this lead to the limitation of radio spectrum. Several studies have shown that the spectrum is not completely used all the time, and most of licensed bands are idle for periods of time , which considered as a wasting of resources. The mentioned studies confirmed that there are unused spaces in the allocated spectrum theses spaces seem to be as spectrum holes as depicted in Fig (1):

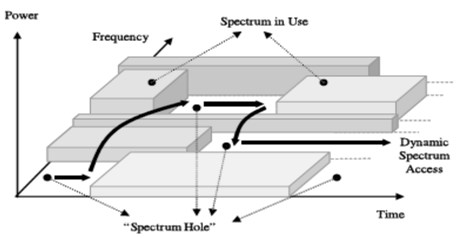

Fig (1): Spectrum holes

These spectrum holes encourage researchers to introduce cognitive radio as new a field concerning in the management and control the radio spectrum scarcity [1]

The studies prove that the static spectrum allocation policy leads to poor utilization of radio spectrum. Cognitive radio enables the access to spectrum in the idle period of time; optimizing the usage of spectrum and increasing efficiency by filling the white holes of spectrum, that are not used by licensed user or Primary User (PU).The unlicensed user or Secondary User (SU) are exploiting the white spaces of spectrum in case of PU absence; to grantee the QoS for PU since they are considered as band owner. The harmony between PU and SU is the main goal of Cognitive radio technology; where it concerns in exploiting any opportunity in the radio spectrum for SU and grantee the acceptable level of interference to the PU [2]

Since cognitive radio adopts the policy of opportunistic sharing for SU, in basis of high priority of PU; it had been important for cognitive radio to optimize spectrum sensing to determine if there are white holes, vacant bands or not. Spectrum sensing implemented by cognitive radio should detect the presence and absence of PU in real time. In case of

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PU presence detection, SU must vacate the band immediately grantee the acceptable level of QoS of PU. Many techniques can be used in spectrum sensing such as energy detection, Matched Filter, Cyclostationary detection, waveform base sensing, radio identification base sensing, sensing with multiple antennas and cooperative sensing. Cooperative Spectrum sensing is the most sophisticated and accurate according to its mechanism in combining the sensing results of many cognitive radio nodes optimizing the awareness of surrounding environment to reach to the appropriate decision of spectrum exploiting. [3]

II. RELATED WORK

Since cooperative spectrum sensing approach classify as the most accurate one in spectrum sensing technique, many studies targeted this area to discover the features to propose the solutions to optimize cooperative sensing accuracy.

Cooperative sensing has many approaches depending on the fusion center rule, where SUs independently provide their spectrum sensing results and forward it to fusion center, in fusion center where the whole data is combining to optimize decision making. AND, OR an Optimal rule represent the fusion rules which compared in basis of required capabilities in the fusion center and channel capacity. In particular optimal fusion rule exceeds the AND and OR fusion rule; since it allows to increase the probability of correct detection while decreasing the probability of false opportunity detection. The benefits of that is reflected on the capability of reducing the cost, increasing control channel capacity and optimizing the sensing technique [4]

III. IMPACT OF ENERGY AND THROUGHPUT IN COOPERATIVE SPECTRUM SENSING AND PERFORMANCE

In cooperative sensing scheme, the spectrum sensing performance in cognitive radio network depends on two parameters; sensing time and the used fusion scheme. Assuming SU uses cooperative sensing technique, with the k-out-of-N fusion rules to determine the presence of the PU, in order to provide the appropriate level of protection to them. Since the spectrum sensing performance relays on time of sensing; then the problem of sensing throughput tradeoff using cooperative sensing scenario is designed to find a pair of sensing time and k value that maximize secondary users' throughput to sufficient protection that is provided to the primary user. A proposed alterative algorithm implemented to obtain the optimal values for the mentioned two parameters. Simulation shows considerable improvement in the throughput of SU, when the parameters of the fusion scheme and the sensing time reach their optimal values. [5]

There for the optimal number of cognitive radios can derive under two scenarios: energy efficient and a throughput optimization setup. The number of cooperating cognitive nodes is minimizing to K out of N fusion rule in the energy efficient setup, with all constrains on the probability of detection and false alarm probability. In throughput optimization setup maximizing throughput of cognitive radio is achieved by deriving optimal time of sensing which is proportional to the number of cognitive users. Simulation methodology is used and the result shows that OR and the majority rule are better than AND rule in terms of energy efficiency, and that due to OR rule achieves higher throughput with smaller number of users compared with AND rule. [6]

Fusion center rule impacts directly in the determination the expected performance of cooperative sensing scheme. Another study focuses on the fusion center rules concerned in cooperative spectrum sensing over Rayleigh fading channel. Using simulation the performance has been investigated via probability of missed detection versus different probability of false alarm values in Rayleigh fading channel. Performance of cooperative spectrum sensing over Rayleigh fading is presented and compared with the non-cooperative spectrum sensing. The study consolidate that OR rule has the better performance than AND and MAJORITY rule. Also it is observed that spectrum sensing is better in presence of cooperation. [7]

Cognitive radio system requires high ability to dependably detect the presence of PU transmission to avoid making any disturbance for licensed users; so SUs cooperation is necessary in order to detect lower SNRs which indicate to PU precession. To optimize cooperative spectrum sensing scheme a proposed model consisting of cooperating nodes and using identical energy detectors with correlated log-normal random variables had been studied focusing in the problem of combing the decisions made by the individual nodes. Also linear-quadratic (LQ) fusion strategy had been designed based on deflection criterion. Simulation results show that the LQ detector significantly outperforms the Counting Rule, which is the fusion rule that is obtained by ignoring the correlation. Also simulation proves that although the

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observations at the sensors are sparingly correlated, it is important to consolidate the correlation between the nodes to integrate the local decisions made at the SU.
The LQ detector is also applicable for more general statistical models for the signals, since all it requires is information about the lower order moments about the correlated decision variables, which can be easily calculated for most standard signal models. For a system contain a larger number of cooperating nodes, better detection probabilities could be obtained with the LQ detector, even without varying the thresholds at the cooperating users. Also it is possible to generalize the LQ detector to the scenario where the cooperating users employ higher level quantizers. However, for such an application, the task of the fusion center would become more complex since computing the moments required for the LQ detector would become more complicated. [8]
Cooperative sensing scheme plays significant role in enhancing and optimizing the spectrum detection with an effective efficiency of determining the wireless environment variables. One of the proposed suggestions in cooperative spectrum sensing is model of fully distributed consensus-based cooperative spectrum sensing scheme deal and overcome both of fixed and random bidirectional connections between SUs. The proposed model based on the ability of SU to initiate coordination on local interaction without central fusion node. Using such scenario can achieve significantly lower missing detection probability and false alarm probability. This contribution enhances cognitive radio performance as it had been approved by simulation results. [9]
It is clear that the important phase in cognitive radio network is identification and detection of PU over wide spectrum. Cooperative seeing scheme offers many benefits such as decreasing the required level of sensitivity of individual device, although of all this benefits it has been shown that the performance of cooperative sensing schemes can be severely degraded according to presence of malicious users sending false sensing data. To mitigate the malicious nodes harmful, new technique is proposed, this technique depends on designing scheme detect and canceling the malicious nodes. Simple and fast average combination scheme had been employed to simplify the decision process at the access point. Simulation results distinguish that the proposed scheme users and malicious nodes. [10]
Although cooperative sensing Scheme considered as an effective sensing scheme in cognitive radio; other sensing schemes such as energy detection scheme, also can detect PUs signals effectively. Since sensing scheme can affect cognitive radio environmental awareness, also modulation scheme affects BER performance of cognitive radio networks. [11]

IV. CONTRIBUTIONS CLASSIFICATION AND ANALYSIS

No	Researcher	Contribution	Advantage	Research domain
1	Virajith Jalaparti, Dr. A.K. Chaturvedi (EE), Dr. Manindra Agrawal (CSE)	Cooperative Spectrum Sensing for Cognitive Radio	1. Study fading and shadowing, which dramatically affect the ability of the cognitive radio system to detect the primary user. 2. Cooperation among the cognitive users can increase the detection probability for a given probability of false alarm. 3. Paper goal is to develop a spectrum sensing scheme for cognitive radio based on a model that is realistic and put in mind all the factors that would affect the system in practice. 4. Investigate the effect of variable channel gain on the cooperation between secondary users. 5. the simulations done based on the analytical results, then presented which show the extent of advantage cooperation between the secondary radios and the effect of the channel gain between the secondary user and the fusion centre	focusing on OFDM modulation give significant result .

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No	Researcher	Contribution	Advantage	Research domain
2	Ian F. Akyildiz; Brandon F. Lo; Ravikumar Balakrishnan	Cooperative spectrum sensing in cognitive radio networks: A survey	Comprehensive study for Cooperative Sensing Scheme in full review for other spectrum sensing technique, giving complete idea about sensing literature.	Study Cooperative sensing technique with extensive explanation of literature.
3	Helena Rifà-Pous , Mercedes Jiménez Blasco, Carles Garrigues	Review of Robust Cooperative Spectrum Sensing Techniques for Cognitive Radio Networks	Review paper for Cooperative sensing scheme with comprehensive discussion of fusion center rules, focusing in Security issues and malicious nodes problem in order to increase reliability of spectrum sensing.	Fusion center rules .
4	Luca Bixio, Marina Ottonello, Mirco Raffetto, Carlo S. Regazzoni, and Claudio Armani	A Comparison among Cooperative Spectrum Sensing Approaches for Cognitive Radios	1. Provide comparison between different cooperative spectrum sensing approaches. 2. Fusion rules are compared in terms of required processing capabilities at the fusion center, secondary terminals and required control channel capacity. 3. Performances compared by Numerical simulations.	Fusion center rules .
5	Edward Chu Yeow Peh ,Ying-Chang Liang, Yong Liang Guan, Yonghong Zeng	Optimization of Cooperative Sensing in Cognitive Radio Networks: A Sensing-Throughput Tradeoff View	1. Study the case of secondary users cooperatively senses a channel using the k-out-of-N fusion rule determining the presence of the primary user. 2. An iterative algorithm is proposed to obtain optimal values for these two parameters of sensing time and k value. 3. Computer simulations show that significant improvement in the throughput of the secondary users gained when the parameters for the fusion scheme and the sensing time are optimized.	Optimization using Throughput as parameter.
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No				
6	Sina Maleki, Sundeep Prabhakar Chepuri, Geert Leus	Energy and Throughput Efficient Strategies for Cooperative Spectrum Sensing in Cognitive Radios	1. Derive the optimal number of cognitive radios under two scenarios: energy efficient and a throughput optimization setup. 2. Maximize the throughput of the cognitive radio network, by deriving the optimal reporting time in a sensing time frame which is proportional to the number of cognitive users, subject to a constraint on the probability of detection. 3. The simulation results show that the OR and the majority rule outperform the AND rule in terms of energy efficiency and that the OR rule gives a higher throughput than the AND rule with a smaller number of users	Concern in fusion center rules
7	Mohammad Alamgir Hossain, Md. Shamim Hossain, and Md. Ibrahim Abdullah	Performance Analysis of Cooperative Spectrum Sensing in Cognitive Radio	1. Study performance analysis of cooperative spectrum sensing in Cognitive Radio. 2. Implement simulation comparison of cooperative with non-cooperative spectrum sensing over Rayleigh fading channel based on AND, OR and MAJORITY rules. 3. Comparing non-cooperative with cooperative curves over Rayleigh fading channels, the obtain result is that spectrum sensing is better in presence of cooperation. Also the OR rule has the better performance than AND and MAJORITY rule.	Study fusion center performance parameter and ignore overall system performance parameters
8	Jayakrishnan Unnikrishnan and Venugopal V. Veeravalli.	Cooperative Sensing for Primary Detection in Cognitive Radio	1. Model the received signals as correlated log-normal random variables, studying the problem of fusing the decisions made by the individual nodes. 2. Design a linear-quadratic (LQ) fusion strategy based on a deflection criterion for this problem, which takes into account the correlation between the nodes. 3. Using simulations show that when the observations at the sensors are correlated, the LQ detector significantly outperforms the Counting Rule, which is the fusion rule that is obtained by ignoring the correlation.	Concern in fusion center rules only

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No	Researcher	Contribution	Advantage	Research domain
9	Zhiqiang Li, F. Richard Yu and Minyi Huang	A Cooperative Spectrum Sensing Consensus Scheme in Cognitive Radios	1. Proposes a fully distributed consensus-based cooperative spectrum sensing scheme to cope with both fixed and random bidirectional connections between secondary users. 2. Prove that inter-connected with unreliable bidirectional communication links, secondary users can still make an average consensus. 3. Simulation results show that the proposed scheme can have significantly lower missing detection probability and false alarm probability	Focus in bidirectional scenario only
10	Praveen Kaligineedi, Majid Khabbazian and Vijay K. Bhargava	Secure Cooperative Sensing Techniques for Cognitive Radio Systems	1. Explain theoretically that the performance of cooperative sensing schemes can be severely degraded according to presence of malicious nodes, which sending false sensing data. 2. Present techniques to identify such malicious users and mitigate their harmful effect on the performance of the cooperative sensing system.	Focusing in security issues degrade performance
11	Yasir Abdelfatah Merghani Ahmed, Dr. Khalid Hamid Bilal	Comparison of Bit Error Rate Performance between BPSK and 16QAM modulation scheme in cognitive radio network	1. Study Bit Error rate performance in Cognitive radio network, using comparison between BPSK and 16QAM modulation scheme 2. The study applies Energy Detection technique as appropriate sensing technique to detecting PU signals. 3. Simulation results prove that BPSK is better than 16QAM in Bit Error rate performance	Study BER performance , and the impact of the applied modulation scheme .

V. Conclusion

Cooperative sensing depends on combining information obtained from many nodes using fusion center rules. Cooperative sensing scheme used in complex environments, complicated circumstances and have special algorithm to trade off between fusion center rules. Many of sensing mechanisms are used in cognitive networks. The accuracy of detecting PU is a bottle neck on Cognitive network performance ; also the Modulation scheme considered as an important parameter in Cognitive network performance due to its affect in BER.

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