NODE SELECTION SCHEME FOR COOPERATIVE SPECTRUM SENSING IN COGNITIVE RADIO

Project report submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

By

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DECLARATION BY THE SCHOLAR

We hereby declare that the work reported in the B-Tech thesis entitled **“Node Selection Scheme for Cooperative Spectrum Sensing in Cognitive Radio”** submitted at **Jaypee University of Information Technology, Waknaghat India,** is an authentic record of our own work carried out under the supervision of **Mr.Alok Kumar.** We have not submitted this work elsewhere for any other degree or diploma.

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CERTIFICATION

This is to ensure that venture report entitled “Node Selection Scheme for Cooperative Spectrum Sensing in Cognitive Radio” put together by Shivam Verma and Abhinandan Sharma in fractional satisfaction for the honor of level of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been completed under my guidance.

This work has not been submitted somewhat or completely to some other University or Institute for the grant of this or some other Degree or Certificate

Date:

Mr. Alok Kumar

Assistant Professor, Dept. of ECE

ACKNOWLEGMENT

We would like to extend our heartfelt gratitude towards our motivating mentor **Mr. Alok Kumar**, Assistant Professor, Department of Electronics and Communication Engineering, Jaypee University of Information Technology, Waknaghat, Himachal Pradesh. His day to day guidance and valuable suggestions, encouragement and reinforcements were solely responsible for the completion of our project. We genuinely appreciate the time spent by him in guiding us throughout the project.

In the end we would like to thank each other for the unfathomable cooperation, participation and pro-activeness towards the successful completion of this project.

Any suggestions for the improvement of the project are promptly welcomed.

Thank you.

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LIST OF ACRONYMS AND ABBREVIATIONS

RF- Radio Frequency

PUs- Primary Users

SUs- Secondary Users

CR- Cognitive Radio

CRNs- Cognitive Radio Networks

FCC- Federal Communications Commission

WB- Wide-Band

NB- Narrow-Band

AWGN- Additive White Gaussian Noise

UHF- Ultra High Frequency

AGC- Automatic Gain Control

PLL- Phase Locked Loop

FC- Fusion Center

RN- Representative Nodes

CSS- Cooperative Spectrum Sensing

DSMF- Dynamic Spectrum Management Framework

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ABSTRACT

Spectrum sensing is an important part of cognitive radio where the goal is to find out whether primary user is present or absent. This can be done in numerous ways such as by cooperative spectrum sensing, non-cooperative spectrum sensing and interference based spectrum sensing. We however use the cooperative spectrum sensing where the data sensed by a secondary user is shared among all the nodes. Since sharing of data with every node increases the data overhead largely so instead we use a base station called the fusion center to which all the data is sent.

Since all nodes take part in the cooperation of data, the overall energy consumed is high.
A single node has to sense the spectrum, make a local decision and then transmit it further. All these steps may consume different energy for differently located nodes. Hence some nodes may not have sufficient energy to complete these steps. Due to the lack of residual energy, these nodes may provide wrong information to the fusion center and reduce the reliability of the system.

To tackle the problems such as high energy consumption, data overhead, and effect of malicious nodes we use a node selection scheme. In this scheme our motive is to filter out ineffective nodes and cooperate only between the genuine nodes.

CHAPTER 1

COGNITIVE RADIO

1.1 INTRODUCTION

We know that Radio Frequency Spectrum is a rare resource and needs to be utilized efficiently. The practice of this spectrum through transmitters and receivers is normally authorized by government. In static spectrum strategy the licensed or primary users (PUs) are allocated fixed channels for using whereas unlicensed or secondary users (SUs) are not allowed to access channels which are free. Currently, it has become noticeable that frequency sharing technique can't accommodate by continuously increasing demands of higher data tariffs. Cognitive radio (CR) is emerging as an innovative skill to resolve this spectrum under-utilization problem in the next generation networks. Following its introduction, a huge effort has been put in to improve the efficiency of cognitive radio networks. This work has been dedicated to build technologies that either exploit opportunities in time, frequency, and space domains or allow SUs to coexist with PUs in the similar spectrum bands with least interference [1].

1.2 TYPES OF COGNITIVE RADIO

Cognitive Radio Networks (CRN) are classified into the following models:

- Interweave Model
- Underlay Model
- Overlay Model

In this **interweave network model** [1], unlicensed or secondary operators are not permit the access of an occupied band by the licensed or primary operator but the Centralized Communications Commission is presently developing innovative spectrum strategies which will permit secondary operators to cunningly access a licensed band once the primary operator is absent. In these networks, the CR identifies the available sub-bands of the radio spectrum, or equally the spectrum holes, that are partially or completely under-utilized at a particular instant of time and at exact geographic location. So, the fundamental task of CR is to sense the spectrum so that it can detect, whether a primary operator is present or not. So, spectrum sensing(SS) is the main feature for the interweave model. In that, SS is the only method that is responsible for sensing the spectrum holes. Also, it is mandatory for the secondary user to swiftly empty the channel as soon as the primary user reappears in such a way that the harmful interference effect on the licensed users is reduced.

SS methods can be well-defined on the basis of the size of band of interest. The major problem of wideband (WB) SS consists an observation of wideband and identify the area of that band which are occupied by a signal and of those which are free.

Now, in the **underlay network model**, the existence of primary and secondary users is permitted and therefore the network is similarly termed as a spectrum sharing network. On the other hand, primary users are always assigned to an advanced priority to use the spectrum than secondary users. Further, the sharing should be kept below the primary user's predefined interference limit. The secondary user extents its signal above a bandwidth that is sufficient to guarantee the sum of interference caused to the primary user is inside the predefined restrictions. Because of this constraint, the underlay method is very beneficial for short range communication purposes [1].

Third, in **overlay cognitive networks**, Secondary and primary clients are permitted to transfer altogether. The major assumption which is made in the present overlay model is that the primary message should be recognized by the secondary transmitter beforehand. There are two main approaches to realize this model:

1. With the help of advanced coding techniques such as dirty paper coding (a technique which completely mitigates a priori known interference over an input power constrained additive white Gaussian noise (AWGN) channel), where the secondary user can pre code the transmitted stream in order to effectively null the interference at the secondary receiver. While this approach violates the cognitive radio principle of protecting the primary users, it provides a theoretical upper bound on the maximum throughput achievable by the secondary users.
2. The secondary user splits its own power into two parts, one used to raise the primary user power in order to mitigate the interference effect caused by the secondary user data and the other part is utilized to carry the secondary user data.

1.3 SPECTRUM SENSING IN INTERWEAVE NETWORK

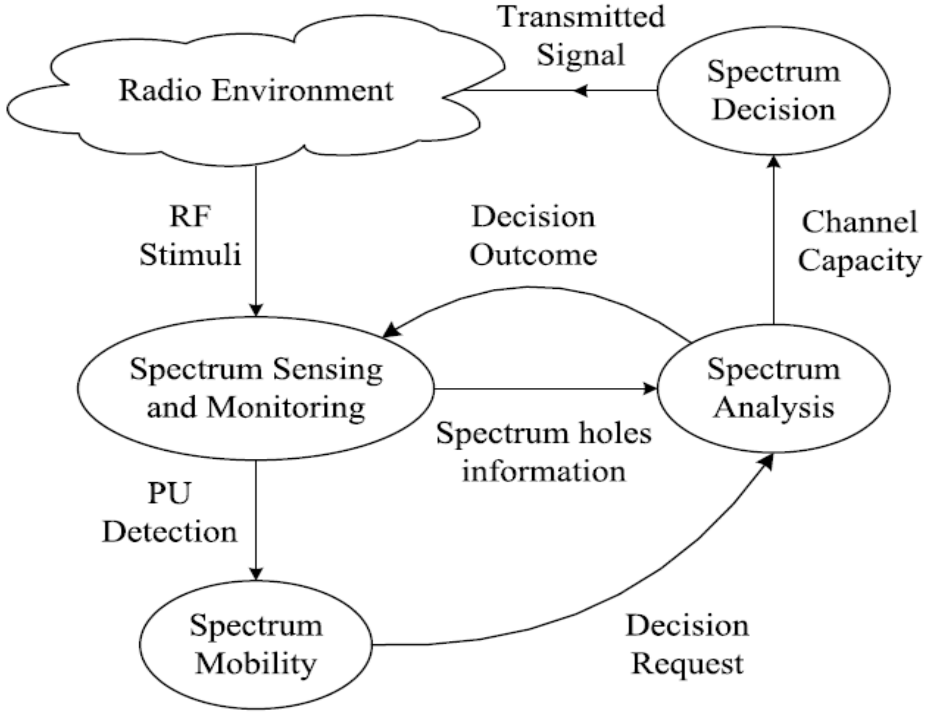

Fig.1 Dynamic spectrum management framework

This section has the important ideas for the interweave cognitive radio model. It also has the allowing technology, namely SS, for this model is well-defined, where its substantial status is discussed as a vital and best evolving portion of the interweave system. The basic rule behind interweave cognitive radio is to motion the existing under-utilized spectral resources by reprocessing unused spectrum in a resourceful way. So the method of understanding effective spectrum utilization the interweave cognitive radio technique requires an active spectrum managing framework (DSMF) which offers an architecture for the model with complete functionalities. The DSMF consist of four main blocks as shown in Fig. 1. The tasks compulsory for adaptive method in one cognitive cycle can be concisely discussed as follows [1]:

- ***Sensing and monitoring:*** A cognitive sense the existing spectrum, captures their data, and then senses the spectrum holes. SS is also capturing the correct interpretations about the spectrum holes in order to support the analysis point for the spectrum classification. If the CR is at present campingon a spectrum portion for communication, then the busy narrowband is there to govern whether the original licensed user returns or not.

- ***Analysis**:* The features of the spectrum holes which are spotted by SS are estimated. The primary user action along with the spectrum band data such as operating frequency and bandwidth must be calculated for individual holes. It is important to define factors such as channel error rate, link layer delay, interference level, holding time, and path-loss that can signify the feature of a particular spectrum band.
- ***Decision:*** A cognitive radio fixes the transmission mode, the data rate, and the bandwidth of the transmission. Later that, the suitable spectrum band is selected by seeing the spectrum features and user necessities. After spectrum holes are considered, the next step is to pick the best existing spectrum right for the user's specific QoS necessities. Due to animatedly varying topologies and varying propagation characteristics, spectrum selection methods can be carefully joined with routing rules. Spectrum prediction based on Graph theory, learning, and game theory selection can provide sufficient information for the spectrum selection challenges.
- ***Mobility:*** Due to the capability of a CR to free the channel as soon as a licensed user is sensed. When a PU reclaims a licensed channel temporarily engaged by a SU, spectrum movement hangs the transmission, free the channel, and continues current communication by means of another empty channel. The hand-off approaches are the important part in this method, where proactive and reactive methods are two key contributions in this direction. The first accepts that SU relates reactive SS to find target backup channel, while the later studies an appropriate knowledge of PU traffic model so that SU will able to guess PU arrival and then SU empties the channel in advance.

1.3.1 NARROWBAND SPECTRUM SENSING

In interweave systems, before correspondence, Secondary client must detect the range to recognize that it is accessible or not. To understand this usefulness, two distinct structures are recommended as beginning answers for perform narrowband detecting: single-radio and double radio.

In this **single-radio architecture**, a single RF cable is used to practice both CR features and data transmission. So, only a definite time slot is allotted for SS. Later the CR users do not have the right to access the spectrum throughout the sensing period, this period is called the quiet period (QP). Because of this restricted detecting term, just certain precision can be ensured for range detecting results. Besides, the range effectiveness is diminished as some bit of the accessible schedule vacancy is utilized for detecting rather than information transmission. The Advantages of the single-radio architecture is its Easiness, low cost, and low power consumption.

In the **dual-radio sensing architecture**, one radio cable is dedicated for data transmission and reception whereas the other cable is dedicated to spectrum monitoring. The disadvantage of such method is the increased power feeding and hard-ware cost. Since the cognitive radio idea is currently in an advanced stage in which execution issues are significantly measured, recent methods challenge to enhance the single-radio architecture.

During communication, SU must be able to sense very weak signals produced by the primary user in order to quickly free the busy spectrum. Thus, primary user discovery is vital by continuously monitoring the used spectrum to release the spectrum. Normally, spectrum checking methods are dependent on the periodic SS in silent periods. The preparing is generally connected above the gotten flag at the SU to investigate a particular element to the essential client. This device is repeated intermittently to screen the range with the goal that the SU can rapidly return the range for a limited period if the PU is sensed. At that point, SU picks another substantial range band in the range for communication. As a general rule, this observing system best suited fot the single-radio design since it utilizes QPs to resense the used band. In any case, we ought to underline that there is no refinement from the execution point of view between the underlying detecting, that happens in any case to ensure that this cut of the range is accessible, and the checking method, which just affirms that the band is accessible and SU is still permitted to proceed with the correspondence.

1.3.2 ADVANCES ON NARROWBAND SPECTRUM SENSING

Generally, the issue of narrowband SS would be to determine that a specific piece of the spectrum is "accessible" or not.

The Functionality of the detection algorithm may be outlined using the likelihood of false alarm PFA as well as two probabilities: the probability of PMD. PMD is your likelihood of miss-detecting a signal when it's actually present. On the flip side, PFA is the likelihood that the test determines when it's actually not, that the consumer is present. H0. Normally, PFA ought to be kept as small as you can so as to stop under-utilization of communication chances although PMD has to be minimized. Basic problem of sensor strategy is to select detection standards, along with the place of threshold γ to attain good detection functionality. These things are handled in the literature of discovery concept in detail. Detection algorithms are considered in the framework of Bayesian statistics, or in the frame of figures. From the Bayesian framework, compared, it's assumed that the origin chooses the legitimate hypothesis randomly, based on a priori probabilities. Within this part, we'll focus on the narrowband sensing methods to. Therefore, coordinated filter detection, energy discovery, and cyclostationary attribute detection will be contemplated.

Energy ED does not need information and relatively low complexity is provided by it. In fact, when sensing is addressed, ED are the first strategy to come to mind because sensing is significantly associated with PU signal power discovery. The availability of ED allows sensing methods to function in execution requirements and environments. Because of these promising benefits, research provides extensive activities to significantly research ED in various channel conditions. Implementation viewpoints are the focus of research attempts. Actual calculations are thought to assess the ED and also to look into the authenticity of their underlying assumptions. As a result, beyond employing ED, the premises are recorded and researched. It's been proven that a significant disadvantage for ED is the fact that it is inferior detection operation under low SNR situations, and cannot distinguish between the signs from PUs and also the disturbance from other cognitive radios. Within this part, we'll concentrate on a succinct history of this ED but we'll elaborate more on these recent research tasks and their related problems and alternatives.

In energy the power sensor is examined. The study assumes that station is supposed to be the AWGN channel using a sound power that is known. Additionally, the SU receiver is an ideal one, in which no distortion is released because of some non-linear frequency blending, amplification, and IQ imbalance. These assumptions are closely researched and in comparison, to the technical situations in, where sound instability, recipient non-linearities, and sensible fading channels reveal that the many degradation factors for electricity sensors. To explore these problems researches are encouraged. Multipath fading as well as shadowing phenomenon lead to electricity fluctuations of obtained PU signals and also the requirement to function under quite reduced PU SNR is inevitable. To attain sustainable operation in these situations, the sound uncertainty and the station effect need to be carefully examined. In reality, sound uncertainty was extensively researched and researched. The principal difficulty is that ED functionality is dependent upon a renowned sound electricity and signal-to-noise ratio. But it's always supposed that SNR estimation are implemented at the SU receiver prior to using the detection mechanism. It's been demonstrated that sound uncertainty will result from the SNR-wall issue where a large number of samples is not sufficient to ensure the unavoidable false alarm and detection speeds when there's uncertainity regarding the sound level. Analytical results for your SNR-wall issue is supplied by. In reality, many strategies are introduced to overcome the sound uncertainty difficulty like [83] which quotes the doubt to be reduced by the sound level. Like the sound uncertainty problem, various research actions have researched the ED operation under different evaporating conditions to examine the constraints of the sensor concerning different fading surroundings. But more complex channel versions like the tumbled Rayleigh fading, Hyper-Rayleigh evaporating, and $\kappa - \mu$ intense vanishing have been recently examined for the ED method. The outcome of this IQ imbalance was observed and the effect was introduced picture signal because of which IQ imbalance is quantified. Further, the answers for this issue consider either utilizing the multi-threshold sensor or using an interference cancellation strategy having an improved cancellation coefficient. The non-linear performance of this receiver is believed by, in which the intermodulation of the Low Noise Amplifier (LNA) in the RF front-end is inspected and its functionality reduction effect is clearly exposed [1].

2) Therefore, it’s known to be an Optimal sensor in character. This technique may be utilized if the SU has info not just concerning the constraints of the creation of the signal, but also the execution to the consumer. In cases like this, MF could be applied by utilizing cross-correlation involving the received signal and the order. Every time there seems a correlation peak, the sensor assumes a main sign is present. Otherwise, there is a ring that was empty maintained. In reality, the majority of wireless network agendas have preludes, pilots, synchronization signs, as well as specific codes that enable detection. Because of its strong functionality in low SNR regime, MF detection was chosen to help the fundamental energy sensor for detecting very weak signs where the operation of these ensuing is significantly besmirched. Besides the large computational difficulty of the strategy, the paired filter was employed in SU receiver to spot the confused

transmissions during a quiet interval. In, MF sensor is not utilized to discover the existence of the PU, but in addition, it recognizes a PU's energy level.

If the SU can assess the energy level of this PU, SU is going to have the ability to adjust its electricity to fit with the interference requirement. As a phase to system implementation, the MF detector performance was replicated and assessed in contrast. The results reveal that MF has a SNR lenience compared to energy sensor, as anticipated. But it was noted that the efficiency and sensitivity to MF sensor quickly decreases with increase in typical fluctuation of sound power and become even worst in low SNR. This occurs only to get a fixed threshold, however the operation could be improved by correcting the threshold variable.

Even though MF sensor seems to offer the functionality, this imposes SU to become attentive to the network. In certain situations, like the spectrum trading where the secondary system is in total coordination with the principal system since the prior rents the spectrum whenever it is idle, this is possible but really, it is not the major norm of becoming cognitive radios. Also, it's not necessary to get this boundless performance by utilizing the paired filter sensor because of the technical implementation problems which obstruct its functionality. For example, without fading station, any understanding about a frequency offset, or timing, the significance become weak and the detection accuracy is reduced.

3) Generally speaking, practical communication methods comprise identifying attributes by definition, in which a few attributes are included for synchronization or signaling functions like preambles, pilots, cyclic prefix (CP), beacon frames, bypassing sequence etc. That’s a cyclostationary, or possibly the figures of this PU signal display for sensing functions, a grade of periodicity which may be researched. Actually, feature detection contains a category of spectrum. These methods share the notion that understanding complete or semi info enables the building. Here, we'll present the most frequent examples for attribute discovery which predominate from the study subjects regarding sensing that is narrowband.

First, a subclass of feature detectors is created on the understanding of this PU signal structure. Normally mid-ambles, preambles, pilot company, or scattering sequences are summed into the PU sign to assist organization process. Waveform detection is a sensing system which uses the sign routines that are famous. At the presence of signs that were known, the decision statistic is shaped by correlating the received signal. To be able to discover the presence or lack of a PU, the outcome is compared to a threshold value.

Second, another subclass of feature sensor is contingent upon the order statistics of the signal that is received. Sometimes like the Orthogonal-Frequency-Division Multiplexing (OFDM), the characteristic is connected to the periodicity of this PU sign itself and second order data like autocorrelation can disclose the explicit correlation construction levied from the clipping of CP in the PU transmitter. Because of the prevalence of OFDM in advanced communication systems today, a particular focus has been designed to design Decent decision statistic that Offers good detection functionality and requires the minimal set of known info concerning the OFDM signal.

Third, A characteristic is exploited by the purchase, Because PU signs are generally controlled. In Fact, most artificial signals show Patterns associated with processor speed, symbol rate, or station code. Cyclostationary attribute method addresses the cyclostationary properties that can't be found in sound or almost any interference signal. Mainly, the sensor utilizes perceptible correlation periodicity from the received main signal to spot the existence of main users, and that's the reason why the cyclostationary attribute detection procedure is reliable technique of SS at low SNR since it owns greater noise immunity than every other spectrum detection method.

1.3.3 WIDEBAND SPECTRUM SENSING

Wideband SS method main objective is to sense a frequency bandwidth which surpasses the coherence bandwidth capacity of the channel. Suppose we want to achieve spectral opening in the entire ultra-high recurrence (UHF) TV band (between 300 MHz and 3 GHz), wideband spectrum detecting methods must to be utilized. We must specify that narrowband detecting methods can't be legitimately utilized to perform wideband range detecting as they settle on a solitary twofold choice for the entire range and in this manner can't recognize individual unearthly open doors that exist in the wideband range [1].

In view of the testing recurrence, two primary classes of arrangements are accessible to manage the wideband detecting issue. The first way to deal with acknowledge wideband detecting expect that it is practical to test the ideal range by the standard Nyquist rate. For this situation, a few methodologies expect that the issue can be changed over into different narrowband identification issues. Others attempt to recognize the involved sections and the empty ones by simply distinguishing an edge identification. The regular test in these methodologies is the great computational intricacy appended to the vital ultra-high inspecting rates, the high computational multifaceted nature of the arrangements, and the vital detecting time particularly as soon as useful contemplations are considered, for example, the Automatic-Gain-Control (AGC) settling time, the exchanging time for the Phase-Locked-Loop (PLL), and the preparing delay.

The second method to do wideband sensing is based on the sub-Nyquist techniques. These methods are utilized to lessen the long sensing delay or the higher computational difficulty and hardware cost resulted from the high sampling rate executions. Compressive sensing becomes a capable candidate to understand this sub-Nyquist approach. Here, a flag can be productively obtained utilizing generally couple of estimations by which one of a kind interpretation of the flag can be discovered dependent on the flag's sparsity or compressibility in some area. Discharge, and diffuses the choice back to coordinating CR clients. Dispersed helpful detecting is another model where SUs trade information with each other as opposed to answering to a typical FC. Initially, customary agreeable detecting centers around one recurrence band amid each round of collaboration (i.e., narrowband detecting). In any case, this procedure can bring about critical exchanging deferral and synchronization overhead if a ultra-wideband range is required to be detected. In the event that wideband detecting is required, CR clients can coordinate to detect different restricted groups as opposed to concentrating on one band at any given moment so as to lessen the all-out detecting period for all clients. One path is to detect K groups from M spatially conveyed CR clients and afterward the insights are joined at the FC which settles on an agreeable choice on each band. Additionally, a parallel helpful detecting plan is proposed to empower the multi-channel detecting by ideally chose participating CR clients. Here, each of participating CR clients detects an alternate channel whose most extreme location rate can be accomplished by the planned CR client. For sure, utilizing multi-band detecting reduces the detecting time and channel exchanging overhead of narrowband detecting.

Further hardware cost is essential to help simultaneous detection in several bands. As stated before, cooperative sensing is one of the several cooperative communication technique and is only valid to interweave cognitive networks to progress the sensing accuracy, with detection probability and false alarm probability, which might not be suitable with any single-user sensing technique. But, an interweave CR working in a passive mode is sensitive to the events of primary users. In the case with a truncated idle probability of licensed spectrum, a cognitive network can scarcely get an opportunity to get to the range for its own interchanges. Surely, in spite of the execution enhancement to sensing accuracy brought by collaboration, there are a few impediments which may demoralize the utilization of agreeable detecting.

First, cooperative methods need the info exchange between the nodes, that increases signaling overheads.

Second, there can be assaulting nodes to destruct the collaboration due to which the reliability of participation would be significantly decreased.

Third, collaboration addition might be influenced by numerous disabilities going with different SU hubs. For instance, different SUs might have distinctive channel surroundings, SNR qualities, and RF blemishes with the goal that the normal choices from different hubs are commonly arbitrary.

1.3.4 COOPERATIVE AND NON-COOPERATIVE SENSING

Because of hidden terminal and non-line of sight (NLOS) communicating problems in the moderate, solitary node sensing functionality is unreliable as well as it raises the miss-detection pace. The CR receiver is going to be levied as receiver sensitivity suggests that the capacity of detecting signals on the execution sophistication increasing. The detection performance can't be enhanced by raising the sensitivity, once the SNR of PU signs is under a level socket. The idea is to boost the functionality through exploiting the spatial diversity from the notes of CR users that are found. All working CR operators report their detection outcomes via a defined controller station. The FC determines the existence of PUs unites the local data that is obtained, and disperses the choice to cooperating CR operators. Cooperative feeling is just another version rather than reporting to a FC, in which SUs exchange information together. In the beginning, conventional cooperative sensing concentrates on a single frequency band throughout every round of collaboration (i.e., narrowband sensing). But this procedure can experience significant switching Synchronization and Wait overhead when a spectrum must be felt. In case wideband sensing is needed, CR users may collaborate to feel multiple narrow bands rather than focusing on a single group at one time so as to cut the total detection time for many users. Additionally, there is a parallel sensing technique suggested for allowing the feeling. Here, of tinkering CR users each detects a station whose detection rate can be accomplished by the coordinated CR user. Really, by sensing channel shifting overhead of sensing and can lessen the time that is feeling. But overhead or additional hardware cost must facilitate detection. As stated previously, combined sensing is merely one of many combined communication methods and is only valid to interweave cognitive systems to enhance the feeling accuracy, such as false alarm probability and detecting probability, which might not be satisfactory with almost any single-user sensing process. But an CR operating in a manner is sensitive to users' actions. In case with a likelihood of spectrum, a system can get a chance. Really, to sensing precision due to collaboration regardless of the performance advancement, there are a few constraints that may discourage using combined sensing. To begin with techniques, demand the data exchange between the nodes. Secondly, there might be some assaulting nodes which can ruin the alliance and the reliability of alliance could be significantly reduced. Third, impairments may affect alliance gain accompanying SU nodes.

To be able to follow along with the implementation improvements in the management of sensing, the fundamentals of the collaboration process are all considered. The main problem is to resolve the problems related to sensing [1].

CHAPTER 2

LITERATURE SURVEY

2.1 RELATED WORK

There is way out a significant research exertion on vitality effective and dependable discovery of accessible range for helpful range Cooperative SS in CRSNs. Vitality effective and unwavering quality are both the most significant elements, since they legitimately impact the lifetime of the system and the precision of range detecting. There have been a couple of research endeavors exploring vitality productivity and unwavering quality in CRSNs.

Following are some related work Lee et al proposed a dispersed vitality identification plot that abuses the spatial– fleeting relationship for heterogeneous CRSN [2]. The sensor hubs participate specifically as per their spatial area which is determined by the recieved signal quality (RSS). Jiang et al. proposed a vitality efficient strategy for dynamic range detecting. Novel SS and hubs choice techniques are proposed to enhance the vitality and spectrum efficiency together in [1]. Mama et al. propose another energy efficient strategy dependent on the developmental amusement for cooperative SS. The contribution-punishment mechanism is intended to give sensor nodes a chance to detect the channel adequately, which can invigorate sensor nodes with high sign to-noise proportion (SNR) to take part in SS. Meanwhile, a periodic sleep-listen mechanism is acquainted to lessen the wasted vitality of sensors when idle. Be that as it may, for substantial scale organizes, the proposed technique will be energy-intensive. Moreover, when there is just a single node to perform SS, it is progressively likely for it to settle on a wrong choice because of such situations as extreme channel blurring and concealed hubs in [3]. A distributed SS scheme is proposed in [4] which considers the unwavering quality of neighborhood spectrum agreeable range detecting technique by applying D– S hypothesis. Besides, considering the flawed nodes in CRSNs, the unwavering quality of the sensor nodes and the shared help between various nodes are considered in [5]. Liuet al. propose a novel agreeable range detecting plan, which is not the same as conventional helpful spectrum detecting, in light of D– S hypothesis, utilizing a multi-modal SS to join the multi-modal sensing data of the PU signal [6]. One method against faulty nodes is proposed in [7]. Because of the difference between unreliable nodes and honest nodes, the reliability of these nodes can be calculated using the similarity between sensor nodes, while the nodes with low reliability should be eliminated from FC. Wang et al. propose a novel cooperative SS method which simultaneously considers the current difference of SUs and the statistical information of each node's historical behavior. But it does not consider the residual energy of nodes, which may lead to nodes failure during data transmissions. Monemian, et al. propose a heuristic algorithm which periodically selects an appropriate set of sensor nodes with minimum average energy consumption for CSS. Meanwhile, a sub-optimal algorithm is proposed to reduce the computational complexity of the heuristic algorithm. In view of the receptiveness, elements and vulnerability of the remote condition, the channel conditions are progressively changing, a relationship mindful node choice plan is proposed in to adaptively choose the uncorrelated nodes for CSS. In, going for saving energy consumption, an optimization framework has likewise been proposed to mutually take care of the issue of detecting node determination and choice node choice. At the point when there are real channel proliferation impacts, has examined and inferred general criteria for decision-approach selection. Taking into account that just part data of SUs and PUs is accessible, Najimi, et al. propose an energy-efficient node selection algorithm to minimize energy consumption while still satisfying the average detection probability.

In any case, the majority of the above existing works use current data to choose nodes or gauge the unwavering quality of every node. Despite the fact that the present data reflects the unwavering quality of nodes somewhat, it is one and only sided, not constantly precise, and it is 'additionally superfluous to gauge the data of most nodes, because of the likeness of the detecting consequences of thickly sent nodes. Not quite the same as the current endeavors, notwithstanding the present data, the verifiable data of nodes which reflects their recorded reliabilities ought to likewise be used in the choice of R-Nodes. Besides, to improve the unwavering quality of range detecting, the dependability assessment is before the final basic leadership dependent on D– S theory, because of the dynamic and questionable character of remote condition.

Therefore, in this paper, we propose a novel node selection scheme for CSS based on D–S theory. It is carried out in three successive steps, which are node filtering strategy, R-Nodes selection and decision making by the combination rule of D–S theory.

CHAPTER 3

PROBLEM STATEMENT AND PROPOSED SYSTEM MODEL

While we were using the non-cooperative method to for sensing earlier we faced many problems such as the high energy consumption, data overhead and the effect of malicious nodes on the performance. The proposed system model will overcome these problems by the use of cooperative SS with a base station called the fusion center. The system model makes the use of a node selection algorithm that filters out ineligible nodes. The cooperation is done only between the nodes that are reliable, have sufficient energy and are randomly distributed. Due to the reduction in the number of nodes the overall energy consumption will get reduced. Since the cooperation is between fewer but reliable nodes, the final decision will be more accurate. We also come across an optimum point where the reliability is maximum along with the probability of detection and least probability of false alarm. We also make the use of Dempster-Shafer theory for decision making. This rule is based on the theory of evidence and optimizes the final decision. The overall performance of the system becomes very which makes these algorithms applicable for the real world.

3.2 PROPOSED SYSTEM-MODEL

To solve the problems stated above such as the data overhead, effect of malicious nodes and we propose a system model. This model has two main steps:

- R-node selection
- Decision based on the Dempster-Shafer theory

An algorithm needs to be followed in order to apply these theories in practice. The algorithm for these two steps is depicted in the **flow diagram below**.

With every step there are some parameters that need to be assumed in order to move forward. These assumptions will be specified at each step accordingly.

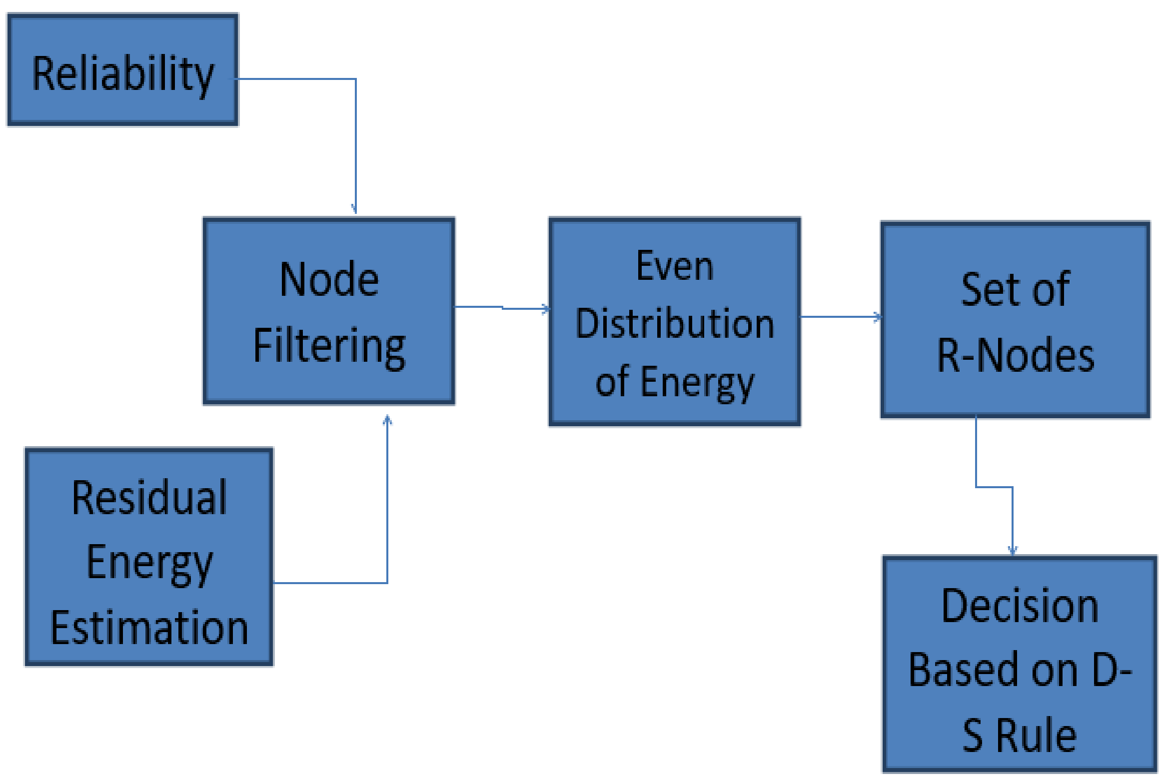

Fig.2 R-node Selection Algorithm

3.2.1 R-Node Selection Algorithm

The steps included int the R-node selection algorithm is as follow:

- Reliability Calculation
- Residual Energy Estimation
- Node filtering
- Even distribution of nodes

In this system model we assume that there exists an area of 100 X 100 meters which consists of primary users, secondary users as well as a fusion center. The primary user is a licensed user who has purchased a chunk of bandwidth for their use but may have some existing white bands. A secondary user is a user who has not purchased any bandwidth but wishes to utilize some based on the requirement. A fusion center is a base station where all the mathematical operations are conducted because we assume that the base station does not have energy constraints. The final decision is taken at the fusion center as to whether the secondary user can occupy the primary user's bandwidth or not.

There are two steps in order to decide whether the secondary user can occupy the bandwidth or not. One decision is taken by every node at its own level i.e. local decision, and a final decision taken at the fusion center i.e. global decision.

Hypothesis:

$$x(t) = \begin{cases} n(t) & H_o \\ h(t)s(t) + n(t) & H_1 \end{cases} \tag{1}$$

The sensing of a bandwidth can give two result; either the bandwidth is vacant and can be occupied by the secondary user, the bandwidth is occupied and cannot be occupied by the secondary user. The former is hypothesized as H_0 and the latter one as H_1.

A. Reliability Calculation

We need to calculate the reliability of every node in order to justify its final decision. The more the reliability of a node the more chances are that the local decision will match with the global decision. Hence reliability calculation is an important step towards the decision making. Accordingly, [2] the reliability of a secondary user can be calculated using the formula:

$$\mathrm{Re}\,l_j = P(H_0)P_d + P(H_1)(1 - P_f) \tag{2}$$

Since there is an equal probability that the primary user is present or absent at a bandwidth. We assume the probability of hypothesis H_0 and H_1 to be equal i.e. 0.5. We require a low level of probability of false alarm so we assume it to be 0.1. Since we have assumed the probability of false alarm to be very low we can calculate the probability of detection. We use the following formulae to calculate the probability of detection:

N= 2TW (3)

$$P_{dj} = P(X_E > \in | H_1) = Q\left(\left(\frac{\in}{N} - \gamma - 1\right)\sqrt{\frac{N}{2\gamma + 1}}\right) \tag{4}$$

$$P_{fj} = P(X_E > \in | H_0) = Q\left(\left(\frac{\in}{N} - 1\right)\sqrt{N}\right) \tag{5}$$

Where N is the time-bandwidth product which is assumed to be greater than or equal to 200. γ is the SNR of the channel that is being sensed by the secondary user, ε is the detection threshold of the received signal power Q (•) is the complementary distribution function of the standard Gaussian.

The total probabilities of detection and false alarm can be calculated using the following formula where the j is the number of users which cooperate to give a global decision.

$$P_f = 1 - \prod_{j=1}^{n} \left(1 - P_{fj}\right) \tag{6}$$

$$P_d = 1 - \prod_{j=1}^{n} \left(1 - P_{dj}\right) \tag{7}$$

B. Residual energy estimation

Energy is consumed at various steps of the process. There are two important processes that consume energy which are:

Energy consumed in sensing

Energy consumed in transmitting data to the Fusion Center

Every node that participates in the process must have sufficient energy in order to work efficiently. If the secondary user does not have energy greater than the sum of the above two mentioned energies, then we consider it to be a dead node.

We assume that every node has an equal and fixed initial energy E_0 i.e. 0.5 joules. The residual energy of every secondary user should be greater than a fixed threshold E_{min}^{j} i.e. 0.2 joules only then will we consider this user for further process. Energy consumed in sensing E_{sj} and for transmitting data E_{tj} can be calculated using the following formulae:

$$E_{tj}(d) = \begin{cases} E_{elec} + \in_{fs} d^2, d \le d_0 \\ E_{elec} + \in_{mp} d^4, d > d_0 \end{cases} \tag{8}$$

Where d is the distance between jth node and the fusion center, E_{elec} is the transmitter electronic energy, E_{fs} and E_{mp} represents the energy coefficient of above two models and d_0 indicates the distance limit **formulated by:**

$$d_0 = \sqrt{\in_{fs}} / \sqrt{\in_{mp}} \tag{9}$$

Residual energy can be calculated using the **following formula:**

$$E_n^j = E_0 - E_{sj} - E_{tj} \tag{10}$$

The results of this can be further used to filter out secondary users from the total users.

C. Node filtering

Using the two parameters i.e. Reliability and Residual energy we filter out the eligible set of users. These users will thereafter be used for further processing.

The threshold level for Residual energy is $\boldsymbol{E_{min}^{j}}$ **and that for reliability is λ:**

$$\mathrm{Re}l \geq \lambda_1, E_n^j \geq E_{\min}^j \tag{11}$$

In order to filter out the users we equate the matrix location to zero.

D. Even distribution of nodes

After filtering out the secondary users we observed that more number of users exited in areas with better physical environment and areas with poor and noisy environment had very few secondary users. Due to this uneven distribution of users, bandwidth in areas with poor environment still was unoccupied. To overcome this problem, we require an even distribution of nodes. We form a matrix of random numbers Θ generated between 0 and 1. Now we set a threshold limit T (n). All the numbers above that threshold are selected for further process and the rest are eliminated out. By doing this we get a random and evenly distributed set of nodes. This completes the filter part of the nodes and the decision-making part starts from here on.

$$T(n)=\begin{cases}\left(\dfrac{p}{1-p\left(r \bmod\left(\dfrac{1}{p}\right)\right)}\right)\dfrac{d(i,FC)}{d_{\max}(i,FC)-d_{\min}(i,FC)}, n\in G \\ 0\end{cases} \tag{12}$$

3.2.2 DECISION BASED ON DEMPSTER-SHAFER THEORY

The D-S theory also known as the theory of evidence allows us to combine the evidences or results from different sources. The decision is based upon the similarity analysis. The algorithm followed for the D-S theory is as follows:

- Basic Probability Assignment
- Similarity Degree Analysis
- Selection and Adjustment of BPA
- Combination Based on D-S Rule

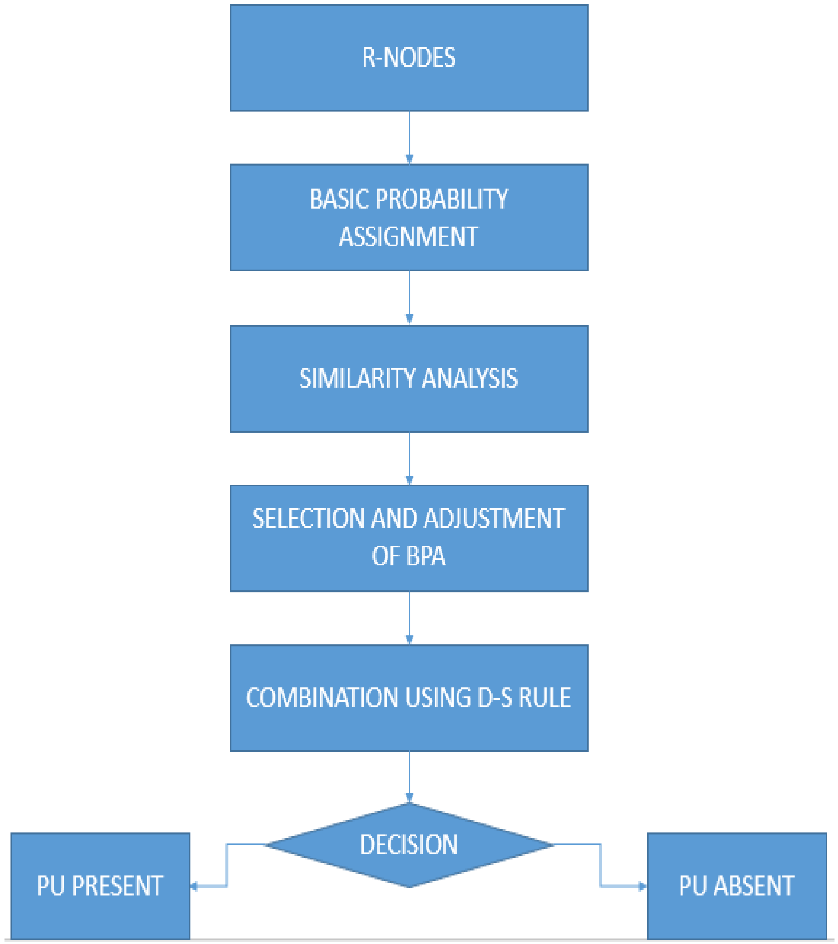

Fig.3 Decision Based on D-S Rule

A. BASIC PROBABILITY ASSIGNMENT

The fact that primary user is present or absent can be explained by a binary hypothesis. Every R-node provides some information to share based on its local decision. Hence every node is giving its result in terms of probability and this is called the BPA of every R-node.

$m_i(H_0) = The\ BPA\ of\ Hypothesis\ H_0$

$m_i(H_1) = The\ BPA\ of\ Hypothesis\ H_1$

After the R-node selection each node has to calculate its BPA and share it to the fusion center. The BPA can be calculated by the cumulated power of the received signal. To simplify this process, we assume that the BPA of H_0 is approximately equal to the probability of false alarm of that particular R-node. Similarly we also assume that the BPA of H_1 is approximately equal to the probability of miss detection of that particular R-node. These assumptions reduce the mathematical calculations for present simulations and we can now proceed for the similarity analysis.

B. SIMILARITY DEGREE ANALYSIS

Now we introduce a new concept of malicious nodes. Due to the environment of a R-node some of the decisions sent by these nodes may be false i.e. the node is communicating false information to the fusion center intentionally.

Our task is to separate these nodes form the ones which are communicating correct information to the fusion center.

We can achieve this by similarity analysis. The idea behind the similarity analysis is to check whether the local decision communicated by the one R-node for a bandwidth is similar to the local decision communicated by some other R-node for the same bandwidth or not. If most of the decision say that the bandwidth is occupied, then the global decision will be occupied and vice versa.

To practically perform this, we require a parameter called credibility. This parameter will give a weight to ever R-node based on the overall performance. If the credibility is high this means that the probability that the decision is correct is high. To calculate these parameters, we have the following formulae:

$$d_i = \frac{\gamma_i}{2\sqrt{1+2\gamma_i}} \tag{13}$$

$$cre_i = \frac{d_i}{max(d_i)} \tag{14}$$

C. <u>SELECTION AND ADJUSTMENT OF BPA</u>

In this step the idea is to calculate the final BPA after the similarity analysis. Here we obtain a BPA that has been adjusted according to the credibility of the R-node. The BPA of malicious nodes is supposed to be low after the analysis and that of healthy nodes is supposed to be high. To calculate this, we use the following formulae:

$$m_i^*(H_0) = cre_i . m_i(H_0) \tag{15}$$

$$m_i^*(H_1) = cre_i . m_i(H_1) \tag{16}$$

D. <u>COMBINATION BASED ON D-S RULE</u>

This is the final step where the global decision is to be taken by the fusion center based on the previous analysis and data processing. The combination can be obtained by the following:

$$m(H_0) = m_1^* \oplus m_2^* \oplus m_3^* \ldots. \oplus m_p^*(H_0) \tag{17}$$

$$m(H_1) = m_1^* \oplus m_2^* \oplus m_3^* \ldots. \oplus m_p^*(H_1) \tag{18}$$

The decision is now based on the following:

$$m(H_0) > m(H_0) \qquad H_0 \tag{19}$$

$$m(H_0) \leq m(H_0) \qquad H_1 \tag{20}$$

This means that if the first equation is true then the final decision is: Primary user is not present in the bandwidth and it is available for the secondary user to use.

If the latter one is true, then the final decision is: Primary user is present and the bandwidth is not available for the secondary user to use.

CHAPTER 4

RESULTS AND FUTURE SCOPE

Cognitive radio is an upcoming technology that makes the use of intelligent software defined radio system to maximize the use of available spectrum. There are various dimensions in which there is scope for improvements like spectrum monitoring, spectrum analysis, spectrum mobility and spectrum decision. The proposed system model makes the use of D-S theory for decision making but there are various other options like the graph theory or the game theory by which this may be possible. Currently a lot of effort is being put into the SS because with poor sensing the whole system can fail. Therefore, it is very essential to have efficient sensing. Various system models are also being designed in build accommodate the cognitive radio architecture.

In order to build a system-model we need various random parameter. The following result is miniature of a 100 x 100 field with nodes i.e. secondary users and a fusion center. All the final decisions will be taken at the fusion center, since we assume that the fusion center has no constraints of energy. The earlier cooperative systems were using every node for sensing and then sharing their information. Whereas, our system model uses an algorithm and cooperates only between the efficient nodes for better results.

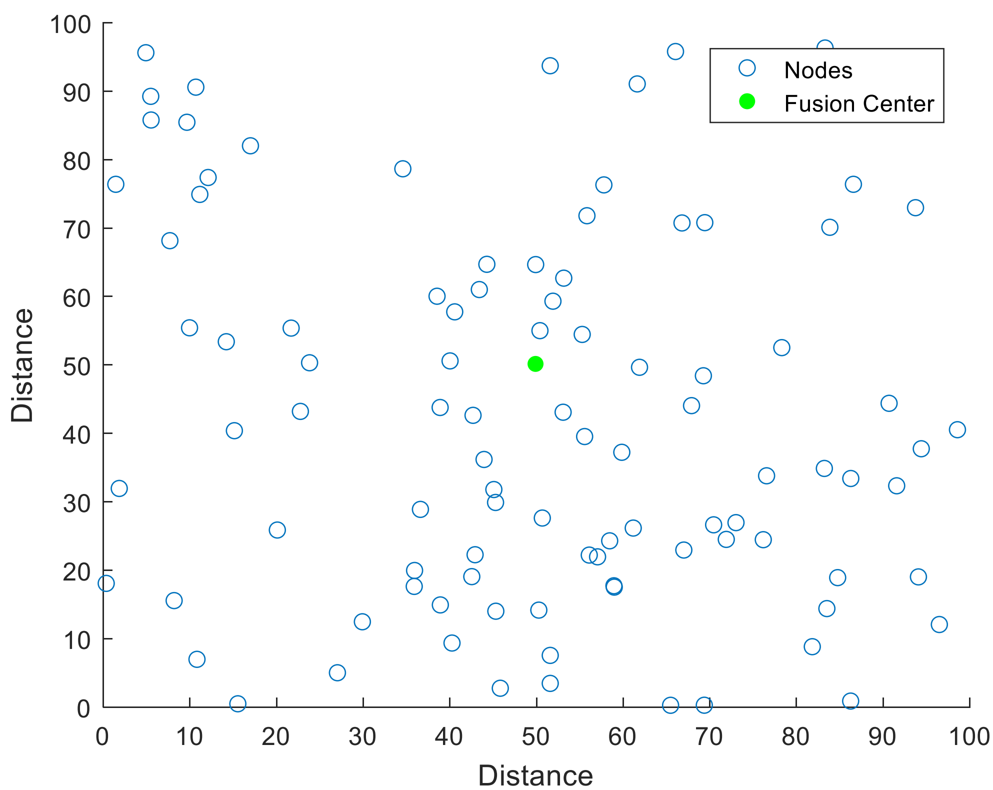

Fig.4 Random Distribution of Nodes

For the purpose of comparison, we see the performance of non-cooperative method and cooperative method using the OR rule, AND rule and the Majority rule. We observe that the Majority rule is the most efficient and non-cooperative the least efficient.

The graph is between the probability of detection versus the probability of false alarm. We want the probability of detection to be maximum i.e. above 0.9 and the probability of false alarm to be minimum i.e. below 0.1.

Further now we will use our R-node selection algorithm and compare the results thereafter.

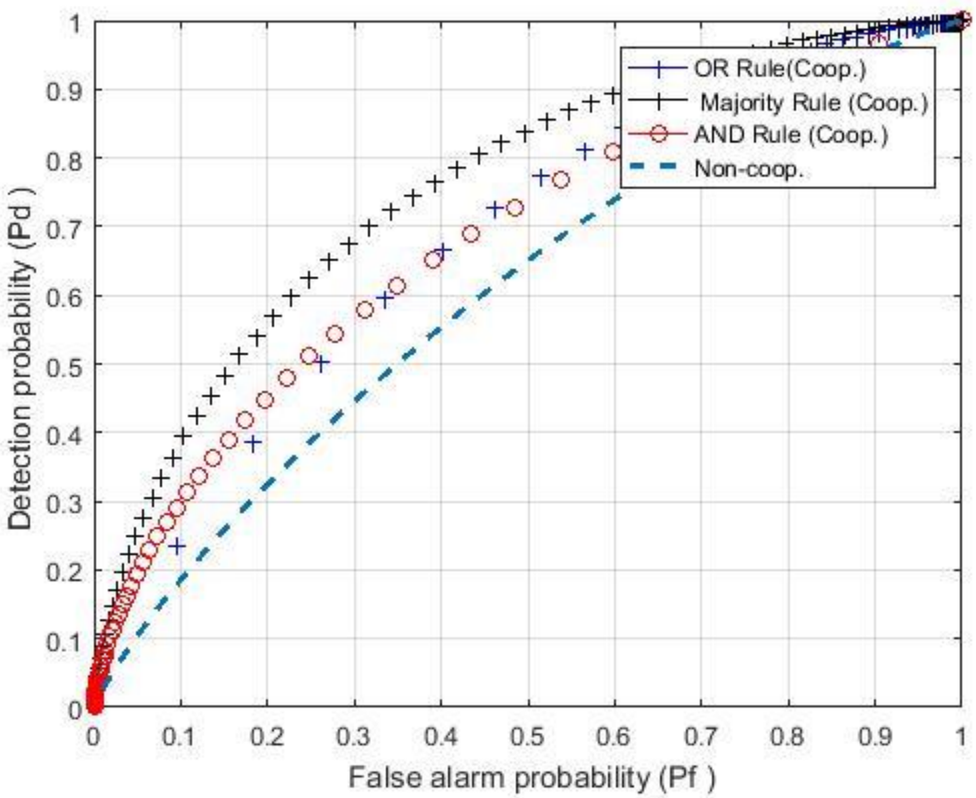

Fig.5 Performance Comparison

This is a graph between probability versus the number of nodes participating in cooperation. We have the probability of detection and false alarm. We observe that as the number of users cooperating reaches 15 (approx) and above the probability of detection goes above 0.9. From this we can conclude that we can get a reliable result with cooperating with only 15 to 20 nodes rather than cooperating with all 100 nodes. This reduces the overall energy consumption and also reduces the data overhead.

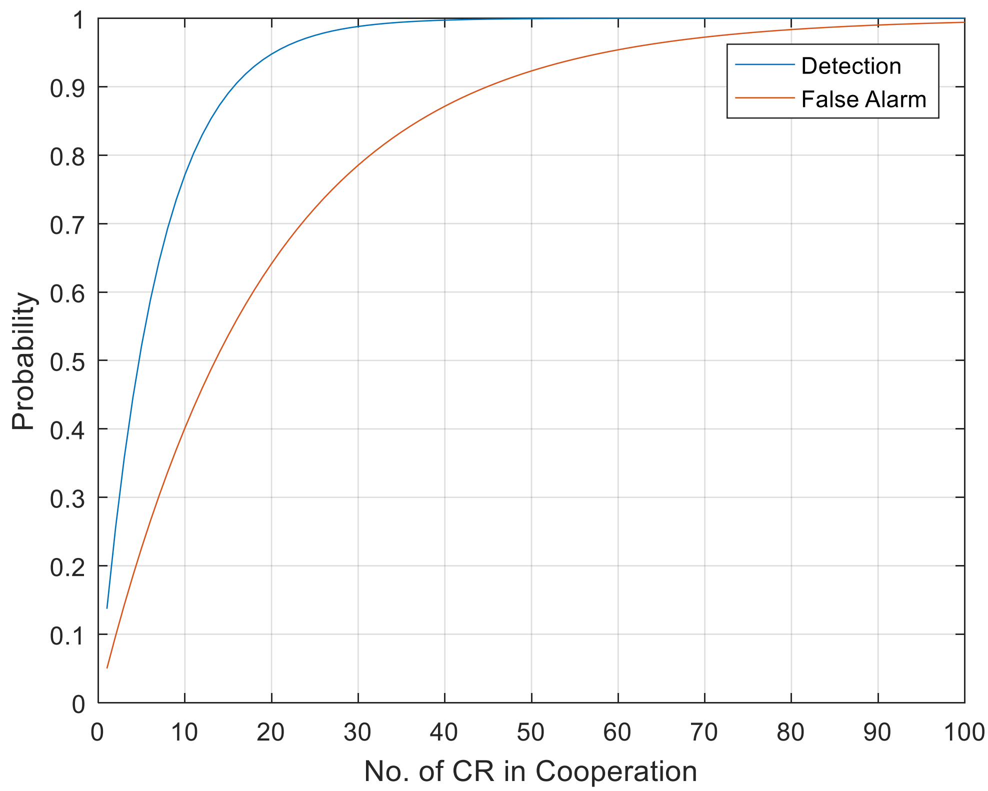

Fig.6 Probability of Detection & False Alarm Before Filtration

This is a plot between the reliability and probability. The graph is for two probabilities i.e. probability of detection and false alarm. We observe similar graphs for the two but that of false alarm shifted.

We see that there is an intersection point of the two. This intersection point is an optimum point where the reliability is maximum with least probability of false alarm and maximum probability of detection. If we move towards the right of this point the reliability of detection will increase but that of false alarm will decrease. Also the probability of detection and false alarm will both increase.

If we move towards the left of this point the reliability of detection will decrease but that of false alarm will increase. Also the probability of detection and false alarm will both decrease.

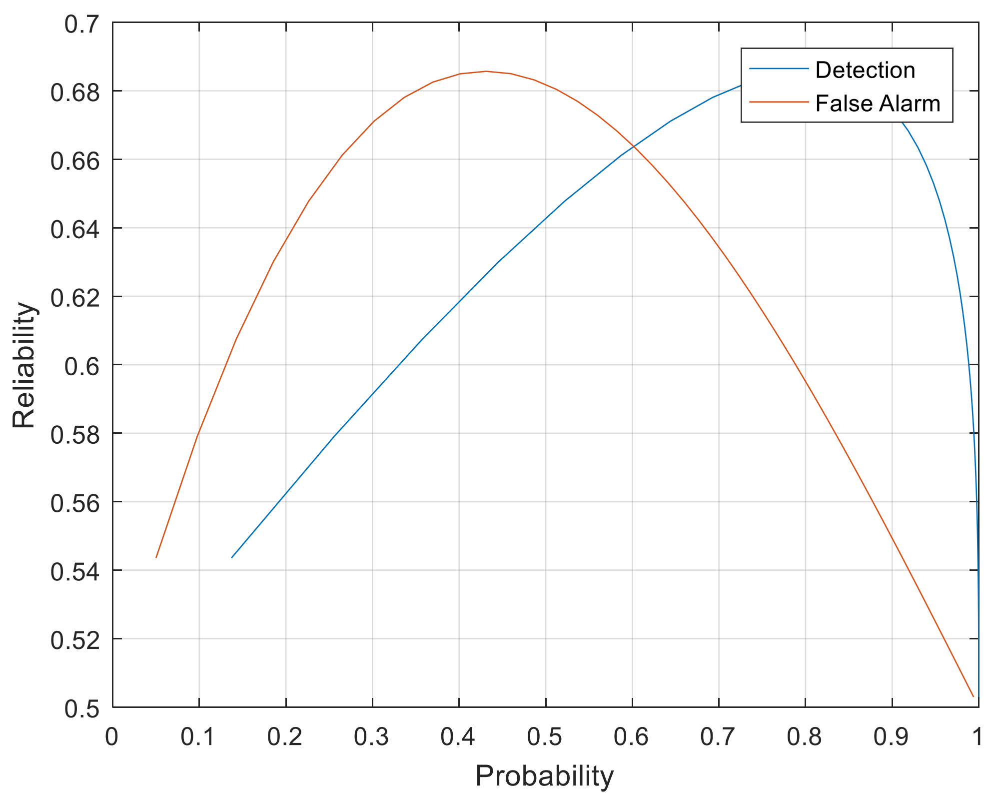

Fig.7 Reliability vs. Probability

This is a plot with probability and number of users participating in cooperation. The difference between this graph and result no. 3 is that this one is after we have filtered out the ineligible nodes. Nodes will sufficient energy and reliability only participate in the process and we observe that the probability of detection almost approaches to 0.9. The probability of false alarm decreases significantly to 0.54. We see that both the probabilities move towards the desired directions. Hence from this we can conclude that the filtering process was successful and we can use it for this purpose.

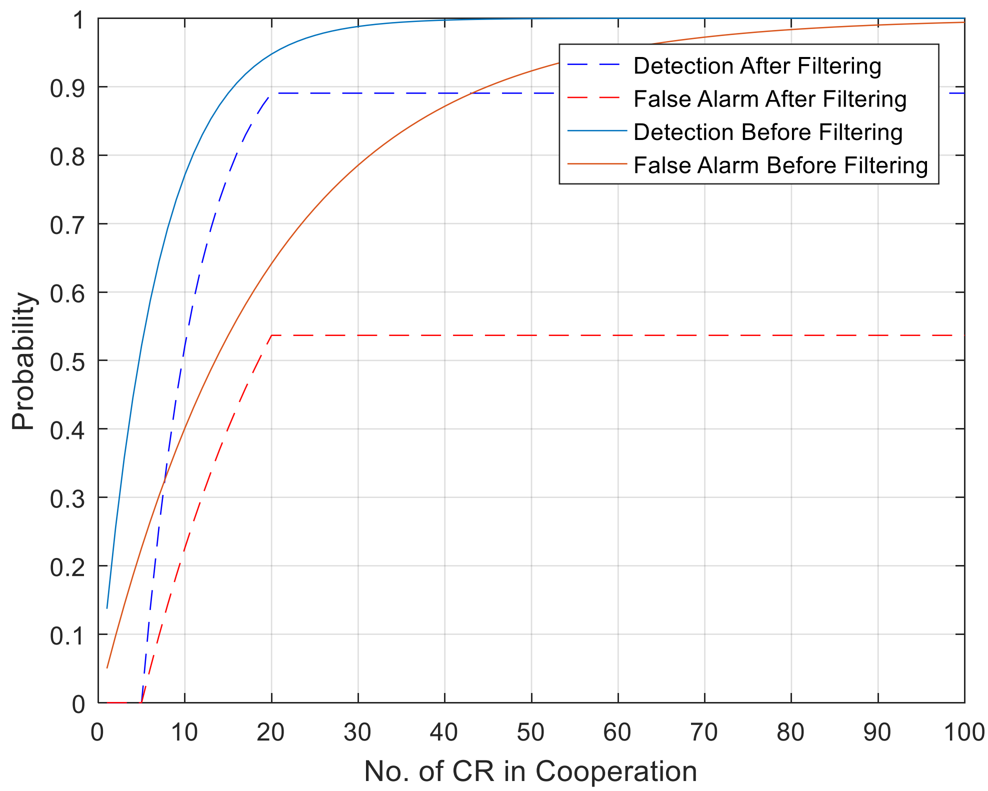

Fig.8 Probability of Detection & False Alarm After Filtration

This is a plot with probability of detection versus the probability of false alarm. Here we introduce the concept of malicious nodes. We assumed in one that there are no malicious nodes, then with 40% malicious nodes and with 20% malicious nodes out of the total. We observe here that the performance of the system decreases as we introduce the concept of malicious nodes. Now we will apply the D-S rule and see the effect of malicious node thereafter. Our assumption is that after applying the D-S rule the performance degrading due to the malicious nodes should not happen.

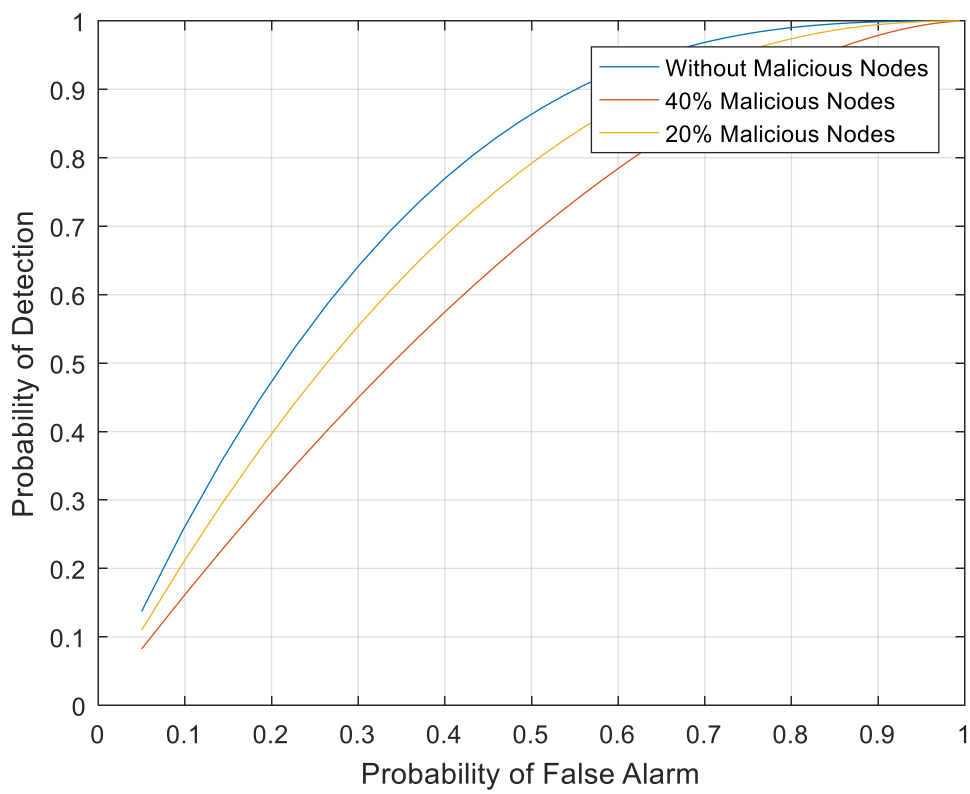

Fig.9 Performance Comparison Before Filtration

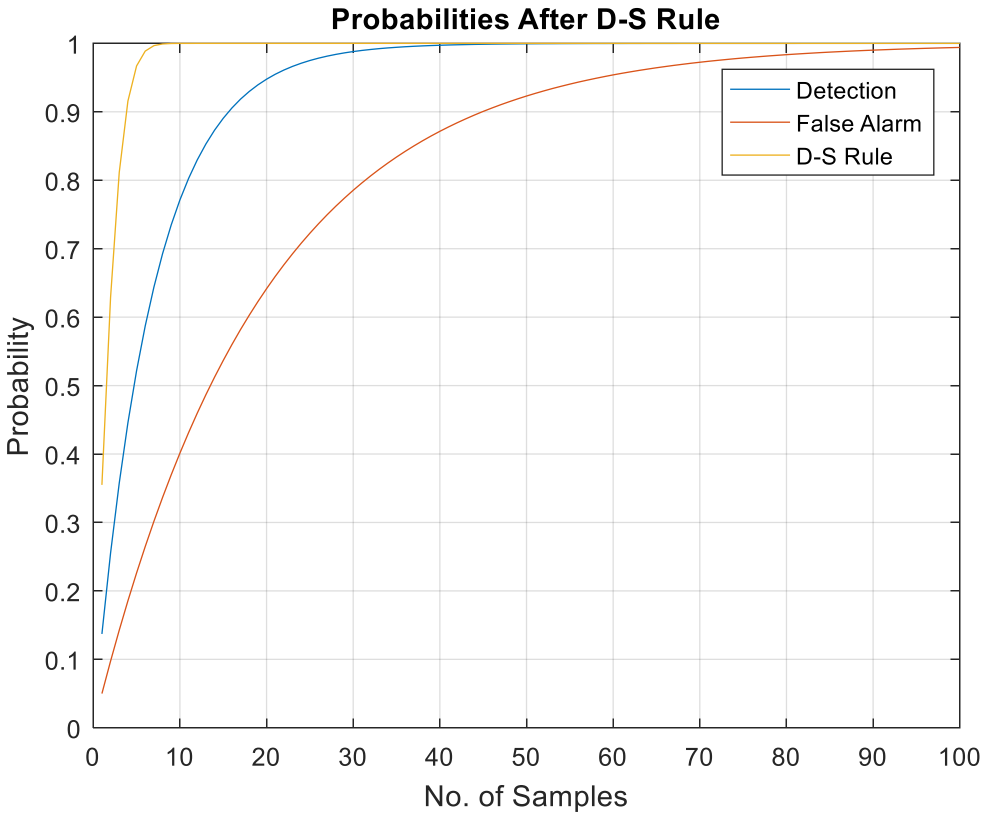

Fig.10 Probabilities After D-S Rule

This is the final result after applying the D-S Rule. We can finally see that the performance after the D-S Rule has increased significantly. We can also conclude that after applying the D-S Rule even if the R-nodes are between 5 to 10 still the probability of correct result is high. There is negligible effect of malicious nodes. The D-S Rule solves this problem. Hence the combined effect of the node selection algorithm and the D-S Rule has increased the performance significantly. From this we conclude that the practical application of it is possible and efficient. We can use it for cooperative spectrum sensing with a fusion center.

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