Cluster based Spectrum Sensing in Cognitive Radio Network with Optimal Number of Overlapping Antennas

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Abstract
The success of cognitive radio network (CRN) depends upon the accurate spectrum sensing. The hidden and open terminal problems are serious threats in the way of reliable communication. Cluster based architecture with cooperative spectrum sensing is widely adapted to overcome these challenges. In this paper, we propose a cluster based architecture with overlapping antennas. The number of overlapping antennas increases the overall performance of the system by improving the accuracy of detection. But on the other hand the overlapping antennas, increases the over heads of the system as well. So in order to achieve a balance between efficiency and system overhead, optimal numbers of overlapping antennas are suggested in this paper. Mathematical model along with simulations are presented in this paper which guarantees the sufficient number of overlapping antennas in the cluster.
Keywords
cognitive radio network, Clusters architecture, Overhead

1. INTRODUCTION

CRN gain enormous popularity in recent days as it is among the best choice to overcome the problem of wireless spectrum scarcity. The concept of cognition is to find the holes (unused spectrum) in the licensed spectrum. The licensed spectrum is the property of licensed users which is called primary users. With the help of cognition, we make sure that there are no primary as well as secondary users are present at this time in these holes. These holes or unused spectrum are assigned to requesting nods. But, on the arrival of primary user, the secondary user has to vacate the holes. The secondary user jumps to another hole which is already detected. So the phenomenon of cognitive radio heavily depends upon accurate spectrum sensing for finding holes [1].

In CRN it is very important to gather each and every detail about the whole network. This information can help for these basic designing parameters.

A. Power control

In dynamic spectrum sharing, there must be co-existence with other primary or secondary users. The primary user should not be interfered by the SUs. It might possible that other secondary users more powerful in the neighbor spectrum hole and responsible for producing a significant amount of noise. So, in order to choose the appropriate power level, it is necessary to have the complete knowledge of the network. [2]

B. Quality of Service control

For a smooth communication among users in CRN, sophisticated schemes for hand-off and distributed QoS controlled are required. To make these schemes more powerful, network information is necessary [3].

C. Information about application

Further to information about the spectrum usage, it is also necessary to have complete knowledge regarding to the application running on the higher layer of the communication protocol stack [4].

The most serious threat on the performance of CRN is hidden terminal problem. This problem occurs when the CRT (Cognitive Radio Terminals) is facing shadowing due to sever multipath fading. It might possible that due to high rise building there is obstacle in the line of sight of the CRT, which sensing the spectrum. Another possible reason for hidden terminal problem is that a CRT is outside the range of primary transmitter but still causing interference for primary receiver. This problem causes a failure of accurate spectrum detection. A CRT could not able to see the presence of primary or other secondary users and will access the channel and ultimate result is collision. To deal with the hidden terminal problem and optimize the probability of spectrum detection, it is necessary that multiple CRT co-operate and create a cluster [5].

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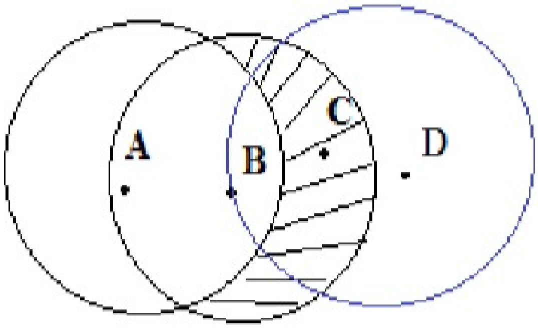

Figure 1: Hidden and exposed node problem

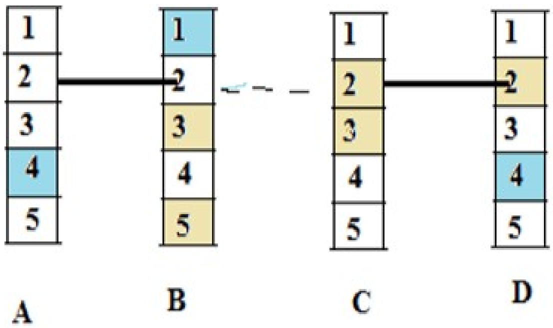

Figure 2: Hidden Terminal Problem [5]

Reliable spectrum sensing is a challenging task in CRN. The concept of CRN heavily depends upon the accurate spectrum sensing. Sophisticated schemes are used to improve the probability of correct detection. However, due to shadowing and scattering, the HTP may occur. That the spectrum is taken as vacant and available but actually some other primary user (PU) or secondary user (SU) is present. So, a collision may occur which can annoy the licensed user (PU). The cooperative scheme proved better to overcome this problem [6].

There are many techniques for spectrum sensing but the cooperative spectrum sensing with common controllers is one of best. In the cooperative spectrum sensing, the cognitive nodes along with cognitive antennas are grouped together to form a cluster. In cluster every cognitive node send its sensing report to a common controller. The common controller than makes the decision on the basis of this sensing reports. The decision of holes is than taken when all the sensing nodes sense that particular hole free from primary and secondary users [7].

The spectrum sensing with the help of clustering is presented in this paper. Although the concept of clustering is not new in CRNs, but still a lot of work is required to cover all detail of the Cognitive radio network. Although, cluster base cooperative spectrum sensing is dicussed in very large context in literature, but it is also mention that by using overlapping antennas, the overheads of the system are increased. These cognitive antennas are placed close to each other to improve the performance of system but, how many overlapping antennas are required to get optimal performance, are not yet addressed [8].

The architecture of the cluster in our model is centralized. All information gathered by the participating nodes is passed on to a Common Controller (CC). Only the CC has authority to decide which spectrum hole is available and to whom it would be allocated.

The basic building block of our proposed model is that the size of cluster is fixed, however no. of antennas could be varied on demand. With the variation of antennas, we produced overlapping, which minimize the Hidden Terminal Problem. The topology to place antennas is presented and furthermore, mathematical equation is presented to calculate the no. of terminals for various levels of overlapping.

With the help of simulation results, it is shown that when the coverage area of the antenna would be increased, the received power of the signal is decreased.

The rest of this paper is organized as follow; Section 2 provides the related previous work and their limitations. Section 3 is comprised on problem statement of CRN while section 4 provides a proposed solution, presented a system model to use in this paper. In section 5 simulation and results are presented. The contents of section 6 are comprised on discussion and analysis to analyze the proposed model. The paper ended with conclusion in section 7.

II. LITERATURE REVIEW

In[9] it is claimed that dividing the spectrum into cluster is an efficient technique for accurate spectrum sensing. The formation of these clusters based on artificial intelligence. Cluster head is selected by the entire secondary user. All secondary users send their messages to fusion center through cluster head. The cognitive node and sensor node work separately in the model proposed in [10]. In this paper *heterogeneous nodes based low energy adaptive clustering hierarchy* (HLEACH) algorithm is proposed. The sink node obtains the necessary information about the cluster and shares it to all participants. This information is about radius cluster and each node compute its distance and act as cluster head until the optimal cluster head is chosen.

In cognitive radio ad-hoc, Q-learning based technique is applied for cluster information in [11]. A cluster scheduling algorithm is proposed in [12]. The advantage of this algorithm is to avoid inter cluster collision. Multiple reporting channels in cluster to reduce reporting delay are presented in [13]. It is claimed that reporting delay affects seriously on the performance of spectrum sensing. A cluster scheme with reference point is suggested in [14]. There reference point are static and reduce the noise in the network. Energy conserving cluster method with distance criteria is suggested in [15]. Cluster head is chosen on the bases of its distance and primary users as well as common controller.

To obtain the optimal number of available spectrum in heterogeneous environment, baysan data mining technique is introduced in [16]. As there is obstacle in the way of sensing, unreliable sensing data which negatively impact on spectrum assignment decision. Another obstacle is unavailable information location. As the behavior of the spectrum is totally dynamic and varies with the respect of time and space. So it also increases the difficulties in accurate spectrum sensing. The fundamental of this cluster technique is that the secondary users are equipped with sensor and a probabilistic model to form a cluster. There is no need to have the information of network topology, locality and size of clusters. A probability distribution method along with their mathematical frame work is applied on base station to achieve correct decision.

In [17], it is claimed that collaborative spectrum sensing is much better than the individual spectrum sensing. In collaborative spectrum sensing, all nodes send their sensing reports to common controller. There are security threats in the way of collaborative spectrum sensing like falsification attack. In this attack, the report of sensing node is blocked and modified. Normally the behavior of attacker is difficult to predict but in collaborative environment, where huge data is available, the behavior of the attacker can be detected. This paper present a cluster based method for detecting of this attack. K-mean and Agglomerative hierarchal clustering is introduced in this paper and final decision of common controller is achieved by the collection of data.

A coordinated multiband spectrum sensing policy is proposed in [18]. In this paper, this policy is referred as cluster in CRN's. By use of this technique the maximum probability of free channels is achieved. The probability of free channel is compromised in such environment where CRN's channel is geographically dispersed. So in order to overcome this situation, the secondary users must be highly equipped with sensing devices to facilitate the base station by sending the sensing reports. The sensing reports of secondary users are gathered into a metric. These metrics acts as input for any clustering algorithm running at the base station. In order to obtain the behavior of primary user's spectrum, the adaptive learning is also introduced.

The challenges of spectrum sensing heterogeneous environment are discussed in [19]. In order to obtain high throughput for secondary users in channel allocation, clustering technique is proposed. The behavior of this channel would be cooperative. This cluster technique is based on maximum-weight-one-sided Bic-Lique problem. The feature of this problem is greedy heuristic and NP complete.

There is a tradeoff between cooperative spectrum sensing and its overhead. In order to obtain, a balance between these two factors, a cluster based algorithm is proposed in [20]. In this scheme all cognitive radio nodes are grouped in such a way to form a cluster and there is only one node which acts a cluster head and also responsible for communicating all sensing reports with the base station. Simulation results depicts that multilevel hierarchal cluster algorithm is more sophisticated in terms of energy consumption and sensing agility.

The famous classification techniques of machine learning are applied for spectrum sensing in [21]. The classification techniques are K-Means clustering and Gaussian mixture model. These techniques are belonging to unsupervised learning method. The supervised learning techniques are support vector machine and weighted K-nearest-neighbor. The input fed into the classification techniques is the energy vector obtained by the estimation of different level of cognitive devices. On the basis of this energy vector, the classifier decides whether this channel is available or not. In the process of classification, the classifier also needs a training phase as a convention of the machine learning algorithm. The K-Mean algorithm divides the energy vector into the cluster. The weight of each energy vector is obtained in weighted classification techniques.

In [22] the bandwidth limitation of the common control channels in cooperative spectrum sensing environment is addressed. This challenge becomes more difficult when number of communicating nodes is increased rapidly in the network and eventually causing congestion at the common control channel. In order to provide a solution for this congestion, a cluster based spectrum sensing scheme is proposed. It is claimed that the spectrum sensing with the help of clusters improved the overall performance of the system. It also improves the sensing reliability and reduced the communication overhead. In order to obtain a balance among cost and benefit, the optimal number of clusters is required. A strategy for achieving the optimal number of clusters is proposed.

In [23], the cluster based architecture is presented for choosing a common control channel in CRN. CR's are grouped together to choose a cluster head. The formation of cluster is based on the range of CR's from cluster head. The design of cluster is derived from maximum edge bic-lique problem. A spectrum opportunity clustering (SOC) which is distributed cluster agreement algorithm is presented. This algorithm addressed two aspects of network such as available idle channels and cluster size. It is used to obtain a balance between these two important but opposite factors. The increasing number of available idle channels enhances the choice of common control channels for handoff, due to arrival of primary users. By using the (SOC), a stable network is achieved and there is no need of re-clustering.

The spectrum would be more feasible, reliable and flexible by using open spectrum allocation. But on the other hand, challenges like coordination and management are also increased. The availability of common control channels in wireless ad-hoc network is also very important. The presence of the primary user and interference of other user make it difficult to communicate with control channels. A clustered based frame work for cooperative sensing in a wireless mesh network is presented in [24]. The formation of cluster is the collection of neighbor nodes and furthermore these clusters are connected to each other. In this paper the issues regarding the formation of a cluster and cluster management like discovery of node, connectivity of these nodes with a cluster, connectivity of different clusters and how these clusters are arranged together, are addressed. It is claimed that the tremendous feature of this network is the adaptability, rapid change in the wireless environment.

It is stated in [25] that the great challenge in the way of CRN is the accurate spectrum sensing specially in the presence of legitimate users. In order to achieve the accurate spectrum sensing, a cluster based spectrum sensing scheme is proposed. This scheme based on cluster formation and selection of suitable node as a cluster head from each cluster to communicate with the common controller. This proposed scheme heavily depends upon the spatial diversity and cooperative behavior of CRN. The decision fusion and energy fusion are also addressed in this paper and performance of proposed scheme is shown in analytical results.

In paper [26], it is suggested that multi hoping, with the help of directional antennas, reduced the interference among PUs and SUs. Although, it is the frame work of cognitive radio adhoc network but it is also an approach towards the development of a zone. In this paper, it is also provided a framework for hop connectivity. There are two phases of this proposed frame work. In first phase, a scheme devises to find all possible connectivity for any random pair of SUs. This scheme provides a shortest path between source and destination. This shortest path would be chosen by using some necessary input data like node position, current state of the node and antenna gain etc. In second phase, the best possible path or topology between two SUs is chosen. This scheme heavily depends upon no. of directional antennas. It is concluded that beam forming schemes with directional antennas improve the performance and reliability of the system which is much better than omni directional antennas. But the success of this scheme totally depends upon the knowledge of exact location of PUs and SUs.

A network like zone with deployment of random no. of SUs, where PUs are already present, is presented in [27]. This paper focus on the limits upon the maximum achievable capacity and power of SUs. It is observed that the computational complexity of cognitive radio network is much greater than any other adhoc network. And analytical approach is used to determine a optimal pair of transmitter and receiver. The capacity of previous node is used as an input to find the capacity of new node. This is achieved with the help of signal to noise ratio for all transmitters. Optimal power is allocated with the help of metric. This metric provides the information about pairs of communicating nodes along the power allocated them. The simulations based on upper and lower bounds power, change of topology and state space deduction with the help dealing concept of dead nodes and SINR.

Cognitive Radio Network is also going to deploy for Internet of Things (IOTs). This can only be possible when several cognitive nodes are connected to each other and making a network. To get the connectivity, with heterogeneous internet devise, it requires a great concerned to architecture. As internet communicating object possess an event driven nature hence, opportunistic spectrum allocation scheme like cognitive radio is most suitable. But there are many obstacles in the way of deploying CRN for IOTs.

It is stated in [28, 29] that a cluster based cooperative spectrum sensing in much better then cooperative sensing and it provide a tremendous impact on reliability in spectrum sensing. As the energy detection scheme for spectrum sensing heavily depends on prefect knowledge of noise power. A CCSS using EVD technique is proposed. This scheme enhances the performance of reporting time slot which is helpful to sense the licensed users signal.

A soft-hard scheme is proposed for spectrum sensing in cluster-based architecture is proposed in [30]. Likelihood Ratio Test is applied on each cluster. And fusion center is charted by weighted decision.

A cluster based scheme to remove the hidden terminal problems is suggested in [31]. This scheme divides the whole sensing area into 4 equal parts. And each cluster is headed by a single cluster node. This cluster head is responsible to collect the data from each node of the cluster. This co-operative behavior reduces the hidden terminal problems.

A secure spectrum sensing from malicious secondary user is promised in [32]. This technique based on the energy efficiency and added extra security bit with the message sent by each node in a centralized and cooperative architecture. It is shown in this paper that this security bits enhance the efficient energy levels. A comparison between independent and collaborative sensing node is also take into account. It is claimed that cooperative behavior of a cognitive radio network with secure bit is much better than independent not sensing environment. The optimum number of cooperative sensing nodes along with the optimal number of extra security is formulated.

A based reporting scheme is presented in [33]. This scheme reduces the delay in spectrum sensing and improves the utilization of bandwidth. The whole cognitive network area is partitioned into several clusters and each cluster head chosen the basis on sensing data qualities of cognitive radio. In order to improve the reporting time from each node in cluster head, each node assigned a different frequency to send their data to cluster head. The optimal Chair-Vashney rule is applied at central hub, to improve the performance of whole network. It is shown that frequency division multiplexing applied in parallel reporting mechanism would be considerably decrease the delay in spectrum sensing reporting.

A survey has been carried out in [34] for the open issues related to the cognitive radio network. The different existing algorithm in the channel assignment is discussed. The salient feature in channel assignment like the routing, channel model and channel assigning strategy is analyzed. The challenges of cognitive radio network like hidden terminal problems and other hot research issues are also addressed. It concluded that the main focus should be given to the channel assignment method, as the efficient channel assigning technique would be reduced the interference for primary user and also for the secondary user. It can only be done by using adaptive channel assigning schemes.

In [35], the more emphasis is given to the efficient spectrum sensing in cognitive radio network. A survey is carried out for the single user in non cooperative environment. It is sum up that the spectrum sensing is the key feature of the cognitive radio network. The more tremendous scheme for spectrum sensing improves the all performance of the system and reduced the interference for primary user. It is also concluded that multipath fading and hidden terminal problems caused by shadowing are the major threats, which results for the signal strength decrement and increase the delay for accurate spectrum sensing.

An energy detection scheme with adaptive threshold for spectrum sensing is proposed in [36]. This adaptive threshold based scheme is applied on multilevel hierarchal spectrum sensing algorithm. This technique improves the overall detection rate of the presence of primary users and secondary users in a channel.

In the survey paper [37], it is emphasis that efficient spectrum sensing is a key factor to improve the efficiency of CRN. But the threats for the efficient spectrum sensing are multipath fading, shadowing and other uncertainty issues on receiving side. In order to overcome these issues, the cooperative spectrum sensing with spatial diversity is the most practical and sensible choice. By using cooperative spectrum sensing, it is observed that cooperative gain is improved, which indirectly enhance the detection performance. But on the other hand, the cost of cooperative spectrum scheme will be increased which results increasing complexity of the model, delay and energy required. This survey paper presents the latest technique of the cooperative spectrum sensing and the issues regarding cooperative gains and overhead. The potential of this survey paper is to encompass the basis issues related to the cooperative spectrum sensing like data fusion, sensing, testing, efficiency of controlling channels etc. are greatly addressed. Furthermore mobility of nodes and security of systems is also addressed.

A new protocol to overcome the difficult hidden terminal problems is proposed in [38].This scheme depends on the allocation of reliable carrier frequency for the receiver side which sensed least noisy frequency. A selection circuit is also designed to allocate suitable carrier frequency. The selection, based on received signal strength. In this paper, the proposed scheme is also compared with the conventional technique such as Multiple Access with Collision Avoidance. It improves the results for throughput and efficiency of system.

Multi channels hidden terminal problems (MCHT) in CRAHNs is presented in [39]. This scheme based on designing a metrics, which contains the information about the trend of PUs, such as delay and throughput. On the basis of this metric the performance of the CRAHNs is measured by increasing the channels. It is concluded that MCHT would be reduced by using distributed spectrum sensing approach.

The hidden and exposed terminal problem is addressed in [40]. The exposed terminal problem is also very worst as it wasting the valuable transmission opportunities. The carrier sense Multiple Access with collision Avoidance (CSMA/CA) not able to combat these two problems due to the lack of information about the spectrum. Full duplex Attachment System (FAST) for cross layer is designed. This protocol runs on the physical layer with some specially coding to provide the transmit information without any extra over head. FAST algorithm has two components.

It is stated in [41] that TCP is facing a new problems in cognitive radio environment due to the presence of PUs which increases the packed loss. It termed as PUs blocking loss SBL. It is also claimed in this paper that in such an environment where spectrum resources are very short, CR sensor network (CRSN) is a better choice.

1) A special coding contained by physical.

2) Sensing information attached with MAC layer.

Due to this information transmitted independently in the air by a full duplex mechanism, it fights greatly with hidden and exposed terminal problems.

III. PROPOSED MODEL

In our proposed model the spectrum sensing is based on clustering [18]. All the nodes are divided into two categories, common node and a cluster head. Common node communicates with cluster heads. Each cluster head sends their report to common controller. In our proposed model a service area is divided into different small clusters and each small cluster has its own cluster head. All cognitive radio terminals (CRT) are equipped with cognitive antennas [42-45].

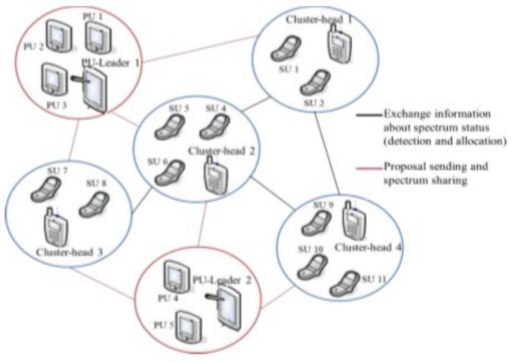

Figure 3: Cluster Based Cognitive Radio Network [46]

A. *Fundamental Design Issues*

From the network designer's view point, two fundamental structural issues must be addressed before going to design the network. These are 1) - behavior of the network and 2) - the architecture of network, the proposed choice of our model is, to design a cluster in CRN, co-operative behavior and centralized architecture. The CC makes the final decision on the basis of AND rule and a spectrum hole is said to be clear if all CRTs reported for the absence of PU.

The computation in CC can be described in (1).

$$\text{Decision} = \begin{cases} (H_0^{CC,1}, \quad H_0^{CC,2}, - - -H_0^{CC,N}), & H_{0 \text{ as PU is absent}} \\ \text{otherwise}, H_{1 \text{ PU is present}} & \end{cases}$$
(1)

Where $H_0^{CC,1}$ denotes the decision H0 received from the first cognitive radio terminal at the CC. The false alarm probability of the cooperative spectrum sensing can be computed by (2).

$$Q_f = \text{Prob}\{H_1|H_0\}^N = 1\text{-Prob}\{H_1|H_0\}^N = 1-(1-Pf)^N$$
(2)

The miss probability of cooperative spectrum sensing is given by (3).

$$Q_m = \text{Prob}\{H_1|H_0\}^N = (P_m)^N \qquad (3)$$

The correct detection probability of cooperative spectrum sensing is given by (4).

$$Q_d = \text{Prob}\{H_1|H_0\}^N = (1-P_m)^N \qquad (4)$$

B. *Spectrum Sensing Technique*

The Architecture of the CRN model is centralized. All CRTs performs local spectrum sensing independently. All CRTs are homogeneous and used energy detection scheme for spectrum sensing. It has been found that the optimal detector to detect a weak and unknown signal by using a well defined constellation scheme is based on the energy detection. The phenomenon behind the energy detection is to measuring the energy of the received signal. The spectrum sensing performed by each sensor has the following two decisions.

$$\textit{if} \sum |Y(f)|^2 \geq \lambda \text{ then decision is } H_1$$
$$\textit{elseif} \sum |Y(f)|^2 < \lambda \text{ then decision is } H_0$$
(5)

Where $|Y(f)|^2$ is the received signal energy, λ is the energy thresh hold and is denoting the presence and absence of pU/SU respectively.

Three types of probabilities could be occur during the spectrum sensing.

- Probability of correct detection: detect a PU is present when it was there or detects a PU is absent when it was not there. Mathematically it is represented as:

$$P_d = prob(H_1 / H_1 \text{ or } H_0 / H_0)$$

This is the most required probability and all optimal sensing parameters are used to get higher probability of correct detection. The equation to get Pd is as follow in (6).

$$Pd = e^{\frac{\lambda}{2}} \sum_{n=0}^{u-2} \frac{1}{n!}\left(\frac{\lambda}{2}\right) + \left(\frac{1+\breve{\gamma}}{\breve{\gamma}}\right)^{u-1} \left[e^{-\frac{\lambda}{2(1+\breve{\gamma})}} - e^{-\frac{\lambda}{2}} \sum_{n=0}^{u-2} \frac{1}{n!}\left(\frac{\lambda\breve{\gamma}}{2(1+\breve{\gamma})}\right)^n \right]$$
(6)

Where μ is the product of fixed spectrum f for sensing and time interval t for observation, $\breve{\gamma}$ is average SNR.

- Probability of false alarm; It is the case when PU/SU is not there but CRT sensed that PU is there.

$$P_f = prob(H_1 / H_0)$$

Furthermore the Pf can be determine as:

$$p_f = \frac{r\left(u, \frac{\lambda}{2}\right)}{r(u)}$$

Where *r(μ)* is the Gamma function and $r\left(u, \frac{\lambda}{2}\right)$ is incomplete Gamma function and it is equal to:

$$r\left(u,\frac{\lambda}{2}\right)=r(u)-\delta\left(u,\frac{\lambda}{2}\right)$$

The P_f is harmful for the system as a possible spectrum which could be occupied is lost but there is no threat of collision with PU.

- Probability of miss; It is the worst case in which a CRT detects that a PU/SU is not there but actually the PU was there and a collision is occurred.

$$P_m = prob\left(H_0 / H_1\right)$$

As the events P_d and Pm are mutually exclusive, hence $P_m = 1 - P_d$.

C. Optimization of Overlapping Antennas

In dense populated areas, the probability for the presence of PU/SU is very high, which ultimately give an extensive increase to hidden terminal problem. The hidden terminal problem could be overcome by employing more antennas and get overlapping gain.

As discussed earlier, the primary factor on which our model is based on, is the size (covered by the cluster) is fixed and no. of antennas are variable. The shape of the cluster is regular hexagon just like cell in GSM system. All the CRTs are homogenous and have the same range for spectrum scanning. Hence, they create small hexagons. An N×N connectivity matrix K (N, N) is used to represent the overlapping of cognitive nodes. The inter-node distance among all the sensors is d.

Each of the sensor nodes operates in one frequency channel among F possible ones. As shown in Fig.3 all CRTs are placed together in such a way that they formed a big hexagon. The big hexagon or the cluster is represented by Z, while small hexagons are denoting by z.

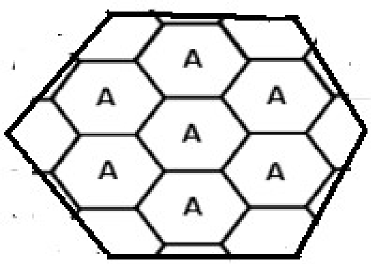

Figure 1: shape of zone

The Fig.4, shows that a regular hexagon consists of six equilateral triangles. So, an antenna placed in the centre of hexagon cover all the six triangles.

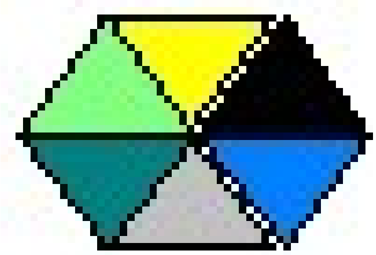

Figure 2:The structure of hexagon

We consider the three different cases:

1) Case 1: Without overlapping

We represent the 7 adjacent small clusters with different colors.

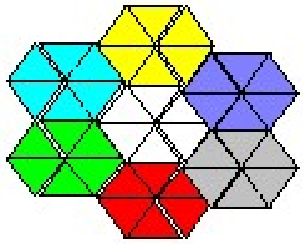

Figure 3:7 z models with different colors

While in Fig.5, it is shown that all antennas are placed in centers. In this case it is obvious that we required 7 antennas to cover 7 clusters.

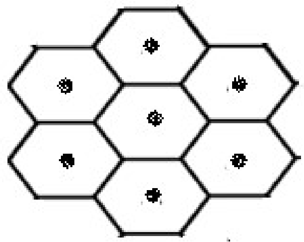

Figure 4:7 z model with antennas placed in centers

2) Case 2: Two Antenna's Overlapping

As shown in Fig.7 and 8, when antennas are placed at the alternative edges of the hexagon, than each triangle of the hexagon is exactly under the range of two antennas.

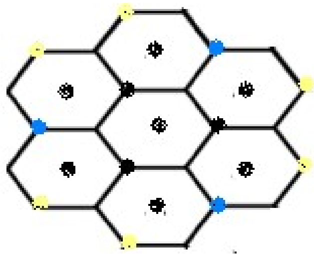

Figure 5:antennas are placed at alternative edges

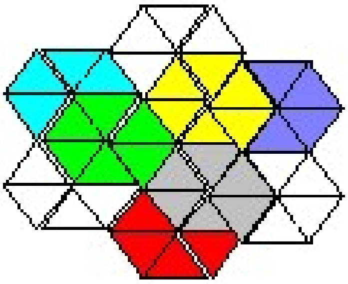

Figure 6:different colored triangles shows the overlapping of two antennas

In Fig.7, black dot shows the antennas which cover all the six triangles, while blue and yellow are small antennas and covering four and two triangles respectively. These antennas are used at the edges of the hexagon. In this case the total no. of antennas required to cover all 72 triangles is 14.

3) Case 3: Three Antennae's Overlapping

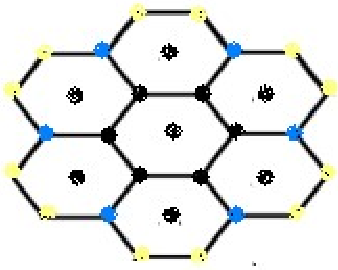

Figure 7:antennas are placed at all the edges of hexagon

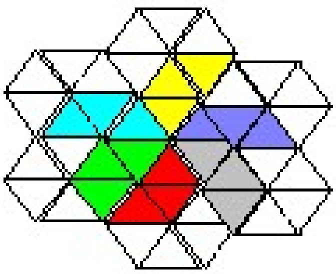

Figure 8:each triangle oh hexagon is exactly under the range of three antennas

In order to get more accuracy and higher Pd, we place the antennas at all the edges of the hexagon (see Fig.9). As shown in Fig.10. This topology for antennas deployment will give the overlapping of three antennas in everywhere a hexagon. The total no. of antennas required in this case is 21.

D. FlowChart

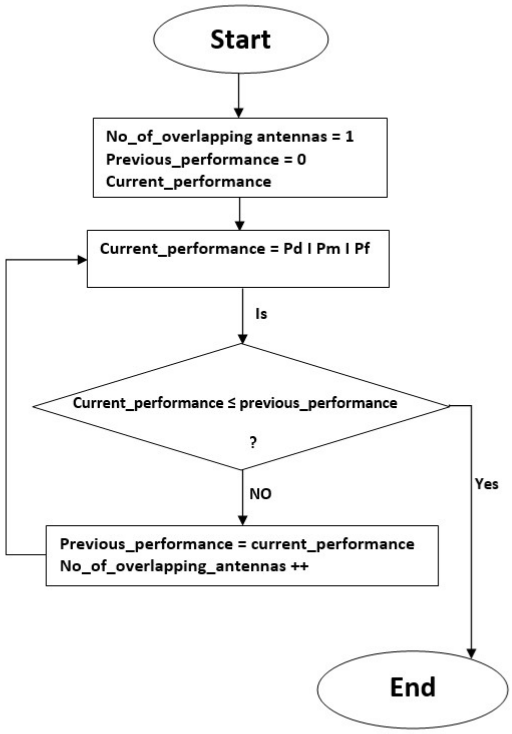

Figure 9:Flow Chart

Let suppose that coverage area of cognitive antennas [1,2,3,4] is a regular hexagon and these hexagon together makes a large hexagon or cluster. Each antennas are placed at the corner are joint edges of the hexagon. So, in order to achieve the overlapping of antennas we can maximum placed 6 antennas in hexagon. But more number of overlapping antennas increases the overheads of the system. To achieve a balance between performance and overheads with overlapping antennas, a flow chart (Fig.11) is given above:

IV. Simulations and Results

In this section simulation results are presented. These simulations are categorized into two groups. The first group of the simulations is based on overlapping of antennas, while second group belonging to fixed cluster size vs. variable no. of antennas. From fig. 10 to 13, the P_d, P_f and P_m are computed for different levels of overlapping antennas. The value of $\breve{\gamma}$ (average SNR) is 10 dB while the μ (product of time interval and bandwidth) is taken 5 for all cases. The value of thresh hold (λ) is taken as 40, 41, 42 and 43 for four different cases.

TABLE I. EXPERIMENTAL SETUP

Parameters	Values
$\breve{\gamma}$	*Is 10dB*
μ	*5*
λ	40, 41, 42 and 43

In fig. 10, it is shown that P_d will increase by increasing the no. of overlapping antennas. But it is obvious from the fig. that the performance will improve until overlapping of three antennas. After three antennas overlapping the curve will becomes almost flat. The overlapping of 4, 5 or more antennas will just increase overhead in terms of cost as well as computational complexity over system. Fig. 11 shows that the P_f will decrease by employing more antennas. Fig. 12 for P_m exhibits that probability will converge at point 3. In fig. 13 a joint comparison of all three probabilities is presented with λ = 40.

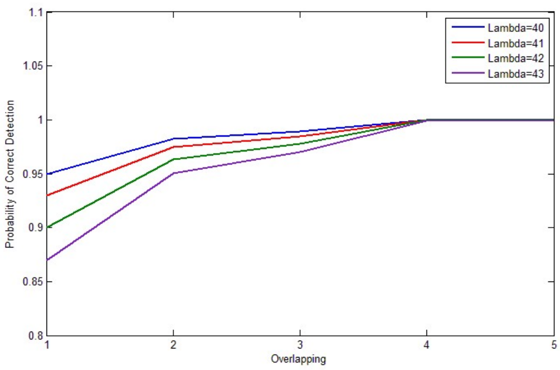

Figure 10:P_d vs overlapping antennas for different thresh hold

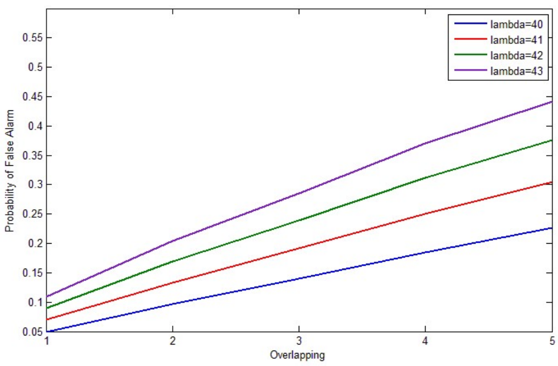

Figure 11:P_f vs overlapping antennas for different thresh hold

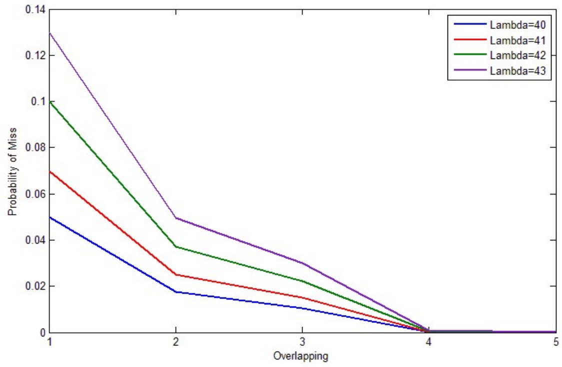

Figure 12:Pm vs overlapping antennas for different thresh hold

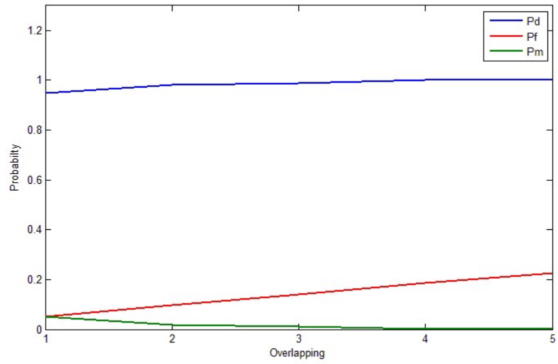

Figure 13:comparison among different probabilities

From fig. 12 to 15 it is shown that increasing the coverage area of cognitive antenna, the P_d, P_f and P_m will effect as they are function of SNR and λ for these simulations a fixed cluster size of 12 km is supposed. The range of CRTs is 1km and there are 12 antennas for without overlapping. When CRT coverage will increase to 2 km than a total of 6 antennas are required. For the coverage area of 3 and 4km, the no. of antennas required is 4 and 3 respectively. From fig. 14 to 17 it is shown that when the coverage area of the antenna increase, even increase in SNR and λ in a balance way, the P_d, P_f increase while P_m decrease. However, applying overlapping will give rise in probabilities. Fig.16 is the comparison of all three probabilities when range of antenna is 1 km.

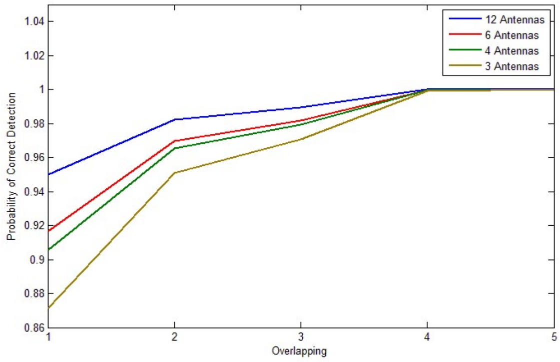

Figure 14:Pd vs overlapping for different antennas

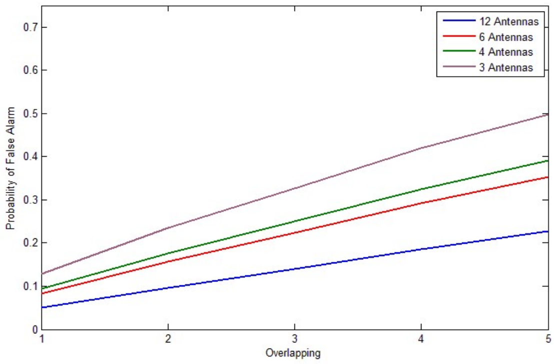

Figure 15: probability of false alarm for various antennas

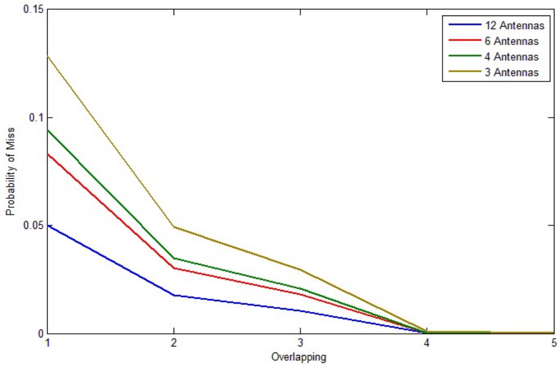

Figure 16:probability of miss for various antennas

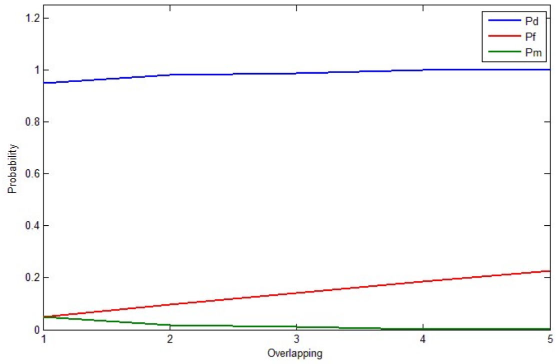

Figure 17:comparison for three probabilities

V. Discussion and Analysis

The size of the cluster presented in this paper is fixed rather than dynamic. All the participating nodes are fixed and have cognitive capabilities. They are working like BTS in cellular architecture but actually possessing multiple functionalities with them. Although, wireless channels are varying over time, space and frequency. This variation further increases due to node mobility. In pure dynamic scenario, nodes leave the cluster and new nodes join at the same time, resulting in very dynamic traffic pattern. Yet, a static model for allocation of spectrum is feasible. As static model reduces the computational complexity and guaranteed for better QoS.

The cluster model presented in this paper is based on area and not on the no. of nodes. The size of the cluster is fixed but no. of terminals may vary. The requirement for the availability of free spectrum holes would be maximum in urban areas due to higher traffic density. As in urban areas, the amount of PUs is very high, so during the spectrum sensing, the probability for miss-detection is also very high due to hidden terminal problem. In order to remove hidden terminal problem, CRTs are placed very near to each other. This placement of CRTs produced overlapping, which in result helps to remove hidden terminal problem. In rural areas, the CRTs are placed at maximum distance due to less traffic.

VI. Conclusion and Future work

In order to improve the performance of cognitive radio network, the cooperative spectrum sensing based on clustering is presented. By creating a cluster, it is analyzed that when a spectrum is sensed by more than one antenna, it reduced the fatal effect of the hidden terminal problems. But how many overlapping antennas are required to improve the probability of correct decision and reduced the probability of false is not answered in any previous scheme proposed earlier. Our scheme guarantees the cost effective no of antennas for reliable communication. Simulation result shows the better performance of this scheme.

This scheme is for static dimension of zone and in future it could be for dynamic dimensions of zone like area of zone, no of terminals in a zone.

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