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Cooperative Spectrum Sensing with Optimal Clustered Architecture

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Abstract: ***Now a day the available radio frequency for wireless communication gets lesser day by day because of licensing .Cooperative spectrum sensing is proposed to overcome this problem by utilizing the cooperative diversity. For cooperative sensing, the cognitive base-station acts as a center controller to instruct the collaboration of cognitive users. However, when the number of users becomes very large, the crowding may occur on the control channel and the sensing delay may be too long to make valid decision. Cluster based cooperative sensing is proposed to tackle these problems. In, a cluster-based cooperative sensing method the performances of both distance and energy fusion schemes are investigated. However, it does not consider how many clusters are needed to maximize the efficiency of network with the guarantee of detection performance. The proposed cooperative sensing scheme with cluster-based architecture obtains the optimal number of clusters by balancing the tradeoff between efficiency and reliability. Furthermore, we propose a clustering strategy and compare it with the clustering scheme in by simulation.***

Keywords: Cluster, Cluster Heads, Optimization

1. Introduction

The main objective of spectrum sensing is to provide more spectrum access opportunities to CR users without interference to the primary networks. Since cognitive radio (CR) networks are responsible for detecting the transmission of primary networks and avoiding interference to them, CR networks should intelligently sense the primary band to avoid missing the transmission of primary users. Thus, sensing accuracy has been considered as the most important factor to determine the performance of CR networks In CR, every process starts with the result of spectrum sensing that is aware of the environments and is informed of vacant bands. Up to now, many precise spectrum sensing techniques have been developed for signal identification in this field. On the other hand, the development of control mechanism to manage the sensing information is in slow progress.

1.1 Cooperative Spectrum Sensing

In sensing period, every node in CR network stops the data transmission to detect licensed users (LUs) and, based on the result; it decides the presence of LUs. The main problem in spectrum sensing is the degradation of detection performance when a CR node is exposed to fading from both shadowing and multi-path. In this case, even precision detector cannot help missing LUs. This motivates the development of cooperative sensing. For example, in case of one CR user not perceiving LU due to the shadowing, collaboration with other CR users helps improve the detection probability of blind CR user. In [4], authors analyzed potential benefits of cooperative sensing. In cooperative sensing architectures, the control channel can be implemented using different methodologies. These include a dedicated band, unlicensed band such as ISM, and underlay ultra wide band (UWB) system. In order to minimize communication overhead, different quantization of the local obtained signal is introduced. It was shown that two or three bits quantization was most appropriate without noticeable loss in the performance. In [6] a hard decision (binary quantization) is proposed for arbitrary large node population. However, the total number of sensing bits transmitted to the central is still very huge. Further to minimize reporting bandwidth a two level quantization method was recently proposed, the method identify the users with a reliable information only to report a binary decision (0, 1) to the common server, however the method reduce the number of reporting bits but with a degradation in sensing performance Their result show that misdetection probability Pm is degraded by the imperfect channel and the false alarm probability Pf is bounded by the reporting error probability. This means that spectrum sensing cannot be successfully conducted when the desired Pf smaller than the bound Pf. If the channels between cognitive users and the central server are perfect the local decision will send to central server without error, in practice, the reporting channels may experience fading which will deteriorate the performance of the cooperative spectrum sensing. A cluster based method was proposed in [10] where the most favorable user in each cluster is selected to report to central server, the method improved the sensing performance comparing to conventional sensing. every cognitive user conduct a local sensing and if a primary user detected, a hard decision ‘1’ is sent to central server, otherwise no action is taken, If the server receives a local decision ‘0’ due to imperfect reporting channel, according to a pre-knowledge, it is able to auto correct the reported error, to make it ‘1’. For simplicity energy detection based sensing is assumed for the local sensing method where the output of the integrator, Q, is compared with a threshold, λ , to decide the presence of a primary user. If Q exceeds the threshold, a reporting decision, R, is taken and binary decision '1' is sent to central server otherwise "no report" decision, R' , is taken.

1.2 Limitations in Simple Cooperative Spectrum Sensing

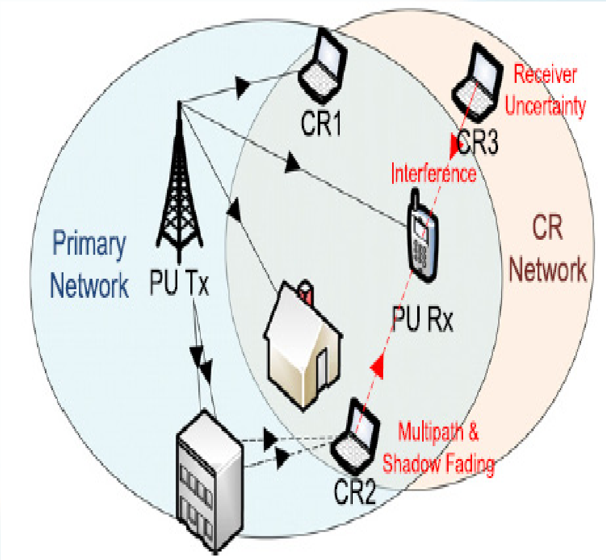

Figure 1: Disturbances in spectrum sensing

In traditional cooperative spectrum sensing, all cognitive nodes have to implement the sensing during the Quite Period independently and upload their sensing result to central control node to make final spectrum decision. Many factors in practice such as multipath fading, shadowing, and the receiver uncertainty problem may significantly compromise the detection performance in spectrum sensing. In Figure 1, multipath fading, shadowing and receiver uncertainty are illustrated. As shown in the figure, CR1 and CR2 are located inside the transmission range of primary transmitter (PU TX) while CR3 is outside the range. Due to multiple attenuated copies of the PU signal and the blocking of a house, CR2 experiences multipath and shadow fading such that the PU's signal may not be correctly detected. Moreover, CR3 suffers from the receiver uncertainty problem because it is unaware of the PU's transmission and the existence of primary receiver (PU RX). As a result, the transmission from CR3 may interfere with the reception at PU RX. However, due to spatial diversity, it is unlikely for all spatially distributed CR users in a CR network to concurrently experience the fading or receiver uncertainty problem. If CR users, most of which observe a strong PU signal like CR1 in the figure, can cooperate and share the sensing results with other users, the combined cooperative decision derived from the spatially collected observations can overcome the deficiency of individual observations at each CR user. Thus, the overall detection performance can be greatly improved. This is why cooperative1 spectrum sensing (simply called cooperative sensing thereafter) [6] is an attractive and effective approach to combat multipath fading and shadowing and mitigate the receiver uncertainty problem. When the number of sensing node is larger, too many messages have to be exchanged in the network; therefore the data transmission efficiency would be deteriorated. In addition, for some cognitive nodes would report error sensing result due to bad wireless channel condition or maliciously, the overall final sensing result would be misguided. Furthermore, all nodes have limited energy. Therefore, the protocol has to assign sensing cycles such that it will not force several nodes to scan excessively thereby balance load. Gathering the entire received data at one place may be very difficult under practical communication constraints. Furthermore, authors of [9] study the reporting channels between the cognitive users and the common receiver. The results show that there are limitations for the performance of cooperation when the reporting channels to the common receiver are under deep fading. Spectrum sensing, as a key enabling functionality in cognitive radio networks, needs to reliably detect weak primary radio (PR) signals of possibly-unknown types. Spectrum sensing should also monitor the activation of primary users in order for the secondary users to vacate the occupied spectrum segments. However, it is difficult for a cognitive radio to capture such information instantaneously due to the absence of cooperation between the primary and secondary users. Thus, recent research efforts on spectrum sensing have focused on the detection of ongoing primary transmissions by cognitive radio devices.

2. Cooperative Spectrum sensing With Clustered Architecture

In our sensing architecture is divided into clusters, where each cluster is managed and represented by a Cluster Head (CH). Nodes from each cluster scan the spectrum at the same time and then send data to CH in slots of a frame assigned to them. All CHs will exchange spectrum measurements with other CHs, and make decisions about the presence of PU. Later, each CH will respond back to its nodes leading to a network-wide decision on the availability of each PU For cooperative spectrum sensing scheme, cognitive users cooperatively detect the absence of the primary users. For simplicity, we assume that the energy detection is used by cognitive user and the primary user does not change its state during the observation. Conventionally, cooperative users are collaborated in cognitive base-station (BS). [8] Cognitive users detect the spectrum independently and then send their local decisions to the cognitive BS. However, for cluster-based cooperative sensing, cognitive users are divided into two types: cluster-heads and ordinary nodes. Ordinary nodes report information to their cluster-heads and cognitive BS only collects information form cluster-heads [10].

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2.1 System Model

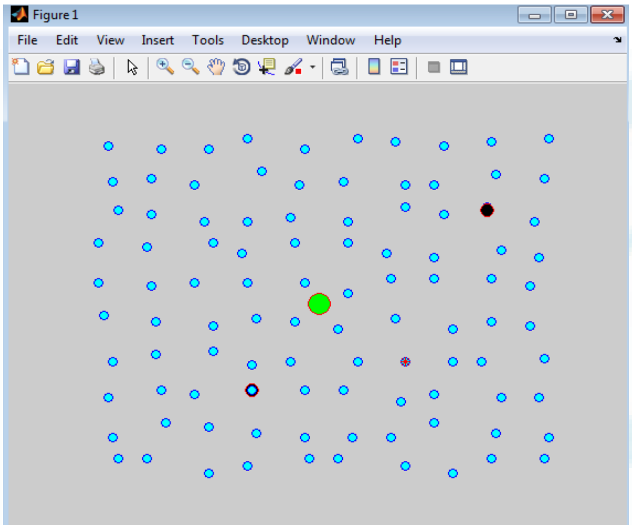

Figure 2: Simulation Scenario for Proposed Architecture

The scenario of the simulation is as follows; as shown in Figure 2, 100 cognitive nodes are randomly placed in a 300m × 300m square with the cognitive BS located in the middle. Given Qf = 0.01, the number of cluster K = 5 then. Two primary users are dispersed randomly in the square. The simulation results are obtained by 1000 iterations. In order to verify the performance of our proposed clustering scheme, we also simulate the K-means clustering algorithm [5] in the same network for comparison. Table I shows the simulation results of different performance with these two clustering schemes. Max num and Min mum represent the value of average maximum and minimum number of nodes in one cluster respectively. Ave D denotes the average distance between node and the center of its cluster. It is noticed from this table that in our proposed scheme, the nodes in each cluster are distributed more equally and the nodes in the same cluster are closer. It implies that the proposed clustering strategy can produce balanced cluster and evenly distribute nodes among the cluster-heads based on the nodes' locations.

3. Proposed Work

In this paper, a novel weighted-clustering cooperative sensing algorithm is proposed. In each cluster, the weighting is about equal because of the closed distances to each other. But the weightings of the clusters are different because of the different fading environments between the clusters and the BS. Work gets progressed in four main blocks. Firstly cognitive users considered in the system are classified as ordinary nodes and cluster heads and then according to clustering strategy clusters are formed with elected cluster heads and ordinary nodes. Then in next step optimization problem of number of clusters is solved and probability of detection Qd is derived. And finally the weighted-cluster algorithm is implemented on the constructed hierarchical clustered architecture in previous stages. In this section, we provide an efficiency clustering strategy for the proposed cluster-based cognitive radio network. We assume that the cognitive network topology is relatively stable status. The objective of clustering strategy in this paper is to gather cognitive users with similar locations into the same cluster, it operates in two phases: cluster-head election and cluster formation. In cluster-head election phase, the cluster heads are elected by BS in a centralized way. In cluster formation phrase, cognitive users join into their clusters in a distributed way. It should be noticed that we exploit distributed scheme in cluster formation to avoid crowding of dedicated control channel and reduce complexity of the algorithm.

3.1 Cluster Formation

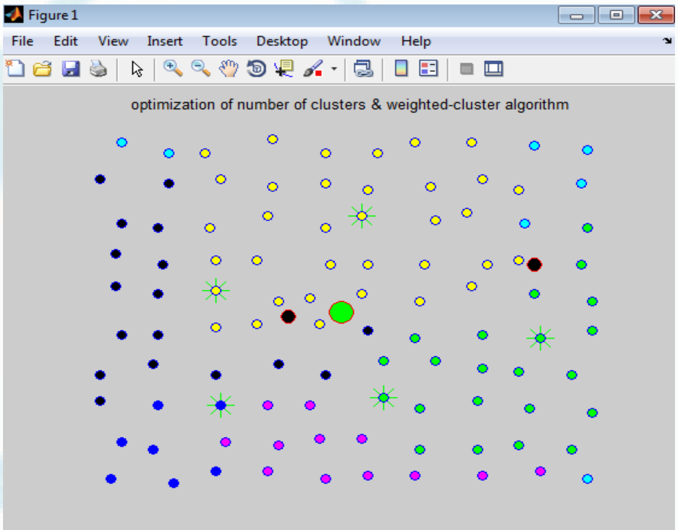

Figure 3: Simulation Result of Clustering by Proposed System

Figure 3, shows the performance of clustering according to proposed system. To form the cluster of various secondary nodes present in the proposed network firstly the clustered head is elected according to rss calculation and distance measurement from BS and then ordinary nodes are distributed under selected cluster heads.

3.1.1 Cluster head election

In order to select appropriate cluster-heads, cognitive Base Station collects information from each node such as the distance from Base Station and the nodes received signal power from primary user. Based on the information, cognitive Base Station assigns cluster-head for each cluster according to a given election algorithm and broadcasts the election to all nodes. The message broadcasted by Base Station contains not only the node ID of elected cluster-head but also the information of time synchronization, resource allocation and the maximum number of permitted access nodes in one cluster. The number of nodes in a cluster is limited to avoid too many nodes crowding in one cluster. Cognitive BS collects information from each node such as the distance from BS and the nodes received signal power from primary user. Based on the information, cognitive BS assigns cluster-head for each cluster according to a given election algorithm and broad casts the election to all nodes. The message broadcasted by BS contains not only the node ID of elected cluster-head

3.1.2 Allocation of Nodes under Cluster Head

The cluster formation phrase is performed in a distributed way, which is divided into 4 steps. First, each cluster-head broadcasts beacon to ordinary nodes, which instructs the ordinary nodes to select their cluster heads. After receiving the beacons from all the cluster-heads, each node decodes the received signal power (RSP) of each beacon and selects one, which has the largest RSP, as its selected cluster-head (SCH). Other cluster-heads are sorted in descending order of RSP to form a candidate cluster-heads pool (CCP). Then, each node requests to join the cluster of its SCH. The request message contains its own node ID and RSP of its SCH. When each cluster-head receives the requesting messages from ordinary nodes, it counts the number of nodes and sorts nodes in a queue in descending order of the values of their corresponding RSPs. If ordinary node receives ACK from its SCH, it signs the SCH as its cluster-head and joins into this cluster. If ordinary node receives NACK from its SCH, it pops up the node ID with the maximum RSP from its CCP as new SCH. After that, the node starts a new process to join into cluster with the new SCH until it receives ACK from cluster-head.

3.1.2 Weighted cluster algorithm

In order to improve the detecting performance, we propose a novel weighted-cooperative spectrum sensing algorithm using clustering. Firstly, all SUs are assumed to have been separated into a few clusters according to a kind of method. In conventional cooperative spectrum sensing, all cooperative users have the same contribution to finally decision. But in factual environment, each secondary user will experience different fading environments and different distances to primary user we propose a weighted-cooperative sensing scheme using clustering, which assigns different weightings to different clusters to enhance the performance of the cooperative spectrum In a practical CR networks, the location of secondary user is randomly distributed. Therefore, some secondary users may suffer deep fading while others may not. On the other hand, some users may locate near to each other, which experience the same path fading and is supposed to have sensing effectively and impartially the same SNR. To implement weighted algorithm randomly distributed secondary nodes must be separated in clustered architecture. In previous stages of our system we are constructing the clustered architecture of secondary users (cognitive users).hence weighted algorithm can be progressed with the same.

3.2 Optimization of Number of Cluster

By optimizing number of cluster we can reduce the delay of the system effectively. Also optimization ensures the better probability of primary user detection. Hence this is the special feature of the proposed architecture. In the previous section we have studied the system model of conventional and cluster-based cooperative schemes. It is intuitive that the sensing overhead and delay are generally reduced with the decrease of the number of clusters. However, the spectrum performance is degraded if the cluster number is decreased. Thus, there exists a tradeoff between the number of cluster and the spectrum performance. Our aim is to determine the minimum number of cluster with the guarantee of spectrum sensing performance. The tradeoff can be expressed in terms of the following optimization problem,

minK
$Qd\_c \geq Qd\_R \mid Qf\_c = Qf\_R$
$1 \leq K \leq N$

Where,
Where Qd_c, Qd_Rand Qf_c, Qf_Rare the global detection and false-alarm probabilities of cluster-based scheme and conventional scheme respectively. K and N denote the number of clusters and cognitive users respectively. by solving the equation and following the optimization limits in above equation the value of optimum number of cluster K. As explained in step 2 of proposed work in our project value of false alarm probability Qf =0.01 and optimal number of cluster K=5 are considered and then with the help of optimization equation probability of detection is calculated and compared with detection probability of previously available algorithms.

The simulation results gave following output which shows the optimum numbers of cluster heads are selected for spectrum sensing. Figure 4 shows the output of simulation for cluster head selection in the proposed network Figure 2 which shows that unnecessary large number of clustered head is selected but due to that total performance time will be increased, but in Figure 5 the output of optimized number of cluster is shown which effectively reduces the delay.

3.2.1 Output of selection of cluster head by optimization

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Before Optimization
=======================
24 is selected as cluster1 head
25 is selected as cluster2 head
26 is selected as cluster3 head
27 is selected as cluster4 head
34 is selected as cluster5 head
38 is selected as cluster6 head
43 is selected as cluster7 head
48 is selected as cluster8 head
53 is selected as cluster9 head
59 is selected as cluster10 head
63 is selected as cluster11 head
65 is selected as cluster12 head
69 is selected as cluster13 head
73 is selected as cluster14 head
74 is selected as cluster15 head
75 is selected as cluster16 head
78 is selected as cluster17 head
79 is selected as cluster18 head
85 is selected as cluster19 head
86 is selected as cluster20 head
87 is selected as cluster21 head
88 is selected as cluster22 head

Figure 4: Output of cluster head selection without optimization

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After Optimization
=======================
24 is selected as cluster1 head
38 is selected as cluster2 head
53 is selected as cluster3 head
78 is selected as cluster4 head
85 is selected as cluster5 head

Figure 5: Output of cluster head selection with optimization

3.2.2 Even Distribution of Nodes

During clustering of ordinary nodes if distribution of nodes is uneven i.e. if maximum number of nodes are concentrated under single clustered and other cluster heads have comparatively less number of ordinary nodes such situation is occurred in the architecture then signaling overload on a particular cluster head will be increased and capability of other cluster heads to manage the ordinary nodes will be un utilized. This is unbalancing in the clustering strategy and this will badly affect on the performance of the spectrum sensing. Hence to avoid such crisis in proposed clustering architecture for spectrum sensing we have also taken care of even distribution of nodes under selected cluster heads. Also we have calculated average distance of ordinary node from its cluster head. This will ensure the even distribution of nodes in the architecture. Table 1, shows the simulation result regarding even distribution of nodes as explained in above paragraph.

Method	*Min*	*Max*	*Avg*
Weighted	19	41	24
Kmeans	23	42	37

Table 1: Output of simulation for even distribution of nodes

4. Conclusion

From simulation results obtained by proposed architecture regarding optimization of number of cluster heads and even distribution of nodes. The efficiency of proposed system is proved and also optimization is done successfully. Following result are improved effectively there is a tradeoff between the number of clusters and the detection performance in the cognitive radio network. By characterizing the tradeoff as an optimization problem, the optimal number of clusters can be obtained. Moreover, the approximation of optimal number of clusters is also derived and simulation results prove its validity.

1) Efficient Data Transfer: clustering strategy is used hence data transfer is done more efficiently.
2) Signal Overhead Reduction: Due to proposed system the signaling overload on base station is reduced hence data transfer is done more efficiently.
3) Optimal Number of Clusters: due to optimization optimum number of clusters is used to sense the primary user hence delay will be reduced.

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