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Cooperative Spectrum Sensing with Weighted Clustered Architecture

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Abstract: ***Wireless communication systems are built based on the transmission of electromagnetic waves (or radio waves) with frequencies in the range of 3 Hz to 300 GHz. today's wireless networks are characterized by a static spectrum assignment policy. Recently, due to the increase in spectrum demand, however, this policy is faced with the spectrum scarcity at particular spectrum bands. On the contrary, a large portion of the assigned spectrum is still used sporadically leading to under-utilization of the significant amount of spectrum. The anticipated explosion of wireless applications creates an ever-increasing demand for radio spectrum. Unfortunately, spectrum is a finite resource. Because of the tremendous societal value of the finite spectrum, its use is carefully managed at the national and international level. Cognitive radio technology is proposed to solve these current spectrum inefficiency problems we propose weighted clustering strategy in which weightings are used to weight the cluster-decisions before combining. and compared it with the k-means clustering scheme in by simulation. The simulation results show that our proposed method improve the probability of detection and reduce the probability of error.***

Keywords: clustering, cluster heads, primary nodes, secondary nodes

1. Introduction

Cognitive radio (CR) is an enabling technology that improves the utilization of scarce radio spectrum resources. Cognitive radios offer the promise of being a disruptive technology innovation that will enable the future wireless world. Cognitive radios are fully programmable wireless devices that can sense their environment and dynamically adapt their transmission waveform, channel access method, spectrum use, and networking protocols as needed for good network and application performance. We anticipate that cognitive radio technology will soon emerge from early stage laboratory trials and vertical applications to become a general-purpose programmable radio that will serve as a universal platform for wireless system development, much like microprocessors have served a similar role for computation cognitive radio is a transceiver which automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters so more wireless communications may run concurrently. In cognitive radio networks, the limitation of control channel bandwidth is a challenge of cooperative spectrum sensing when the number of cognitive users becomes very large. Cluster based architecture is applied for cooperative sensing to avoid the congestion on control channel and reduce the sensing delay. In this paper, we propose a cluster-based cooperative spectrum sensing scheme to improve the efficiency of the network. The number of clusters affects both the system efficiency and detection performance significantly. By balancing the tradeoff between the communications overhead and sensing reliability, we can obtain the optimal number of clusters, which can minimize the cooperation overhead without any performance loss of reliability. Moreover, a clustering strategy is proposed based on a given number of clusters and simulation results show the superiority of the proposed strategy [6].

1.1. Spectrum Sensing Methods

1.1.1 Transmitter Detection

Cognitive radio should be able to differentiate between used and unused spectrum .so it should be able to determine the signal from primary transmitter is present in the spectrum or not. Transmitter detection approach is based on detection of signal from primary transmitter. But transmitter detection is based on assumption that the location of primary user is unknown due to absence of interaction between primary and secondary user .also transmitter detection model cannot prevent the hidden terminal problem. Sometimes secondary user is unable to reach up to primary user due to shadowing problem [2].

1.1.2 Cooperative Detection

Sensing performance can be improved if local observations of multiple sensing nodes are incorporated for primary user detection. It has been shown many times in the literature that with an increase in the number of cooperating partners sensing performance can be greatly improved however; incorporation of large number of users is not possible in bandwidth constrained systems.

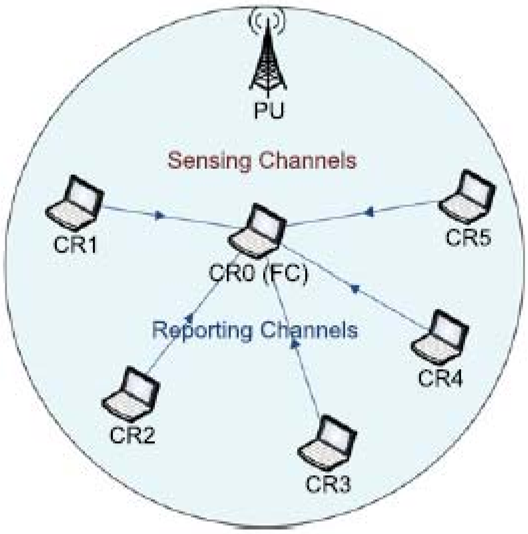

Figure 1: Basic cooperative spectrum sensing

Censoring sensors using double threshold method were outlined in and to reduce number of cooperating users and hence communication overhead. Optimum number of cooperative users in spectrum sensing was derived in and optimal decision fusion rules were derived [7]. Cooperative spectrum sensing for the case of correlated and un-trusted users was outlined in and it was concluded that few independent and trusted users are more robust than many correlated and un-trusted users. Cluster based cooperative spectrum sensing algorithms were proposed in where cluster heads send sensing information to the common receiver using imperfect channel

1.1.3 Interference Temperature Detection

Interference temperature detection technique provides way to avoid the interference without accurate primary transmitter detection .instead interference at the primary receivers is limited by interference temperature limit. The difficulty of this receiver detection model is accurate measurement of interference temperature and limit Cognitive user is usually aware of its transmitted power level and can decide the precise location with the help of positioning system. with this ability however its transmission could cause significant interference at an neighboring receiver at same frequency Currently, there exist no practical way in cognitive radio to measure or evaluate interference temperature at nearby primary receiver since primary receivers are usually passive devices.CR cannot be aware of precise location of primary users. Furthermore, if CR users can not measure the effect of their transmission on all possible receivers a useful temperature interference measurement is not possible. Another important limitation of this system is to determine an interference temperature limit. Since CR users try to control their transmission according to this limit an accurate technique to measure this interference limit is necessary. However the accurate and optimal measurement of this limit is dependent upon density and traffic characteristics of primary users. Furthermore the physical layer characteristics such as modulation and transmitted power as well as operating frequency of primary user also affects the limit.henc adaptive techniques for interference detection are needed. Due to all these drawbacks, and with consideration of all types of spectrum sensing, Cooperative spectrum sensing method is optimal way of sensing [5].

2. System Model

We assume CR networks have a centralized network entity such as a base station in infrastructure-based networks. Ad hoc networks are assumed to have a cluster head node. This centralized network entity can communicate with all CR users within its coverage and decide the spectrum availability of its coverage 100 cognitive nodes are randomly placed in a $300m \times 300m$ square with the cognitive BS located in the middle. Given $Qf = 0.1$, the number of cluster $K = 5$. 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. Simulation results of different performance with these two clustering schemes. Simulation result shows the superiority of proposed system.

2.1 Conventional Architecture for Spectrum Sensing

Conventional cooperative sensing is generally considered as a three-step process: local sensing, reporting, and data fusion. In addition to these steps, there are other fundamental components that [6] are crucial to cooperative sensing. We call these fundamental and yet essential components as the elements of cooperative sensing. In this section, we analyze and present the process of cooperative sensing by seven key elements:

(i) Cooperation models, (ii) Sensing techniques, (iii) Control channel and reporting, (iv) Data fusion, (v) Hypothesis testing, (vi) User selection, and (vii) Knowledge base. As shown in Figure [2]. These elements are briefly introduced as follows: Cooperation models consider the modeling of how CR users cooperate to perform sensing. We consider the most popular parallel fusion network models and recently developed game theoretical models.

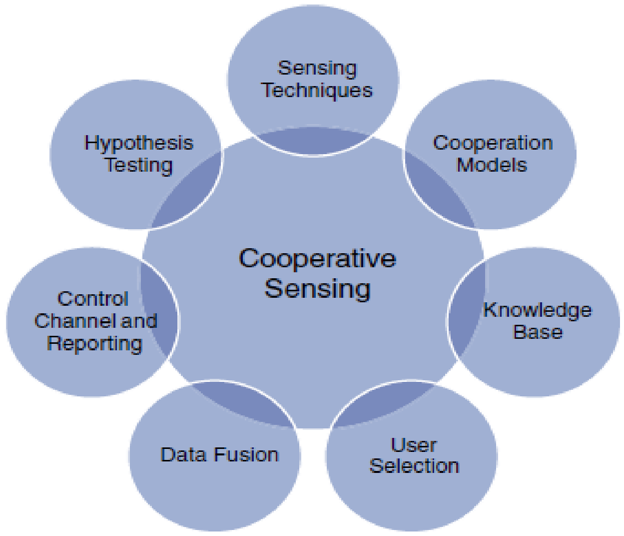

Figure 2: Parameters of cooperative spectrum sensing

- Sensing techniques are used to sense the RF environment, taking observation samples, and employing signal processing techniques for detecting the PU signal or the available spectrum. The choice of the sensing technique has the effect on how CR users cooperate with each other.
- Hypothesis testing is a statistical test to determine the presence or absence of a PU. This test can be performed individually by each cooperating user for local decisions or performed by the fusion center for cooperative decision.
- Control channel and reporting concerns about how the sensing results obtained by cooperating CR users can be efficiently and reliably reported to the fusion center or shared with other CR users via the bandwidth-limited and fading-susceptible control channel.
- Data fusion is the process of combining the reported or shared sensing results for making the cooperative decision. Based on their data type, the sensing results can be combined by signal combining techniques or decision fusion rules.
- User selection deals with how to optimally select the cooperating CR users and determine the proper cooperation footprint/range to maximize the cooperative gain and minimize the cooperation overhead.
- Knowledge base stores the information and facilitates the cooperative sensing process to improve the detection performance. The information in the knowledge base is either a priori knowledge or the knowledge accumulated through the experience. The knowledge may include PU and CR user locations, PU activity models, and received signal strength (RSS) profiles

2.2 Disadvantages of available system

In cognitive radio networks, cognitive users access the licensed spectrum dynamically to guarantee the primary signals not to be interfered. Consequently, cognitive users can be aware of the existence of primary users. Due to the absence of information from primary users, the occupied/unoccupied state of spectrum is only decided by spectrum sensing directly. Therefore, the capability of spectrum sensing is considered as one of the most important issues in cognitive radio networks. However, the performance of spectrum sensing will be degraded in a fading environment on account of the uncertainty of the primary signal. Although advanced signal processing and pattern recognition techniques can ease the task of spectrum sensing, several limitations and challenges remain, especially when real environments are considered. In fact, CR terminals have to detect any primary user's activity within a wide region corresponding to the coverage area of the primary network and the coverage area of the CR networks. For this reason, a CR terminal needs a high detection sensitivity which is a challenging requirement for wireless communications, especially when spread spectrum transmission techniques are used by primary users [8]. Furthermore, spectrum sensing is more complex in those frequency bands where primary users can adopt different transmission standards, for example, Industrial, Scientific, and Medical (ISM) band. In this case, a CR terminal has to be able to identify the presence of primary users to reduce all these limitations and to improve the performance of cognitive radio system we have proposed the clustered architecture with weighted cluster algorithm for spectrum sensing, and by comparing the results with simple cluster algorithm efficiency of proposed system is proved [7].

3. Proposed Work

3.1Cluster 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.

Algorithm of cluster head election is implemented step by step

1. Initialization: Calculate all nodes' distance from BS and sort nodes in ascending order of the distance in a queue
2. Iteration:
a) Allocate each node into the cluster
b) For each cluster, update the node ID of cluster-head
c) Restore all nodes ID of cluster-heads

3.2 Cluster Formation

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.

3.4 Implementation Of The Weighted-Cluster Algorithm

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

3.4.1. Clustering Scheme

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 [13].

4. Results

For cooperative sensing, the cognitive base-station acts as a center controller to instruct the collaboration of cognitive users [3]. 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 problem. In a cluster-based cooperative sensing method is proposed and the performances of both decision and energy fusion schemes are investigated and on the same network k-means clustering algorithm is implemented and comparison is done.

4.1 Probability of primary user detection

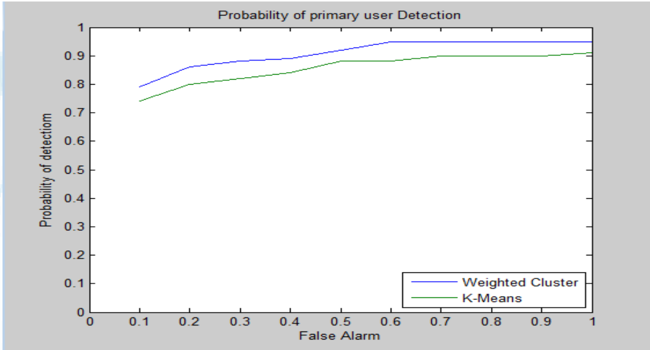

Figure 3: Probability of primary user detection Q_d of both proposed architecture and k means algorithm

Figure 3 shows the graph of probability of detection with false alarm for k-means as well as proposed weighted cluster algorithm. In cooperative spectrum sensing probability of detection is dependent upon the false alarm. Probability of false alarm increased then probability of detection of primary user decreases. But if we observe the graph then it is clear that for same value of false alarm. Proposed system gives better probability of detection which improves the efficiency of the cooperative spectrum sensing.

4.2. Performance ROC Graph

1. False Alarm: While detecting the presence of PU in vicinity, CR detects the PU even if no PU is present. This is called false alarm.
2. Missed Alarm: If there is a PU present in the surroundings of CR and it does not observe its presence, this is known as missed alarm.

Probability of missed alarm and probability of false alarm these are the important entities which affect the probability of primary user detection hence performance of the proposed system is analyzed with graph of false alarm V_s probability of missed alarm. As shown in figure 4 and from graph it is justified that the performance of proposed system is better than performance of k-means cluster algorithm.

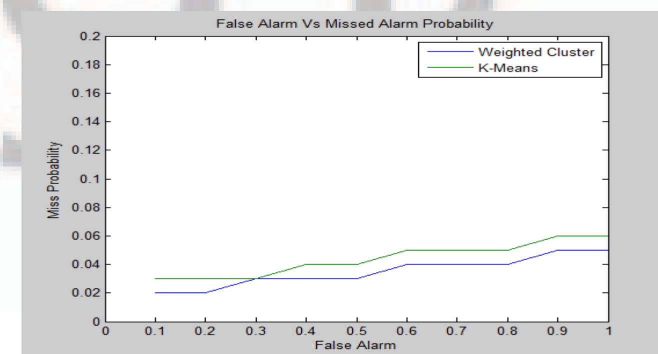

Figure 4: Graph of probability of false alarm V_s probability of missed alarm

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4.3 Signal to Noise Ratio

Figure 5 shows the graph of signal to noise ratio V_s error probability. According to the graph it is clear that the probability of the error is effectively reduced in proposed weighted cluster algorithm which proves the efficiency and accuracy of proposed algorithm with comparison to k-means clustering.

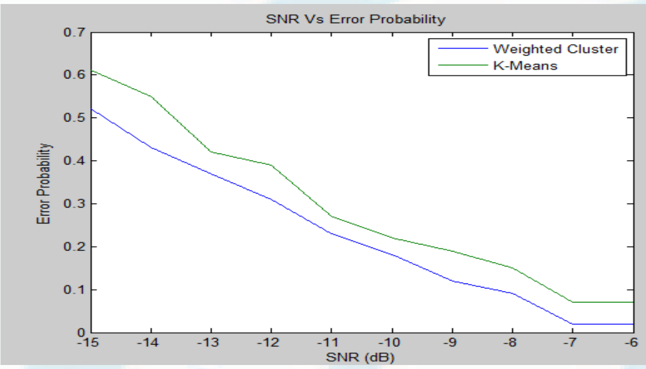

Figure 5: Graph of error probability V_s SNR

5. Conclusion

From the various graphs obtained by simulation for the network of cognitive radio system it is observed that;

1) Due to weighted cluster algorithm increases the efficiency of the algorithm.
2) Hidden node problem is significantly reduced: By using a cooperative sensing system, it is possible to reduce the possibility of reducing hidden node problem because a greater number of receivers will be able to build up a more accurate scenario of the transmissions in the area.
3) Increase in agility: An increase in the number of spectrum sensing nodes by cooperation enables the sensing to be more accurate and better options for channel moves to be processed, thereby providing an increase in agility.

Hence we conclude that A cluster-based cooperative sensing scheme is proposed in this paper to reduce the overhead and delay of sensing and improves the performance of spectrum sensing.

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