Node Selection Score based Clustering scheme for Cognitive Radio Networks

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Abstract— Cognitive radio means a radio system whose parameters is changing dynamically according to the external environment. By using the several cognitive radios' in the network they built Cognitive Radio Networks (CRNs). CRNs has the capability to deal with the exact requirement of the radio spectrum as well as take care of its shortage .Cognitive Radio Networks plays an important role to solve the problem of insufficient amount of radio spectrum for use.

In cognitive radio ad hoc networks (CRAHNs) , due to the absence of network infrastructure and heterogeneous spectrum availability , there is a need of the self-organization of cognitive radio users (CRs) , for efficient spectrum coordination . In case of CRAHNs ,the channel availability among cognitive radio nodes is varying in nature , hence connectivity and durability are the challenging issues . To address this challenge , clustering of neighboring cognitive radio nodes is the suitable approach. Clustering supports a coordinated channel switching and simplifies routing in CRAHNs. In this paper a node selection score based clustering scheme is introduced , which considers spectrum heterogeneity, node degree, intra cluster delay and stability of the topology.

Index Terms— Cognitive Radio , CRNs , CRAHNs, Primary Users (PU), Secondary Users (SU), spectrum heterogeneity , Node selection score, Clustering .

1 INTRODUCTION

The fast developing wireless communication technologies are facing the spectrum shortage problem. Cognitive radio (CR) is an encouraging technology to solve this problem of insufficient amount of spectrum for use [1]. Primary User (PU), also known as the licensed user, has the whole right to use the radio spectrum. On the other hand, Secondary User (SU) is the unlicensed user, also known as the cognitive user, who has to give up the spectrum band as soon as there is an appearance of PU . That is , in CR systems, whenever there is information to be transmitted , the Primary Users (PUs) access their allocated spectrum band and the secondary user seeks the opportunity to use the spectrum holes or the free spectrum when the primary user is not active [2]. In a different way it can be said as , the CR users which forms cognitive radio networks (CRNs) can only access primary channels after confirming that the channel is idle. This refers to the process of sensing a particular channel and verifying that it is not used by a primary user currently. This form of accessing the spectrum is called as opportunistic spectrum access.

The spectrum holes identifying process is known as spectrum sensing. In spectrum sensing technique , there are two main approaches : (i) primary receiver detection and (ii)primary transmitter detection [1]. Due to the non-uniformed distribution of primary users' location and spectrum usage , there is a problem of spectrum heterogeneity in CRN. Heterogeneity in CRAHNs is caused by the dynamic changes of spectrum availability[3] , which are caused due to the random behavior of the primary and secondary users and by the reconfigurability of SUs. The available spectrum for SUs may be different from node to node. Heterogeneity of resources is nothing but the various channels are available as well as the radios are available on the same node, and cooperation between nodes on the availble channels. In CRNs , for more reliable operation of the network one of the best solution is forming clusters . Cluster formation is giving better results because when clusters are used for sensing, the reliable sensing operation can be performed [4]. Which causes the prevention of CR users from interfering to the primary users , which is more useful. Even, the prevention of using the occupied channels by CR is possible , which are already in the use by primary users . By clustering , the collision occurance (while vacating the channel due to PU appearance) between neighboring clusters is reduced [5]. For easy routing , the clusters are formed in cognitive ad-hoc networks [6] . In clustering , the communication reliability can be increased by adjusting the transmission range of cognitive nodes.

Usually , the activity of primary users is not known to CR users in advance, the connectivity between CR nodes in a CRN is not guaranteed. If two communicating CR nodes are communicating with each other , and a primary user is detected at that particular time and want to use the working channel, then CR nodes have to switch very quickly to other idle channel. Due to which there is a problem of disconnectivity , in case of the unavailability of alternative channel . As clustering gives the direction for dependency between the used working channel and the availability of the working channels for all CR nodes in a cluster , the clustering algorithm has a big effect on stability . Even , with the help of the clustering algorithm , the

International Journal of Scientific & Engineering Research Volume 5, Issue 11, November-2014
ISSN 2229-5518

connectivity between various clusters is assured , on which the connectivity of the whole network is dependent. That is a clustering algorithm is giving connectivity robustness, which means that while forming clusters it is seen that there are more common channels shared by cluster members and more common channels are maintained between neighboring clusters. In this paper , a clustering scheme is discussed , which is based on the metric called as node selection score . This clustering scheme considers spectrum heterogeneity, the node degree, and the intra cluster delay as well as the stability of topology.

The rest of paper is organized as follows. In Section 2 related work is reviewed. Section 3 describes neighbor discovery process. Then the clustering scheme is discussed in Section 4. In Section 5, the experimental results are presented. Finally, paper is concluded in section 6.

2 Related Work

For ad-hoc networks [7], [8], [9] there are many clustering algorithms been proposed in the literature. In ad-hoc networks, the major focus of clustering is to preserve connectivity (under static channel conditions) or to improve routing. For clustering in sensor networks [6] , the special importance is given to longevity and coverage .Thus, none of this work takes into account the robustness as well as the channel availability in CRNs. In [10] , the balance between the number of idle common channels within cluster and cluster size is considered and an algorithm is proposed which increases the number of common channels within clusters. But its drawback is that it doesn't take into account the connectivity between clusters. Cogmesh [2] gives a practical MAC protocol for clustering but it doesn't consider the set of common channels and sizes of clusters. Chen et al. proposed a cluster-based CSS scheme , in [11] , to give better results in the cooperation overhead as well as the sensing reliability. This scheme can reduce the amount of direct cooperation with the fusion centre but cannot reduce the communication overhead between CR users and the cluster header. One of the clustering scheme proposed in [12], in which the same problem is observed. Distributed coordination of CRs via a locally computed control channel that changes in response to PR activity [13], was proposed by Zhao et al. In this , overhead of cluster management are reduced by minimizing the number of distinct frequency bands needed for control . For control in each neighborhood, the band available to the largest set of one-hop neighbors is selected. But because of the variations in PR activity this results in re-clustering repeatedly. In [14], a clustering algorithm is proposed which is based on the conception of control cloud. In this , a common channel is shared by CRs which is defined as control cloud. It make up a cluster and for decreasing the control overhead , the largest clusters are found. The main drawback of the scheme is that the architecture is not stable and re-clustering is easily caused by few mobility of CRs or little activity change of primary users (defined as ripple effect).In [15], the Max Node Degree clustering algorithm and the Lowest ID clustering algorithm [16]. But, main drawback of these two clustering algorithms is that , the heterogeneity of available channels is not considered in these two algorithms. Another multi-hop clustering scheme with load-balancing capabilities is Adaptive multi-hop clustering [17]. It is not capable to decide that which node is to be selected as the cluster head for the newly detached cluster.

3 Neighbor Discovery Process

As the nature of the available channels is heterogeneous , in CRNs , clustering plays an important role for the stable operation of the network. Clustering can reduce the routing protocol overhead [18] by reducing the network scale. It is suitable to form a cluster because the moving nodes are communicating with each other over longer distances using a line-of-sight path . It is assumed that coverage of each cluster is two hops , which can be extended to k-hop. Cluster formation process includes the following steps :

To participate in the cluster formation process , each CR have to know about the position of other CRs which are in its neighborhood and their local spectrum availability. To get this information is nothing but neighbor discovery process.

Neighbor discovery process in cognitive radio ad hoc networks is a challenging job because CRs have to meet all their k-hop neighbors in a multi-hop and multichannel network. Hence, these neighbors can be tuned on different channels, as their channel availability highly depends on the activity of primary users in the area. Let there are N no. of airborne nodes and C no. of spectrum channels , In a Cognitive Radio Network (CRN), if both the nodes A and B are within transmission range of each other and have at least one common channel between them then node A and node B are said to be neighbors of each other . Each node can periodically scan and identify the available channel set for the node. If a CR node can transmit and receive on channel C for reasonable amount of time without causing/having interference to/from primary users [19] then Channel C is said to be available. A node's neighbors are determined by its transmission range , as well as the channel being used.

4 Cluster Formation Process

After discovering the neighbor , the main steps for cluster formation are as follows:

1. At first , each node pass the information about its available channel set, location, speed, position, and mobility characteristics . Mobility characteristics includes the position of the node in the cluster as well as the position of the node in the network , at each available channel.
2. To select a cluster head , at first , number of two hop neighbors of each node n on channel C ,is calculated.
3. Calculate node selection score on the basis of following factors :
    - The number of two-hop neighbors of node n on channel C.

International Journal of Scientific & Engineering Research Volume 5, Issue 11, November-2014
ISSN 2229-5518

- The average number of hops from all one-hop and two-hop neighbors to node n.
- The average channel switching steps.

4. To calculate node selection score , number of two-hop neighbors to node n on channel C , given by $N_{n,C}$, is divided by the addition of average number of hops from all one-hop and two-hop neighbors to node n, which is given as

$$hop\_count = 1/N\_(n,C) \ \sum\_(k = 1)\hat{}(N\_(n,C)) ▒ 〖Count〗\_k$$

and average channel switching steps are given by :

$$ST = 1/N\_(n,C) \ \sum\_(k = 1)\hat{}(N\_(n,C)) ▒ 〖Cswitch〗\_k$$

Thus the formula to calculate node selection score of each node can be given with the following equation.

$$\beta\_(n,C) = N\_(n,C)/(1 + hop\_count + ST) \qquad (1)$$

The node with the largest node selection score is selected as the cluster head (CH).Following table (Table 1) gives the calculation for $\beta_{n,C}$ of each node. As the network assumes C number of potential channels , having indices from 1 to M. SU(node in the network) is operating in a time slotted fashion, where the length of each time slot is T. The SU also has a sensng order {s1,s2,……………sM}, which is permutation of set {c1,c2,…………cM}. Depending on some specific criteria(the channel is either free and has an acceptable channel quality) , SU senses the channels sequentially according to the sensing order within the given time slot, until it stops at the channel based on the selected criteria and transmits its information in that particular channel during the remainder of that time slot. It is assume that without any error the accurate channel sensing is done. From the values of node selection score in the table it is clear that , Node 4 has the largest node selection score on channel 1. Hence node 4 is selected as CH. As it is selected as CH, it is used as intra cluster control channel. Each node will select the node with the largest “node selection score” and use it as its CH in the cluster formation process, as shown in the following figure (Fig. 1) ,we take example of only six nodes in the figure.

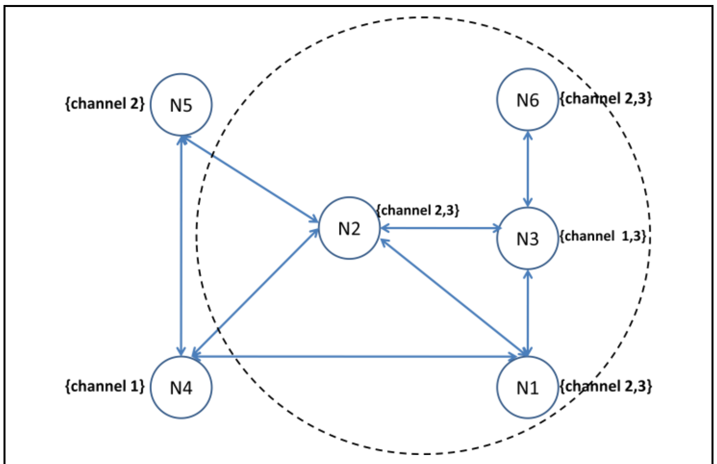


Fig.1 Cluster Formation.

TABLE 1

NODE SELECTION SCORE OF EACH NODE WITH RESPECT TO THE CHANNEL USED

Node No.	Channel Used	Node selection score
1	c2	0.07591
	c3	0.9419
2	c2	3.2297
	c3	3.3440
3	c1	0.3353
	c3	0.1416
4	c1	3.8751
5	c2	1.5305
6	c2	1.3593
	c3	0.8173

As channel 1 cannot be used by node 6 , node 3 works on channels 1 and 3 and acts as a switching node for node 6. For the communication in between the two clusters , the CH broadcasts the channel used as well as the list of all the nodes in that particular cluster , to other CHs on each channel , which is to be used at that particular time , with maximum transmission power. When the CH does not hear response from other CHs, it knows that other CHs are out of its coverage area. A new CH or an another channel is to be selected if a CH’s intra cluster control channel is occupied by other users after some time. Here in both these cases, a member node is selected as new CH, which is having next largest node selection score. The newly selected CH must be connect with other CHs and can operate on the inter cluster control channel as well. The CH and its one-hop neighbors can switch to different channels because the coverage of a CH is two-hop neighbors. While shifting there are chances of happening a deaf problem . A deaf problem can be solved by sending a join and a leave message over the control channel by the node before switching to another channel. The nodes can be arranged in the cluster as shown in Figure 2. In which three clusters are shown with the connectivity between the nodes as well as the Cluster Heads (CHs).

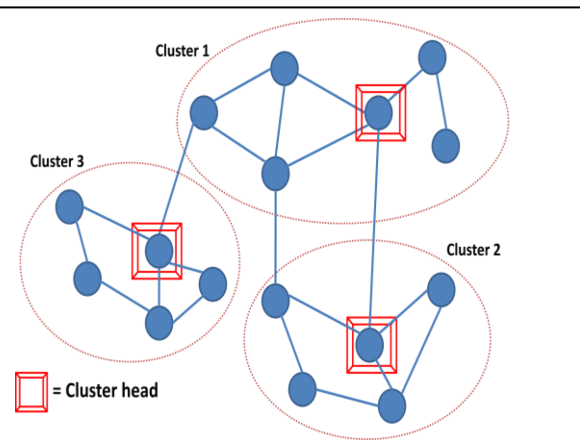


Fig.2 Cluster Architecture.

International Journal of Scientific & Engineering Research Volume 5, Issue 11, November-2014
ISSN 2229-5518

5 Experimental Results

In this section, we discuss the performance of CRN clustering scheme. The simulation set up uses the transmission range – 2.000*2.300 km , the mobility model used is the - bird flock mobility model. the no. of nodes - 32.avg. no. clusters = 5. Available channels = max10 , initial energy level 100joules and simulation time =50 sec.

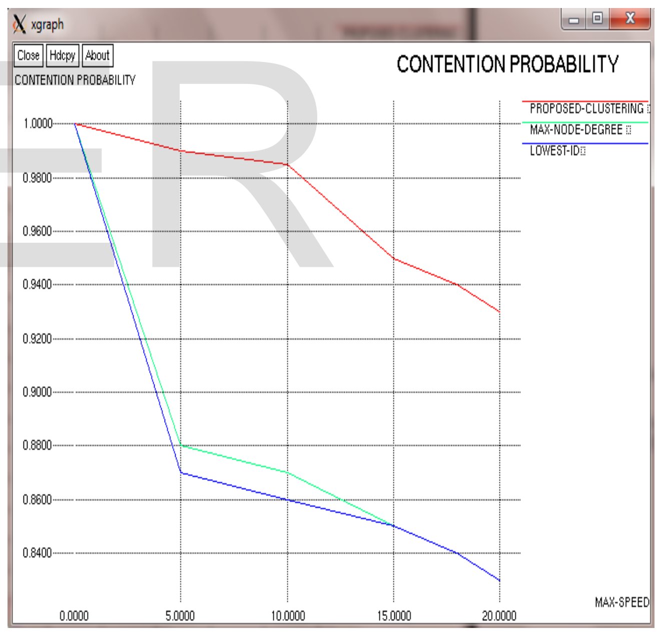
The average number of clusters tries to show how many clusters are formed with different clustering algorithms, while the contention probability of the CRN shows the probability that the formed clusters can communicate with each other. Since the primary and secondary users are randomly deployed, the statistical values are calculated after the nodes fly for a period of 50 s.

(a)

(b)

Fig. 3 Clustering scheme's performance for number of nodes used in CRNs. (a) Average number of clusters. (b) Contention probability of the CRN.

(a)



(b)

Fig. 4 Clustering scheme's performance for Maximun node speeds. (a) Average number of clusters. (b) Contention probability of the CRN.

6 Conclusion

Clustering scheme discussed in this paper is based on a clustering model in which cluster heads (CHs) are selected on the basis of node selection score , average number of hops as well as channel switching from member nodes to the CH. In the neighbor discovery process of cluster formation , the channel availability is checked hence it is more suitable for topology

International Journal of Scientific & Engineering Research Volume 5, Issue 11, November-2014
ISSN 2229-5518

management in CRN. As this clustering scheme considers the number of two hop neighbors of all communicating nodes , the clusters forms are less in number. Thus "node selection score" based clustering scheme is more suitable for CRN for finding out the path between the source and the destination ,because there is no any problem for selecting cluster head (CH) for newly detached cluster.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to my guide Prof. S. S. Barve, MIT Academy of Engineering, India, under whose supervision this research was undertaken.

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