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RESEARCH ARTICLE

Control Channel Allocation in Cognitive Radio Networks using Clustering

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Abstract— ***The static allocation schemes have led to the problem of spectrum under-utilization. In many bands, spectrum access is a more significant problem than physical scarcity of spectrum, in large part due to legacy command-and-control regulation that limits the ability of potential spectrum users to obtain such access. Dynamic spectrum management allows adaptive allocation of spectrum to various users in a multiuser environment as a function of spatiotemporally varying physical environment. A Cognitive Radio Network is a multi-hop multi-channel network with dynamic channel set for each user. Establishing a self-organizing cognitive radio network requires extensive exchange of control messages, needed to coordinate various network functions such as cooperative sensing, channel access, topology management, and routing. In wireless networks, control messages are broadcasted over a channel known to all nodes, commonly referred to as the common control channel. The concept of a single frequency band as control channel is not practical. It is considered wise to form smaller group of secondary users such that the number of available channels that are common to them is maximum. This paper deals with the methodology of obtaining the optimum groups. The major thrust of this paper is on the formation of the groups in such a way that graceful tradeoffs is achieved between the number of nodes in a group and the number of idle channels common to all the members of the group.***

Keywords— Cognitive radio network, control channel, idle channels, graceful tradeoff, clustering.

I. INTRODUCTION

The emergence of Cognitive radio to realize dynamic access in order to address the issue of spectrum underutilization hints towards a shift in the spectrum usage paradigm. The shift from static command-and-control towards dynamic access is primarily the outcome of numerous reports indicating inefficient usage of precious natural resource – the electromagnetic spectrum. The conception and usage of cognitive radios is meant to achieve better utility of spectrum by proper co-ordination between unlicensed cognitive (secondary) users (CU). In order to co-ordinate the CUs need to communicate with each other. This communication and co-ordination may result in overcrowding of control messages on frequency channels that are already facing congestion. The transmission of data on already congested frequency channel would inevitably elevate the problem of spectral inefficiency. The solution to avoid further inefficient usage of spectrum is to co-ordinate multiple users simultaneously. This simultaneous co-ordination implies information transferral regarding radio environment must reach multiple users through a single co-ordinating entity, the clusterhead (CH), via broadcasting technique. This reduces the co-ordination overhead significantly because each user does not have to separately share information with others.

Today, smart utilization of limited natural resources is a highly challenging task. Since the number of wireless users are growing exponentially, it is the need of the time to manage and efficiently use the precious electromagnetic spectrum.

For broadcasting, there is a need of a frequency channel common to all secondary users. Such a channel is termed as Common Control Channel (CCC) and the problem of defining such a channel is referred to as Control Channel Allocation (CCA) problem. The CCA problem for secondary users in a particular neighbourhood/vicinity needs to be dynamic spatio-temporally. The aspects of space and time need to be considered simultaneously because the spectrum opportunities for the CUs keep on changing with respect to time and CUs can be mobile nodes moving from one location to another with respect to time. The methodology of CCA is required to be dynamic and self-evolving. In general, two approaches have been proposed for CCA, namely, centralized and co-operative distributed. In centralized approach, the control and co-ordination is carried out by a single entity. On the other hand, in co-operative distributed approach, the control and co-ordination is achieved by communication between neighbourhood nodes with or without single controlling entity.

Our Contribution: We develop a node centric cluster-based method for CCA in CRN. The clustering problem is formulated as a bipartite graph problem given the inherent partioning of the network into clusters due to the space- and time-dependent spectrum availability. The clustering is mapped to two instances of biclique i.e. the maximum edge biclique problem which allows us to control the tradeoff between the set of common idle channels within each clusterand cluster size[1]. For every node, the maximum amongst the candidate products of cluster size and common idle channels for that cluster is selected. Our node centric approach facilitates overlapping clusters depending on spectrum opportunities. The overlapping clusters realize the concept of gateway nodes which addresses the problem the intercluster communication.

Paper Organization: The remainder of this is organized as follows: Section 2 discusses related work. In section 3, we formulate the CCA problem and present our system model. In Section 4, we evaluate performance. In Section 5, we summarize our contributions.

II. RELATED WORK

Previously proposed clustering algorithms for dynamic CCA in CRNs can be classified into: 1) Cluster first, and 2) Cluster head first. We describe both categories in detail [2]. The detailed survey of control channel allocation is described in [3].

Cluster first approach: All the cognitive radio nodes sense the spectrum holes sensed in its vicinity and generate a list of idle channels. It is assumed that each node has the information of its neighbours beforehand. After generating the idle channel list, the nodes that observe similar spectrum opportunities are to be grouped in a single cluster. The cluster formation is considered if and only if there is at least one common idle channel for each cluster. Though, it is desirable to have more than one channels' to accommodate the PR activity on the single common control channel. The higher number of CCCs in a cluster formation will inevitably reduce the size of the cluster. There is a need for balancing these two complementary constraints.

Cluster head first approach: The cluster head first approach is extensively dependent on neighbours. In cluster head first approach, a node initiating the cluster formation process is the cluster head and then other nodes having similar spectrum opportunities join the cluster one by one. The network is formed by interconnecting the clusters.[4]

III.SYSTEM MODEL

Clustering is a popular grouping technique in distributed wireless networks. CR users are divided into clusters based on cluster formation algorithms. One member of the cluster is elected as the CH, which acts as the central entity for coordination. As a result, the CH selects one channel commonly available to all cluster members as the CCC of the cluster. Since neighbouring clusters use different channels as the CCC, the CHs or the cluster members on the cluster border are responsible for intercluster communication. For CCC designs, how clusters are formed is related to how the CCC is allocated, or vice versa. For inter-cluster communications and the CCC change to avoid the encounter with PUs, the cluster-wide channel hopping over all CCCs of the cluster is used. However, the hopping of the entire cluster requires strict synchronization among cluster members. More importantly, neighbouring clusters may not be able to communicate with each other by such hopping.

A. Assumptions made:

1. *Spectrum Sensing*: The process of spectrum sensing is currently not a part of the project. The process is assumed to be occurring at frequent intervals of time and is a flawless process. The various issues like multipath

shadowing, fading, interference are not considered as the focus area for the project. The sensing is assumed to be carried out on the USRP hardware with the use of suitable daughterboard. The frequency channels sensed idle are then noted and written in a file and the clustering algorithms are expected to read it from the file. The frequency of spectrum sensing is fairly periodic and every scan of electromagnetic space is noted in the same file so as to discard historical data and to focus on dynamically achieved data.

2. *Neighbour Discovery*: The clustering algorithms are supposed to create clusters for each node and finalize the one with the highest biclique. The necessity of the knowledge of the one-hop or immediate neighbours is of utmost importance; but diverts the focus of the project. Hence the neighbour discovery process is assumed to be carried out before the process of clustering starts. Neighbour discovery in itself is another field of study and research but there are many algorithms available as on date which can efficiently carry out the process. In this project it is assumed that the nodes do not move in space and do not fail during the clustering process.

3. *Programming of Clustering process*: The input to the clustering algorithm for each node is the neighbours list i.e. nodes that are one hop away and a list of channels sensed idle during the process of spectrum sensing. The project is currently not using the USRP hardware hence the list of channels is given as a static input and remains unchanged. As for the efficiency of program, we have taken five sample networks to demonstrate the process of clustering. As the number of nodes increases considerably, the clustering process can be achieved through a certain level of concurrency, for instance use of threads for every node. Each node has to form cluster with the inputs, currently achieved through individual iterations of a loop. The use of multithreading has two advantages i.e. firstly the clustering process is significantly faster as compared to the existing one and secondly the concept of device intelligence would be realized.

B. Working Flow:

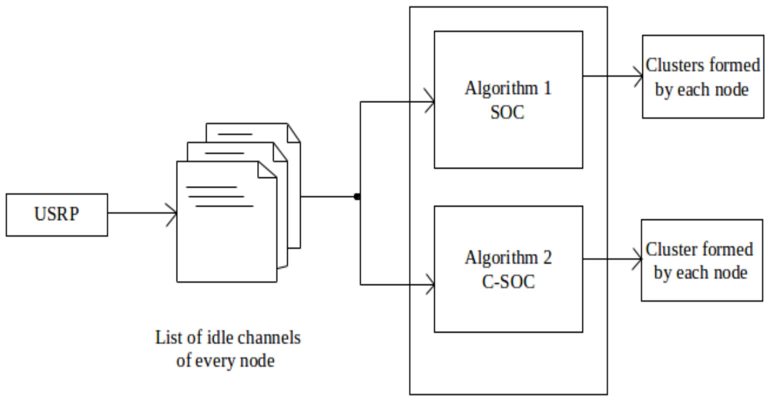

Fig.1: System Architecture

1. The USRP hardware as shown in the figure scans the specified range of electromagnetic spectrum for spectrum holes i.e. idle channels.
2. The spectrum holes are noted and treated as input to the clustering algorithms.
3. The clustering algorithms i.e. SOC and C-SOC are used for formation of clusters.
4. The output of the algorithms is the clusters formed using node-centric notion.

The clustering algorithms from [1] are used and for each node the cluster is noted. The cluster with the maximum product of number of edges and cluster size is finalised from among the candidate clusters. The approach used here is of lazy learner. Each node initiate the clustering process and nodes with similar spectrum opportunities join the initiating node. In each iteration, the product is noted and from that the maximum is selected as the final cluster for that node.

IV. PERFORMANCE EVALUATION

The process of clustering is applied on networks of various sizes. The results presented here are for networks containing nodes 5, 8, 10, 13, 15. It should be noted that the clustering is carried out from the point of view of the node and not the network as a whole.

Evaluation Metrics:

A. *Gateway Nodes*: The nodes that facilitate the intercluster coordination are termed as gateway nodes. These nodes typically belong to two clusters.

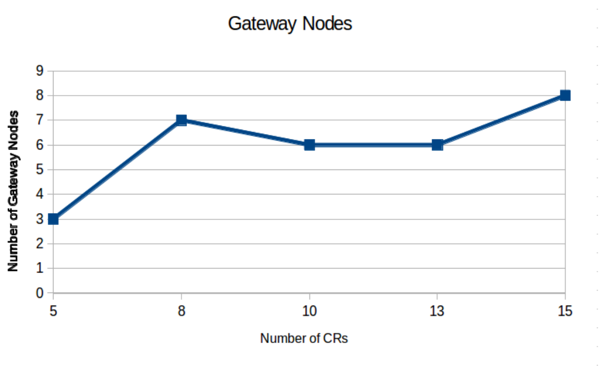

Fig. 2: Gateway Nodes

B. *Single Node Clusters*: The spectrum availability varies widely in a spatio-temporal context. This may lead to smaller clusters, in some cases even with a single member node. The single node cluster, to some extent can be considered as an inefficiency of the mapping to biclique philosophy. Single nodes are treated as a burden for communication. The failure of idea of clustering results in single nodes clusters and hence it is desirable to avoid such clusters.

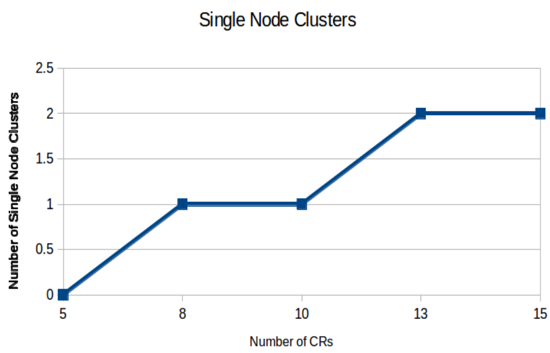

Fig. 3: Single Node Clusters

C. *Nodes belonging to more than two clusters:* The node centric nature of the algorithm results in situations wherein one node can be a member of multiple clusters.

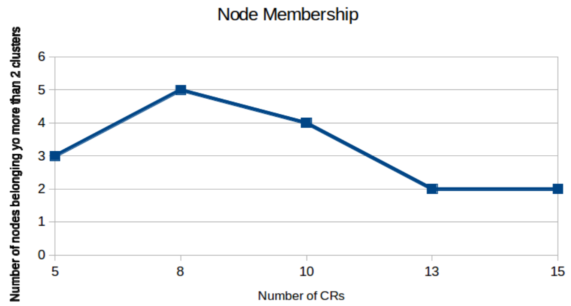

Fig. 4: Node Membership

D. *Average number of common idle channels per cluster:* The most important metric to consider is the average number of common idle channels per clusters because this holds the key various functionalities regarding the primary and secondary user communication. It is desirable to have multiple idle channels per cluster simply for the reason that, if primary activity occurs the control channel, the control channel can be migrated to another channel. This is necessary characteristic of cognitive radios to coexists with the primary legacy radio networks. The average number of common idle channels per cluster are expected to increase proportionally with increase in the network size. The first algorithm, SOC, does not place any condition on the number of channels per cluster; whereas the second algorithm, C-SOC, specifies the minimum number of channels required for the cluster formation.

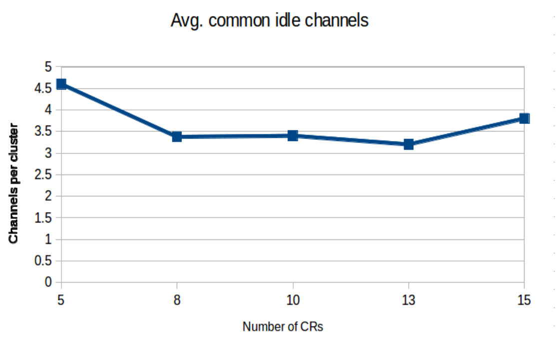

Fig. 5: Average common idle channels

E. *Average cluster size:* The average cluster size is the average number of nodes in the clusters formed. It is desirable to have large sized cluster keeping a balance between the idle channels per cluster and the number of nodes in that cluster. Larger clusters may result in fewer channels in that cluster and vice versa. Also, smaller clusters may render the clustering process useless. So, a graceful tradeoffs needs to be achieved in the cluster size and the number of idle channels per cluster.

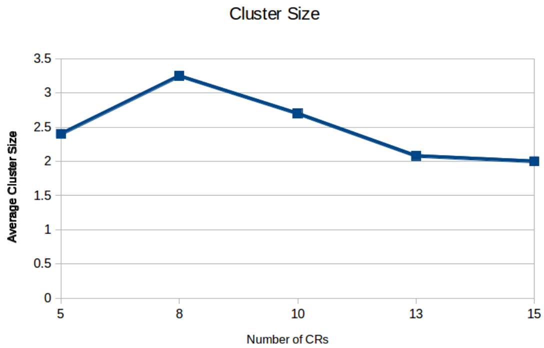

Fig. 6: Average cluster size

F. *Ordinary Nodes:* The ordinary nodes have single cluster membership and have least functionality. The ordinary nodes belong to a single cluster or are generally single cluster nodes, hence it is clear that these nodes have different spectrum opportunities as compared to its neighbourhood scenario. Depending on the connectivity of neighbours, ordinary nodes can assume the functionality of a cluster head. The cluster heads are deliberately not elected because it is to some extent contradictory to cooperative communications and the concept of clustering. This is evident from the implementation of cluster first technique as against cluster-head first technique.

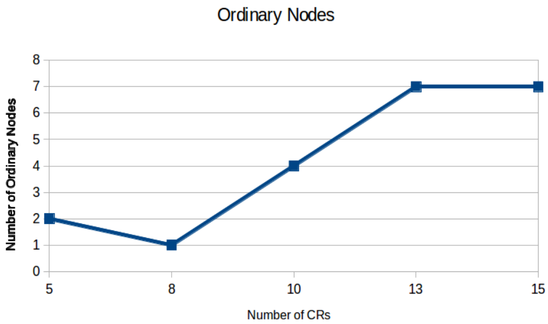

Fig. 7: Ordinary Nodes

V. CONCLUSIONS

We mapped the clustering problem into instances of a bipartite graph problem, and showed that this mapping allows for a graceful tradeoffs between the cluster size and the set of common channels in each cluster. In particular, we mapped the clustering process to the maximum edge biclique problem, and the maximum one-sided edge cardinality problem. Since both problems are known to be NP-complete, we proposed two greedy heuristics for finding bicliques that satisfy our requirements. We proposed two distributed clustering algorithms called SOC and C-SOC that takes into account the channel availability in deciding cluster memberships. The challenge of intercluster communication is also addressed by overlapping clusters with the use of gateway nodes. The gateway nodes pave the way for efficient inter- cluster communication. Furthermore, the subclusters formed by iteration of every node is also beneficial in case of failure of node or communication link. The existing clusters remain intact until the clustering process is repeated for achieving better efficiency with regard to spatio-temporal context for Cognitive nodes.

Presented work is aimed at providing the applicability of spectrum efficiency, and tested for the same. Still there is scope of improving performance for presented work. Several opportunities exist for potential future work. The conception in [1] and the working of the thesis is focused on the cluster formation but no attention is paid towards the intelligence of individual nodes. The network as viewed by each node is not given any thought. For a network to be of Cognitive in nature, intelligence and coordination of individual entities is of utmost importance. This will not only help in overcoming the problems identified in [1] regarding the intercluster coordination of nodes belonging to different clusters but which are one hop away from each other. The communication can occur on any channel sensed idle common to both; bypassing the conventional route through the cluster heads and realizing the peer to peer communication. The advantages of such peer to peer communication is reduced traffic in the network and lesser load on the cluster head to handle and route. Realization of such a peer to peer network with intelligent entities within the network will lead to a Cognitive Network and new class of truly intelligent devices.

REFERENCES

[1] S. Liu, L. Lazos, M. Krunz, "Cluster-based control channel allocation in opportunistic Cognitive Radio Networks," IEEE Transactions on Mobile Computing, Vol.11, no.10, pp.1436-1449, October 2012.

[2] N. Dhamne, M. Bhalekar, M. Kharat, "Cluster based Cognitive Radio Network: A review," International Journal on Recent and Innovation Trends in Computing and Communication, Vol. 2, Issue 6, pp.1589-1593, June 2014.

[3] B. Lo, "A Survey of common control channel design in cognitive radio networks," Elsevier, Physical Communication No. 4, pp.26-39, January 2011.

[4] T. Chen, H. Zhang, G. Maggio, I. Chlamtac, "CogMesh: A Cluster-Based Cognitive Radio Network," Proc. Int'l Symp. New Frontiers in Dynamic Spectrum Access Networks (DySPAN), pp.168-178, 2007.

[5] S. Haykin, "Cognitive Radio: Brain Empowered Wireless Communication," IEEE Journal on Selected areas in Communication, Vol.23, No.2, pp.201-220, February 2005

[6] Federal Communications Commission, "Spectrum Policy Task Force Report," 2002.

[7] I.F. Akyildiz, W.Y. Lee, M.C. Vuran, and S. Mohanty, "NeXt Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey," Computer Networks J., vol. 50, no. 13, pp. 2127-2159, Sept. 2006.