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Performance Analysis of Distributed Coordinated Spectrum Sensing in Cognitive Radio Networks

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Abstract: This paper present the work on Cognitive Radio Networks (CRN) to improve the spectrum sensing performance. By using distributed coordinated spectrum sensing all the Secondary Users (SUs) are grouped into optimum number of clusters, selection of each cluster is based on the priority of predefined Cluster Heads(CHs) among secondary users. All the CHs collects the source information from the remaining nodes, then transmit decision to the common receiver. The proposed method provide dynamical clustering Distributed Coordinated Spectrum Sensing (DCSS) scheme with bandwidth constraints according to the inter and intra cluster channel conditions with reduced overhead and delay of sensing. DCSS provides preferable scalability and stability because of its low complexity under dynamic Primary Users (PUs) activity.

Key words: Cognitive Radio Networks(CRN) · Primary User(PU) · Secondary User (SU) · Distributed Coordinated Spectrum Sensing(DCSS) · Dynamic clustering · Bandwidth constraints

INTRODUCTION

The channel capacity of the spectrum holes depends on the interference at the nearby primary users. Furthermore, if primary users appear in the spectrum band occupied by secondary users, secondary users should vacate the current spectrum band and move to the new available spectrum immediately, called spectrum handoff. Thus, the interference avoidance with primary users is the most important issue in this architecture. In order to overcome this problem cooperative spectrum sensing has proposed can reduce the average time to sense the primary users and can solve the hidden node problem. Cooperative sensing is capable of mitigating the noise effect and the effect of fading and shadowing by providing spatial diversity[2]. In a cluster based cognitive radio network, the wideband spectra could share some common spectral components, such a data fusion center based cooperative wideband sensing technique will lead to a heavy data transmission burden in the common control channels. An alternative is to develop cluster based Distributed Coordinated Spectrum Sensing method.

Spectrum Sensing Aware Clustered Structure: The proposed clustered structure is two fold [1]. On the one hand, the structure is aware of the radio environment. On the other hand, the structure should be energy efficient. In addition to the following basic assumptions, features and objectives are used in this paper:

- Spectrum sensing capability: possessing spectrum sensing capability, each SUs node can correctly determine the available channels at its location.
- Spectrum aware constraint: SUs nodes that belong to the same cluster have at least one common channel available.
- Efficient source sensing: Form a Cluster Heads (CHs) in every cluster. The sensed source information should be first aggregated to CH and then relayed to the sink node.
- Energy efficiency: spectrum aware clusters are organized such that the total communication power is minimized, in order to extend the lifetime of the Sus.

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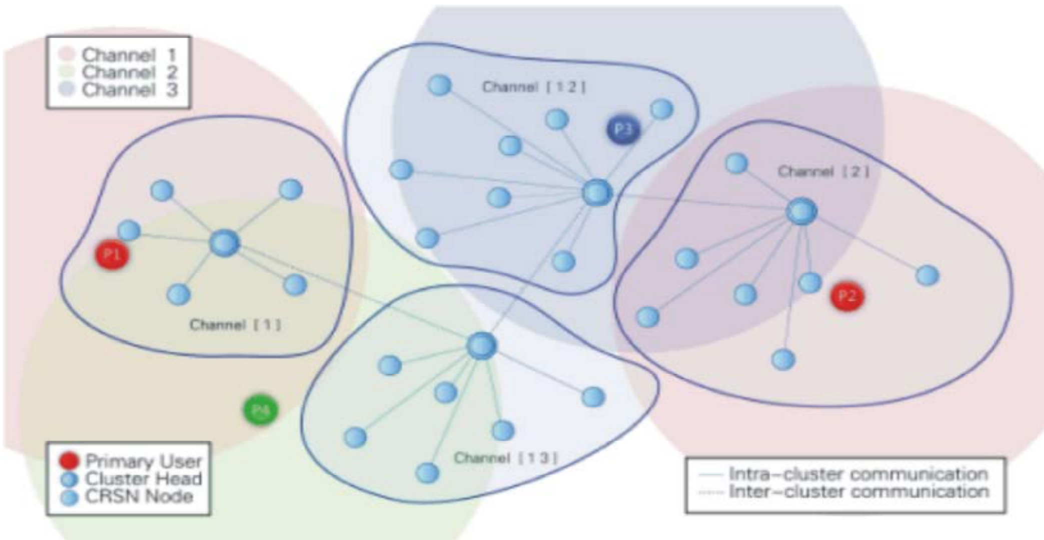

Fig. 1: An example of spectrum sensing aware clustered structure for CRSN

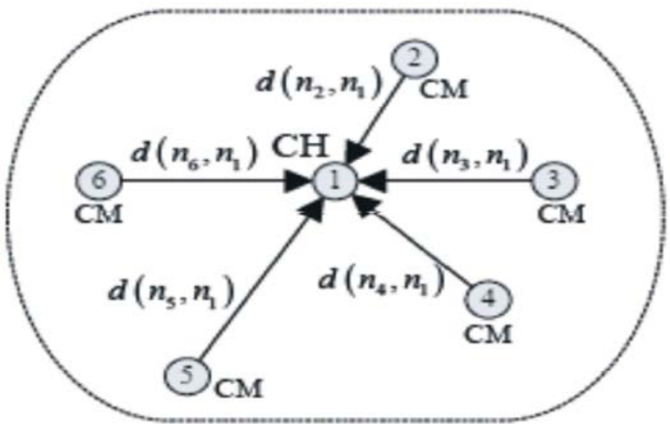

Fig. 2: Intra Cluster Communication

The proposed sensing spectrum aware clustering structure is shown in Fig. 1. PUs occupying different channels are represented in corresponding Colours. These channels are not available to Cognitive Radio Secondary Nodes (CRSN) located within the PU's protected range (translucent area). Neighboring nodes who share common channels form a cluster and one node has to be selected as CH in each cluster. We assume that there are N CRSN nodes and K clusters. The kth cluster is denoted as c_k and has N_k CRSN nodes. The ith node of c_k is n_i^k, whose coordinate is (x_i, y_i). The network communication can be categorized into two classes: intra cluster communication and inter cluster communication.

During the intra cluster communication phase, all the CRSN nodes send their readings of source information to their CH through the local common channel.

When the jth node is selected as CH, all other Cluster Members (CM) report to CH, as shown in Fig. 2. The sum intra cluster power is: where Pr is the minimal receiving power required and $d(n_i^k, n_j^k)$. Is the Euclidean distance between the ith and jth node which can be acquired through channel estimation.

During the inter cluster communication phase, the CH first compress the aggregated source information, then transmit it to the upstream neighbor CH using maximal power. With this structure, the sensed source information is collected efficiently through intra cluster aggregation and inter cluster relaying. To accommodate CRSN's unique features, we model communication power consumption and derive the optimal number of clusters in CRSN. We prove that minimizing the communication power is equivalent to minimizing the sum of squared distance between CRSN nodes and their cluster centers. This objective coincides with many clustering problems [3, 4] and the ideas of constrained clustering [5, 6] can be employed to cluster CRSN nodes under spectrum aware constraints. We propose a novel Distributed Coordinated Spectrum Sensing (DCSS) protocol to form clusters with low intra cluster distance and hence reduces communication power. Moreover, DCSS is performed in a fully self organized way and has preferable scalability and stability.

Distributed Spectrum Aware Clustering Protocol: The centralized clustering algorithm can effectively partition the CRSN into clusters that satisfy the spectrum aware constraint, it has two major drawbacks. First, massive signal exchange between the CH and BS is required to collect network wide node information. In practice, it is difficult to find a wireless channel for direct connection between the CH and BS, since such a connection requires much higher transmission power and will bring interference to a nearby PU system. Moreover, the complexity of the Centralized Coordinated Spectrum Sensing (CCSS) algorithm is proportional to the size of the proximity matrix, which is N^2. As a result, the growing size of the network will result in greater complexity, making the algorithm difficult to implement for large scale networks. Obviously, these shortcomings will inevitably limit the practical application of this algorithm.

To address these problems, we propose a novel Distributed Coordinated Spectrum Sensing (DCSS) technique, with even lower complexity and higher stability. The DCSS protocol is described by the flowchart in Figure 3. It consists of three stages: channel sensing, beaconing and coordination [6]. In the channel sensing stage, each CRSN node determines the vacant channels individually and compares it with the previously sensed result. In the beaconing stage, the CRSN node beacons its node information in the vacant channels according to the channel sensing results. If any change in the PU state is detected, the node declares itself as a new cluster by beaconing a new cluster ID. Otherwise, the node stays with the current cluster. After the node beaconing, the CH updates and beacons the cluster information, including cluster size and common channels. In the intra cluster coordination stage, each node in a cluster first measures the strength of neighboring beacon signals and then announces the pair wise distances. From these distances, the CH determines the inter cluster distance according to the complete link rule and the group wise constraint, in which the inter cluster distance is defined as the maximum distance between the nodes of two clusters. In inter cluster coordination, each CH sends merge invitation to the nearest neighboring cluster that is within its transmission range. If any two clusters send merge invitations to each other, they merge into a single cluster by unifying the new cluster ID and common channels and selecting a new CH with the largest residual energy. Otherwise, the cluster selects a new CH while the topology remains unchanged.

Spectrum Sensing (SS) is the key technology in CR system to improve the efficient utilization of spectrum by allowing Cognitive Radio Users(CUs) to use the “white space” (spectrum hole) [7] of licensed spectrum without causing harmful interference to the Licensed Users(LUs). Usually, spectrum sensing of a single CU in the CR system bases on energy detection. However, when the detecting channels experience severe path loss or shadowing effect, the sensing performance of the CU may be degraded seriously and the hidden terminal problem may occur [8]. In order to improve the sensing performance, Distributed Coordinated Spectrum Sensing(DCSS) has been proposed [9, 10]. It is usually performed in two successive stages: *sensing* and *reporting*. In the sensing stage, every CUs performs spectrum sensing individually. In the reporting stage, all the local sensing observations are reported to a common receiver(Fusion Centre) and the latter will make a final decision on the absence or the presence of the primary user.

Assume that there are K clusters and the number of the CUs in the ith cluster is K_i. All the CUs are formed into clusters. In order to reduce the reporting time and bandwidth, CUs are divided into two types: Cluster Heads(CHs) and ordinary nodes. Ordinary nodes report information to their CHs and cognitive common receiver (Fusion Centre) only collects information from CHs. The FC will combine all cluster decisions to make a final decision and broadcast the final sensing decision to the whole network as shown in Fig. 4. The local RF observation used in PU detection sensing is based on the following hypothesis model:

r(t)= h(t) H_0-Absense of user

hs(t)+n(t) H_1-Presence of user (1)

where r(t) is the signal received by the CR user, s(t) is the transmitted signal of the PU, n(t) is a zero mean additive white Gaussian noise (AWGN) and ‘h’ is the amplitude gain of the channel. ‘H_0’ is a null hypothesis, which states that there is no licensed user signal in a certain spectrum band. On the other hand, ‘H_1’ is an alternative hypothesis, which indicates that there exists some PU signal.

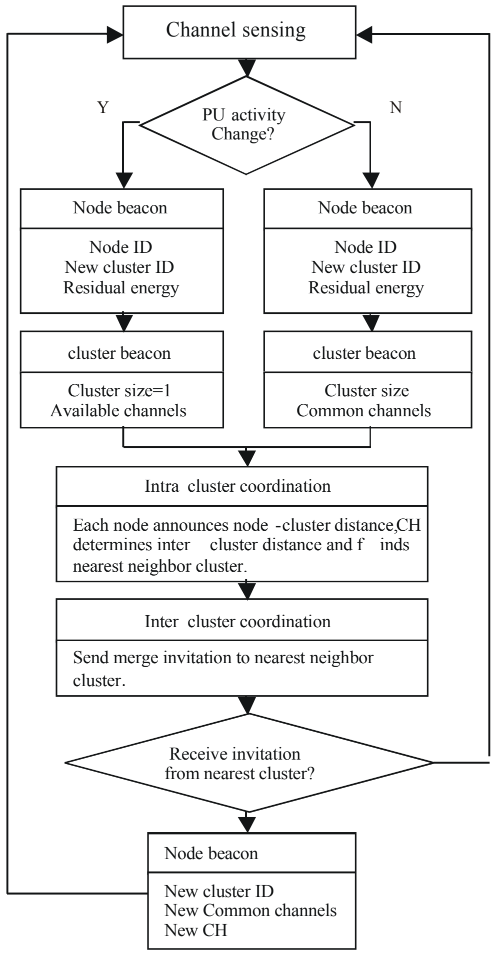

Fig. 3: Flowchart of the DCSS protocol

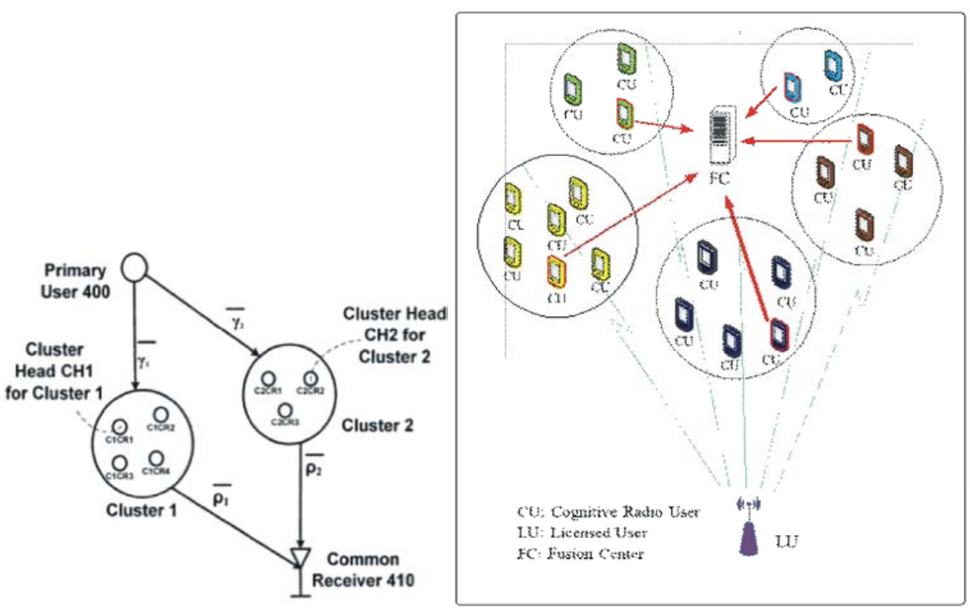

Fig. 4: Dynamical clustering cooperative spectrum sensing with bandwidth constraints

RESULTS AND DISCUSSION

NS or the network simulator is a discrete event network simulator. ns is popularly used in the simulation of routing and multicast protocols, among others and is heavily used in ad-hoc, Cognitive Radio networking research. NS supports an array of popular network protocols, offering simulation results for wired and wireless networks alike.

System Requirements:

Operating System: Fedora Linux
Simulator used: NS v2.31

After the tcl simulation script is built, we can run the simulation by executing the simulation script created in the previous section. To run the simulation, following command is used: */ns filename.tcl.*

Random Node Generation: For random node generation we use the following parameters.

The Network Simulator (NS) is used to implement the simulation model. The simulation model consists of number of nodes allocating bandwidth in multi channel environment. As increase in the number of nodes, the throughput improves by using proposed DCSS algorithm in mul tichannel scheme as shown in all results analysis.

Throughput: Ratio of the packets delivered to the total number of packets sent (transmitted).

Throughput = packets delivered / total number of packets sent

Number of Nodes vs MAC Throughput: In Fig. 5, show the MAC throughput of a node is the number of bits received by the MAC layer of that node per second. As the Number of Nodes Increases MAC throughput increases exponentially in proposed method and it would be the best when compared to the existing method.

Number of Nodes vs End to End Throughput: In Fig. 6, show the end to end throughput of a node is the number of bits received by the destination node per second for a given traffic flow. As Number of Nodes increases, Throughput increases exponentially till the node 4.0000. Then the throughput decreases slightly from the node 4.0001 till 10.0000 in the proposed method. and in the existing method as number of nodes increases, throughput decreases exponentially.

Table 1: Random Node Generation

Parameter	Specification
Channel Type	Wireless channel
Channel	4
Network Interface Type	Phy/Wireless Phy
Queue	Queue/ Drop Tail/Pri Queue
MAC Protocol	IEEE 802.11
Radio Propagation Model	Two Ray Ground
Antenna Model	Omni Directional
Packet Size	1000 bytes
Routing Protocol	DSDV
Traffic Sources	CBR(UDP)
Coverage Area	100 x 100
Number of Nodes	10-100

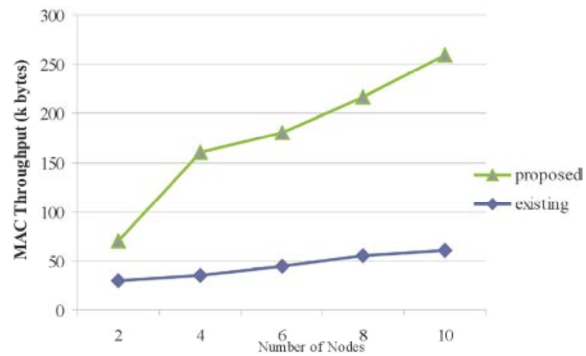

Fig. 5: Performance Of Bandwidth Sharing Analysis of Number of Nodes vs MAC Throughput

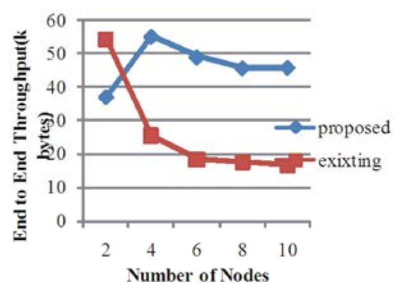

Fig. 6: Performance Of Bandwidth Sharing Analysis of Number of Nodes vs End to End Throughput

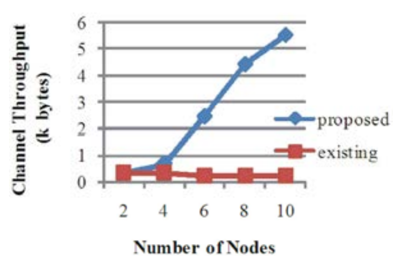

Fig. 7: Performance Of Bandwidth Sharing Analysis of Number of Nodes vs Channel Throughput

Number of Nodes vs Channel Throughput: In Fig. 7 As number of node increases, throughput slightly varies till 4.0000; then the throughput increases exponentially from

4.0001 till 8.0000; then from 8.0001 till 10.0000, the throughput decreases slightly in the proposed method. and in the existing method number of nodes increases, throughput decreases constantly. when compared to the existing method, proposed method is best one.

CONCLUSION

DCSS algorithm for bandwidth balancing in multi channel used to increase the network capacity, hence the achievable throughput. The simulation performance provides preferable scalability and stability with its low complexity and quick convergence under dynamic spectrum variation, dramatically reduce the reporting time and energy consumption.

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