# Radio spectrum collision avoidness in cluster cognitive network through gazer nodes


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**Abstract:** The spectrum deficiency in cognitive radio can be solved effectively by utilisation of radio spectrum. The spectrum is not effectively shared among all the other users. Since the users are spread across different locations the spectrum allocation and spectrum sharing is important to use spectrum effectively and to allocate communication channel to all the devices in the network, by doing so all the nodes in the network can communicate covering large area. In cognitive radio, spectrum sensing, spectrum allocation, and reuse scenarios approaches with the different algorithm help improve the utilisation of the spectrum. Traditional spectrum allocation technique such as fuzzy logic and harmony search replaces the spectrum with the new spectrum scheme. However, the new technique brings more efficiency in achieving spectrum utilisation. Still the cognitive in mesh network has the problem of collision between the secondary and primary users. To minimise the effect of collision we introduce a gazer-based cognitive radio network (GCRN) which provides more freedom for frequency sharing paradigm. The novel algorithm provides the network to adopt automatically for every change in the environment of the cluster in cognitive radio network.

**Keywords:** cognitive radio network; gazer nodes; spectrum sensing; resource sharing; control channel.

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## 1 Introduction

Cognitive radio, the future technique to transfer data efficiently through sharing of the spectrum in communication devices. Spectrum should be utilised efficiently for effective communication. Today, traditional method to command and control spectrum allocation generates uneven network traffic, which leads to overload in network usage. To overcome this paradigm, open spectrum sharing is implemented in cognitive radio networks. The sharing of the frequency with all the nodes establishing communication at a time also the load will be equally spread in the spectrum, so unbalance spectrum utilisation is avoided.

The term cognitive radio is derived from the concept software defined radio with the cognitive brain. The principle of cognition applies in the spectrum sharing. The spectrum sharing is the main theme to utilise maximum frequencies to transfer the data from sender to destination nodes. Even though it is more efficient, spectrum sharing technique brings a problem of collision. In cluster radio, network collision avoidance plays the main role when the same frequency is utilised by two individual nodes. Primary and secondary users (SU) of the same frequency collide to each other when both the nodes try to communicate at the same time.

To avoid this problem more techniques and algorithms are proposed to identify and prevent the collision in the cognitive cluster network. Here we proposed a cluster-based technique to prevent the occurrence of the collision. The group of nodes is joined into small clusters. Each group posses a cluster head. The cluster heads are connected by the gazer nodes. The gazer nodes sense the spectrum utilisation by the nearby clusters and allocate the frequency for all the other clusters without any collision occurrence.

Spectrum sensing, spectrum sharing, and spectrum management is performed by the gazer nodes placed between the clusters. The slave nodes transfer data to cluster heads, cluster heads transfer data to the gazer nodes, and the gazer nodes pass the data to the base station. So the frequency used by one cluster will not affect the neighbouring cluster.

## 2 Related work

The evaluation in a high-fidelity emulation testbed and implementation with software-defined radios (SDRs) of the distributed cognitive radio network architecture for joint routing and spectrum access is proposed. The implementation of CREATE-NEST is distributed with plug-and-play devices which run identical codes and scales up seamlessly. A full protocol stack with distributed coordination (no common control channel) and local network state information is deployed by CREATE. It integrates the spectrum sensing, neighborhood discovery and channel estimation with joint routing and channel access implemented with backpressure algorithm. Under various path loss, fading, delay, and mobility scenarios for cognitive networks the NEST provides realistic physical channel environments and protocol design verification and evaluation of realistic RF channels with digitally controlled channel impulse responses. To verify the CREATE-NEST implementation, extensive emulation testbed results are provided.

Cognitive radios require study of cognitive engines which have been under study and development for a long time. Recent efforts suggest that expansion has been made in the area of cognitive engines to address the needs of networked cognitive radios (Shah, 2013).

The significant functional and parametric differences between cognitive algorithms that optimise cognitive radio and cognitive algorithms that optimise cognitive radio network. The compromises in the application of various algorithms to each task. The algorithms most suitable for networking tasks. A set of parameters characterises candidate algorithms exploring the benefits and drawbacks of each for cognitive engine algorithms that work one after the other to enhance the use of networked cognitive radios (Soltani et al., 2015).

In the next generation mobile and wireless access networks, the concept of cloud network and cognitive radio could become new features, which are driven by the requirements from the traffic volume versatile services and spectrum scarcity, For example, white spaces provide a new way for traffic offloading and enables spectrum sharing as a cognitive radio network, to deploy long term evolution femtocells and Wi-Fi networks in the TV. A prototype software defined network architecture for heterogeneous network spectrum sharing in the TV white space with the open flow protocols. Then, the open flow-enabled infrastructure and controller architecture for cognitive radio is analysed. Software defined cognitive radio network prototype with this SDN controller and LTE/Wi-Fi network simulator is implemented (Sonnenberg et al., 2013).

Cognitive radio nodes form a wireless network automatically based on the 'group' concept. According to the group concept, in a given area, cognitive radio nodes are assumed to be activated randomly. These activated cognitive radio nodes form multiple 'groups'. Each consists of a leader node, bridge nodes, and regular nodes. The leader node communicates with any group member node, and bridge nodes do the function of connecting different groups to form a scalable network. From the above, incorporating the available spectrum, cognitive radio nodes can form a network even if there is no common channel availability. A scheme for the node communication, analyses the numbers of nodes and channels required to maintain full connectivity of the cognitive radio network formed for the emergency situation and finally investigates the connectivity of the group-based cognitive radio network with arbitrary topology proposed (Sun et al., 2014).

The concept of cognitive radio network has implemented in fully utilise radio resources by intelligently filling in radio spectrum gaps as much as possible. The allocation of resources by learning and adapting to a specific radio transmission environment is a challenge inherent in this technology. A scheme that is specifically designed for allocating radio resource as cognitive resource management scheme in a cognitive radio ad hoc network (CRAHN) environment. The proposal acquires knowledge from the physical layer, the medium access control (MAC) layer, and application layer by applying cognitive processes in a cross-layer design. It allocates resources according to traffic demands, traffic priorities, link capabilities, and link qualities efficiently (Li and Zekavat, 2012).

An investigation of network coding-aware channel allocation and routing scheme for multi-hop cognitive radio networks is done. Network coding and channel availability in the cognitive radio network is considered and throughput is increased by allocating the channel and link rate accordingly. First, the activities of the primary users (PUs) and the interference among the SUs in a cognitive radio network are modeled, and implementation of network coding in the multi-hop cognitive radio network is shown. Second, an optimisation problem to maximise the throughput of the network is formulated. The advantage of the network coding opportunities is taken, and the channel availability constraint is considered. By solving this optimisation problem, allocation of channels and rates of links in different channel availability scenarios can be determined. Furthermore, the performance of our scheme with the coding oblivious routing for different scenarios of channel availability and a maximum number of channels in a random wireless network are compared. With this knowledge, insights on the benefits of network coding-aware routing in multi-hop cognitive radio, networks can be further studied (Wang and Zheng, 2009).

The cognitive radios as a countermeasure against spectrum scarcity and inefficient utilisation of spectrum are recommended by FCC. Temporally or spatially unused wireless channels allocated to other licensees to transmit data are used by the cognitive radios. Routing protocols will accomplish the channel assignment in a multi-hop cognitive radio network. Since classical routing protocols are not aware of spectrum opportunities, they are not suitable for cognitive radio networks. In this paper, we propose a Geographic routing protocol for large scale heterogeneous hybrid cognitive radio mesh networks termed as GCM. It is a multi-objective routing protocol which is aware of the-the spectrum, energy, load, and link quality (Shu et al., 2012).

The outline of the ad hoc cognitive radio network (ad hoc CRN), the network model and the dynamic spectrum access (DSA) for ad hoc CRN is discussed first. Moreover, the analysis is crucial for cross-layer design in the ah-hoc CRN. At last, a detailed architecture in which the dynamic channel allocation is achieved by a cross-layer design between the PHY and MAC layers for ah-hoc CRN is proposed. Simulation indicates that the performance of the network is improved significantly by using the above concept (Li, 2013).

Cognitive radio is a disruptive technology innovation which is used to improve the spectrum efficiency. MAC protocols do not provide a mechanism to ensure fair and efficient coexistence of cognitive radio networks since most of them have not considered the coexistence of cognitive radio networks. A novel MAC protocol which overcomes this drawback, termed as fairness-oriented media access control (FMAC). It utilises a three-state spectrum sensing model to distinguish whether a busy channel is being used by a PU or a SU from an adjacent cognitive radio network due to which SUs will be able to share the channel together using co-existing cognitive radio networks. It is indicated that the fairness of coexisting cognitive radio networks through maintaining a high throughput can significantly improve using FMAC (Peng et al., 2009).

Leader election protocol is a recognised approach for coordination and synchronisation between nodes in a network. Cognitive radio network is the upgraded version of the wireless network in which the main concern is spectrum sharing or spectrum utilisation among the SU nodes. Therefore, for this type of network, leader election approach for the synchronisation and coordination among SUs is also required, since they access the less-used free spectrum of PUs. An enhanced method for the election of the leader in CRAHN Networks is presented, which can be implemented with minor changes to a leader election protocol for this network. The PU involvement during leader election phase in CRAHN Networks neighbor considered (Kumar, 2015).

The cognitive radio is capable of improving the application performance for unlicensed users using the available portions of a licensed spectrum. To efficiently utilise the available resources, the available channels in the wireless environment require dynamic channel assignment with minimising the interference in the network. In cognitive radio networks, a comprehensive survey on the state-of-the-art channel assignment algorithms is presented. The algorithms are classified by presenting a thematic taxonomy of the current channel assignment algorithms in cognitive radio networks. In order to determine the strengths and weaknesses of such algorithms, the critical aspects of the current channel assignment algorithms in cognitive radio networks are analysed. Based on the important parameters, such as routing dependencies, channel models, assignment methods, execution model, and optimisation objectives, the similarities, and differences of the algorithms are also investigated. Also, the open research issues and challenges of channel assignment in the cognitive radio networks are discussed (Ahmed et al., 2014).

Cognitive radio is considered as an efficient means to spectrum sharing between primary and SUs. The two-phase channel and power allocation schemes by Hoan (xxxx) The scheme considers a network of SUs that consists of multiple cells and total throughput is equal to the total number of subscribers. Here, the network is self-organising. Also, the average probability of success transmission is equal to the throughput. Each time slots in a TDMA is assigned to one active cognitive user so that all the users get an opportunity to access the spectrum. The performances of the spectrum access approach according to the system throughput and energy efficiency is evaluated (Li and Li, 2008).

Here, for collaborative packet recovery in hybrid (interweave and underlay) cellular cognitive radio networks, a prioritised multi-layer network coding scheme is proposed. To minimise their own as well as each other's packet recovery overheads, the uncoordinated collaboration between the collocated primary and cognitive radio base-stations is performed. This scheme ensures that from its help to the other network, each network's performance is not degraded. In the collocated primary and cognitive radio networks that allows the reduction of the recovery overhead. This allows the cognitive radio base station to transmit at higher power without fear of violating the interference threshold of the primary network due to the perfect detection of spectrum holes. Compared to the non-collaborative scheme, the secondary network, simulation results shows the reduction of 20% and 34% in the packet recovery overhead, for low and high probabilities of primary packet arrivals, respectively. For the primary network, this reduction was found to be 12% (Sorour et al., 2013).

Cognitive radio networking is a standard by which secondary cognitive users dynamically access the RF spectrum without creating harmful interference to PUs. The waiting probability of SUs in the cognitive radio network is analysed. A cognitive radio network where multiple SUs can access spectrum using time division multiple access over idle PU channels is considered. Here queue dynamics is used as Poisson driven the random process, where the waiting probability of SUs is characterised. In practical systems, SUs of cognitive radio network have no knowledge of activities of other users. Thus, the decrease of being idle or accessing probabilities of SUs' in cognitive radio network have to be assigned according to the availability of local information. The SUs waiting probability analysis is focused, for which a systematic understanding is lacking. Simulation results prove that the use of multiple channels is more advantageous since they lead to significant delay reduction and transmission fairness (Rawat et al., 2013).

The cognitive radios require to detect the PU signal promptly and accurately since the protection of the PU is the most important activity in a Cognitive radio network while network lifetime and energy consumption are major issues in wireless sensor networks. A network architecture that guarantees the protection of the PU by enhancing the sensing accuracy of a single radio and increases the lifetime of the network by efficiently consuming energy. The sensor nodes perform the spectrum sensing for the mobile cognitive radios by exploiting their spatial diversity. The communication range of the cognitive radios of the sensor nodes lies from clusters based on their distances. Due to the mobility of the cognitive radios, the clusters are regularly updated. These are further divided into disjoint sub-clusters, one of the sub-clusters in a cluster remains active while others are switched to sleep mode for energy conservation. Effectiveness regarding energy consumption, lifetime, and detection error, of the proposed network, is shown through simulations (Usman and Insoo, 2016).

The introduction of MIMO nodes to sense and optimise communication frequency. MIMO nodes affects the neighbouring node and possibility of occurrence of interference is high and overcoming interference occurrence is low. Beam scanning is focused in particular angle so occurrence of interference is limited compared to the MIMO technique (Nguyen and Krunz, 2012).

Interference alignment technique applies to cognitive radio to manage interference and to share spectrum in communication. In addition power allocation also play a major role in improving performance of cognitive radio networks. Moreover, the sum rate is short compared to theoretical value which affects the quality of service of PUs. In this paper, power allocation for interference management cognitive radio network is studied. The authors propose three different algorithms to improve throughput, energy efficiency, and requirement of SUs in the network. In addition a transmission mode scheme improves the performance of SUs in the network (Zhao et al., 2016).

In this paper the femtocell in addition with macrocells improves the coverage region of the cellular systems. The system also creates cross tier problem and intra-tier issues in the network which affects the performance. To solve the issue a resource allocation method is studied which has an OFDM system and cognitive radio function. The cognitive radio networks identify radio signals and share the channels. The channel sharing does not affect the macrocells users. To improve the system throughput the femtocell users leaves out available imperfect spectrum. A conservative convex approximation technique recognises perfect spectrum by reframing the structure. Results show that the proposed method improves throughput with out making any significant changes to the cellular network infrastructure (Zhang and Wang, 2015).

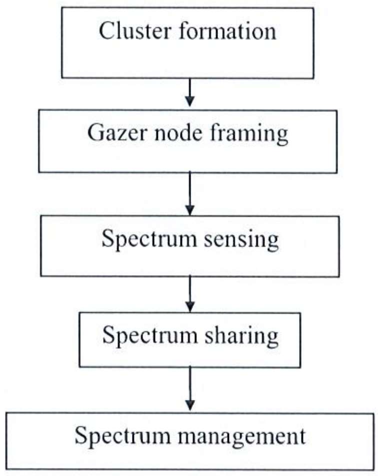
Resource allocation plays a major role in FDMA cognitive radio networks. The system comprises of many SUs and base station to which all the users report to. To sense spectrum in the network the system employ two phases. During the first phase a cooperative spectrum sensing is done to find unused sub channels. In the second phase, SUs contact base station using OFDMA technique. The method reduces the sensing parameters such as transmit power and channel assignment which reduce the energy consumption in the network. A system with bilevel problem is introduced and evaluated how energy consumption is. The proposed optimisation method reduces the energy consumption and save energy by 16% (Modarres-Hashemi et al., 2016).

The wireless communication is growing rapidly. The introductions of 5G systems make way for improve capacity than compared to previous generations. In wireless networks, improving the spectrum efficiency is important. Joint spectrum allocation improve spectrum efficiency in the system. The location of primary transmitter and secondary transmitter help share spectrum between two different transmitters. The cooperative spectrum sensing optimise the PUs status and allocates available spectrum to the SUs. The S-OSP algorithm further improves the spectrum efficiency by hard information fusion strategy. The proposed method is simulated and the performance is evaluated (Hu et al., 2016).

## 3 Methodology

Cognitive radio mainly concentrates over the efficient utilisation of spectrum in the network. Spectrum sharing and reuse provides maximum throughput for the network. PUs and SUs are the common issues in the network in allocation of free spectrum. To avoid the collision between primary and secondary nodes clusters are created and all the clusters are connected through the gazer nodes.

**Figure 1** Work flow methodology




Gazer nodes allocate spectrum to the clusters. The approximate time for gazer node to allocate spectrum to the cluster node is 200 ms. The fast spectrum allocation work as a shielding between the clusters, so, spectrum sharing is possible between the individual groups. The gazer node communicates with cluster head based on a time slot basis. The gazer node communicates with a particular cluster head at a time to avoid congestion in cluster head. Initially, the nodes are placed in random position and the nodes are grouped each other by scanning the neighbour nodes. All the nodes are equipped with antennas for beam scanning purpose. The scanning technique avoids interference from other nodes in the network. The nodes which have maximum links were selected as cluster head, to cover all the nodes in the cluster. The other nodes connect to cluster head as normal nodes. Figure 1 shows the work flow of methodology.

Normal nodes shares data with cluster head and cluster head transfer data to the other clusters through gazer. The spectrum sensing and allocation was performed by gazer node and provide the information to cluster heads. The cluster head divides and allocate frequencies to the slave nodes for intercluster communication. The block diagram shows the steps of the process performed by our proposed method. The spectrum was shared and managed by gazer nodes when any nodes move from one cluster to another or dissolving of clusters to form a new one. Through this method of creating clustering primary, secondary nodes collision was avoided.

| **Algorithm** | |
|---|---|
| Step 1 | Sensing neighbour nodes to frame clusters. |
| Step 2 | Node with maximum links is selected as CH. |
| Step 3 | Slave node Sn checks the possibility of joining with the cluster. |
| Step 4 | If the broadcast period is small joins with the cluster else move to another cluster or frames a new cluster. |
| Step 5 | GN starts spectrum sensing and allocates sensed frequencies to the cluster heads. |
| Step 6 | Cluster heads allocates frequencies for the slave nodes for communication. |

The process repeats each time the cluster was destroyed and a new one was created. The proposed work was implemented in NS2 and the performance of the system was evaluated. For comparison we have compared the result with an existing DOSS-MAC algorithm which is implemented in general cognitive radio networks. The platform was created in the ns2 with following descriptions:

```
set val(chan) Channel/WirelessChannel;
set val(prop) Propagation/TwoRayGround;
set val(netif) Phy/WirelessPhy;
set val(mac) Mac/802_11/CRCN;
set val(ifq) Queue/DropTail/PriQueue;
set val(ll) LL;
set val(ant) Antenna/OmniAntenna;
set val(ifqlen) 500;
set val(nn) 50;
set val(rp) AODV;
set val(x) 1000;
set val(y) 1000;
set val(stop) 10.0;
```

The nodes are grouped into clusters and the node at the centre of the group with more neighbour node is selected as cluster head. The cluster heads was connected to the gazer node and the gazer nodes provide communication with other nodes.

Slave nodes monitor the environment and collect the data's. The collected data's are transferred to the cluster head through the allocated frequency. The cluster heads establish connection between the slave nodes based on the free channels provided by the gazer node. And collects the data from slave node and submit it to the gazer node. The gazer node monitors the network communication and develops a table of free and used channels in the network. The gazer node provides information about the free channel to the cluster head and cluster head generates communication between the normal nodes to other nodes in different cluster.

The gazer nodes are the centre nodes which monitor and manage the network from occurrence of collision. Gazer nodes connect to each other and transfer the information about the free channels in the network between them. The Figure 2 shows the initial node placement. The nodes are plotted and generated communication to calculate the parameters to prove the efficiency of the proposed system. The proposed method GCCRN generates 78% increased throughput when compared with the traditional DOSS_MAC algorithm.

## 4 Performance of GCCR nodes

Simulation for cluster-based cognitive radio network was developed, and outputs are compared with the existing algorithm DOSS_MAC algorithm and plotted as a graph as asses the efficiency of the proposed algorithm. Initially, the nodes are placed at random and all the nodes spectrum allocation and sharing are carried out by the cluster head and the gazer node.

**Figure 2** Initial nodes placement (see online version for colours)

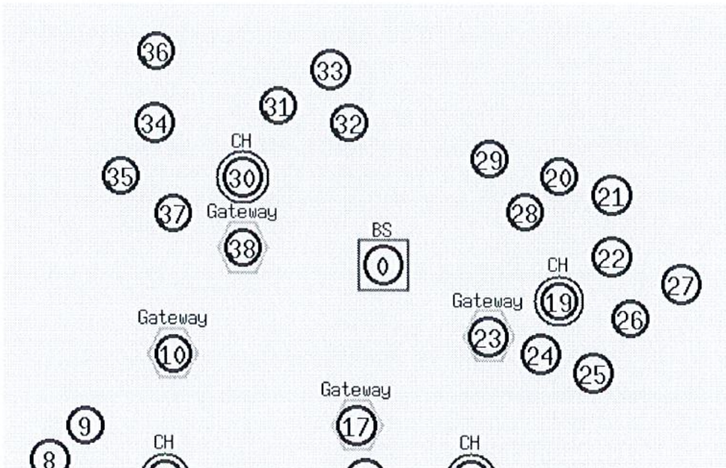
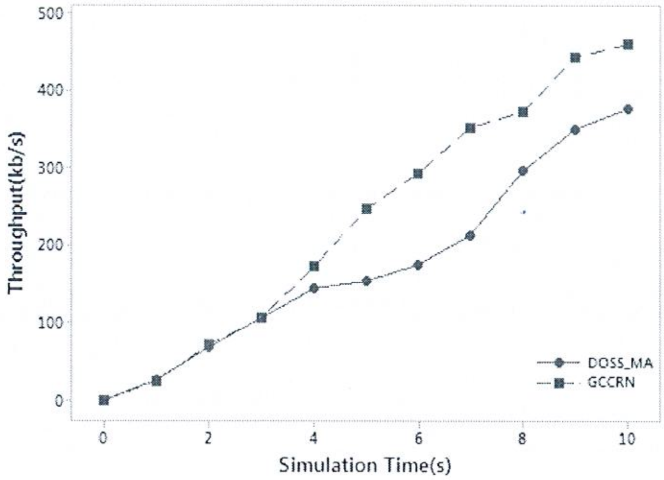


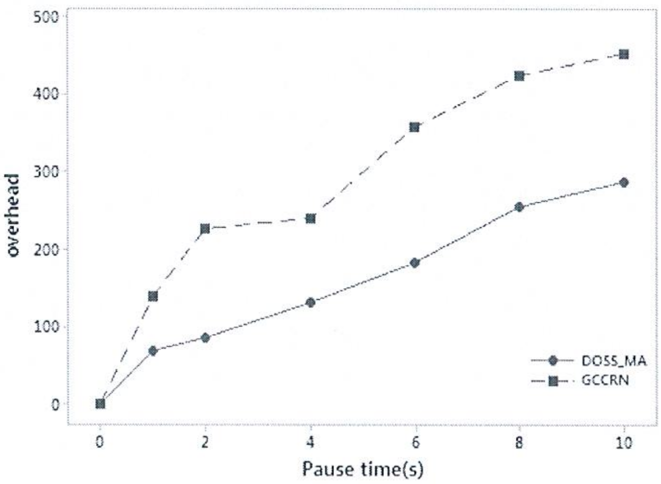
**Figure 3** Throughput of GCCRN (see online version for colours)




The throughput of GCCRN is shown in Figure 3. Amount of packets transferred within the network in specific time was compared with proposed clustering network and traditional DOSS_MAC algorithm. The throughput is obtained higher when compared to the existing algorithm.

Throughput = (Packets received / Data transmission period) / 1024

**Figure 4** Overhead (see online version for colours)




## *4.1 Overhead for GCCRN*

This is the comparison of stability of the system when the load is increased. The overhead was calculated based on total routed packets in initial simulation time. The comparison was clear showing that the cluster-based system withstands higher over head than the existing algorithm. Figure 4 shows the overhead for GCCRN.

$$\text{Routing Overhead} = \text{Routing Packets Count} \quad (1)$$

### *4.2 Packet delivery ratio for GCCRN*

The ratio of successful data transmission was calculated and plotted. It shows that proposed method provides steady delivery rate all the time from beginning to end of the simulation time with lesser packet drop.

$$\text{Packet delivery ratio} = (\text{packets received} / \text{packets generated}) * 100 \quad (2)$$

### *4.3 End to end delay for GCCRN*

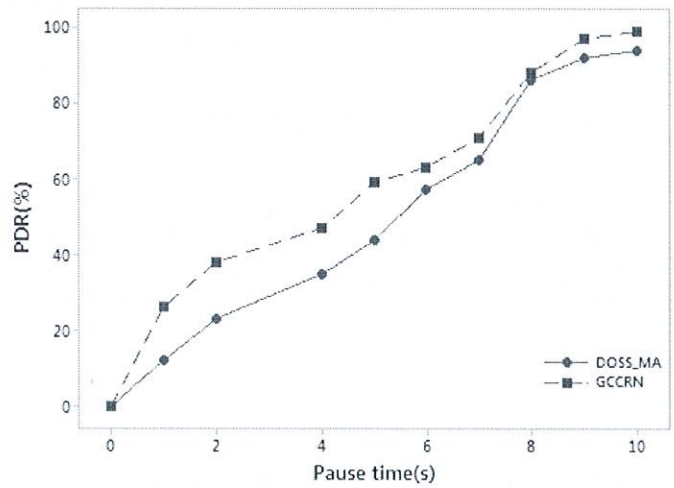
Time taken by the packets to reach destination form the source is called delay. End to end delay is indirectly proportional to throughput and packet delivery ratio. When throughput and PDR increase the end to end delay decreases. The delay should be stable or decreasing when communication becomes stable. The rate of time to become stable is compared and plotted as graph for both proposed and existing system. Figure 6 shows end to end delay for GCCRN

$$\text{Delay} = \text{Receiving time} - \text{Sending time} \quad (3)$$

$$\text{Total Delay} = \text{Total delay} + \text{Delay} \quad (4)$$

$$\text{Average Delay} = \text{Total delay} / \text{Packets sent} \quad (5)$$

**Figure 5** Packet delivery ratio (see online version for colours)




This shows that the proposed method cluster-gazer node cognitive radio network is more efficient than the normal spectrum sensing methods. The results show the clear understanding about the cluster formation in cognitive radio network.

**Figure 6** End to end delay (see online version for colours)

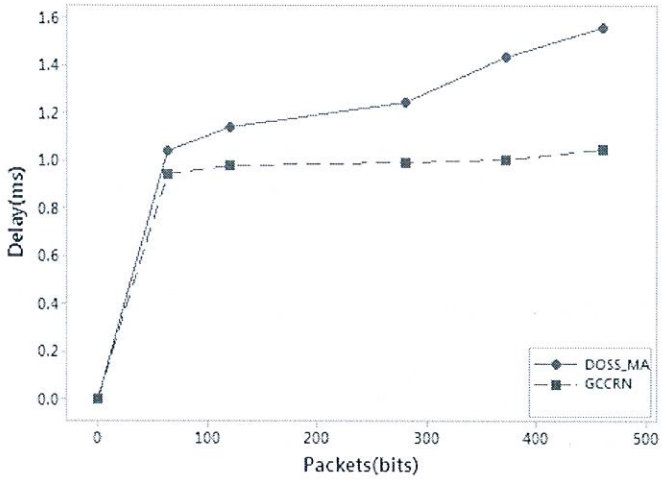



**Table 1** Comparison of parameters between proposed and existing methods

| *Parameters* | *DOSS_MAC* | *% improved of GCCRN* |
|---|---|---|
| Throughput | 375 | 78% |
| PDR | 50.8 | 84% |
| Overhead | 144 | 18% |
| End to end delay | 1.0687 | 77.41% |

Table 1 shows the comparison of proposed GCCRN method with existing traditional DOSS_MAC algorithm in terms of percentage in all the parameters calculated using NS2 simulation platform.

## 5 Conclusions

In this paper, we developed a gazer node cluster-based cognitive radio network where the nodes were grouped into small clusters headed with cluster heads. The nodes equip with antenna, which use beam scanning technique to avoid interference with neighbouring nodes working in the same channel. The cluster heads are the interface through the gateways, which provides spectrum sharing for the network. Reuse of free channel is the main theme in this paper. The performance of our system is compared with the existing methods and found to be efficient. Load managing and sensing was equally divided between the cluster head and the gateway nodes. Throughput we calculated for the proposed method is 78% more efficient than the existing DOS_MAC and GCCRN algorithm.

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