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Design of Cluster-based Cognitive Radio Network Using Beam Scanning Spectrum Analysis Technique

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ABSTRACT

Spectrum sharing is the key role in the cognitive network. In Cognitive network Secondary Users use the frequency of Primary User, when the PU not in use. However process leads to interference when the PU starts to transmit the data. To avoid interference problem, cluster based beam scanning technique (CCRNBSA) is implemented. The cluster based system is easier than a flat network, & performs spectrum sensing and sharing. In addition, beam scanning technique monitors the spectrum utilization of the nodes in each cluster to improve the performance. Furthermore a directional antenna is used in gazer nodes to perform beam scanning function. The performance of the CCRNBSA algorithm compare with Gazer based cluster cognitive radio network (GCCRN). Moreover, simulation is performed to plot the efficiency of the system as a graph & hardware is also implemented.

Keywords: Cognitive radio network, Cluster formation, Gazer nodes, Directional Antenna, Beam Scanning, Spectrum sensing, spectrum sharing

1. INTRODUCTION

Wireless communication is growing field in engineering. The traditional wireless network allots licensed spectrum for every network so the spectrum other than licensed cannot be utilized by the network. In the case of heavy network traffic, these wireless networks lead to failure. To overcome this paradigm cognitive radio is introduced. The cognitive radio network breaks the fixed frequency allocation method and provides open spectrum allocation technique. The main theme of the Cognitive Radio (CR) is to use underutilized spectrum in an efficient manner. By scanning the environment, the CR will assign frequency by itself based on the current situation.

Primary and secondary users are the major roles in the cognitive radio network, where the primary node poses licensed channels for communication, and the secondary nodes access the licensed channels when the primary users are in idle state. Cognitive Network (CN) automatically controls the usage of spectrum in the network. Spectrum holes otherwise called as free spectrum & frequency identification are known as spectrum sensing. The spectrum sensing performs the spectrum sharing. However the secondary node which tries to communicate must find the spectrum hole and utilize the free frequency for its communication.

Clustering is the easiest way to maintain and monitor the spectrum utilization in the cognitive network. The nodes are grouped into clusters each cluster holds its frequency channel. The node other than its cluster is named as secondary nodes.

The clusters are combined by the gazer nodes. The gazer nodes are placed at center of the cluster, and also provide communication between other gazer nodes. The gazer nodes are the only way to perform inter-cluster communication. Gazer node scans the free channels in other clusters and performs communication between the clusters. Beam scanning technique is introduced in the Gazer nodes. The gazer nodes are empowered by directional

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antennas. The directional antennas are used to send beam scanning signal to other gazer nodes to find the spectrum holes in other clusters. Using of directional antenna reduces the interference problem in the network and reduces collision of data. More existing techniques involved in spectrum sensing and spectrum sharing in the cognitive radio network is discussed in related work.

2. RELATED WORK

While traditional cognitive radio (CR) system is conatus at providing the foremost possible custody for the regime of primary users (PU), light attention has inured to ensure the quality of service (QoS) of secondary users (SU) applications. The lag is unendurable for real-time applications with stiff QoS requirements. The author presents the blueprint and utilization of a sensing-based CR system – RECOG. RECOG can fulcrum the real-time communications encompassed by SUs. Here, a long period is divided into a train of shorter blocks, converting a long delay into imperceptible short delays with an on-demand scheme based on MAC band information. To run-over the potential buffer cataclysm, a CR-aware QoS manager is adduced. The experimental evaluations approve that the RECOG will not only improve protections for PUs, but also support real-time passage among SUs with aerial quality. [1]

To increase the throughput of cognitive without affecting the performance of primary users. To solve a point-to-multipoint cognitive network sharing channels with primary networks are considered. Two phase algorithms are used. First, a distributed power updating process is used at the secondary and primary nodes and second, a centralized channel assignment within the secondary network to increase throughput. The results of the proposed algorithms are obtained for performance and behaviour [2].

The author presents an allocated class-based spectrum-alert coordination design for CSMA/CA-established CR networks (CRNs), known as Virtual Clustering Distributed Coordination (VCDC). VCDC stand apart from the previous cluster-based designs in that it stunt the Discrete Orthogonal Frequency Division Multiplexing (D-OFDM) technology to clip neighbor-discovery interval and aid inter-cluster connection and broadcasting. The VCDC scheme is related with the existing clustering designs. From, the simulation results, the VCDC compose a fewer number of preponderant capacity clusters with a proper number of common frivolous channels, and set a lesser percentage of clusters plus no shared frivolous channels.[3]

The author deals with the identification of Primary Users (PU) traffic patterns and then maximization of Secondary Users (SU) transmission accordingly. First, a theoretical framework is developed based on a Bayesian nonparametric inference model. Second, a study is conducted on sensing-transmission structure to optimize the SU transmission strategy. Finally, a proposal for threshold-based sensing-transmission method that optimizesthe SU utility, while protecting PU transmissions is made. From the simulation results, the proposed algorithm performs better than the standard nonparametric mean shift clustering algorithm. Furthermore, these clustering results are used to optimize the SU's transmission strategy with perfect and imperfect sensing. The proposed technique is compared with the probabilistic sensing-transmission structure, and the performance gain is shown regarding throughput [4].

Network forensics becomes an apparent interdisciplinary used to trace cyber crimes and identify network abnormality for a collection of applications. The author presents a systematic way to absorb data in cerebral radio system with a low number of monitors. It exploits incremental support vector retrogression to predict occurrence packet time and logically switch monitors among channels. It also adduces a protocol that appoints multiple monitors to achieve channel examine and packet arresting in a handy manner. Monitors used again in the time domain, and the topographical analysis is taken into account.[5]

The Joint beam forming, power and channel allocation in multi-user and multi-channel underlay multiple input single output (MISO) cognitive radio network (CRN). This system allows reusability of primary users' (PU) spectrum by secondary user transmitters (SU-TXs). The first stage of the feasible solution, power allocation and beamforming vectors is derived with semi definite relaxation (SDR) approach. The second stage includes genetic algorithms and simulated annealing (SA) based algorithms that determine sub-optimal channel allocations. From the simulation results, it can be shown that the proposed technique with SA can achieve the optimal solution with minimum computational than Genetic Algorithm. Furthermore, the proposed allocation scheme proved to be an improvement over the existing methodology [6].

The Sheppard's interpolation way to estimate a contiguous distribution of spectrum handling over a region of attraction called as the spectrum map. By astutely fusing the data chunk by the secondary nodes by considering their bilateral distances and contiguous coordination with each other, the interpolation is achieved. The obtained plan is a two-dimensional interpolation operation that is continuously incomparable, and canyon through all the rainbow usage values catalogued at arbitrary locations. It acknowledges an IEEE 802.22 based WRAN and demonstrates how the rendezvous chances can be corrected for better radio assets allocation, thereby booming the secondary spectrum application.[7]

The author compares two downlink multi-cell interference mitigation techniques, Large scale (LS) multiple-input multiple-output (MIMO) and network MIMO. In LS-MIMO system, each Base Station (BS) uses BM antennas to remove interference caused by zero-forcing (ZF) beam forming. In network MIMO, BS is equipped with M antennas & interference is made zero by data and channel state information by ZF beamforming. However, the users experience a better quality of service under LS-MIMO than network MIMO. Hence LS-MIMO is the preferred route towards interference mitigation due to lower costs [8].

The author introduces a novel aggregate spectrum-sensing mode based on spatiotemporal dope mining methods. In each cluster, author presume that the spectrum divine is executed in a correspondence way. The cluster head (CH) handle the operations, and an accepted sparseness hyper-parameter is worn to make a concord decision. To venture the time-domain applicability among consecutive Compressive Sensing study, a hidden Markov miniature is employed to recite the relationship between the undetected subcarrier states and the sequential CS measurement, and the Viterbi algorithm is worn to make an authentic spectrum decision for various secondary users. It is shown that the proposed algorithm can auspiciously exploit the spatiotemporal affiliation to achieve greater spectrum-sensing execution regarding furnished mean square error, correct detection probability, and false alarm probability compared with other related works.[9]

The author deals with improving spectrum access without interfering with licensed primary users by using a new relay based cooperation scheme. In this method, only one multi-antenna relay node can assist either primary or secondary transmission using beam-forming (BF). The BF weights are designed under imperfect Channel State Information (CSI). From the simulation results, the channel capacity is improved and outperforms the existing transmission schemes. The results also contain information on the impact of the imperfect CSI and the efficiency of the solution to reduce the interference [10].

A new way for cognitive radio network accumulation conferred that is not forced by the fling of common channels. The suggested approach is established on the 'group' theory. Actuated cognitive radio buds from multiple 'groups' render to some criteria. While sensing, buds channels and accommodate the channel and time socket assignment. The study shows the network forming course including neighbor node identification, group formation, node communication, channel assignment, time slot assignment and medium access control protocol.[11]

The RF spectrum is limited. Hence, a cognitive radio is required to actively observe the spectrum, orient itself to the current spectrum, decide on a mode of operation and act accordingly. The author researches a novel architecture for adapting radio operation to current RF spectrum environment. Three contributions are made, namely, testing algorithms of cognitive networks, new RF spectrum tested on a field programmable gate array (FPGA), and a long cognitive network emulation for testing as a means of communication [12].

The author scrutinizes the trade-off between execution and efficiency of energy in cooperative cognitive curb systems. With a flexible collaboration scheme, optimizes the assembling and the beam forming to attenuate the overall power utilization while fulfilling the secondary users' aspects of service and regarding the primary users' meddling limits. Then, we acquire an iterative coup based on the induced Benders decomposition mode to find an optimal resolution. In contrast to former works, algorithm grasps the total interference power restraints coupling the coarse cognitive stations. The benefits of the coalition in the cognitive wireless grill is shown by the simulation.[13]

The author addresses the problem of spectrum sharing by considering a secondary link composed of a secondary transmitter (SU-TX) equipped with multiple antennas and a single-antenna secondary receiver (SU-RX).The SU-TX sends random beams over the available spectra and PU-Rx sends back the index of the spectrum and value of interference. The information is received by the SU-TX and resends new beams to the SU-RX. The SU-RX selects the beam with the maximum signal-to-interference-plus-noise ratio (SINR) for transmission in the next frame. A statistical analysis is developed for the SINR statistics and the secondary link with numerical results for studying the impact of different system parameters [14].

The author proposes a novel cooperative spectrum sensing (CSS) method for cognitive radio (CR) networks established on machine learning procedure which is utilized for pattern allotment. In this regard, unaided (e.g., Gaussian mixture model (GMM)) and supervised (e.g., K-nearest-neighbour (KNN)) learning-based allocation techniques are invoked for CSS. For a radio channel, the trajectory of the energy levels predicted at CR devices are account as a feature vector and deliver into an allotter to adjudge whether the channel is achievable or not. The execution of each allocation technique is appraised regarding the mean training time, the Receiver Operating Characteristic curve, and the pattern allocation delay. The comparative result shows that the considered algorithms outperform the current state-of-the-art CSS techniques.[15]

2.1. Methodology

Over and under utilization of spectrum plays a vital role in the communication network. The traditional methods of fixed channel allocation bring uneven network traffic and produces failure in network by leaving unused channels. To overcome these problems a concept named Cognitive radio is introduced, which shares the free spectrum channels for communication. Cognitive Radio network allows the secondary user to use primary spectrum channels when the primary users are in the sleep condition.

Spectrum sensing and sharing are the key points of cognitive radio. To make spectrum sharing easier clustering technique is involved to group the nodes based on the physical circumstance. Cluster-based network posses more advantage over the flat network. Clusters are majorly created to make simpler network topology and also to allot spectrum frequencies. The center node in the cluster which covers other clusters region was considered as Gazer node, which provides inter-cluster communication. The directional antenna is placed in the gazer nodes to provide collision-free communication between the clusters. The directional antennas are widely used to perform beam scanning technique to find the free channels in the group.

Beam scanning is performed by gazer nodes to find the free channels in nearby clusters to avoid the collision. The communications between the primary and secondary users are performed through gazer node to provide and receive the information about the used and free communication channels in the network. The algorithm for proposed beam scanning technique in cluster based cognitive network is presented below.

2.2. Algorithm

Step 1 : Clusters are framed based on the physical position of the node in the network.

Step 2 : Node having the maximum link with other clusters was selected as Gazer node (GN).

Step 3 : GN performs beam scanning to avoid collision between primary and secondary users.

Step 4 : If free channels present establish communication. Else repeat the step 3.

Step 5 : The slave node (SN) connects with GN to perform successful communication.

Step 6 : GNs shares information about the free channels between them.

Table 1
Network Description for NS2 Simulation.

Channel	*Wireless*
Radio Propagation	Shadowing
Network Interface	802.11
Queue type	Drop tail/Pri queue
Antenna	Directional Antenna
Max Packets	500
Total nodes	35
Routing Protocol	AODV
Modulation	BPSK
Max X & Y Plot	1000,1000
Simulation Time	10s

The proposed method is implemented in NS2 simulator using the descriptions in Table 1.

The nodes are placed in the plot based on the network description. The slave nodes and gazer nodes are selected to form the cluster. The initial node placement in the ns2 simulator is shown in Figure 1.

Communication is established between the nodes & the clusters. Before transfer the data from one cluster to another, beam scanning is performed to find the information about the usage of frequency in other clusters. The primary frequency of one cluster can be utilized by the secondary users in other clusters. To avoid collision, beam scanning is performed before the data transmission. Using the directional antenna provides more flexibility in the same frequency in different clusters; beam scanning provides additional flexibility for reusing the free spectrum in the network.

Figure 2 shows the transmission of beam scanning signal between node0 and node16. The communication between node2 and node22 was established through the gazer nodes 0 and 16. The frequency is selected by the gazer nodes after performing the beam scanning technique.

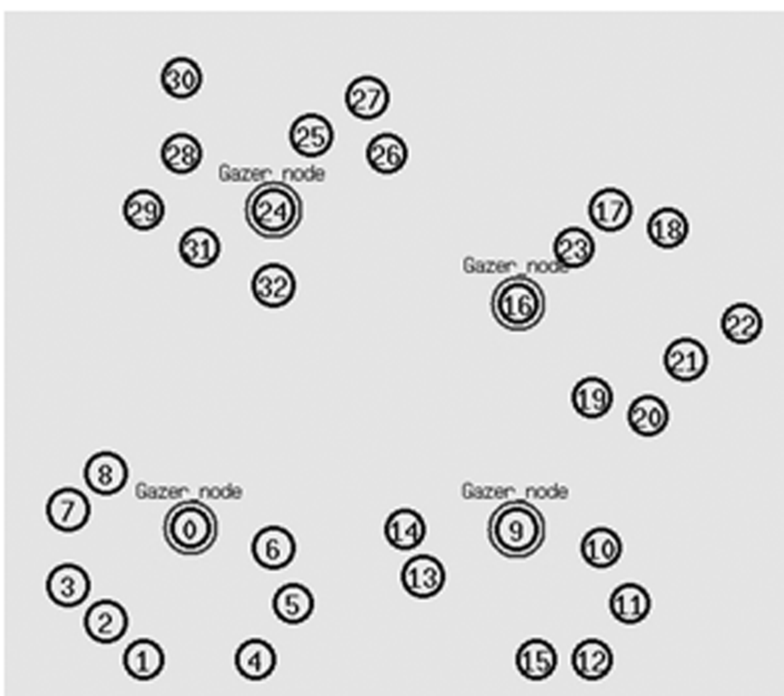
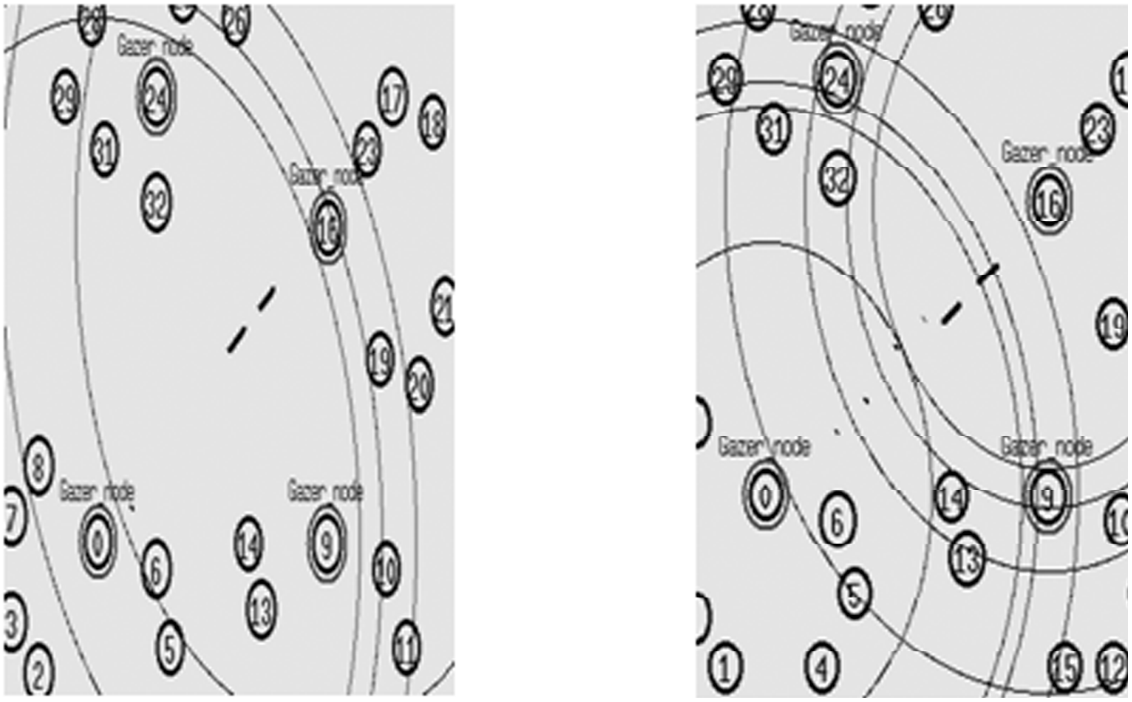


Figure 1: Initialization of node.



(a) (b)

Figure 2: (a) beam scanning signal sent from node0 to node16. (b) Reply for beam signal from node 16 to node 0.

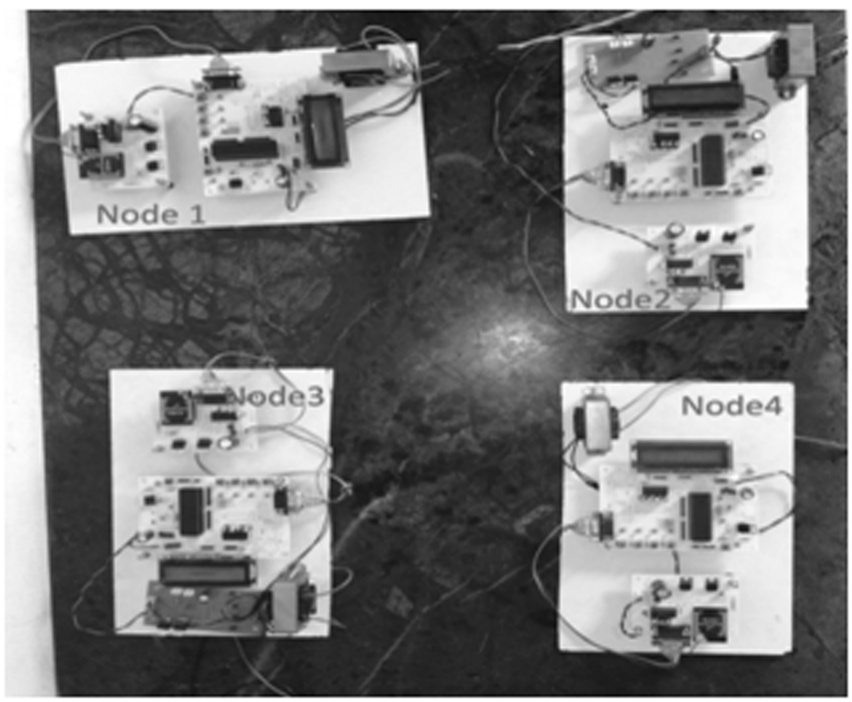


Figure 3: Hardware implementation

A further communication is established by repeating the process by the corresponding gazer nodes.

The clusters are created in Hardware using PIC microcontroller and Tarang zigbee modules powered with 12v transformers. Sensing of channels and allocating free channels is performed in gazer node and the performance of the system was monitored in the real time circumstance and found the output generated using NS2 simulation results are close to the design in the hardware. Figure 3 shows the hardware setup of our model.

3. RESULTS AND DISCUSSION:

The performance of the cluster based cognitive radio network using beam scanning technique is measured by implementing the method in NS2 simulation environment.

Throughput in terms of time and SNR, Delay, and gain are calculated and plotted as the graph.

Figure 4 and 5 represents the throughput on simulation time and Signal to Noise Ratio(SNR). The throughput of the network is the amount of data transmitted successfully from sender nodes to the destination node in a period.

Throughput shows the efficiency of data transmitted through the network. Higher the data rate shows the successful creation of the network. The proposed method CCRNBSA provides more data rate then the existing GCCRN algorithm.

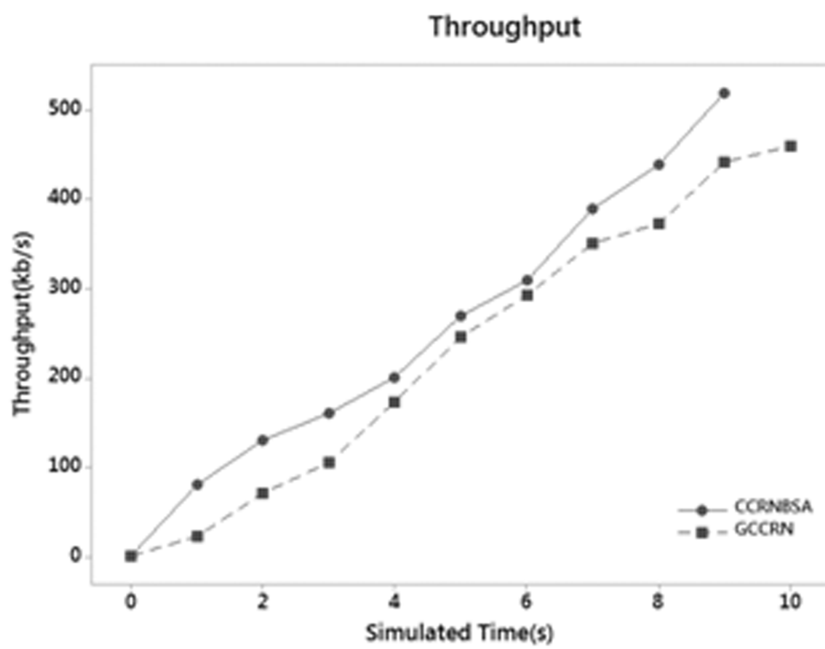


Figure 4: Throughput vs Time

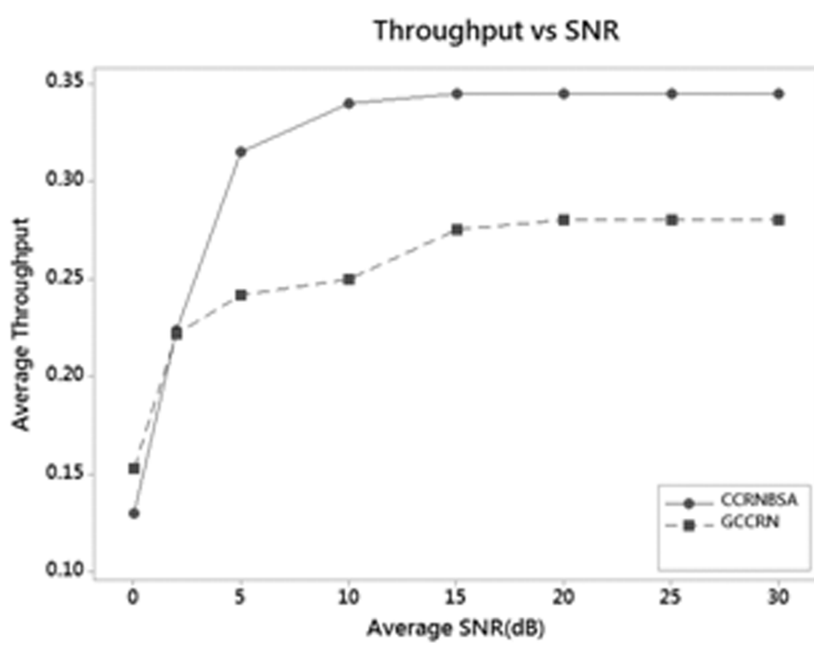


Figure 5: Throughput vs SNR

The average throughput is measured when the SNR value of the network increase. The throughput is seen to be maintained even at higher SNR values. Moreover, even the average throughput of proposed is high when compared to that of the existing method. Beam scanning technique provides maximum throughput in higher SNR values.

Network delay is the important characteristic to measure the performance of the network. The time is taken by the bit of data to travel along the network to reach the destination node from the source node. Figure 6 shows the network delay compared between CCRNBSA and GCCRN. The network delay was generated on SNR value. The performance of the methods is analyzed in various SNR values. GCCRN took maximum delay at the initial stage of the network and dropped down at the end of the simulation. The uneven delay is measured in the existing system. The network delay generated in CCRNBSA is lower and maintained when compared to the existing algorithm.

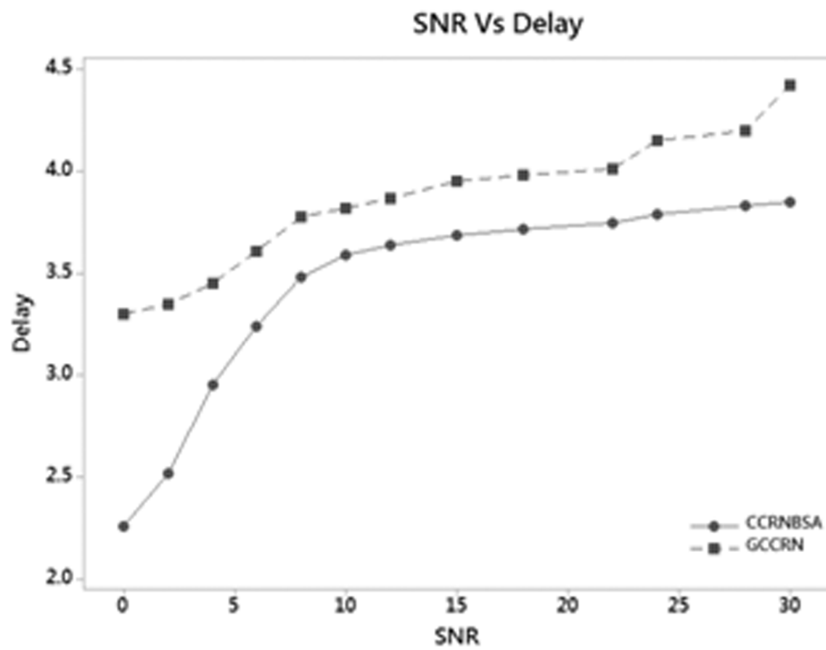


Figure 6: Delay vs SNR

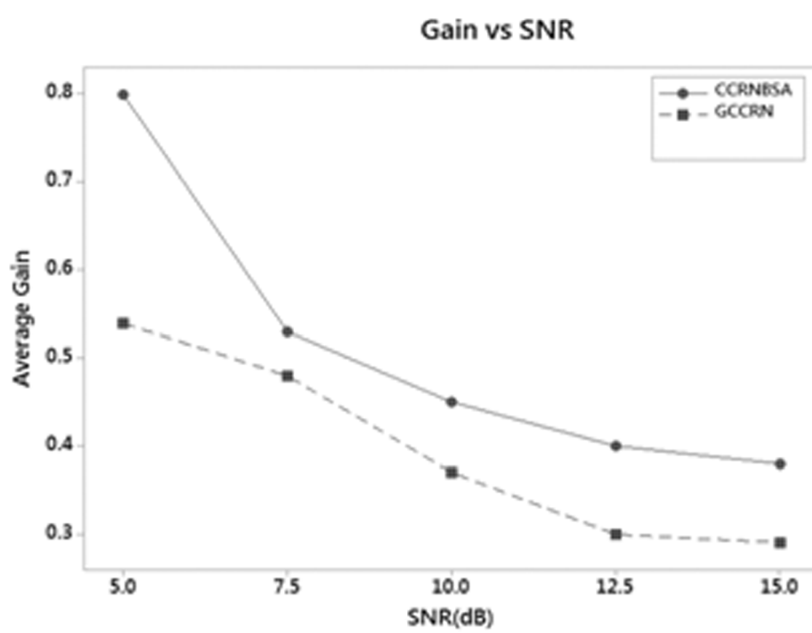


Figure 7: Gain vs SNR

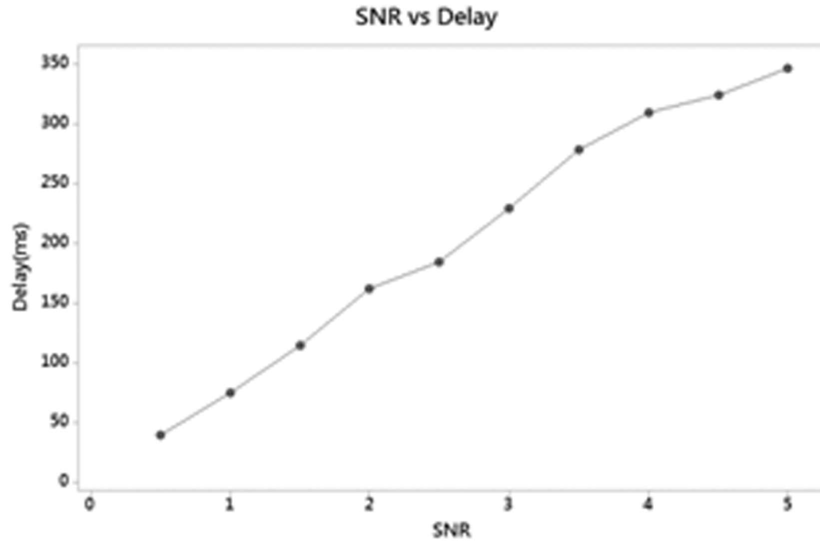


Figure 8: SNR vs Delay in hardware

The channel gain is calculated based on the path loss effect. The data transmitted from the sender node may travel through a number of paths in the network. Each path provides some loss or neutral transmission. Channel gain helps to identify the path efficiency in the network. Figure 7 shows the gain vs SNR. The gain of the proposed method is calculated in various SNR regions and estimated to be more than the GCCRN algorithm. The gain value may be drop gradually when to increase in SNR value.

The time to transmit a data from sender to receiver is calculated using hardware setup in various SNR values and plotted as a graph shown in figure 8. The delay in transmitting data was slowly increased when the SNR value gets increased. The value generated in hardware is approximately equal the value generated using NS2 simulation.

The Table 2 show the efficiency of CCRNBSA over GCCRN algorithm regarding percentage.

Table 2
Parameters comparison

Parameters	*GCCRN*	*CCRNBSA(%)*
Throughput / Time	460	86
Throughput / SNR	0.280	76
Delay	2.8053	64.8
Gain	0.396	71

4. CONCLUSIONS

In this paper, beam scanning based spectrum sharing algorithm in the cluster based cognitive network is implemented. The network was formed to small clusters and clusters are headed by a gazer node. The gazer node performs beam scanning technique to sense the spectrum used by other clusters based on the monitored result the spectrum will be shared between primary and secondary users. The proposed method CCRNBSA is compared with GCCRN algorithm. Moreover, the proposed method is found 86 percent more efficient than the existing method.

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