Heuristic Greedy Method for Spectrum Sensing in Cognitive Radio Network

D. Muthukumaran, S. Omkumar

Abstract: In recent years, radio frequency spectrum in wireless communication is not effectively utilized. To utilize the spectrum effectively, an optimistic technology called “Cognitive Radio network” used. It is the best preferable next generation wireless networks. Using DSA (Dynamic Spectrum Access) approaches, it shares the spectrum effectively between the primary and secondary users. It allows the secondary users to use the spectrum by dynamic spectrum sharing algorithms. When the primary users and secondary users are using same frequency band and transmitting simultaneously, there is a spectrum underlay problem in the network. A novel heuristic greedy algorithm proposed for improving the performance parameters of cognitive radio network using co-operative spectrum sensing.

Keywords: Cognitive radio network, DSA (Dynamic Spectrum access), Heuristic greedy algorithm.

I. INTRODUCTION

In the traditional wireless network, we have a fixed spectrum allocation for the users for various applications. Due to overcrowd in some frequency bands, there is a shortage for the spectrum allocation for the new applications, whereas some frequency bands not utilized effectively. The unutilized spectrum in the frequency band is termed as spectrum holes or white spaces. It has proposed recently that the frequency bands of the unutilized spectrum can utilized whenever it is available. It can be possible only by introducing cognitive radio network. Cognitive radio network does the cognitive process to understand the network condition and makes the decisions by acting on the particular network condition. It is the network, which utilizes the radio spectrum resources and wireless station resources depending on its availability. The fundamental aim of the cognitive radio network is to utilize the unused frequency band. The aim of the network is to use the spectrum effectively for all reliable users. In cognitive radio network, we have Primary user, which is the one who holds the license for the frequency spectrum.

Secondary user is one who uses the spectrum of primary users when primary user is not utilizing the frequency spectrum without having any interference with primary user. Secondary users also called as cognitive radio users. The cognitive radio networks periodically scan the spectrum in order to utilize the spectrum whenever the opportunity comes. In cognitive radio technology, spectrum sensing is an essential component in the network. It involves the spectrum sensing process (i.e. identifying the vacant spectrum in the frequency bands).

In order to identify the available spectrum in the primary users, the secondary users must identify the spectrum holes by directly sensing.

In practically, sensing the spectrum is a challenging task in cognitive radio network because of fading and shadowing problems. In order to detect the primary users, secondary user has to make observations regarding the usage of spectrum of the primary users. Under low SNR conditions, single secondary user is not enough to observe the primary user. To observe the primary user, multiple numbers of secondary users are used and there must be a communication between the multiple secondary users while sensing the spectrum in the primary user in order to achieve the Co-operative spectrum sensing by reducing the sensing time to find the unused spectrum in the primary user which in turn reduces interference. Anyone of the technique used for accessing the portion of radio spectrum. Considering the overlay technique in spectrum sensing, when the primary user is not utilizing the spectrum the secondary users can utilise the frequency band spectrum. If you consider the underlay technique in spectrum sensing, both can utilise the same frequency band spectrum without having interference.

II. RELATED WORKS

Two limited feedbacks based on the spectrum sharing system are been presented. The first one is the spectrum sharing system with Poisson distributed cognitive radio, and another one is networks with and without primary regions. The local primary users will be active, when it reaches above threshold. In opportunistic sharing system with the primary region, the secondary transmitters are used to transmit [1] In cognitive radios, the fair and effective spectrum sharing is a significant issue. The low complexity hierarchical spectrum sharing technique is presenting in the clustering view along with the capacity-limited channels. The unused spectrum has been assigned as clusters in a dispense way using colouring technique. The channels in the unused spectrum holes have been assigned using the cluster head. This cluster head reduce the outage probability. [2] Consider the Spectrum sharing scenario among the primary user (PU), and cognitive radio network. The primary network is the cognitive base station (CBS). However, the cognitive radio network user scheme can transmit along with primary user scheme. This method calculates the transmit beam forming weights. As well as, to raise the overall throughput, we are promising quality-of-service (QoS) of the primary user. Using zero-forcing beam forming (ZHB) algorithm technique.
A cognitive radio system is considered which is built by secondary data links \( N \), having a transmitter receiver single pair. These \( N \) secondary data links coincides with primary links \( M \) in the same location. Assume that, available frequency bands, every primary transmitter utilize a single frequency band. Also assuming that time is separated into slots. A spectrum server is considered to select a group of secondary data links to be activated at every time slot. The selected secondary data link should use the same frequency band for transmit with fixed time slot. Figure.1 Shows that a scenario of spectrum sensing which has one primary transmission and two secondary transmissions.

III. METHODOLOGY

A cognitive radio system is considered which is built by secondary data links \( N \), having a transmitter receiver single pair. These \( N \) secondary data links coincides with primary links \( M \) in the same location. Assume that, available frequency bands, every primary transmitter utilize a single frequency band. Also assuming that time is separated into slots. A spectrum server is considered to select a group of secondary data links to be activated at every time slot. The selected secondary data link should use the same frequency band for transmit with fixed time slot. Figure.1 Shows that a scenario of spectrum sensing which has one primary transmission and two secondary transmissions.
For the Secondary transmissions the transmit power can be enabled by splitting the frequency band which have some limitations as expressed in equation (2). Therefore a simple uniform power allocation method is used. The \( P_i \) on \( i \) link while using the same frequency band \( p \) is given as

\[
P_i = \frac{\Gamma_p}{\text{card}(S_p)} |f_{i,p}|^2
\]

\( \text{card}(\cdot) \) represents the elements number.

**Definitions**

1. **Vertex Colouring:** Let \( G = (V, E) \) be outweighed and not directed graph in which \( E \) is the set of edges and \( V \) is the set of vertices. The minimum vertex colouring problem assigns separate colour for every \( V \), so various colours will be received by the adjacent vertices and the number of colours used is minimized. Such colouring is represented by \( C_V \). This issue is NP-hard.

\[ C_V : V \rightarrow N, \text{ then } C_V(u) \neq C_V(v) \]

2. **Colour Sensitive Tree Colouring:** Let \( G = (V, E) \) be not directed graph. In colour sensitive tree colouring problem finds subset \( V' \subseteq V \) in which, there is a vertex colouring \( C_V \) of \( V \) with mostly \( L \) colours through which the value of

\[
\sum_{i \in V'} w_i^{(i)}
\]

is maximized. \( l' \) is the colour assigned to \( i \) node. This issue formulated interms of mathematical expression \( C_V'. \) s. t. The maximum colours are used by \( C_V' \) and also improves \( \sum_{i \in V'} w_i^{(i)} \).

**Tree representation:**

Every vertex \( v_i \) represents the link of secondary data. The two secondary data transmissions having the mutual interference \( j \) and \( i \). It can be provided as

\[
\alpha_{ij} = |h_{i,j}|^2 |h_{j,i}|^2
\]

The weights of every vertex \( v_i \) are given as

\[
w_i^{(i)} = \log_2 \left( 1 + \frac{P_i |h_{i,j}|^2}{\sigma_{ii}^2 + P_i |g_{i,p}|^2} \right) \quad p = 1, \ldots, M
\]

**Spectrum Sharing Algorithm**

For every time slot, numbers of pairs\((p,i)\) are selected by the spectrum in which every set belongs to frequency band and secondary data link, these links should be initiated. To resolve spectrum sharing problem, a new solution based on heuristic greedy with less complexity called the spectrum sharing algorithm based on heuristic greedy is used. It develops through a starting step where the graph was constructed by secondary networks. It uses the channel coefficients of input.

In the heuristic greedy algorithm, based on greedy manner the secondary data link and the frequency band are selected. The greedy spectrum sharing algorithm is described in the flow chart, shown in Figure 2. At every, new iteration, the algorithm determines, which secondary data link and the frequency band are scheduled in the selected frequency band. The algorithm can’t drop or change secondary data links already selected in the upcoming iterations. After constructing the secondary network graph, the algorithm initially finds the \( v \) vertex that has \( t \) great weight and allocates the colour matching of vertex weight. Additionally, it finds whether any vertices in the graph are non coloured if it is found then it assign the colours for the vertices. It will be going on until all the vertices to be coloured.
The Heuristic Greedy Algorithm is implemented in the Simulation environment using NS2 simulator and the performance of the network is compared with the Cat Optimisation Algorithm. The networks parameters that represent in table 1 are applied to analyse the performance of the cognitive radio network in NS2 simulator.

**Table 1: Parameters for NS2 simulator**

| MAC LayerType       | 802_11/Cognitive Radio |
|---------------------|------------------------|
| Type of Queue       | Pri Queue/ DropTail    |
| Antenna Type        | OmniDirectional Antenna|
| Length of Queue     | 500                    |
| Nodes number        | 50                     |
| Routing Protocol    | AODV                   |
| Size of network     | 2000 * 2000 meters     |
| Time                | 16 seconds             |
| Initial Energy      | 1000 Joules            |
| Transmitted power   | 1.015 J                |
| Received power      | 0.015 J                |

The performance parameters, like throughput, packet delivery ratio, delay, packet loss ratio and residual energy are measured to analyse efficiency of algorithm over the existing COA algorithm. Delay can be calculated that how much time taken for the data transfer. It increases due to the network congestion or processing time taken by the nodes to identify the routing path and bandwidth in the network. The packet drop and retransmission rate increases the delay in the network. The figure 3 shows the end-to-end delay measured for HGA and COA algorithm. The delay is measured by changing the size of the packet in the communication path. The delay generated by the HGA algorithm is staid constant above the packet size of 250 bytes. However, the COA algorithm generates the constant delay after the packet size of 400 bytes. This shows that COA algorithm requires more processing time to stabilise the delay in the network.

**Figure 3 – End-to-End delay**

Packet delivery ratio can be calculated by the ratio of packets delivered successfully from the origin node to the destination node in the communication path. It does not include the retransmitted packets due to packet drop. Figure 4 represents the packet delivery ratio generated for COA and HGA algorithms.

**Figure 4 – Packet Delivery Ratio**

The packet delivery ratio is measured by based on the simulated time. The HGA algorithm provides the maximum packet delivery ratio of about 89% and the COA algorithm generates 85%.

**Figure 5 – Packet Loss Ratio**
Packet loss ratio is inversely related to packet delivery ratio but it also measures the packet drop during the retransmission period. The packet loss ratio is shown in Figure 5. The packet loss ratio of the COA algorithm is not stable, the value is increased dynamically at 4 sec and dropped at 6 sec. This shows the instability of the network using COA algorithm. The maximum packet loss of about 0.11% is measured for COA and 0.8% for HGA algorithm.

Residual energy represents nodes energy level in the network after transmitting and receiving the packets. Here it is measured based on the size of the transferred data packet. Increase in data packet increases the consumption of energy in the node. Retransmission of large data packets dynamically increases the residual energy. The Figure 6 shows the residual energy plot of the network. COA consumes more energy than HGA algorithm over the packet size of 500 bytes. COA consumes maximum energy of about 0.75 joules and HGA consumed 0.5 joules for maximum data packet size of 1200 bytes with simulated time of about 12 seconds.

The network efficiency was measured by throughput of the network. Throughput was affected due to the delay. Increase in the ratio of packet loss affects the throughput measurement. HGA algorithm generates steady increase in throughput and reaches maximum throughput of 320Kb/s as shown in Figure 7. Due to the increase in packet drop and delay throughput generated by the COA algorithm is widely affected after 5th second. This drop in the throughput represents the instability of the network which increases the energy consumption. This leads to early failure of nodes in the network.

V. CONCLUSION

A cognitive radio network is developed to perform dynamic spectrum access using Heuristic Greedy algorithm to maximise the secondary user communication with lesser probability of occurrence of congestion with the primary transmission. The proposed greedy algorithm is compared with the cat optimisation algorithm and the performance metrics were generated using NS2 simulator. The greedy algorithm generates 65% more throughput than the cat optimisation algorithm, which proves that the greedy algorithm generates more successful transmission in cognitive radio network.

REFERENCES:

1. J. So and R. Srikant, “Improving Channel Utilization via Cooperative Spectrum Sensing With Opportunistic Feedback in Cognitive Radio Networks,” IEEE Commun. Lett., vol. 19, no. 6, pp. 1065–1068, 2015.
2. T. Düzenli and O. Akay, “A New Spectrum Sensing Strategy for Dynamic Primary Users in Cognitive Radio,” IEEE Commun. Lett., vol. 20, no. 4, pp. 752–755, 2016.
3. H. He, G. Y. Li, and S. Li, “Adaptive spectrum sensing for time-varying channels in cognitive radios,” IEEE Wirel. Commun. Lett., vol. 2, no. 2, pp. 227–230, 2013.
4. L. Arienzo and D. Tarchi, “Statistical modeling of spectrum sensing energy in multi-hop cognitive radio networks,” IEEE Signal Process. Lett., vol. 22, no. 3, pp. 356–360, 2015.
5. S. H. Lee, M. Shamaiah, H. Vikalo, and S. Vishwanath, “Message-passing algorithms for coordinated spectrum sensing in cognitive radio networks,” IEEE Commun. Lett., vol. 17, no. 4, pp. 812–815, 2013.
6. C. C. Huang and L. C. Wang, “Dynamic sampling rate adjustment for compressive spectrum sensing over cognitive radio network,” IEEE Wirel. Commun. Lett., vol. 1, no. 2, pp. 57–60, 2012.
7. S. Srinivasa and S. L. Sabat, “Spectrum Sensing for Cognitive Radio Networks,” White Spy Commun., vol. 18, no. 8, pp. 117–151, 2014.
8. N. Nguyen-Thanh and I. Koo, “Optimal truncated ordered sequential cooperative spectrum sensing in cognitive radio,” IEEE Sens. J., vol. 13, no. 11, pp. 4188–4195, 2013.
9. H. Qin, Y. Sun, X. Chen, M. Zhao, and J. Wang, “Optimal Power Allocation for Spectrum Sensing and Data Transmission in Cognitive Relay Networks,” Power, vol. 1, no. 1, pp. 1–13, 2012.
10. D. Sun, T. Song, B. Gu, X. Li, J. Hu, and M. Liu, “Spectrum Sensing and the Utilization of Spectrum Opportunity Tradeoff in Cognitive Radio Network,” IEEE Commun. Lett., vol. 20, no. 12, pp. 2442–2445, 2016.
11. Y. Gao, W. Xu, K. Yang, K. Niu, and J. Lin, “Energy-efficient transmission with cooperative spectrum sensing in cognitive radio networks,” IEEE Wirel. Commun. Netw. Conf. WCNC, vol. 17, no. 5, pp. 7–12, 2013.
12. S. Sadogari and H. Jafarkhani, “Enhanced Spectrum Sharing and Cognitive Radio Using Asynchronous Primary and Secondary Users,” IEEE Commun. Lett., vol. 22, no. 4, pp. 832–835, 2018.
13. K. Hamdi, M. O. Hasna, A. Ghrayeb, and K. Ben Letaief, “Priority-based zero-forcing in spectrum sharing cognitive systems,” IEEE Commun. Lett., vol. 17, no. 2, pp. 313–316, 2013.
14. B. Bai, W. Chen, and Z. Cao, “Low-complexity hierarchical spectrum sharing scheme in cognitive radio networks,” IEEE Commun. Lett., vol. 13, no. 10, pp. 770–772, 2009.
15. Z. Wang, W. Zhang, and S. Member, “Feedback in Poisson Cognitive Radio Networks,” IEEE Trans. Wirel. Commun., vol. 13, no. 12, pp. 7098–7109, 2014.

AUTHORS PROFILE

D. Muthukumaran, is working as Assistant Professor in Department of ECE at SC bundle University, kanchipuram, Tamilnadu State. He has 10 years of teaching experience. He is pursuing Ph.D in the area of Cognitive radio network. His area of interest in Wireless communication and Cognitive radio network.
Dr. S. Omkumar, is working as Associate Professor in Department of ECE at SCSVMV University, Kanchipuram, Tamilnadu State. He has published more than 20 research papers in indexed journals and conferences. He has 17 years of teaching experience. His area of interest in Wireless communication and Adhoc networks.