Quality of service (QoS) Evaluation of Routing protocols in Multi-Rate Cognitive Radio Ad-Hoc Networks (CRAHN)

Vipin Kumar G[1], Dr. B Lethakumary[2]
[1]*Research Scholar, University College of Engineering, Thodupuzha, Idukki, Kerala, India*
[2]*Research Guide, University College of Engineering, Thodupuzha, Idukki, Kerala, India*

***Abstract*—Quality of service (QoS) provisioning is an important constraint in cognitive radio networks. Apart from the heterogeneous service environments, study has to be conducted for the coexistence of multi rate secondary users in the cognitive network. In this paper we focus on the evaluation and analysis of quality of service (QoS) parameters of multi-rate secondary users (SU) in real time (RT) and non-real time (NRT) user applications. The evaluation has been carried out to test the behavior of cognitive ad hoc on demand vector (CAODV) and weighted cumulative expected transmission time (WCETT) routing protocols in multi-rate secondary user test beds using cooperative scenarios. Simulation results are provided to analyze the performance of the above routing protocols.**

***Index Terms*— Cognitive Radio, Multi-rate, Secondary Users, QoS Provisioning, Heterogeneous service**

I.INTRODUCTION

Over the last few years, with the emergence of new wireless devices and applications, consumers' interest in wireless services has increased exponentially. This has resulted in a dramatic increase in demand for radio spectrum. Moreover, the need for broadband wireless access is expected to spiral up in future.

Radio spectrum is naturally limited and thus it is a precious resource. The conventional approach to spectrum management is very inflexible in the sense that each operator is granted an exclusive license to operate in a certain frequency band. This is called static allocation. However, with most of the useful radio spectrum already allocated, it is becoming exceedingly hard to find vacant bands to either deploy new services or enhance existing ones.

Cognitive radio technology comes with the dynamic spectrum allocation policy where the users exploit the underutilization of radio resources. Over the last decade a lot of research has been done in the area of spectrum sensing, mac layer and network layer of both infrastructure and ad hoc cognitive radio networks. Dynamic spectrum allocation is not limited to any communication standards. Once dynamic spectrum allocation emerges all the existing radio standards need to coexist in the same environment. The basic issue of this coexistence is the provision of quality of service to all the users belonging to different network standards. In this paper we are focusing on the cognitive radio ad hoc networks (CRAHN). Various routing protocols [1] have been proposed for the cognitive radio ad hoc networks where the CAODV [2] and the WCETT [3] emerge as novel techniques and vigorously tested in various environments. But the evaluation [4] of these protocols is limited to general test beds and routing structures. In the present scenario with the emergence of the internet of things we need to consider the compatibility issues of these devices in a fully cognitive environment. The multi user environment will comprises of devices using different communication protocols and standards. This scenario must be taken into account while creating test beds for evaluation of any protocols in the cognitive environment. In this paper we have tested the performance of CAODV and WCETT protocols in a multi-rate secondary user test bed.

II.MULTI –RATE NETWORKS

One of the latest trends in wireless communication is to enable a multi rate environment among users without dropping the QoS metrics. Many existing communication standards have multi-rate capability. There are many factors affecting the quality of the communication such as transmission range, bandwidth of the channel etc. Every user demands higher speed but generally there is a tradeoff between range and data rate. Number of network devices has grown enormously in these years, where the node capabilities are heterogeneous in nature. Heterogeneity refers to inequality among nodes in terms of throughput. But every node coexists in the network where the advanced nodes will be reverse compatible with the primitive technology nodes. In a heterogeneous environment the difference in the data rate of secondary users will lead to an unfair path selection in conventional cognitive routing scenarios. The multi-rate nodes when organized in ad-hoc mode will face many issues in terms, fairness and average throughput of the network will go down with respect to the primitive nodes participating in the data forwarding process. So in future this fairness study should be incorporated in designing new protocols in cognitive radio ad-hoc networks the delay constraints as well as the throughput fairness among node selection should be considered to overcome this issue. In this paper we are going to analyze the performance of the mentioned routing metrics in a multi rate environment.

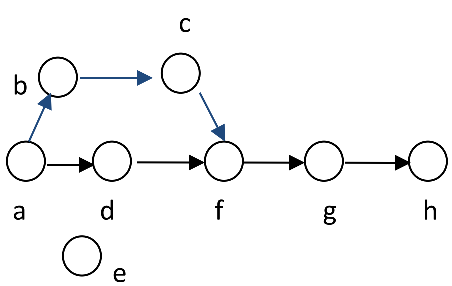

Figure 1: Multi-rate scenario in Ad-hoc network

In Figure 1 node a wants to send data to node h where two paths are available. Normally routing protocols prefer to route the data through the minimum hop path. In the scenario shown in figure assume node f is primitive with respect to other nodes where its throughput is low .in this situation if the route is preferred over the shortest hop path the average throughput will be less than that of node f even if other nodes perform better in the network. So study has to be done in order to address this problem

In figure 2 shown below two primary networks are interfering with the nodes with different coverage areas here the nodes have the responsibility to avoid the channels associated with these primary networks. Here it has to consider the switching delay considerations along with the node capabilities to find the optimum path to the destination. In the scenario given below the optimum path from node a to node h will be through node b and node c while considering minimum interference and minimum switching delay consideration

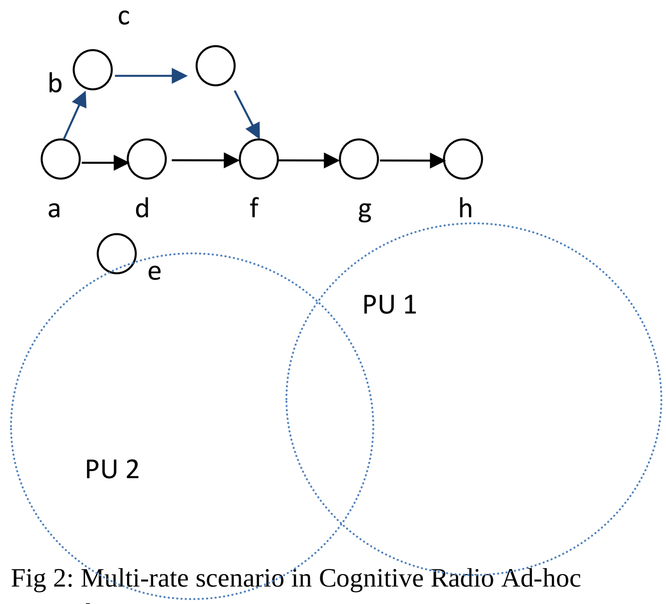

Fig 2: Multi-rate scenario in Cognitive Radio Ad-hoc network

III. ROUTING PROTOCOLS

A. CAODV

Cognitive ad hoc on-demand distance vector (CAODV) was derived from the ad hoc on demand vector routing (AODV) protocol. This protocol comprises route discovery/ maintenance process as well as forwarding mechanism similar to the AODV. But the cognitive part enables the protocol to route the packets along with the channel selection mechanism. Apart from AODV features CAODV should take account of working in a licensed band and their complexities. The Secondary users (SU) should be able to exchange the control packets through the licensed spectrum free from PU activity. CAODV exploits the available channel to improve overall performance. A network scenario consisting of ‘n’ SU’s are created. As said earlier when channel switching comes to play the CR user must find another available channel for further transmission. Figure 1 represents the general flow chart of CAODV which includes the Route Request phase (RREQ phase) and Route Reply phase (RREP). As the route discovery process is initiated by broadcasting the RREQ packet, it checks for the desired destination. If the proper destination is found, a reply packet is sent in return through the reverse path setup. Otherwise it checks out the available channel information to find out the PU activity free channel to continue the packet transmission to reach out to the destination.

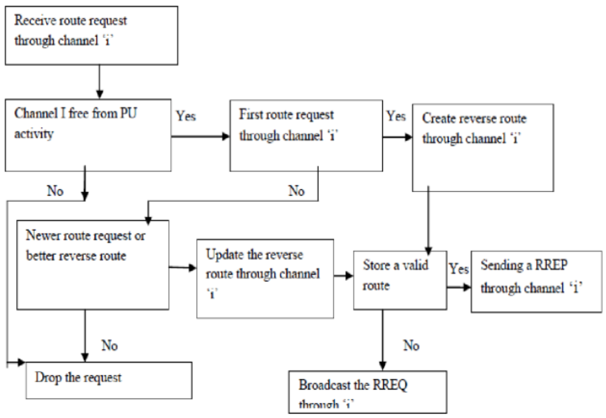

Figure 3: CAODV RREQ Flowchart

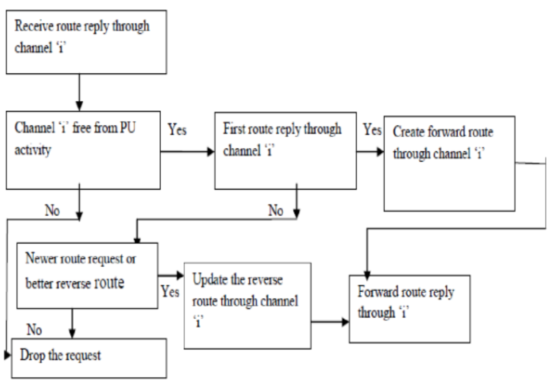

Figure 4: CAODV RREP Flowchart

B. WCETT ROUTING

The path matrix developed from weighted cumulative expected transmission time (WCETT) is a sum of all the hops in the path. Whenever a route is demanded the routing process starts by sending a RREQ packet across the network. The packet will be embedded with a pre-calculated weighted cumulative transmission time of the corresponding channel. Whenever an intermediate node receives the packet and has a valid route to the destination it acknowledges with a valid route reply packet to the source. If the destination sequence number doesn't match with the previous entry it will send a route error message. The WCETT is an advanced form of ETT metric and it involves assigning weights to each of the links. Channel diversity and bandwidth are also considered for the weight calculation. Expected transmission count (ETX) is defined as the number of transmission required to successfully deliver a packet over a wireless link

$$ETX = \frac{1}{Df \times Dr} \quad (1)$$

$$ETT = ETX \times \frac{S}{B} \quad (2)$$

Where S is the average size of the packet and B denotes the link bandwidth. For an n hop path, where n is the number of hops.

$$WCETT = \sum ETT_i \quad (3)$$

Where i= 1 to n and n is the number of hops

$$X_j = \sum ETT_i \, 1 \le j \le k \quad (4)$$

X_j is the sum of transmission time of all hops on the jth channel.

$$WCETT = (1-\beta) \times \sum ETT_i + \beta \times maxX_j \quad (4)$$

i= 1 to n, j=1 to k, k is total no of channels and β is the tunable parameter ranging from 0 to 1.The performance of WCETT is depended on the value β .The throughput for β =0 is lower than β =0.1.That is at higher concentration of load the network throughput is maximized by lowering β values. The ETT metric captures the impact of link capacity on the performance of the path. However, the remaining drawback of ETT is that it still does not fully capture the intra-flow and interflow interference in the network

WCETT performs well in ad hoc networks but it needs considerable change to perform in cognitive radio ad hoc networks. Generally there won't be any issue to identify channel information in normal ad hoc networks but here it requires lower layer information for successful transmission of data. To evaluate the performance of WCETT in cognitive radio networks we have enabled the multi radio environment in the physical layer where it performs a channel scan and identifies the available channel in the radio environment. The information will be delivered, y not considering the channel switching delay .It calculates Xj for every channel available and assumes the channel will be free for every hop. The main advantage of this routing is it will consider the bandwidth requirements available with each link and calculate the transmission time so it will be an added advantage while considering routing among heterogeneous nodes.

IV.QUALITY OF SERVICE METRICS

1) Delay

Delay is an important parameter which determines QoS in any wireless network. CR users are frequently prone to a variety of delays due to channel uncertainty. Compared to the existing networks, CRN faces complexities in delay analysis. This occurs due to the presence of PU.

2) Throughput

In data transmission throughput is the measure of how many units of information a system can process in a given amount of time. It is applied broadly to systems ranging from various aspects of computer and network systems to organizations. It is the speed with which some specific workload can be completed and response time, the amount of time between a single interactive user request and receipt of the response.

3) Packet Delivery Ratio (PDR)

PDR is defined as the ratio between the received packets by destination to the generated packets by the source.

V.TESTBED

Simulations are carried out in NS2. A cognitive test bed of 2 to 20 nodes are created in mesh topology and they are randomly deployed in 1000*1000sq m area. A total of 11 channels are allotted and primary user occupancy for these channels are defined with a probability function. In the simulation both time sensitive traffic like audio as well as normal traffic is routed to the destination nodes to analyze the delay constraints. The 802.11 MAC and physical wireless parameters were further modified to match the required specifications of multi rate devices. The data rates designed were 11Mbps, 5.5Mbps 3Mbps and 1Mbps respectively. Table 1 shows the parameters used for simulation.

Parameter	value
Frequency	2.4 GHz
Transmit Power	20 dBm
11.0 Mbps Receive Threshold	-82 dBm
5.5 Mbps Receive Threshold	-87 dBm
3.0 Mbps Receive Threshold	-91 dBm
1.0 Mbps Receive Threshold	-94 dBm
Carrier Sense Threshold	-100 dBm
Propagation Model	Two Ray Ground
Loss	0 dBm

Table 1: Simulation Parameters

VI.RESULTS

Simulation results show WCETT performs better than CAODV in a multi-rate environment. But when compared with the homogenous network scenario there is a considerable drop in throughput among nodes. Average throughput among nodes and packet delivery ratio are calculated.

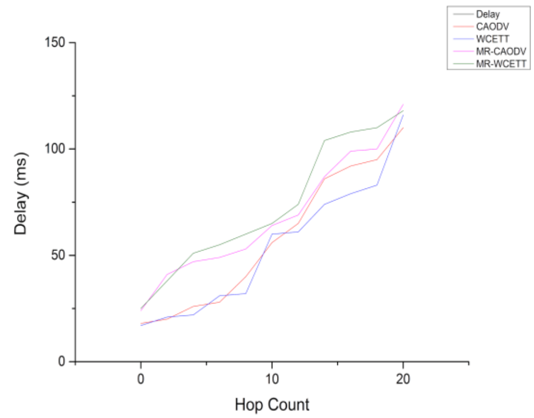

Figure 4: Hop Count vs Delay

When we consider the multi rate network both the routing protocols have shown a slight delay in delivery of packets when compared to homogenous mode. Delay tends to increase when the number of nodes in the network increase (Figure 4).

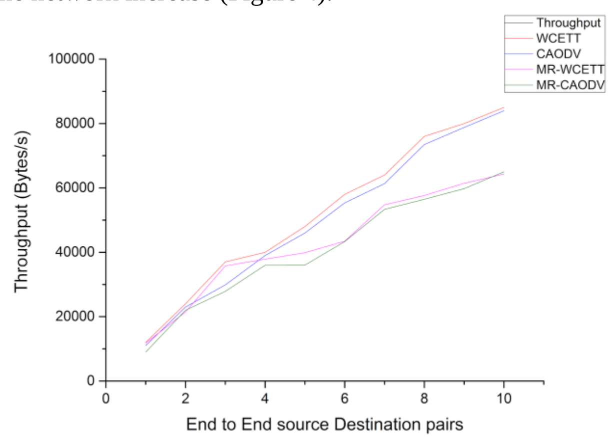

Figure 5: End to End Source Destination Pairs vs Throughput

Throughput has been calculated for the test bench where the performance has been considerably dropped with respect to the homogenous environment. The considerable drop is visible when more nodes engage in the communication process. The multi rate nodes will reduce the average drop in the throughput even though they don't belong to the source destination pair (Figure 5).

Figure 6 shows the rebroadcasts happening in the network .Re broadcasts increase the total control overhead of the system and thereby decline the overall performance of the network. In our scenario the rebroadcasts occur when there is non-availability of channel for transmission and both routing protocols have shown an increase in the overhead when they switched to the multi rate radio environment.

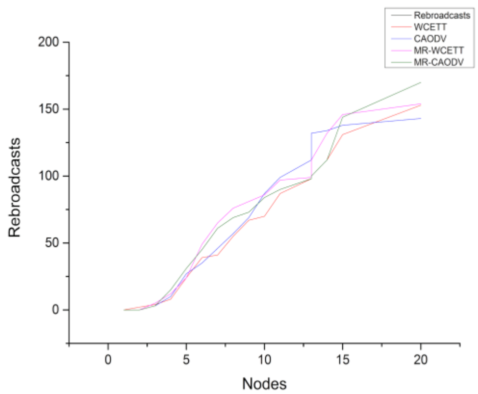

Figure 6: Nodes vs. Rebroadcasts

Packet delivery ratio also has shown decline when more heterogeneous nodes participate in the routing process (Figure 7).the packet delivery ratio has shown a decline when more noes engage in the communication scenario and because of the fairness issue arise due to the multi rate node environment it has shown a decline from the normal environment.

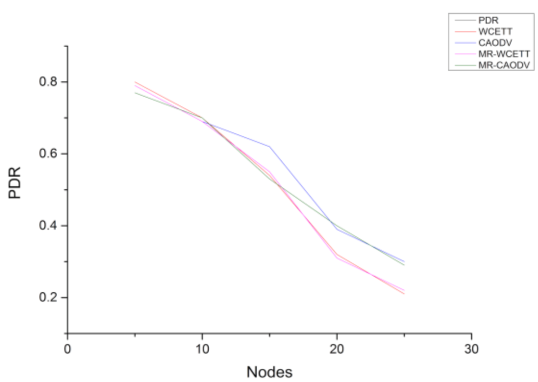

Figure 7: Packet Delivery Ratio

VII.CONCLUSION

Multi-rate environment requires routing protocols incorporated with the device throughput capabilities to meet the QoS constraints. From the analysis of results both routing protocols need considerable change in the route discovery process by incorporating the data rate capabilities of devices participating in the process.

REFERENCES

[1] Lolita Singh and NitulDutta "Routing Protocols for CRAHN: A Comparative Evaluation, "Trends in Communication, Cloud, and Big Data, pp 3-11, January 2020.

[2] Angela Sara Cacciapuoti, Cosimo Calcagno and Marcello Caleffi Luigi Paura CAODV: Routing in mobile ad-hoc cognitive radio networks," IEEE 2010 IFIP Wireless Days, 20-22 Oct. 2010.

[3] R. Rai, V. Tiwari, and S. Kansal, "Comparison of Routing Protocol AODV and WCETT in Cognitive Radio Network, "International Journal of Engineering, vol. 2, no. 10, 2013.

[4] R. Ruslan, R. Saian and N. Mohd. Teramizi, "Performance Analysis of AODV and WCETT Routing Protocols in Cognitive Radio Ad-HocNetwork (CRAHN)," 2014 5th International Conference on Intelligent Systems, Modelling and Simulation, Langkawi, 2014, pp.625-6

[5] J.I. Mitola, Cognitive Radio - An Integrated Agent Architecture for Software Defined Radio. Royal Institute of Technology (KTH), 2000.

[6] S.Haykin, Cognitive radio: Brain-empowered wireless communications. IEEE Journal on Selected Areas in Communications, Vol 23, Issue 2, Pages 201-220, February 2005

[7] Facilitating opportunities for flexible, efficient and reliable spectrum use employing cognitive radio technologies: Notice of proposed rulemaking and order. FCC, ET Docket No. 03-108 Dec 2003

[8] F. K. Jondral, Software-Defined Radio - Basic and Evolution to Cognitive Radio. EURASIP J. Wireless communication. And Networking, 2005.

[9] QoS Routing for Cognitive Radio Ad-Hoc Networks: Challenges & Issues. 978-1-4799-0059-6/13/ ©2014 IEEE.

[10] W. Y. Lee, Spectrum Management in Cognitive Radio Wireless Networks. Georgia Institute of Technology, 2009.

[11] Routing Layer solution for mitigating frequent channel switching in Ad hoc CR Networks. IEEE Communication Letters,vol.19,no:11November 2015.