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Performance Evaluation of WCETT in Cognitive Radio Networks with Heterogeneous Channel Bandwidth Conditions and Switching Delay Considerations

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Abstract: *Cognitive Radio is an intelligent radio which effectively utilizes the spectrum white spaces. It opportunistically access the available spectrum and provides an optimum solution for spectrum scarcity.WCETT(Weighted Cumulative Expected Transmission Time) gives a better routing solution in cognitive radio adhoc environments .Performance evaluation of WCETT protocol in QoS constrained data traffic is analyzed using simulation in single radio multi channel cognitive radio test bed. Simulation of spectrum scarce environment with variable bandwidth channel conditions also has been studied. The simulation is done using NS-2.and various network parameters has been evaluated.*
Keywords – *Cognitive Radio,Routing,ETX,ETT,WCETT*

I. INTRODUCTION

Cognitive Radio technology[1] is proposed to solve the issue of spectrum scarcity.CR opportunistically access the vacant spectrum without interfering with the activities of Primary User (PU) over licensed band .A flexible network can be implemented which timely reuse the spectrum.This way it establishes a good QoS for transmission needs in wireless networks.There are lot of challenges faced regarding the performance of the network as well as the average delay.CR faces problem on working with QoS constrained networks.Due to spectrum scarcity the channel efficiency cannot meet the saturation or a 100% occupancy is not attained.The available bandwidth may not be fully utilized.So in such condition QoS constrains cant be satisfied with respect to CR. When we make a switch decision in the process of proactive channel access, we take the channel bandwidth into consideration to achieve the best QoS. When we make the spectrum switch channel decision, we consider which mentioned switching cost to achieve more realistic simulation. In real life, spectrum switch decision making must consider more situations such as packet-loss-ratio, synchronization and delay. It must produce non-negligible handoff delay .The available amount of the bandwidth is the key to determine the channel switch. When the remaining channel idle time is the same, the channel with bigger bandwidth possesses higher data transmission rate so that secondary users can finish their transmission faster.

This section presents a routing metric called Weighted Cumulative Expected Transmission Time(WCETT) in Cognitive Radio networks.CRN are categorized as centralized and distributed network structure.In the former one,a central entity takes control over the network topology and gathers information related to channel availability .The network should not be effected by any type of intereference.The channel assignment strategy is optimized as its maximum so as to evolve the best routing scheme.This ensures the throughput of network largest.Routing in networks is an active area of research.The main focus on routing algorithm is to improve the network capacity of networks.In [2] Richard Draves has proposed WCETT metrics by assigning weight to each link.The experiment shows that a new routing metrics is necessary for achieving good performance in heterogeneous ,multi-radio environment. A wireless testbed is created with different nodes multiple number of radios.In [3] authors has proposed and simulated the basic routing protocols in traditional ad hoc network and CRAHN environments on the current available routing metrics and results highlighted that there are some challenges and issues still open to provide the QoS routing in CRAHN environment. A number of multipath routing protocol solutions [6],[7] have been proposed for ad hoc networks that discover multiple paths between a source and destin.In [4],a new routing protocol WCETT is considered . We assume a network with Cognitive User(CU) and freely moves in a two dimensional plane .The aim is to describe the effects of PU activity on routing when it varies in frequencies. As CU number becomes lower and higher the performance varies while considering their end to end delay. Since there is a challenge faced by CRN due to the less availability of routing algorithm ,a new routing metrix is proposed in this paper.It describes the WCETT protocol in heterogeneous environment .The proposed routing metric is implemented over multiradio multichannel environment among network layer. To ensure good performance, routing metrics must satisfy four requirements. First, the routing metrics must not cause frequent route changes to ensure the stability of the network. Second, the routing metrics must capture the characteristics of mesh networks to ensure that minimum weight paths have good performance. Third, the routing metrics must ensure that minimum weight paths can be found by efficient algorithms with polynomial complexity. Finally, the routing metrics must ensure that forwarding loops are not formed by routing protocols.

II. WCETT ROUTING METRIC

II.1.WCETT

The path metrics formulated with WCETT is the sum of all hops on the path.When a route is needed between two nodes, the routing process is started and the source node sends RREQ packet across the network. The RREQ packet transmitted by a node on a channel contains the calculated value of weighted cumulative transmission time. When an intermediate node receives RREQ packet, and have valid route to the destination specified in RREQ it sends RERR packet to the source if the received RREQ's destination sequence number is less than or equal to destination sequence number in the route entry.WCETT value is added to the routing table based on the latest route information.WCETT is an extension of ETX and is evaluated which involves assigning weights to each of the links. They periodically broadcast hello messages to discover nodes and links .The difference in band width of the link and channel diversity is taken in to account in WCETT. Expected Transmission Count (ETX) is defined as the number of transmission required to successfully deliver a packet over a wireless link .The sum of ETX of each link along a path constitute the ETX.

ETX=1/(D_f*D_r),Where D_f is the forward delivery ratio and D_r is the reverse delivery ratio. Expected Transmission Time (ETT) is an extension of ETX[5] which includes the packet size and bandwidth of the respective link.

$$ETT = ETX * \frac{S}{B} \quad (1)$$

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.

$WCETT = \sum ETT_i$ (2) where i= 1 to n and n is the number of hops

$$X_j = \sum ETT_i \;,\; 1 \le j \le k \quad (3)$$

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

$$WCETT = (1-\beta) * \sum ETT_i + \beta * max X_j \quad (4)$$

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.

II.2 EXPECTED TRANSMISSION COUNT (ETX)

ETX is defined as the expected number of transmissions that is needed for successfully delivering a packet through a wireless link. The problem with ETX metric is that it does consider interference related issues or the transmission rate prior to each link varies differently.The computation of ETX metric includes sending a probe packet to all its neighbours every second and records the received packets.

II.3 EXPECTED TRANSMISSION TIME (ETT)

This metrics represents the number of required MAC retransmissions to reach a destination. To compute ETX[5], the implemented method works under 802.11 environment. This method will not work under other environment since it is based on the fact that 802.11 does not retransmit broadcast packets. To compute ETX we send probe packets every second to all neighbours.Every 10 seconds, reports the number of received packet to the sending node. 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 inter-flow interference in the network.

III. QOS IN WCETT

CRNs shall provide support for QoS demands, such as throughput and delay, without interfering with PUs operating in the same set of channels. The QoS provisioning in cognitive heterogeneous environment is an Important area to be taken in to account.Due to this heterogeneous nature and cognitive capability the process became more complex.By addressing the QoS requirements among different networks the problem can be solved.Compred to QoS ideas in traditional networks,the QoS dealing in CRN have extra ability to realize the environment as a self configurable and self learning nature.The problem of ensuring good QoS over a chain of components involves many aspects like their specification,mapping resources provisioning scheduling etc..

Specifically, SUs opportunistically access for vacant channels, within a heterogeneous multi-channel. In case of incoming PU activity, they need to find vacant channels that will sustain their traffic needs. The search of such resources incurs a delay, since it is generally performed sequentially over multiple channels using a single transceiver, by means of spectrum sensing and channel estimation. Conversely, the more channels are searched, the higher the likelihood of finding better resources to support the desired QoS.The number of channels, sustainable data rates, sensing time are related to each other and depends on CRN characteristics and PU activities .We have identified the need to research and develop optimal channel selection algorithms to provide QoS in heterogeneous CRNs environments. Delay is evaluated in cognitive radio using WCETT in real time applications.

When primary user(PU) activity is more,the required bandwidth maynot be obtained .In such situation the sensing standalone receivers have to allocate channels with high interference inorder to satisfy QoS needs.The performance of the network in such conditions are studied.As new channels are sensed over time,the bandwidth allocated to each channel may vary.Thus to meets QoS needs the users are forced to work in alloted channels.The list of allotted channel are made according to the sensed information studied over different channels.Based on the above list the channels are allocated according to some constrains which are followed in channel allocation.

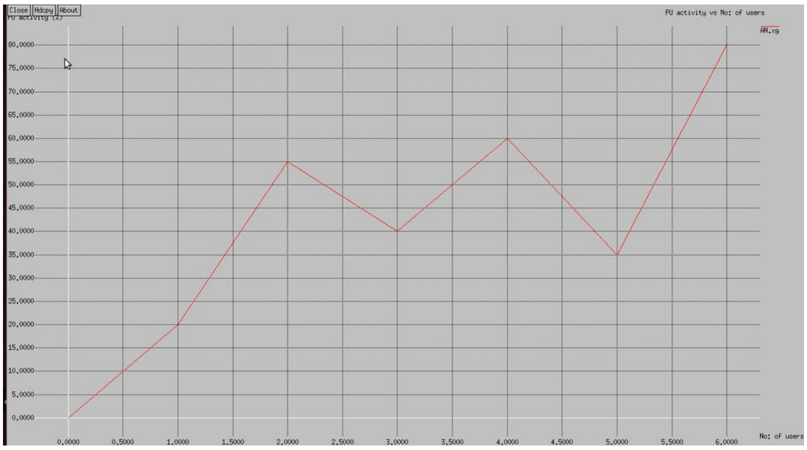

Figure1: PU activity over channel

The primary user activity over the channel determines the performance of the proposed network conditions. The user activity may vary over time.The parameter calculation should be done accordingly with the given Conditions satisfying the QoS needs which is the major task.

Figure 2 Variation in bandwidth for required channel

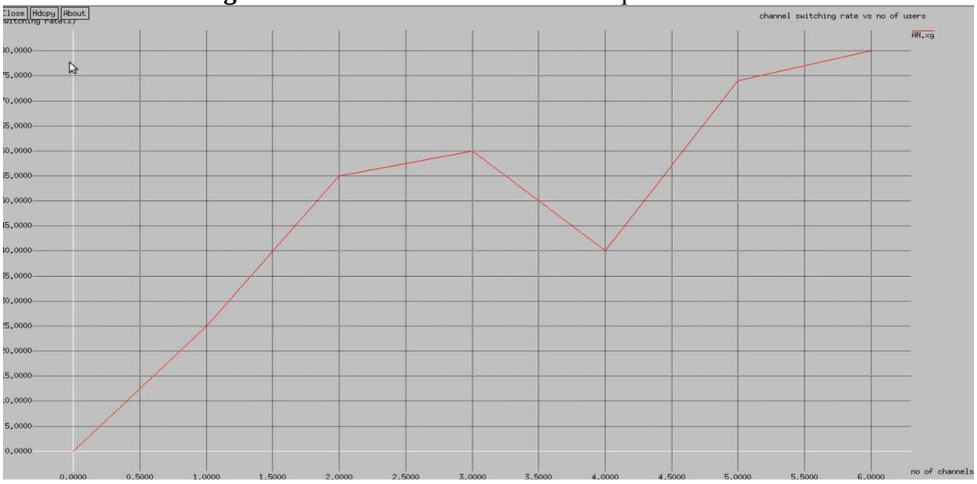

Figure 3: channel switching rate

To ensure that the proposed protocol works better,a sharp analyzing over different response in various scenario has to be done.The following results shows the flows that are initiated with UDP flows.In the graph we notice some variations interms of throughput .The presence of PU activity as said makes a major decision maker for calculating network performance over network conditions.The primary thing of avoiding intereference and immediate switching of SU's to vacant channels faces further issues other than those solved by different protocols implemented. The Figure1 shows the primary user activity noted over time with increasing number of users. Figure 2 illustrates the bandwidth variation in required channel.The throughput value is also calculated for variable channel bandwidth.The switching delay considerations are discussed in Figure 3 and throughput value is also calculated in Figure 4 and F igure 5.As said earlier,the network performance depends on the primary user activity ,the evaluated readings are based on primary user activity.We used the combination of different metrics with WCETT to carry out the proposed algorithm.The response over different scenarios makes the study accurate to finalise the better result.The routing metric evaluation is carried out with in different time intervals and average measure is taken in to account.The accurate measurement over time intervals can be plotted and comparison can be done easily.

Figure 4: throughput calculated for variable bandwidth

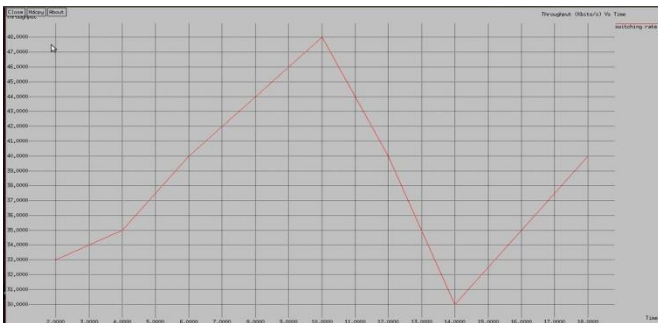

Figure 5: throughput calculated during switching

III.1 COGNITIVE TESTBED

An adhoc testbed is created with 6 nodes and a total of 5 channels.In the simulation testbed ,a time sensitive traffic such as audio voice is sent from source to destination.Here a 64Kbps audio is selected with constant bit rate.We have choosen node 1 and node 3 to sent the data.The other nodes screens the background traffic. The network topology with 6 nodes is shown in Figure 6.The transmission across nodes are also depicted in the testbed shown below.The main aim of the algorithm is to select a network conditions that meet the demanded QoS requirements of the admitted conditions. Different paths may be available from source to destination.Through some selected nodes the sensitive traffic is carried out .The testbed can be created with any number of nodes .The network topology created is according to the number of nodes with which the proposed model is done.The throughput value for different QoS parameters can be studied and compared.

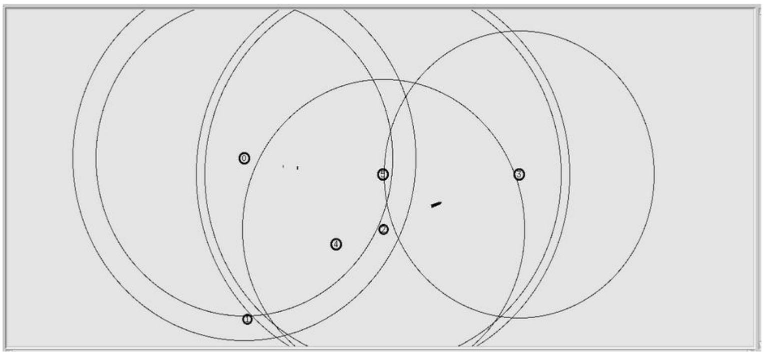

Figure 6: Network topology for 6 nodes

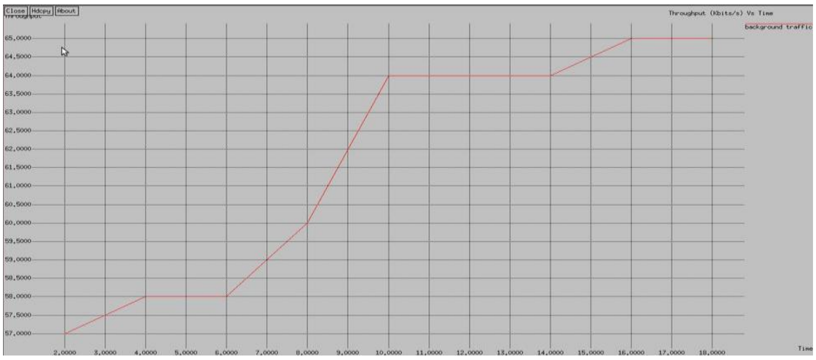

Figure 7: throughput for background traffic for nodes except 1 and 3

The result shown in Figure 7 is the throughput calculated for background traffic.The Figure 8 shows the throughput calculated for data sent from node 1 to node 3.

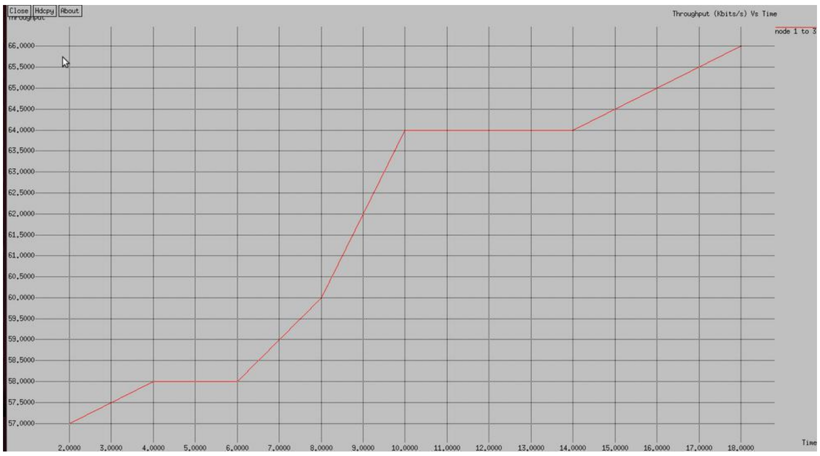

Figure 8: Throughput for node 1 and 3

IV. IMPLEMENTATION AND RESULTS

We consider network equipped with multiple radios tuned to different frequency channels.The number of nodes per radio is variable.The selected path should maximize the throughput.The proposed metrics should account for interference issues over the link.The researches shows that the network capacity mainly depends on the radios to channels.Before going to multiple radios one radio per node is considered.A testbed to work in single radio environment is created with UDP connection active.The main results from these experiment is that WCETT works well in single radio environments The performance increase is a resullt of the fact that WCETT takes link bandwidth into account.In two radio case, we draw two main conclusions that there is an improvement in throughput gain compared to single radio.But the problem is with the multihop wireless path TCP performs poorly and diversity over channel only helps in reducing contention between hops of same channel.

In Cognitive Radio,while considering channel demands or QoS requirements,the sensed channel information may not be enough to satisfy the bandwidth requirements.That is when channel bandwidth tends to be heterogenous in nature or varies with channel,the WCETT performance is studied.The throughput variation for different scenario is plotted in Figure 9.

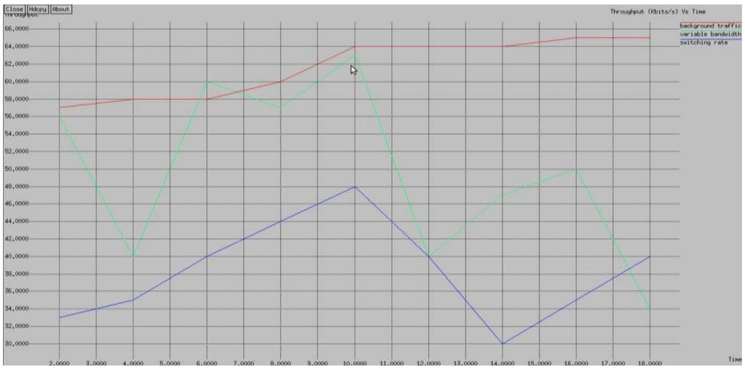

Figure 9: throughput variation over 3 scenarios

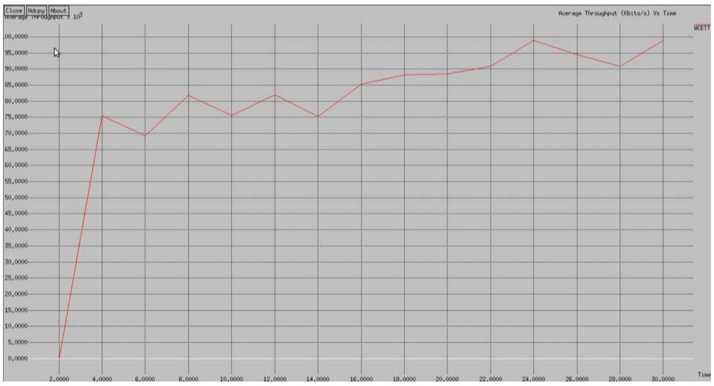

Figure 10: WCETT with 6 user 5 channel

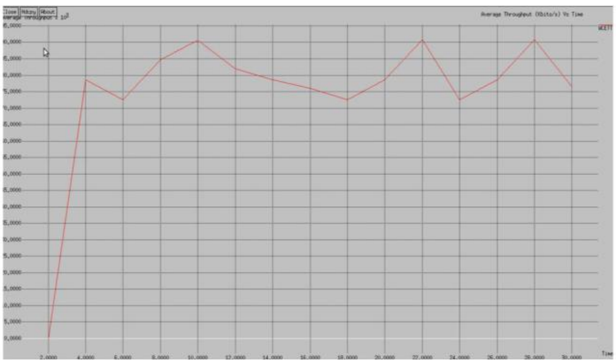

Figure 11: WCETT with 2 Radio 2 channel

The graphical representation of result shown in Figure 10 and Figure 11 is according to the network topology created.In single or two radio environment the average throughput value is compared with those in heterogeneous environment. The result is analysed using random values from trace files corresponding to WCETT.In heterogeneous environment a testbed with 5 channel 6 user is created.The graph shows the throughput value has been decreased in Figure 10 in multi channel environment and QoS requirements are not satisfied compared to those obtained in Figure 11.
Channel assignment strategy has to be reworked inorder to meet the QoS needs with respect to WCETT routing metric.

V. CONCLUSION AND FUTURE WORKS

Based of analysis of different routing metrics we have presented a viable routing protocol.The protocol behaviour with WCETT in heterogeneous environment doesnot provide 100% throughput throughout the simulation.The future work include working with the packet size and link bandwidth.The dynamic WCETT based routing protocol with various QoS constrains are involved to guarantee high throughput in heterogeneous environment.

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