IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 11, November 2016

Performance Analysis of ROPCORN and WCETT Routing Protocols in Cognitive Radio Ad-Hoc Network (CRAHN)

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Abstract: In the past few years, cognitive radio paradigm has emerged as a solution to avoid problems of spectrum scarcity and inefficiency in spectrum usage. Cognitive Radio (CR) capable to identify the unused spectrum in order to allow CR users to occupy it without interfering the primary users (PUs). Routing is a crucial task in CR network (CRN) due to diversity in available channels. In this paper, Routing Protocol for Cognitive Radio Ad Hoc Network (ROPCORN) and Weight Cumulative Expected Transmission Time (WCETT) routing protocols used to address the efficient route selection between the source and destination in a Cognitive Radio Ad-Hoc Network (CRAHN). The performance of ROPCORN and WCETT is evaluated on the basis of average throughput in three kinds of routing structure to satisfy different requirements from users: 1) single radio multi-channels, 2) equal number of radios and channels and 3) multi-radios multi-channels. The simulation result shows ROPCORN has a significant average throughput in single radio multi-channels where the average throughput is 48.25% higher compared to average throughput in WCETT. However, WCETT has a significant average throughput in equal number of radios and channels; as well as in multi-radios multi-channels where the difference of average throughput is 38.22% and 34.63% respectively.

Keywords: cognitive radio; routing protocol; ROPCORN; WCETT.

I. INTRODUCTION

Wireless communications and networks have experienced rapid development at an exponential rate in recent years. This situation is due to the increasing of wireless applications that leads to increasing wireless devices such as smart phones, tablets and other gadgets. Malaysian Communications and Multimedia Commission (MCMC) reported that there would be a bombastic increasing of mobile devices in the years to come. In addition, Wireless World Research Forum (WWRF) has outlined a grand vision of "7 trillion wireless devices serving 7 billion people by 2020". This shows increasing of spectrum that leads to congestion in the network traffic. As a result, mobile users may experience intermittent or slow access during their communications. [1]

This situation shows that there is a portion of the frequency spectrum is overloaded and another portion of the frequency spectrum is being underutilized or never been utilized. Furthermore, most wireless networks follow a fixed spectrum allocation policy, which results in only 15%- 85% spectrum usage with high variance in time. In 2010, M. H. Omar, S. Hassan, and A. H. M. Shabli reported similar scenarios Malaysia. MCMC routine scan confirms these scenarios occur in cities such as Kuala Lumpur, Alor Setar and Johor Bharu. Therefore, fixed allocation policies setup by the regulator is the reason for mobile users experienced congestion.

The Federal Communications Commission (FCC) is responsible to synchronize the use of radio spectrum resources and the guideline for radio emissions. FCC shows that the heavily crowded spectrum in frequency allocation chart is mostly assigned to the PU for specific services. Meanwhile, CR users (also known as unlicensed users) allowed utilizing the amount of unused licensed spectrum based on the dynamic spectrum access techniques.

Cognitive radios have the capability to fully utilize the valued spectrum by identifying the current spectrum, sensed the spectrum holes (as shown in Fig. 1) and alter the parameters such as frequency, transmission rate and power. This is to ensure the spectrum usage more reliable and satisfy users' requirement. In order to obtain an efficient spectrum allocation and sharing scheme, effective route selection is essential. Therefore, a performance analysis of ROPCORN and WCETT routing protocols need to simulate. [2]

Very less work has been done so far in the context of comparison of routing protocols in cognitive radio ad-hoc networks for different routing structures. The most relevant work that found in the literature is also comparison between ROPCORN and WCETT in CRAHN. However, the work did not take into consideration various number of radios and channels. The overall result shows WCETT is better than ROPCORN due to the efficient route selection strategy in CRAHN. Two other researches proposed a new routing protocol CR-AODV and ROPCORN. CR-AODV is evaluated and compared the

DOI 10.17148/IJARCCE.2016.51114

end-to-end throughput with Multi-radio Multichannel AODV (MM-AODV). ROPCORN is evaluated and compared the throughput and end-to-end delay with AODV. A comparison of four routing protocols for CRN i.e. Ad-Hoc On-Demand Multipath Distance Vector (AOMDV), Ad-Hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Destination Sequenced Distance Vector (DSDV) is presented. The result of comparison determines that AOMDV is excellent routing protocol due to the better delivery rate and reducing packet delay. No simulation detail is discussed.
The remaining of the paper is organized as follows: In Section II, CRAHN architecture and CR routing structures is described. In Section III, the ROPCORN and WCETT routing protocol is explained. Section IV shows the simulation framework and the obtained results. Finally, some conclusions are provided in Section V.

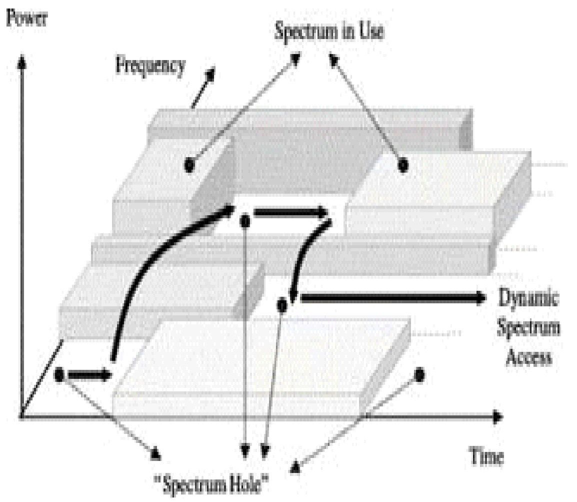

Figure 1: Concept of Spectrum Holes

CRN architecture can be deployed in infrastructure-based and ad-hoc network also known as Cognitive Radio Ad-Hoc Network (CRAHN). [3] The infrastructure-based CRN need to have a central network entity (i.e. access point or base station) to coordinate communication. However in CRAHN, communication amongst CR users is direct to one another on licensed or unlicensed spectrum bands. The CRAHN architecture as illustrated in Fig. 2 shows the differences between primary network and CR network. CR users can utilize both licensed and unlicensed bands, whereas Pus only can operate in licensed bands. Pus has the priority to operate in licensed band with no interference from CR users. However, they should share and communicate with each other in a multi-hop manner between both licensed and unlicensed spectrum bands depends on their local observations. In this research, three kind of CR routing structures are presented: 1) single radio multi-channels, 2) equal number of order to simulate the experiment scenarios, the network simulator used is NS2 with Cognitive Radio Cognitive Network (CRCN) patch. These environments are created through the TCL library, which invokes the creation of several copies of LL, queue, MAC, NetIf and channels for each radio in C++ library.

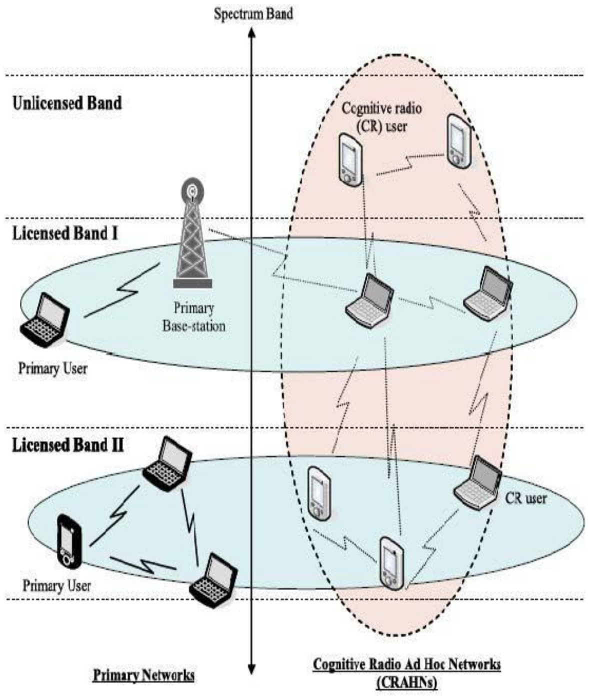

Figure 2: CRAHNs Architecture, following are the three CR routing structures:

II. SINGLE RADIO MULTI-CHANNELS

Fig. 3 shows single radio multi-channels structure in NS2, channels created in this part have identical spectrum parameter.

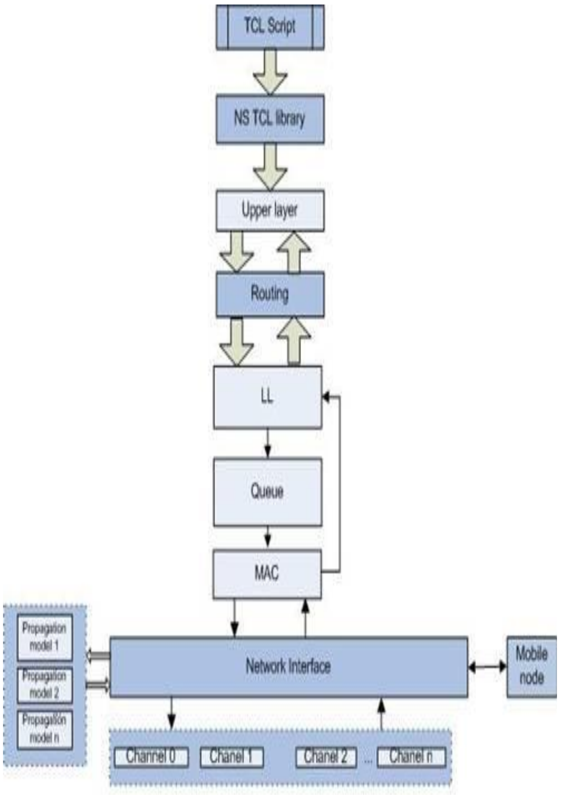

Figure 3: Design overview of single radio multi-channels

DOI 10.17148/IJARCCE.2016.51114

There are four steps involved:

- Define channel number in TCL script
- Create new channel objects according to the interface number
- Configure the multiple channel option
- Assign the channel objects to the channel array of the simulator.

III. EQUAL NUMBER OF RADIOS AND CHANNELS

Fig. 4 shows equal number of radios and channel in NS2. There are four steps should be added in the simulation script:

- Define the radio number in TCL script
- Create new channel objects according to the interface number
- Configure radio and channel option through the API provided
- Assign the channel objects to the simulator through the script created; the radio is associated with each channel.

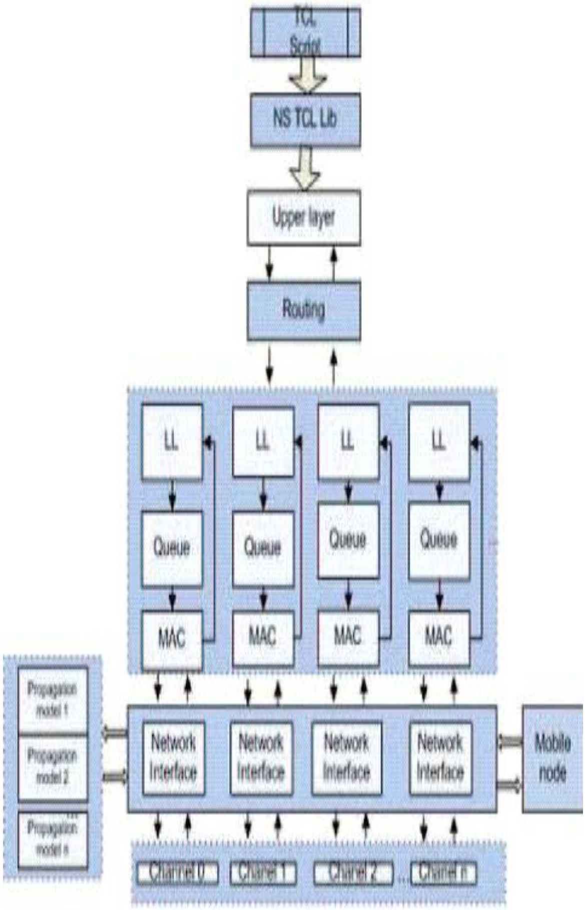

Figure 4: Design overview of equal number of radios and channels

IV. MULTI-RADIOS MULTI-CHANNELS

Fig. 5 shows multi-radios multi-channels structure in NS2. There are four steps should be added in the simulation script:

- Define the radio and channel number in TCL script
- Create new channel objects according to the radio and channel number
- Configure the multiple radio and channel option
- Assign the channel objects to channel array of the simulator

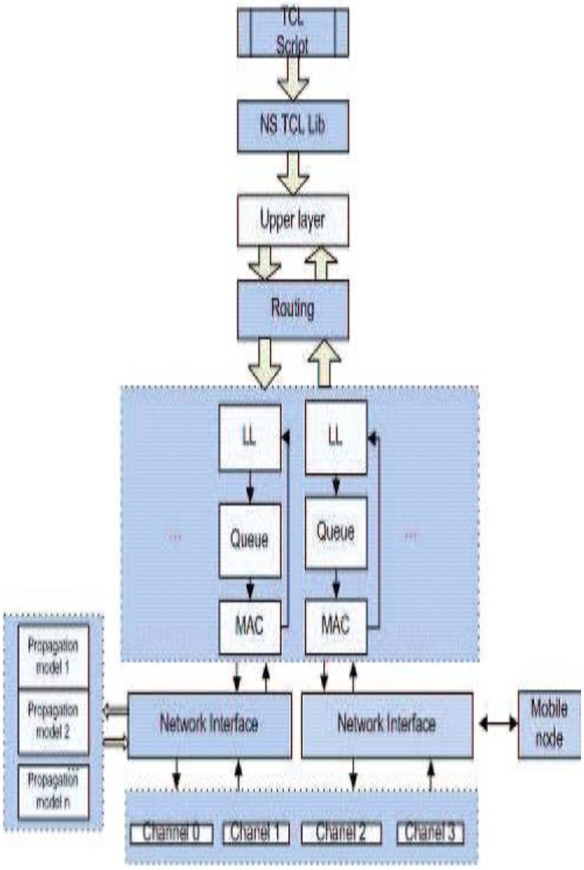

Figure 5: Design overview of multi- radios and multi-channels

V. ROUTING PROTOCOLS

The most challenging issue in dynamic topology of ad-hoc networks is related to the routing techniques. On top of that, there are different routing protocols proposed between Mobile Ad-Hoc Network (MANET) and CRAHN. MANET routing protocols are classified into three categories: 1) table driven (proactive routing protocol), 2) on demand routing protocol (reactive protocol) and 3) hybrid protocol. However, this research only focusing on ROPCORN, which is one of the MANET routing protocol reactive type. In reactive routing protocol, ROPCORN can be known as the protocols that produce maximum average throughput to broadcast messages over the channel. [4] In addition, ROPCORN can be implemented in CRN environment as well. Another efficient routing protocol in CRN is WCETT routing protocols. WCETT remains almost 100% of maximum throughput during the simulation due to the requirements on demand in cognitive radio implementations.

A. ROPCORN

Cognitive radio users are not likely to access spectrum randomly, or have a path to a specific node definitely random but rather get connected in a predictable fashion based on repeating behavioral patterns such that if a node has gain opportunity to access a specific unused spectrum band and has connection to a specific node several times before, it is likely that it will gain connection to that node again. We would like to make use of these observations and information to improve routing performance by defining a cost metric and doing probabilistic routing. To accomplish this purpose, we establish spectrum availability and destination reachability prediction.

Our design for ROPCORN routing associates a unique message identifier, a hop count, and an optional ack request with each message. This unique identifier is a concatenation of the host's ID and a locally-generated message ID (16 bits each). Assigning ID's to mobile hosts is beyond the scope of this paper. However, if hosts in an ad hoc network are assigned the same subnet mask, the remaining bits of the IP address can be used as the identifier. In our implementation, the hosts in the network are assigned ID's statically.

The hop count field determines the maximum number of exchanges that a particular message is subject to. While the hop count is alias to the TTL field in IP packets, messages with a hop count of one will only be delivered to their end destination. As discussed below, such packets are dropped subject to the acknowledgment of message delivery. These acknowledgments are modeled as simple return messages from receiver back to the sender. Of course, the acknowledgment can also be piggybacked with any other message destined back to the sender after the message is successfully delivered. [5]

Each host reserves a maximum buffer size for message distribution. In general, hosts will drop older messages in favor of newer ones upon reaching their buffer's capacity. Of course, there is an inherent tradeoff between aggregate resource consumption and message delivery rate/latency. To ensure eventual delivery of all messages, the buffer size on at least a subset of nodes must be enough. Otherwise, it is possible for older messages to be flushed from all buffers before delivery in some scenarios. A number of buffer management strategies are possible for per-host basis. The simplest policy is well-known first-in-first-out (FIFO) technique. This policy is very simple to implement and bounds the amount of time that a particular message is resident in at least one buffer (i.e. live). [6]

B. WCETT

WCETT is a Weight Cumulative Expected Transmission Time protocol is also one of the on demand ad-hoc routing protocols. The concept starts by selecting the best path from source user node to find their destination. This protocol use the RREQ and route reply RREP messages to begin the communication. [7] The RREQ packet will be develop once source node need to route between two nodes. Furthermore, at the same time this packet contains the calculated value of WCETT. That value is important to identify the way to route in two cases. The first case occur when every time to make a route, the existing of sequence number will determine if RREQ packet that come from source is new or not. If the sequence number is new, the WCETT value is stored in routing table. [8] However, the second case occurs when the sequence number is not new. This case will be process if the WCETT value is smaller compared to the previous value that sends from the same sequence number. Furthermore, when the RREQ meet the destination, the RREP will make the connection based on the smaller value of previous RREQ. The lowest value is used by the source to transmit data and stores as other best paths. [9]

VI. SIMULATION SETUP

The performance of routing protocol ROPCORN and WCETT are evaluated by multiple random topology in random.tcl and random wcett.tcl where cognitive users are placed in an area of 1000x1000m2. Tab. 1 summarized he simulation parameters.

TABLE 1. SIMULATION PARAMETERS

Parameter	Values
Topology	1000 X 1000 m^2
Traffic type	FTP
Packet size	512 bytes
Simulation duration	50 seconds
Transport layer	TCP

Fig.6 shows is the output of scenario 1 simulation which is single radio multi-channels for ROPCORN and WCETT,

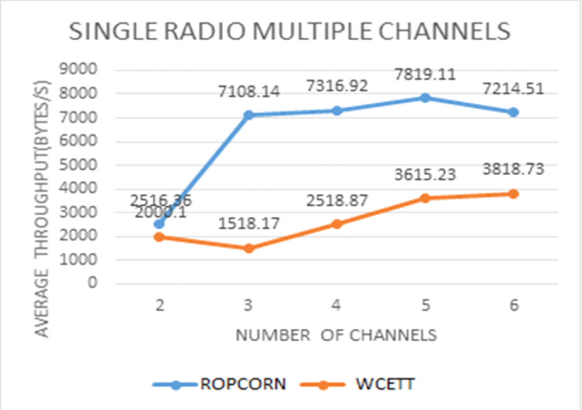

Figure 6. Result for Single Radio and Multi-Channels for ROPCORN and WCETT

It shows the throughput gathered is affected by increasing number of channels. Based on the scenarios created in

DOI 10.17148/IJARCCE.2016.51114

development phase, the results of each experiment were recorded and analyzed. ROPCORN routing protocol provide higher average throughput compared to WCETT routing protocol with single radio multi-channels which is 7819.11. Meanwhile, for WCETT routing protocols, providing 10 nodes with single radio and multi-channels, shows lower average throughput, which is 1518.17. ROPCORN routing protocol has a significant average throughput in single radio multi-channels environment where the average throughput is 10.42 % higher than WCETT routing protocol where the percentage of average throughput for WCETT routing protocols is 4.37%.
As shown in Fig. 7, the summarized results from simulation of scenario 2 which implements equal number of radios and channels for ROPCORN and WCETT routing protocols.

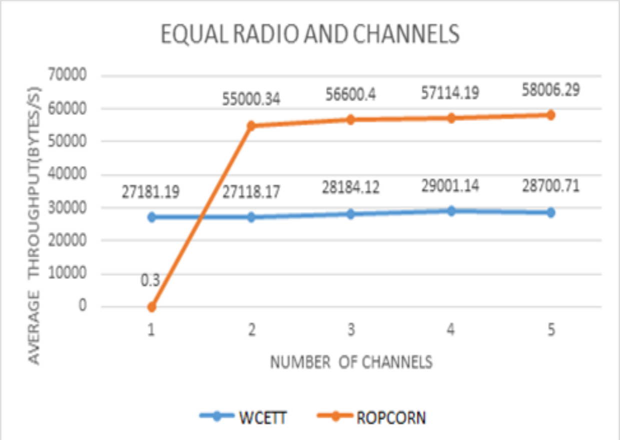

Figure 7. Result for Equal Radios and Channels for ROPCORN and WCETT.

The figure shows the throughput gathered is affected by increasing number of channels. Fig. 7 shows the WCETT routing protocol provide higher average throughput compared to ROPCORN routing protocol which is 58006.29 and 29001.14 respectively.
Fig 8 below is summarized from the simulation of scenario 3 which is multi radios and multi-channels for ROPCORN and WCETT routing protocols.

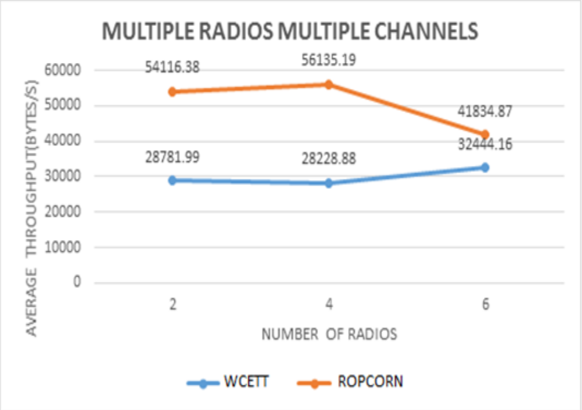

Figure 8. Result for Multi-Radios and Multi-Channels for ROPCORN and WCETT.

The throughput gathered is affected by increasing number of channels. WCETT routing protocol provide higher average throughput compared to ROPCORN routing protocols which is 56135.19 and 32444.16. The results also show WCETT routing protocol has a significant average throughput in multi-radios multi-channels environment where the average throughput is 72.29 % and for ROPCORN is 34.63 %

VII. CONCLUSION

In conclusion, this project meets the objectives, which are to investigate ROPCORN and WCETT routing protocols in CRAHN and analyze the network performance based on the average throughput. Three kinds of routing structure involved which are single radio multi-channels, equal numbers of radios and channels as well as multi-radios multi-channels.
Based on the data collected and observation from three sets of scenarios created, ROPCORN routing protocol is more efficient to be implemented in single radio multi-channels structure. This is due to the increasing of optimal average throughput whereas WCETT routing protocol is more efficient to be implemented in other two routing structures, which is equal number of radios and channels as well as multi-radios and multi-channels.

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