Performance Evaluation of Multi Radio Reactive Routing Protocols in CRAHN

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Abstract: Cognitive radio (CR) has paved the way to exploit the unused licensed spectrum in a judicious and opportunistic way. The class of networks evolved to realize this goal is called Cognitive Radio Ad hoc Network (CRAHN). Establishing effective routes in a CRAHN is an important and challenging task with issues like scattered portions of free spectrum and intermittent activity of licensed users. In CRAHNS multi radio based Dynamic Source Routing (DSR), Ad-hoc On-demand Distance Vector (AODV) and weighted cumulative expected transmission time (WCETT) routing protocols in their multi radio (MR) versions are employed extensively to address the challenge of an optimal route selection for transmission. In this work, we have compared the performance output of MR-DSR, MR-AODV and WCETT protocols on the basis of parameters like average throughput, average end to end delay, jitter and average packet delivery ratio. In the simulation results, MR-DSR has shown least end to end delay and average jitter values. Also WCETT outperforms DSR and AODV in throughput parameter owing to its better route formation strategy for CRAHNS.

Keywords: Cognitive Radio (CR), Multi Radio (MR), Cognitive Radio Ad Hoc Network (CRAHN), weighted cumulative expected transmission time (WCETT).

1. INTRODUCTION

These days wireless ad hoc networks are characterized by a predefined fixed spectrum assignment strategy i.e. the allocation of spectrum is controlled by governmental agencies like Federal Communications Commission (FCC) and is provided to license holders [1]. The spectrum utilization has been seen distributed unevenly on certain portions of the spectrum range while a larger proportion of the spectrum remains unutilized. Dynamic Spectrum Access (DSA) technology has been devised to solve these current problems of underutilization of spectrum [2]. The key operating technology of DSA networks is Cognitive Radio (CR).

CR technology empowers the cognitive users (CU) to be aware of the unutilized portions of spectrum known as spectrum holes and also detect the presence of licensed users (when they become active for transmission known as spectrum sensing). CR aims to choose the best available part of unutilized spectrum (known as spectrum management) in coordination of other CUs accessing the spectrum (known as spectrum sharing), and leave the channel when a licensed or primary user (PU) activity is detected (spectrum mobility) [3]. CR technology has led to the evolution of (CRAHNS) to use the vital spectrum resource more efficiently in an opportunistic manner without interfering in the activity of the PUs [4].

CRAHN architecture, as shown in Fig 1, is divided into two segments, first the licensed or primary network and the CR or secondary network [3]. The primary network comprises of only PUs which are authorized to operate in the allocated spectrum band.

The CR network consists of Cognitive Users (CU) that cannot operate all the time in the spectrum bands as they do not have the license from the spectrum allocating agencies. Hence, they need additional functionalities to opportunistically use the licensed spectrum.

The routing techniques in the ad hoc networks are generally categorized as: table-driven (proactive) and on-demand (reactive) routing [6]. In proactive routing, each node in the network keeps an updated record of routes to all other nodes in the routing table. However, this results into higher bandwidth consumption and greater routing overhead. In reactive routing, the routes are devised only when source node requires it and hence leads to lesser routing overhead as compared to proactive protocols.

In this paper, we compare the performance of DSR [7], AODV [8] in multi-radio multi channel routing scenario and weighted cumulative expected transmission time (WCETT) protocol [14] in CRAHN
based on varying simulation period and simulation parameters. In Remaining part of the paper in section 2, the related work survey is given. In section 3, the routing protocols MR-DSR, MR-AODV and WCETT are discussed. Simulation scenario and obtained results are presented in section 4. Section 5 presents the conclusion drawn from the study and analysis.

II. RELATED WORK REVIEW

Kaushik R. Chowdhury et al. [3] have discussed the basic attributes of CRAHNs and have figured out potential research challenges in them. They have also emphasized on the formation of a common control channel for establishing distributed coordination between CR users. They concluded with a new direction called the commons model to enable the CR users to take decisions about spectrum characteristics prior to transmission and thus manage their own operation.

I.F. Akyildiz et al. [4] have given a briefly reviewed CR technology, its network architecture and its current research challenges. They have also discussed the influence of characteristics like spectrum management, sharing and mobility on the working of protocols in the upper routing and transport layer.

Matteo Cesana et al. in [5] have focused on issues of designing and maintaining of routes in multiple hop CRNs with their strengths and drawbacks. They have figured out the prime challenges for routing in multi hop CRNs as spectrum-awareness, quality routes establishment and finally route maintenance.

S. Selvakannmani et al. [9] have given overview of various ad hoc routing protocols for multiple channel utilization, link modeling, geographic routing, awareness of spectrum and connectivity. They have classified mobile cognitive radio ad hoc network as Infrastructure CR (licensed) and Infrastructure-less CR (unlicensed) components.

Ms. Shubhangini et al. [10] have evaluated the special features of CR networks using AODV and DSDV protocols for the wireless communication. They have also proposed new routing metrics, including transmission delay.

K. Chowdhury et al. [12] have given a distributed CR routing protocol (CRP) for CRAHNs. CRP safeguards the PU communication by protecting sensed PUs explicitly. It enables service differentiation in CRAHNs by providing multiple classes of routes. It also enables joints route and spectrum selection. At the destination node, it reduces the overhead by capturing the spectral information for the intermediate nodes during route formation.

Rafiza Ruslan et al [15] have considered AODV and WCETT routing protocols for the better route selection for transmission from source to destination nodes in CRAHNs. On the basis of average throughput parameter, the performance of AODV and WCETT has been compared in three different kind of routing scenarios: single radio with multi channels, equal number of radio and channel and multi radios with multi channels to fulfill requirements from users.

III. CR REACTIVE ROUTING PROTOCOLS: DSR-MR, AODV-MR AND WCETT

1) Multi Radio Multi Channel DSR (MR-DSR):

In [7] Biaz et al. have put forth the extended version of Dynamic Source Routing (MR-DSR) protocol in multi radio multi hop scenario to cater the scalability issue. The MR-DSR works on the principle of source routing where a source determines the entire hop-by-hop route to destination.

In MR-DSR route discovery and maintenance, work together to establish and maintain those routes from source to destination. Unlike regular DSR, while discovering a route, if source node does not know a route to the destination then it broadcasts a RREQ packet to all its neighbors on all radio interfaces. A RREQ packet consists of the request ID, the source and destination node address and record of the sequence of nodes on path from the source to the destination node.

2) Multi Radio Multi Channel AODV (MR-AODV):

In [8] Multi-Radio Ad-hoc On-demand Distance Vector (MR-AODV) protocol has been developed as an extension to AODV protocol. The MR-AODV makes judicious use of the multi interfaces in multi-radio scenario to enhance spectrum usage and minimize interference to the licensed users in ad hoc networks. In MR-AODV each radio operates on non-overlapping channel for other radios.

Unlike traditional AODV, if a source node does not know the route to destination node then it broadcasts a RREQ packet on all interfaces to its neighbors. Also the hop-count is used as routing metric in MR-AODV as its counterpart in single radio scenario. This implies that MR-AODV always chooses the shortest possible path for communication. If a link fails, the node which detects the link failure generates a Route Error (RERR) packet and transmits it to all of its neighbors which are utilizing the same route for communication.

3) Weighted Cumulative Expected Transmission Time (WCETT) Protocol:

In multi-hop CRNs availability of spectrum bands, quality of links and intermittent PU activities are some key factors that should be considered while designing a routing metric. The expected transmission time (ETT) metric [14] is an efficient routing metric that considers several other factors other than just the summation of values of individual links comprising any route. The WCETT metric is a further improved extension to the ETT metric. WCETT is employed to minimize the intra-flow interference by limiting the number of nodes transmitting on the same channel. Let the total number of channels of spectrum be N then on any
channel \( j \), the sum of transmission time for all hops, \( 1 \leq j \leq N \), can be given as:

\[
X_j = \sum_j \text{ETT}(i)
\]

As the channel with the largest value of \( X_j \) will have maximum effect over total path throughput, which has the authors in [14] have proposed a weighted average in between the maximum value of \( X_j \) and sum of all ETT's. This gives the following equation:

\[
\text{WCETT} = (1 - \beta) \sum \text{ETT}(i) + \beta \max_{1 \leq j \leq N} X_j
\]

Where \( \beta \) parameter can be tuned as \( 0 \leq \beta \leq 1 \). The \( \max_{1 \leq j \leq N} X_j \) value determines intra-flow interference as the paths that have greater channel diversity would have lower value for weights. Hence above equation shows the tradeoff between channel diversity and path latency of path selected.

### IV. SIMULATION AND RESULTS

We consider CRAHN environment with stationary or fixed primary users (PUs) and mobile cognitive users (CUs). It is assumed that the position, the number and the transmission parameters of the PUs are unknown to CUs. We also assume that the channel state information (CSI) is provided by lower layers, and multiple radios for the nodes are tuned to different non overlapping channels. Further MAC layer does the channel assignment.

Here in this work we evaluate the performance of MR-DSR, MR-AODV and WCETT routing protocols under various conditions and different traffic loads. The evaluation is done in Network simulator (NS2.31) with CRCN patch [15]. The NS2 code was extended to support multi radio multi channel. The simulations are carried out with CUs placed in 1000×1000 m area under random topology. We use FTP as traffic source and IEEE 802.11 Mac. Each simulation round varies from 25 seconds to 200 seconds.

Simulation’s parameters are given in the table below:

<table>
<thead>
<tr>
<th>Table 1: Simulation Parameters</th>
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</thead>
<tbody>
<tr>
<td><strong>Topology Area</strong></td>
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<tr>
<td><strong>Channel Type</strong></td>
</tr>
<tr>
<td><strong>Propagation Model</strong></td>
</tr>
<tr>
<td><strong>Radio</strong></td>
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<tr>
<td><strong>Routing Protocol</strong></td>
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<tr>
<td><strong>Interface Queue Type</strong></td>
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<tr>
<td><strong>MAC Protocol</strong></td>
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<tr>
<td><strong>Packet Interval</strong></td>
</tr>
<tr>
<td><strong>Number of CU nodes</strong></td>
</tr>
<tr>
<td><strong>Time of Simulation</strong></td>
</tr>
<tr>
<td><strong>Mobility Model</strong></td>
</tr>
</tbody>
</table>

Following routing metrics have been used for comparing the performance of considered routing protocols in CRAHN for MR scenario.

1) **Average Throughput:**

Throughput is the ratio of amount of data received successfully to the simulation time. Fig 2 shows the impact of increasing simulation period on average throughput. It is observed that, with the increased simulation period, the throughput is rising in value. In comparison, the WCETT gives the highest throughput on average of complete simulation. However, MR-DSR gives better average throughput as compared to MR-AODV. The possible reason can be that the route expiry approach is used in MR-AODV. Following this approach, when the current route expires many packets are dropped and a new route needs to be discovered. This leads to higher drop rates and lower throughput values.

2) **Average End to End Delay:**

End-to-end delay is calculated as the time taken for a data packet to be transmitted successfully from the source to destination across a network.
The comparison of performance results for average end-to-end delay is depicted in Fig. 3. The graph clearly shows that MR-DSR outperforms other two protocols. The WCETT routing protocol records the maximum delay because in its route discovery process, link weights as per formula of WCETT metric are used to find the optimal path. Furthermore factors like loss rate of link, bandwidth, channel diversity and interference are considered for selecting routes. This consumes lots of time and hence increases delay in packet transmission as compared to delay with shortest-path approach in both MR-DSR and MR-AODV. However, since MR-AODV has slower route discovery, it records higher end to end delay than MR-DSR.

3) Average Jitter:

Fig. 4 Average Jitter analysis

Fig 4 shows the performance comparison of the three protocols on the basis of average jitter parameter with respect to simulation period. Jitter is defined as a measure of variability of the data packets latency over time across a network. Average jitter plays a significant role in performances of real-time applications. Lower jitter systems provide better Quality of Service (QOS). MR-DSR performs better than MR-AODV and WCETT protocols for average jitter parameter due to its shortest path scheme and fast route discovery process. Though WCETT obtains better and robust transmission path, it mostly leads to a long length route and hence high average jitter.

4) Packet Delivery Ratio (PDR)

PDR is the ratio of data packets successfully delivered to the destination compared to the number of packets that have been generated by the source. Fig 5 shows the performances of the considered protocols over packet delivery ratio parameter with respect to simulation time. MR-DSR routing protocol has the highest PDR value than the rest of the two due to faster route discovery from the source node to the destination node.

Fig. 5 Average Packet Delivery Ratio analysis

Here, the PDR of WCETT routing protocol is better than MR-AODV routing protocol throughout the simulation.

V. CONCLUSION AND FUTURE WORK

In this work, the on demand routing techniques in CRAHN has been actively researched. An attempt is made to make a comprehensive performance evaluation of MR-DSR, MR-AODV and WCETT routing protocols in CRAHN under FTP traffic using CRCN NS-2 simulator. Performance metrics employed are average throughput, average end-to-end delay, average jitter and average PDR. The simulation results clearly show that MR-DSR has lower end to end delay and jitter statistics which are better than MR-AODV and WCETT that have more complex routing procedures. On the other hand WCETT performs better than MR-DSR and MR-AODV protocols in terms of throughput. So the networks that aim to maximize the throughput should use WCETT protocol.
REFERENCES