A Cross Layer Routing Protocol in CRMANET

Yan Sun, Chris Phillips
Queen Mary University of London
School of Electronic Engineering and Computer Science,
Mile End Road, London, UK
Yan.sun@eecs.qmul.ac.uk, Chris.phillips@eecs.qmul.ac.uk

Jingwen Bai, Liumeng Song, Rina Wu,
Queen Mary University of London
School of Electronic Engineering and Computer Science, Mile End Road, London, UK
jingwen.bai@eecs.qmul.ac.uk,
liumeng.song@eecs.qmul.ac.uk, ee08b361@eecs.qmul.ac.uk

Abstract— *This paper proposes a cross layer routing protocol which operates with Cognitive Radio (CR) Ad Hoc Networks. The new routing protocol exploits the passage of CR performance information from the Physical/MAC layers up to Network layer as contributing factors within the route selection algorithms. The performance of the proposed protocol is investigated via simulations and the results confirm its favorable operation within ad hoc network environments.*

Keywords— *Cognitive Radio,MAC layer, Multi-channel, Internet of things, cross layer, routing*

I. INTRODUCTION

Cognitive Radio (CR) [1] has been identified as one of the promising techniques that is being adopted within wireless research to improve the utilization of scarce spectrum resources. Considerable research work relating to CR networks has been carried out on the physical layer and the, CR performance is improving. In this paper, we propose a novel cross layer routing protocol in CR Ad Hoc mobile Networks (CRAHN). With perfect knowledge of frequency usage data from the Physical layer, the Network layer works efficiently together with MAC layer to provide suitable path selection and multi-channel allocation for data forwarding and transmission.

The rest of the paper is organized as follows: Section II gives the overall cross layer design and route selection scheme. The implementation and simulation results are evaluated in Section III and conclusions are presented in Section IV.

II. CROSS LAYER DESIGN AND ROUTE SELECTION SCHEME

A. Cross layer protocol design

In this paper, the proposed routing protocol takes suitable sub-channel information of each hop into account. With the sensing capability of each node, the condition of all sub-channels between two neighbours will be fully captured and the information will be forwarded from the Physical layer to MAC and Network layers via the cross layer mechanisms in each node.

B. Routing inforamtion collection and maintainace

After each sensing activity, the corresponding SNR value for each sub-channel pair are also calculated and saved in the neighbor tables. Let $SNR_{c_j}^{ik}$ denote the SNR of sub-channel c_j between node i and node k.

$$SNR_{c_j}^{ik}(dB) = 10.0 \times \log 10\left(\frac{P_{rcvd}^{k}}{N_{accum}^{ik} + N_{bkg}^{ik}}\right)$$

Let SNR_{th} be the SNR threshold. SNR_{th} is an empirical value in this scenario. If $SNR_{c_j}^{ik} \geq SNR_{th}$, it will be included within the available sub-channel list.

C. Route selection scheme and algorithm

Every intermediate node will add the following two information into the message before re-broadcasting Route Request Broadcast Query (RRBQ): n_{ij} (CHAN) which is number of available sub-channels between node n_i and node n_j, n_{ij} (TICKS) indicates the associativity ticks of each neighbor for this node [2].

The destination node, instead of immediately responding to the first RRBQ message to arrive, waits for a certain time for all possible RRBQ messages to reach it via different routes. The destination will then run the following algorithms to achieve the measures identified:

Let $\theta_{\partial}(\mathrm{CHAN})$ denote the mean value of the available channels per hop for each RRBQ, and let $\theta_{\partial}(\mathrm{TICKS})$ denote the mean value of the available channels per hop for each RRBQ, the selected route, denoted as Path ρ, should have the greatest mean number of available channels per hop, as shown below,

$$\text{Path } \rho = \max\{\theta_1(\mathrm{CHAN}), \theta_2(\mathrm{CHAN}), \dots, \theta_\delta(\mathrm{CHAN})\}$$

But if $\theta_{\partial}(\mathrm{CHAN})$, $\partial = 1, 2, \dots, \delta$ are all equal to each other, then the path with largest mean value of associativity ticks per hop (i.e. the most stable route) should be the preferred choice, as shown below

$$\text{Path } \rho = \max\{\theta_1(\mathrm{TICKS}), \theta_2(\mathrm{TICKS}), \dots, \theta_\delta(\mathrm{TICKS})\}$$

III. SIMULATION AND EVALUATION

We adopt Opnet as the simulation platform. 802.11a is chosen as the wireless access technology for the Physical layer in the CRMANET supporting OFDM.

Figure 1 show the CRMANT topologies used for the first scenario. The hop between the source node and destination node in these scenario increases from two to five. There is one source-destination pair in the network, which are node_0 and node_1, respectively.

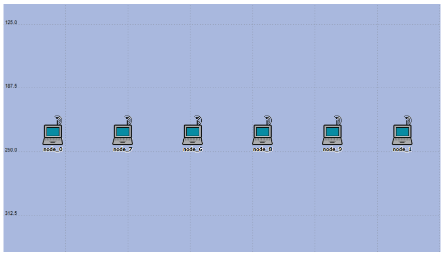

Figure 1 CRMANT Topology 2 – Five Hops without Interference

The throughput results and delay are measured at the destination node_1 and results are shown in Figure 2 and Figure 3.

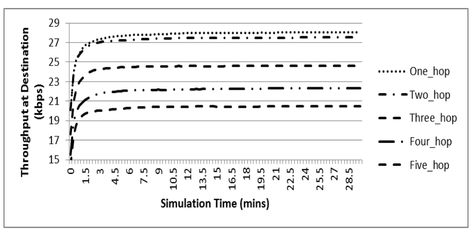

Figure 2 Throughput at the Destination

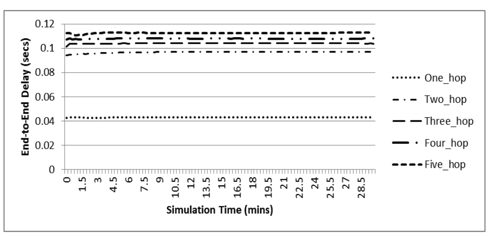

Figure 3 End-to-End Delay

The throughput drops a little when the hop count increases to 2 but decreases greatly when more hops are involved. Throughput reduces by around 30% when there are five hops between source node and destination node. Therefore we can observe that a maximum four hops can be accommodated in order to guarantee around 80% throughput.

The delay results show that when the hop counts is more than two, the end-to-end delay increases dramatically. The big "jump" is because of the ACK scheme employed in this simulation. A longer ACK waiting time would be more suitable if more hops are involved to avoid unnecessary retransmissions. However, this results in greater end-to-end delay.

In the second key scenario node_2 and node_3 are within direct transmission range close to node_7. Similarly, node_4 and node_5, node_10 and node_11 form another two pairs of nodes that are close to node_9 and node_8, respectively. Their purpose is to introduce interference in nearby nodes.

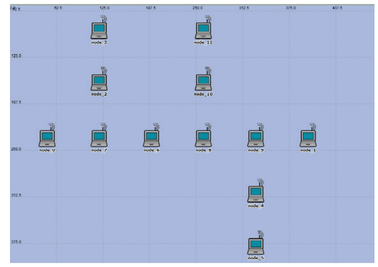

Figure 4 CRMANT Topology 3 – Five Hops with Interference

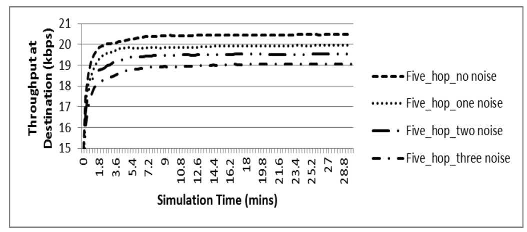

Figure 5 Throughput of Five_hop in a Noisy Environment

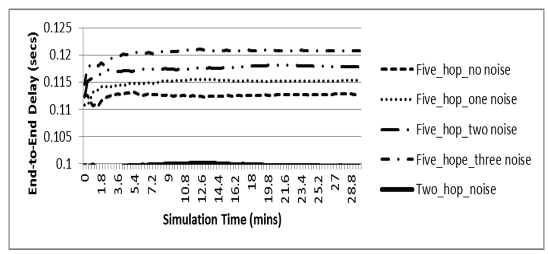

Figure 6 End-to-End Delay of Five_Hops in a Noisy Environment

The throughput results show that although the performance drops when noise affects more nodes along the route, around 90% throughput can still be obtained in this scenario when there are no broken links.

The end-to-end delay results show no big variation due to the same hop counts. However, due to the inference introduced by the nearby nodes, retransmissions happen in the MAC layer so the overall delay variation is less than 10%.

IV. CONCLUSION

This paper proposed a cross layer routing protocol for CRMANET that allows the route selection algorithm to benefit from real time radio sensing results. In general, introducing more hops will degrade both the throughput and end-to-end delay but the performance is well maintained even when the noise environment becomes severe.

REFERENCES

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