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IIBC The Institute of Internet, Broadcasting and Communication

IPACT The International Promotion Agency of Culture Technology

Preface

We would like to welcome you to the proceedings of the First International Symposium on Advanced and Applied Convergence (ISAAC 2013) and the First International Conference on Advanced Culture Technology (ICACT 2013), which was held on November 14-16, 2013, at The Korea Science and Technology Center, Gangnam, Korea.

ISAAC 2013 is focused on various aspects of advanced and applied convergence, and ICACT 2013 is focused on fields of culture technology. It provided a chance for academic and industry professionals to discuss recent progress in the related areas. We expect that the conference and its publications will be a trigger for further related research and technology improvements in this important subject. We would like to acknowledge the great effort of all the Chairs and members of the Editorial Committee.

We would like to express our gratitude to all of the authors of submitted papers and all the attendees for their contributions and participation. We believe in the need for continuing this undertaking in the future.

Lastly, we would like to thank all the organizations and individuals who supported and contributed as a whole and, in particular, for the success of ISAAC 2013 and ICACT 2013

November 2013

Jeong Jin Kang on behalf of the Volume Editors

Foreword

Advanced and Applied Convergence & Advanced Culture Technology are areas that attracted many academic and industry professionals to research and develop. The goal of this conference is to bring together the researchers from academia and industry as well as practitioners to share ideas, problems and solutions relating to the multifaceted aspects of Advanced and Applied Convergence & Advanced Culture Technology.

We would like to express our gratitude to all of the authors of submitted papers and to all attendees for their contributions and participation. We believe in the need to continue this undertaking in the future.

We acknowledge the great effort of all the Chairs and the members of Editorial Committee of the above-listed event. Special thanks go to KOFST (The Korean Federation of Science and Technology Societies) for supporting this conference.

We are grateful in particular to the speakers who kindly accepted our invitation and, in this way, helped to meet the objectives of the conference.

November 2013

Chairs of ISAAC 2013

ICACT 2013

Routing Protocol for Prolonging Network Lifetime in Ad Hoc Cognitive Radio Networks

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Abstract

In this paper we propose a power and spectrum aware routing protocol for mobile ad hoc cognitive radio networks for prolonging network lifetime. The proposed protocol selects next hop with the help of spectrum availability information received from MAC layer. This protocol also distributes packet forwarding workload to the neighboring nodes so that nodes battery deplete slowly. Simulation results show that the proposed protocol extends network lifetime maintaining higher data delivery ratio.

Keywords: *Cognitive radio networks, routing protocols, cross-layer, network lifetime.*

1. Introduction

In cognitive radio networks, protection of primary user (PU) is a primary concern. Therefore, secondary users (SUs) have to evacuate channel immediately whenever PU claims the channel currently using by SUs. However, in the routing layers prospective, if a SU is in active PU's area, it has not necessarily detour the route, instead the SU has to change the channel. Although some of the works in the literature change the route[1]. Of course rerouting is very costlier in terms of delay, frequent channel switching is also costlier.

In CRNs, spectrum available in one geographical location may not be available in another geographical location. Therefore, it is necessary for the cognitive ad hoc routing (CRAR) protocols to get spectrum information from MAC layer to calculate the route cost. To explain the reason, a simplest scenario described here.

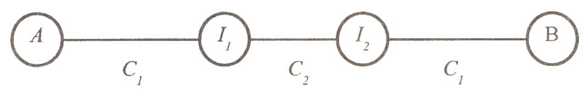

Figure 1.A simple four nodes ad hoc networks scenario.

Let's assume that there are four SUs in a single plane, sender node (A), intermediate nodes (I) and destination node (B) as in Figure 1. Each node has only one idle common channel. When I_1 receives packet from node A in channel C_1, it has to tune its transceiver to the channel C_2 to forward the packet to I_2. Again, it has to switch back to the channel C_1 to receive another packet. Although, channel selection and channel switching is a MAC layer issue, switching channel for each packet is costlier in terms of delay, especially to the CR node that has only one or two transceivers.

This situation can be worst if the intermediate node has to forward packet for different destinations. Nodes have to switch channel several times and delay may increases exponentially, leading to channel bottleneck problem. Therefore, if we can include spectrum availability related parameter in route cost, the channel switching delay due to frequent channel hopping can be mitigated.

2. Related works

There are several routing protocols for cognitive radio ad hoc networks in the literature. Cesana et al. [2] discussed challenges and solutions in cognitive radio networks. Authors also categorized the cognitive routing schemes in to full spectrum knowledge-based routing and local spectrum knowledge based routing.

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Salim and Moh[3] reviewed some of the routing protocols for cognitive radio ad hoc networks. Zhang et al. [4] classified and analyzed some of the existing routing protocols compared their characteristics. Joshi et al. [5] also described some of the routing related issues in cognitive radio wireless sensor networks.

3. Proposed approach

Due to the dynamic nature of the arrival of the primary users the number of available channel in the multichannel scenario can vary. The primary users can claim the channel any time. Therefore we calculate the stability factor of each channel. It can be calculated as how often the primary comes in a particular channel. Once they arrive how long they occupy the channel. It depends upon the frequency of the arrival of the PU in the channel as well as the dwelling time of the PU in the channel. The total idle time t_i is calculated by summing up all the idle periods of channel from the time when the CRN nodes joins the networks in a particular area. Considering the average sum of idle time (t_ε) and the stability S_n, time in which the SU can use the channel can be calculated, we can identify the channel which are vacant and rank them. A predefined threshold is set for the S_n factor. If S_n is maximum then the predefined threshold value then the channel is ranked as highly preferred channel. If this value is less than the maximum value but higher than the threshold value then it is considered as the medium. If the value is less than the threshold then that channel is discarded. As random channel selection is costlier in terms of channel switching delay, the commonality of the channel between the nodes needs to be considered to avoid the channel switching.

The channel stability S_n is calculated as in Eq. (1).Every time the channel changes from the OFF to the ON state the value of stability S_n recalculated and new updates is stored. The higher the value of S_n, the more stable the channel.

Therefore, we calculate the stability and idle time as

$$S_n = \delta t_{n-1} + (1-\delta)t_\varepsilon \qquad (1)$$

Where,t_{n-1} is the idle period in the immediate last measurement, δ is the smoothing factor and t_ε is the average of the sum of idle time period. $t_\varepsilon$is calculated as

$$t_\varepsilon = \frac{\sum_{i=1}^{N} t_i}{N} \qquad (2)$$

Where,t_i is the length of the idle period of the channel in the i^{th} measurement and N is the number of idle period from the time when CR node joins the networks and performs sensing.

The proposed protocol calculates cost of route considering (i) number of available stable common channels, (ii) residual battery of the node, and (iii) number of hops to the destination. The cost of a node according to residual battery will be calculated as

$$Cb_{CR_i} = \left(\frac{b_{CR_i}^{\max}}{b_{CR_i}^{res}(t)} \right)^{\beta} . \qquad (3)$$

Where, Cb_{CRi} is the cost due to the battery capacity of cognitive radio node CR_i, b_{CRi}^{max} is full capacity of the battery of node i, $b_{CRi}^{res}(t)$ is the residual battery capacity of the CR_i, and β is the waiting factor.

A source node that has packets to send starts broadcasting RREQ packet. Once an intermediate SU node receives RREQ packet, if the SU has no route to the destination in its cache, the SU node rebroadcasts the packets. Also, the SU drops the RREQ, if it has already broadcasted the RREQ with the same sequence number and sender ID. Each intermediate SU calculates link cost from its own Cb_{CRi}, and number of available common stable channels (S_n) as in Eq. (1). The cost is calculated in Eq.(4)

$$C_l = \alpha . S_n + \left(\frac{b_{CR_i}^{max}}{b_{CR_i}^{res}(t)} \right)^{\beta} \qquad (4)$$

Where, C_l is the link cost, $\alpha$is the waiting factor. Intermediate SU nodes add this in to the path cost in the header of the RREQ packet.

When an intermediate SU node receives a RREQ packet, it starts a timer and keeps the cost in the header of that packet as minimum cost (C_{min}). If additional RREQs arrive with same destination and sequence number, the cost of the newly arrived RREQ packet is compared to the C_{min}. If the new packet has a lower cost, C_{min} is changed to this new value and the new RREQ packet is forwarded. Otherwise, the new RREQ packet is dropped.

After the first packet received destined to it, the SU starts timer and waits for other RREQs. After the timer expires, the destination SU compares route. The node generates RREPs with the route with minimum cost. The route cost is calculated as in Eq. (5).

$$Route\_Cost = \sigma \cdot h_n + \sum_{\forall Nodes\_in\_Route} C_l \quad (5)$$

Where, h_n is the number of hope and σ is the waiting factor.

Node generates RERR packets to start route maintenance. Energy depletion, node mobility and no common channel available between two intermediate nodes (i.e. occupied by PUs) are the main reason for route maintenance.

SU search for the available number of stable channel that has the higher value. If it does not find the most stable one then search for the lower ones. The SU generates the RERR message immediately if the number of available stable common channels are zero, however, if the difference between current cost Cb_{CRi} and route discovery time is higher than the given threshold value or the number of available common channels in between two intermediate nodes is zero, the SU generates RERR packet after t time to inform the source that the route is invalid. This is because frequent route invalidation is expensive in terms of delay and throughput. After receiving RERR packet, source starts re-routing. This strategy of generating RERR considering difference between current cost Cb_{CRi} and cost at the route discovery time, balance load among SU nodes by enforcing route change. Therefore, it extends the network lifetime.

4. Simulation Results

In the present work, we extend the ns-2 [6] for cognitive radio. The network consists of 100 nodes confined in a 1000×1000m^2 area. Transmission range of each node is assumed 50m. The simulation runs for 10000 seconds. CBR traffic is generated over UDP with generation rate of 10 packets per second. Packet size is 1024 bytes. Nodes have a limited mobility of 5 m/sec. Each simulation is run for 10 times and averaged values are presented in the graphs. Number of licensed channels available for the opportunistic use is set to 10. PUs use the ON/OFF arrival model. We used CR-MAC protocol [7]. There are 3 flows from the random sources.

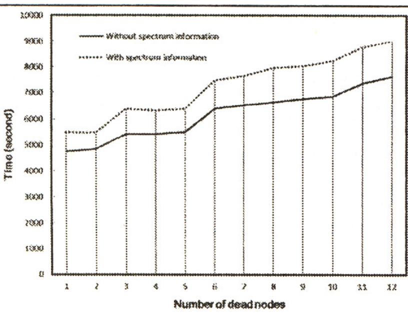

Figure 2. Number of dead nodes with and without spectrum information.

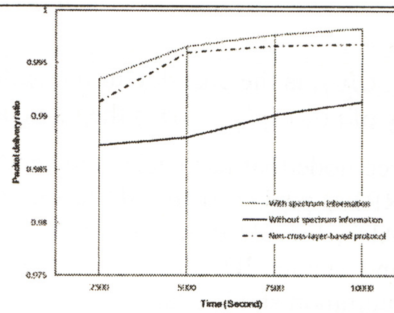

Figure 3. Packet delivery ratio.

Packet delivery ratio and SUs lifetime are evaluated as a quantitative metrics for evaluating the performance of the proposed protocol. Because, there is no de facto standard protocol to compare with the proposed protocol, therefore we compare with the proposed protocol (i.e. protocol with spectrum information), protocol without spectrum information and non-cross-layer-based protocol.

Figure 2 shows the number of dead nodes with and without spectrum information. First node without spectrum information dies at 4751 second after the simulation starts, however first node dies at 5492 second. The later nodes energy depletion rate is higher in without spectrum information.

Figure 3 shows the packet delivery ratio. This is calculated as the number of packets received by destination through the number packets originated from source. The results show that the proposed protocol with the spectrum information achieves higher packet delivery ratio than the without spectrum information and non-cross-layer-based protocol. It is because of the reason explained in the introduction; the proposed protocol has to switch the channel less than the other two approaches.

6. Conclusion

In this work we presented a power and spectrum awarerouting protocol for cognitive radio networks. Because rerouting is expensive in terms of delay and throughput, it is better to select a route that has less probability of PUs arrival. Also, excessive workload on a particular node cause network partitioning and leads to the rerouting. This protocol incorporates power awareness and spectrum information with cross-layer approach.

Acknowledgement

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References

[1] Bandyopadhyay P. *Routing in Cognitive Radio Ad-Hoc Networks,* Report, University of Helsinki, Helsinki, Finland

[2] M.Cesana, F. Cuomo, and E. Ekici, "Routing in cognitive radio networks: Challenges and solutions, "*Ad Hoc Networks*, Vol. 9, No. 3, pp. 228-248, 2011.

[3] S. Salim, and S. Moh, "On-demand routing protocols for cognitive radio ad hoc networks, "*EURASIP Journal on Wireless Communications and Networking*, Vol. 2013, No. 1, pp. 1-10, 2013.

[4] L. Zhang, X.W. Zhou, and J.P. Wang, "Routing Protocols for Cognitive Radio Networks: a Survey, "*Journal of Chinese Computer Systems*, Vol. 31, No. 7, pp. 1254-1260, 2010.

[5] G. P. Joshi, S.Y. Nam and S. W. Kim, "Cognitive Radio Wireless Sensor Networks: Applications, Challenges and Research Trends, "*Sensors*, Vol. 13, No. 9, pp. 11196-11228, 2013.

[6] The network simulator. Available online: http://www.isi.edu/nsnam/ns/.

[7] G. P. Joshi, S.Y. Nam and S. W. Kim, "Decentralized Predictive MAC Protocol for Ad Hoc Cognitive Radio Networks", *Wireless Personal Communications*, pp. 1-19. doi: 10.1007/s11277-013-1322-6, July 17, 2013.