Far East Journal of Electronics and Communications

Published: December 2016
http://dx.doi.org/10.17654/EC016040889
Volume 16, Number 4, 2016, Pages 889-895 **ISSN: 0973-7006**

CHANNEL SELECTION SCHEME IN MULTI-HOP AND MULTI-CHANNEL COGNITIVE RADIO NETWORKS

Young-Min Kwon and Hyung-Kun Park

Information and Communication Eng. DGIST, South Korea

School of Electrical, Electronic and Communication Engineering
KOREATECH, South Korea
e-mail: hkpark@koreatech.ac.kr

Abstract

In cognitive radio networks, it is important to efficiently use spectrum resources without causing interference to the primary user. In multi-hop routing, collision with the primary user and interlink interference can reduce system throughput. Also, channel selection is an important issue in multi-channel cognitive radio networks. In this paper, we propose a channel-selection scheme to reduce the collision rate and interlink interference in multi-hop and multi-channel cognitive radio networks. We evaluate the proposed channel-selection scheme using extensive simulation, and simulation results show that the proposed scheme can reduce the collision rate and obtain higher network throughput.

1. Introduction

Cognitive radio (CR) technology is expected to solve the problem of spectral limitation by exploiting the spectrum hole in conventional wireless

Received: August 31, 2016; Accepted: October 7, 2016
Keywords and phrases: cognitive radio, multi-hop, channel selection, multi-channel, interlink interference.
Conference held during June 23-25, 2016 in Novotel Danang Premier Han River, Danang, Vietnam.

networks [1-3]. CR users monitor the spectrum owned by licensed users, who are also called the *primary users* (*PUs*), to find and exploit the spectrum hole for communication. To efficiently utilize the spectrum holes, channel allocation is an important issue, and it must be designed to minimize interference to the primary network.

Ad-hoc networks have advantages that they can make arbitral networks independent of other networks and that their nodes can join and drop the network freely [4]. Also, ad-hoc CR networks can be applied to various wireless services. Generally, ad-hoc CR networks have short transmission ranges and establish a mesh network that requires multi-hop transmission [5].

In multi-hop CR networks, routing and channel selection are important technical issues, and significant research has been done on this topic. Opportunistic spectrum access MAC [6] proposed opportunistic channel selection in a multi-channel environment, and the opportunistic cognitive MAC using spectrum-hole prediction was also proposed [7]. These channel selection protocols are not for multi-hop transmission but mainly for the single link. In this paper, we consider both multi-hop routing and channel selection to reduce collision with primary users and interlink interference.

2. Interference-aware Channel Selection

In a single-channel mesh network, adjacent links interfere with each other. Therefore, adjacent links cannot transfer data simultaneously and network throughput can be reduced [8]. Figure 1 shows an example of multi-hop routing and link interference, where the dotted lines show interference between links, and the links connected by dotted lines cannot transmit data simultaneously.

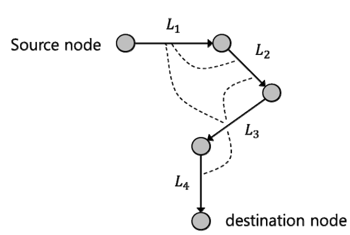

Figure 1. Multi-hop routing and link interference.

We assume that the maximum capacity C can be obtained if there is no interlink interference. If there is interlink interference, then interference-free links can form a group, and the number of groups is represented by N_G. Then the maximum capacity R can be described by $R = C/N_G$. Links in the same group can be used simultaneously without link interference, but links in different groups have link interference with each other and cannot be used simultaneously; this can reduce the overall capacity. As the number of groups becomes smaller, a higher capacity can be obtained.

Multi-channel networks provide various combinations of transmission channels for a multi-hop network. Channel combinations should be selected to minimize interlink interference. The number of available channel combinations is given as:

$$N_T = \prod_{j=1}^{N_H} N_{F_j}, \quad (1)$$

where N_{F_j} is the number of available channels in the jth link and N_H is the number of hops. A channel combination to minimize interlink interference can provide the maximum capacity and maximize network throughput. Figure 2 shows interlink interference in a multi-channel network.

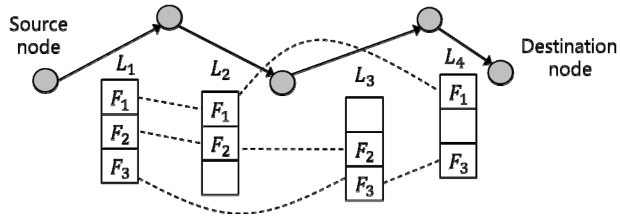

Figure 2. Interlink interference in a multi-channel network.

3. Link Classification and Routing Path

In multi-hop transmission, conventional routing protocols select the path with the minimum hop count, but interference to the primary network is the most important issue in a CR network. Each link can have a different probability of PU appearance, and the routing path should be selected to minimize the interference to the PUs. In this paper, we classify links into two groups: safe and danger links. A safe link has a low probability of PU appearance and a lower interference than the required interference level. A danger link implies that the probability of PU appearance is higher than the threshold, λth, and the interference to PU exceeds the network requirement.

When we select a channel combination, there are two cases: the first case is that there are only safe links in the routing path. In this case, only the number of interference-free groups is considered to select the channel combination. We look for a channel combination with the minimum N_G because the probability of PU appearance is small enough to ignore the collision.

The second case is where danger links exist in the routing paths. If there are danger links and they cannot be evaded, then we should select channels that have the minimum number of danger links because minimizing interference to the primary network is the most important performance issue in a CR network. If the number of danger links is same, similar to the first case, then we look for a channel combination that has the minimum N_G.

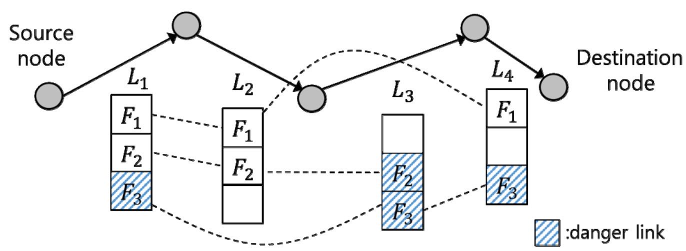

Figure 3. Routing path with danger links.

Figure 3 shows a case where danger links exist and they cannot be evaded. In this case, the total number of possible channel combinations is 24. The number of channel combinations with the minimum number of links among the 24 combinations is eight. Each of the eight combinations has only one danger link. Of the eight candidate combinations, one combination has the minimum N_G : $\{F_1, F_2, F_3, F_1\}$.

4. Simulation and Results

To evaluate the performance of the proposed channel-selection scheme, the proposed scheme and random channel selection were simulated. Figures 4 and 5 show the channel capacity according to the hop count and number of channels, respectively. As shown in Figure 4, the throughput decreases with increasing hop count. Figure 5 shows that as the number of channels increases, the probability of the proposed scheme to select better channels increases. A better channel is the one with a lower probability of PU appearance and lower interlink interference. Also, as shown in Figures 4 and 5, the proposed scheme has a higher throughput than random selection.

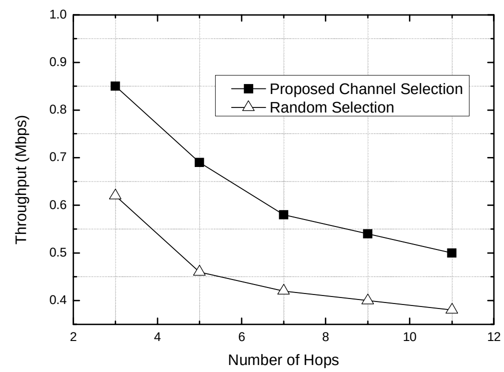

Figure 4. Throughput performance according to the number of hops.

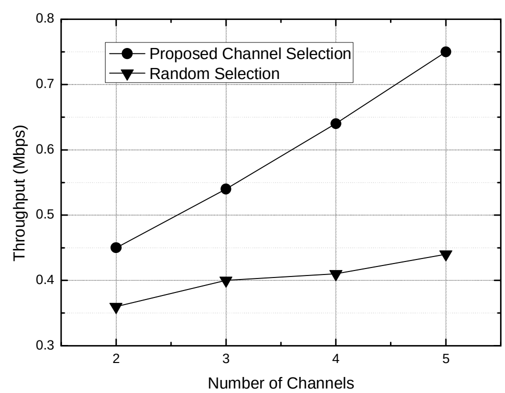

Figure 5. Throughput performance according to the number of channels.

Figure 6 shows the collision rate with PUs. In CR networks, interference to the PU may be a serious problem, and minimizing such interference level is the most important requirement. In random selection, a large number of hops can increase the collision rate, whereas the proposed scheme can avoid danger links and shows almost the same collision rate regardless of the number of hops. As the number of hops increases, the difference between the collision rates of the proposed scheme and random selection increases.

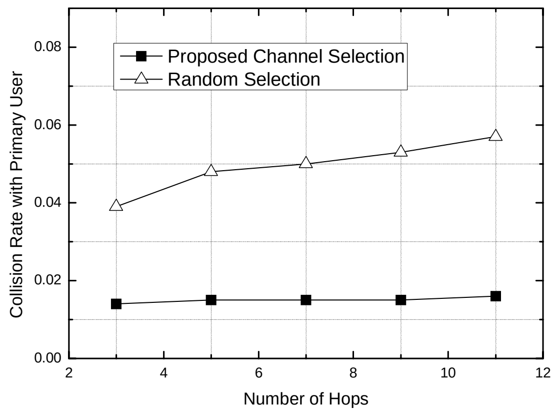

Figure 6. Collision rate according to the number of hops.

5. Conclusion

In this paper, a channel selection scheme was proposed by considering the probability of PU appearance and interlink interference in multi-hop and multi-channel cognitive radio networks. To reduce the collision rate with the PU, links are classified into two types: safe and danger links. When the routing paths are established, the proposed routing and channel selection scheme minimizes the danger link in the routing path and minimizes interlink interference to increase capacity. Simulation results show that the proposed channel selection scheme can increase throughput and reduce the collision rate with primary users.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0021164).

References

[1] J. Mitola and G. Q. Maguire, Jr., Cognitive radio: making software radios more personal, IEEE Pers. Commun. 6(4) (1999), 13-18.

[2] S. Haykin, Cognitive radio: brain-empowered wireless communications, IEEE J. Sel. Areas Commun. 23(2) (2005), 201-220.

[3] Hiep Vu-Van and Insoo Koo, Optimal sensing time for maximizing the throughput of cognitive radio using superposition cooperative spectrum sensing, J. Inf. Commun. Converg. Eng. 13(4) (2015), 221-227.

[4] S. Basagni, M. Conti, S. Giordano and I. Stojamenovic, Mobile Ad Hoc Networking: The Cutting Edge Directions, 2nd ed., John Wiley & Sons, Hoboken, NJ, 2013.

[5] W. Y. Shin, Performance evaluation of parallel opportunistic multihop routing, J. Inf. Commun. Converg. Eng. 12(3) (2014), 135-139.

[6] Long Le and Ekram Hossain, A MAC protocol for opportunistic spectrum access in cognitive radio networks, Proc. IEEE Wirless Commun. Net. Conf., 2008, pp. 1426-1430.

[7] S. Y. Hung, Y. C. Cheng, E. H. K. Wu and G.-H. Chen, An opportunistic cognitive MAC protocol for coexistence with WLAN, Proc. IEEE Int. Conf. on Commun., 2008, pp. 4059-4063.

[8] Z. Jia, R. Gupta, J. Walrand and P. Varaiya, Bandwidth guaranteed routing for ad-hoc networks with interference consideration, Proc. IEEE Symp. on Comp. and Commun., 2015, pp. 3-9.