Poster: A Simulation Analysis on the Hop Count of Multi-hop Path in Cognitive Radio Ad-hoc Networks

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ABSTRACT
The number of hops between source node and destination node is one of key parameter in studying multi-hop ad-hoc networks. Although hop count in conventional ad-hoc networks has been well studied, to the best of our knowledge, there have no works that intensively investigate the hop count of multi-hop path in cognitive environment. This paper presents detail simulation analysis on the hop count of multi-hop path in Cognitive Radio Ad-hoc Networks (CRAHNs). The effect of network parameters such as node density of Secondary User (SU) and Primary User (PU), operating frequencies, average activating rate of PUs, in the networks are studied. Simulation experiments with different network parameters are conducted to clarify the features of hop count in cognitive ad-hoc networks.

Categories and Subject Descriptors
C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *Network Topology*

General Terms
Performance, Measurement, Verification

Keywords
Cognitive Radio Ad-hoc Networks, Multi-hop Paths, Hop Count

1. INTRODUCTION
Wireless ad-hoc network is a collection of wireless nodes which dynamically form a network without relying on any infrastructure. The network is formed as soon as one of wireless nodes wants to communicate with one or more of the other nodes. The routing paths in wireless ad-hoc network are often multi-hop paths because destination node is usually out of the transmission range of source node. Thus, before reaching the destination the packets travel through some intermediate nodes between source node and destination node.

The hop count specifies the number of hops on the path between source node and destination nodes. The study of the hop count of multi-hop path in wireless ad-hoc networks is very important because it can provide evaluation of the networks performance such as: (i) estimation of the delivery ratio of packets, (ii) estimation of end-to-end-delay if per hop delay is known, (iii) estimation of network traffic if the number of simultaneous communication flows is given, (iv) determining the flooding cost and search latency of route stabling process in routing protocols, (v) studying of connectivity and capacity of multi-hop path.

Many studies have been carried out to analyze the hop count of multi-hop path in conventional ad-hoc network by using both mathematical analysis approach and simulation approach [1-4]. These works give us an insight into how hop count is influenced by major network parameters such as node density, node mobility.

Recently, CRAHNs have already received much attraction from researchers. One of main research topic in CRAHNs is routing protocol and its challenges in cognitive environment [5]. Because of the presence of PUs in the networks, routing in CRAHNs takes more effort than in conventional AHNs which results in different values of hop count.

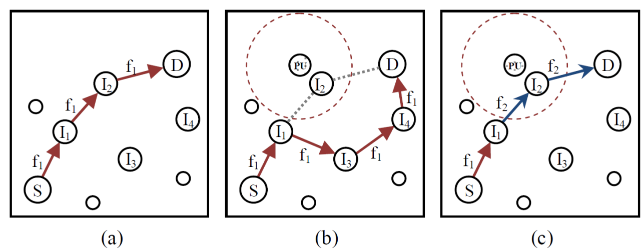

Figure 1. Routing challenges in CRAHNs compared with conventional AHNs; (a) Routing in AHNs, (b) Rerouting and (c) Switching frequency channel of affected wireless link.

The contribution in this paper is to find out the relation patterns of hop count with network parameters in cognitive ad-hoc networks.

2. ON THE CHARACTERISTICS OF HOP COUNT IN COGNITIVE RADIO AD-HOC NETWORKS
For better illustration, we provide several examples of network topologies to show how cognitive environment influences the hop count of multi-hop path in CRAHNs.

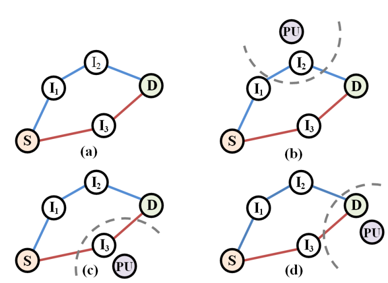

Figure 2. Different PU locations result in different hop counts.

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As we can see in Fig 2, when no active PUs influences all wireless links as in Figure 2(a) or influence wireless links of I_2 as in Figure 2(b) the shortest path is still $S \rightarrow I_3 \rightarrow D$ whose hop count is 2. When an active PU locates near I_3 as in Figure 2(c) the new shortest path is $S \rightarrow I_1 \rightarrow I_2 \rightarrow D$ whose hop count is 3. In the worst case, when an active PU locates near S or D as in Figure 2(d), multi-hop path between S and D cannot be established. In summary, the hop count depends on the locations of active PUs. It also depends on number of PUs, radio ranges of SUs and PUs (corresponding to operating frequencies).

3. RESULTS AND DISCUSSIONS

In this section, the simulation results of average hop count of multi-hop path in CRAHNs are presented and discussed. To obtain the average hop count, we use MATLAB to generate 10000 random network topologies of CRAHNs with different settings of network parameters such as SU and PU density, the average activating rate of PUs, the number of licensed frequency channels. Number of SUs = 50 and different number of PUs in network area of 1500 m × 1500 m. Node transmission power $P_t = 10^{-3}$ W, reception power threshold $P_{th} = 1.58 \times 10^{-12}$ W.

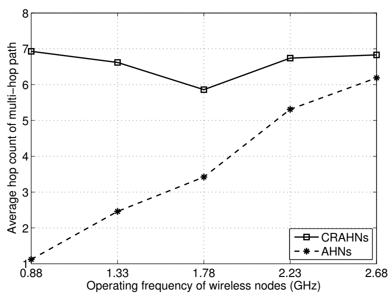

Figure 4. Average hop count of multi-hop path in CRAHNs compared with that in CRAHNs as a function of operating frequency; network size a = 1500m, one frequency layer with f = 0.88 GHz ~ 2.68 GHz.

Figure 4 shows that the average hop count in CRAHNs is high when operating frequency is low (large radio range). Because of the effect of PU's presence in SU's radio range, the average hop count decreases then increases as operating frequency increases. This feature does not appear in AHNs.

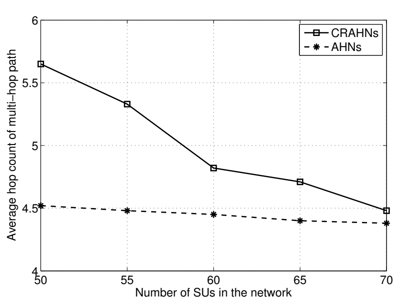

Figure 5. Average hop count of multi-hop path in CRAHNs compared with that in CRAHNs as a function of SU density; network size a = 1500m, number of PUs = 5, PU's activating rate = 0.1, one frequency layer with f = 2.4 GHz.

Figure 4 shows the average hop count in CRAHNs remarkably reduces compared with that in AHNs as SU density increases.

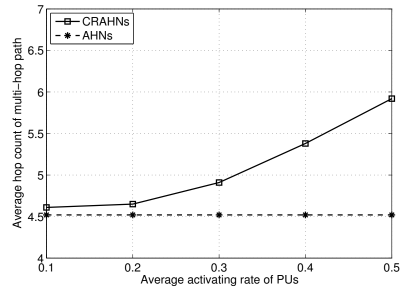

Figure 6. Average hop count of multi-hop path in CRAHNs compared with that in CRAHNs as a function of PU's average activating rate; network size a = 1500m, number of SUs = 50, number of PUs = 5, one frequency layer with f = 2.4 GHz.

Figure 6 shows that the average hop count in CRAHNs is greatly affected by the average activating rate of PUs, while in AHNs it is almost constant because of having no PUs in the networks.

4. CONCLUSIONS

In this paper, we investigate in detail the characteristics of hop count in cognitive radio ad-hoc networks. We perform intensive simulation with different network parameters. The simulation results show that depending on specific locations of active PUs, hop count in cognitive radio ad-hoc network may greater or equal to the hop count in conventional ad-hoc network. Moreover, from the simulation results we can conclude that different network parameters, such as SU and PU density, average activating rate of PUs, and the distribution of PUs on each frequency layers result in different average hop count of multi-hop paths in CRAHNs.

5. ACKNOWLEDGMENTS

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