IJCSE International Journal of Computer Science and Engineering Open Access
Research Paper Volume-2, Issue-1 E-ISSN: 2347-2693

Neighbor Discovery in Distributed Heterogeneous Wireless Networks using Cognitive Radio

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www.ijcseonline.org

Received: 11/01/2014 Revised: 18/10/2014 Accepted: 28/01/2014 Published: 31/01/2014

Abstract— In many wireless networks, each node has direct radio link to only a small number of other nodes, called its neighbors. Before efficient routing or other network-level activities are possible, nodes have to discover and identify their neighbors. This is called neighbor discovery. By neighbor discovery, every node tries to determine the set of nodes it can communicate within one wireless hop Fast and efficient discovery of all neighboring nodes by a node new to a neighborhood is Essential and critical to the deployment of wireless networks. The recently emerged technology Cognitive radio (CR) has a promising approach to improve the available spectrum utilization efficiency so as to meet the increased demand for wireless communication, which attempts to search for unused or underutilized channels in the spectrum by scanning the part of wireless spectrum.

Index Term—Cognitive Radios, Neighbor Discovery, Heterogeneous Network

I. INTRODUCTION

The first step in configuring and managing a wireless network is Neighbor discovery. A wireless sensor network is a multihop wireless network that does not rely on any preexisting infrastructure [1]. Wireless networks are characterized by dynamic topologies due to uncontrolled node mobility, limited and variable shared wireless channel bandwidth, and wireless devices constrained by battery power [2]. One of the key challenges in such networks is to design dynamic routing protocols that are efficient, that is, consume less overhead. Cognitive radio (CR) technology has recently emerged as a promising approach for improving spectrum utilization efficiency and meeting the increased demand for wireless communications [3]. Unused or underutilized channels in the spectrum will be scanned by the CR node in a wireless spectrum and when needed, CR nodes in a network then use these channels for communication among themselves even if the channels belong to licensed users. The licensed users are referred to as the *primary users*, and CR nodes are referred to as the *secondary users*. When primary users are not using their allocated spectrum, the CR nodes, i.e. secondary users, can verify that the primary users are idle and can use the unutilized spectrum for communication with other CR nodes. Thus, a CR node can find a set of channels in which it can communicate with other CR nodes and this channel set varies with time and geographical location. When a primary user arrives (starts using his/her allocated spectrum), the CR nodes is required to switch to other channels that will not interfere with the primary user. Cognitive radios have been proposed as a way to increase the utilization of the currently designated spectrum [6]. Because of uneven propagation of wireless signals, two CR nodes that are geographically close to each other may have different subsets of channels available to them for communication. This makes the network *heterogeneous* [2]. The neighbor discovery problem is difficult to solve for heterogeneous cognitive wireless networks in due to:

- The available channel set of a node varies with time and location.
- A node does not know the IDs of its neighbors, nor the channels it can use to communicate with them
- The CR nodes may be geographically scattered resulting in a multi-hop wireless network
- A node may not know the size of its 1-hop neighborhood

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II. Related Work

Timely discovery of a node's neighbors is a critical issue in wireless networks as it typically affect other protocols such as MAC, routing and topology control, especially when the network is dynamic. Most of the prior work on neighbor discovery assumes a single channel wireless network [2][3][4]. Some of those algorithms for a single channel network can be easily extended to work for a multi-channel network including a heterogeneous network. Algorithms such as "birthday protocol" [7], directional antenna neighbor discovery [8], [9] and slotted random transmission and reception have been proposed to enable all nodes in a network to find out their neighbors either synchronously or asynchronously. These algorithms can be categorized as random access discovery, which requires nodes to be randomly in a “transmitting” or “listening” state in each time slot so that each node gets a chance to hear every neighbor for at least once in a sufficient amount of time. Such random access discovery schemes allow one transmission to be successful at a time, and hence generally require a large number of time slots until reliable neighbor discovery is achieved. Timely discovery of a node’s neighbors is a critical issue in wireless networks, especially when the nodes are mobile. References [10]–[12] suggest solution of the neighbor discovery problem from the multiuser detection perspective. The idea is to let all neighbors simultaneously send their unique signature waveforms which identify themselves, and let the center node detect which signatures are at presence. The advantage is rapid detection achieved using multiuser detectors, which are well-understood. However, the difficulties of scaling the scheme as well as implementing coherent detection without training have not been adequately addressed.

III. SYSTEM MODEL

A cognitive radio (CR) node consists of a processing element (with memory, etc.) coupled with a wireless transceiver. The node has the physical ability to operate over a wide range of frequencies (channels). We assume a hop multi-channel heterogeneous wireless network consisting of one or more radio nodes. Let N denote the total number of radio nodes .for simulation, we have supposed the value of N be 40 (from 0 to39). Nodes do not know N. Each node is equipped with a transceiver, which is capable of operating over multiple frequencies or channels. However, at any given time, a transceiver can operate (either transmit or receive) over a single channel only. A transceiver of different nodes need not to be identical, In fact, a transceiver cannot transmit and receive at the same time. Different nodes in a network may have different sets of channels available for communication.

In CR network, each node can scan the frequency spectrum and identify the subset of unused or under-used portions of the spectrum, even those that have been licensed to other users or organizations [11]. A node can potentially use such frequencies to communicate with its neighbors until they are reclaimed by their licensed (primary) users [11]. Due to spatial variations in frequency usage/interference and hardware variations in radio transceivers, different nodes in the network may possess different subsets of frequencies available to them for communication. For the sake of simulation we are using first 20 users as primary users, once primary users stop using channels they will be allotted to secondary CR nodes from the available channel set. The subset of frequencies or channels that a node can use to communicate with its neighbors is referred to as the *available channel.*

The routing protocol going to be used for path detection is AOMDV than Simple AODV. Since AOMDV shares several characteristics with AODV. It is based on the distance vector concept and uses hop-by-hop routing approach. Moreover, AOMDV also finds routes on demand using a route discovery procedure. The main difference lies in the number of routes found in each route discovery. In AOMDV, RREQ propagation from the source towards the destination establishes multiple reverse paths both at intermediate nodes as well as the destination. Multiple RREPs traverse these reverse paths back to form multiple forward paths to the destination at the source and intermediate nodes. It’s important to note that AOMDV also provides intermediate nodes with alternate paths as they are found to be useful in reducing route discovery frequency [13]

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1. **if** ($seq\_num_i^d < seq\_num_j^d$) **then** /*Enforce the sequence rule*/
2. $seq\_num_i^d = seq\_num_j^d$;
3. advertised_hop_$count_i^d = \infty$;
4. $route\_list_i^d$ =NULL;
5. **if** ($j=d$) **then** /*Neighbor is destination*/
6. insert (j, i, 1) into $route\_list_i^d$;
7. **else**
8. insert(j, $last\_hop_{jk}^d$, $advertised\_hop\_count_j^d + 1$) into $route\_list_i^d$;
9. **end if**
10. **else if** (($seq\_num_i^d = seq\_num_j^d$) **and** ($advertised\_hop\_count_i^d > advertised\_hop\_count_j^d$)) **then** /*Enforce the route acceptance rule*/
11. **if** ($j = d$) then /*Neighbor is destination*/
12. **if** (($/\exists_{k1}$: ($next\_hop_{ik1}^d = j$)) **and** ($/\exists_{k2}$: ($next\_hop_{ik2}^d = i$))) **then**

13. insert(j, I ,1) into $route\_list_i^d$;

14. end if

15. else if $((\nexists_{k3} : (next\_hop_{ik3}^d = j))$ **and** $((\nexists_{k4} : (next\_hop_{ik4}^d = last\_hop_{jk}^d))$ **then**

insert (j, $last\_hop_{jk}^d$, $advertised\_hop\_count_j^d$ +1) into $route\_list_i^d$;

16. end if

17. end if

IV. PERFORMANCE EVALUATION

We study neighbor discovery performance using ns-2 simulations. Our main objective is to evaluate the effectiveness of heterogeneous neighbor discovery with CR relative to single channel neighbor discovery in the presence of mobility-related route failures. Other objectives include: understanding the effect of Network Load, Combined Cost, and Packet Loss on the benefit of multiple paths with respect to number of evaluation.

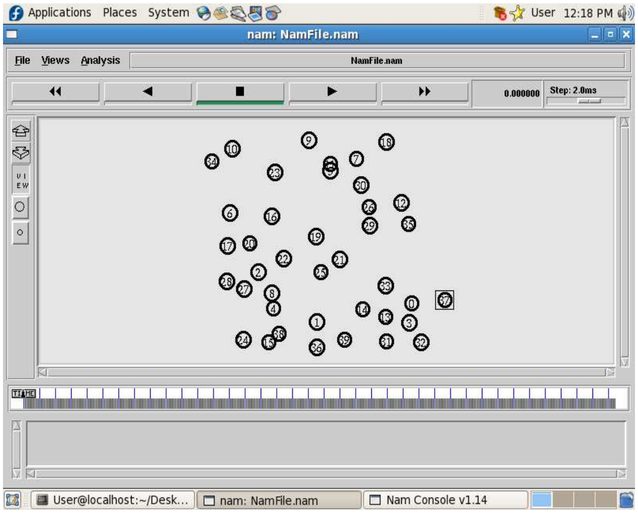
Initially we are given with N no of nodes whose value for simulation is taken as 40. The number of communications can be set during runtime which asks for number of communication and the respective source and destination for each N number of times. Algorithm starts by searching for Unused and underutilized channels in the available spectrum and broadcasts the RREQ request message and waits for RREP i.e. reply message. The destination only replies to RREQs arriving via unique neighbors. After the first hop, the RREPs follow the reverse paths, which are node disjoint and thus link-disjoint. The trajectories of each RREP may intersect at an intermediate node, but each takes a different reverse path to the source to ensure link-disjointness. The advantage of using AOMDV is that it allows intermediate nodes to reply to RREQs, while still selecting disjoint paths. But, AOMDV has more message overheads during route discovery due to increased flooding and since it is a multipath routing protocol, the destination replies to the multiple RREQs those results are in longer overhead. Implementation of wireless ad-hoc networks in the real world is quite hard. Hence, the preferred alternative is to use some simulation software which can mimic real-life scenarios. Though it is difficult to reproduce all the real life factors such as humidity, wind and human behavior in the scenarios generated, most of the characteristics can be programmed into the scenario.

Our neighbor discovery algorithm implicitly makes the assumption that all nodes start executing the algorithm at the same time. Our neighbor discovery algorithm is to satisfy the following properties:

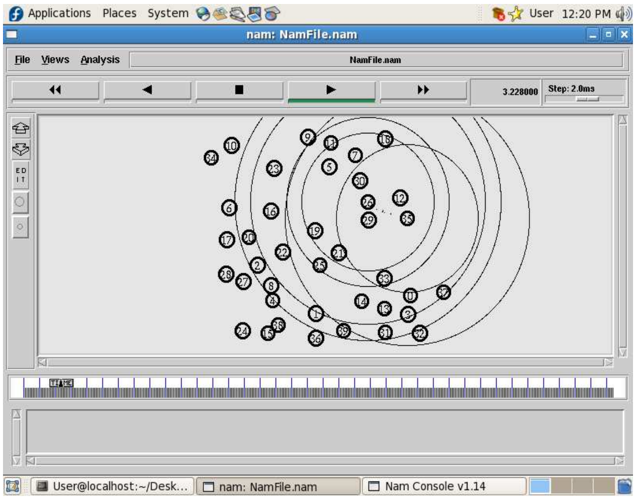
• **No false discovery:** A node considers another node to be its neighbor only if the two nodes are neighbors of each other.

• **Eventual discovery:** Every node eventually discovers all of its neighbors on every channel.

• **Termination:** Neighbor discovery at every node eventually terminates

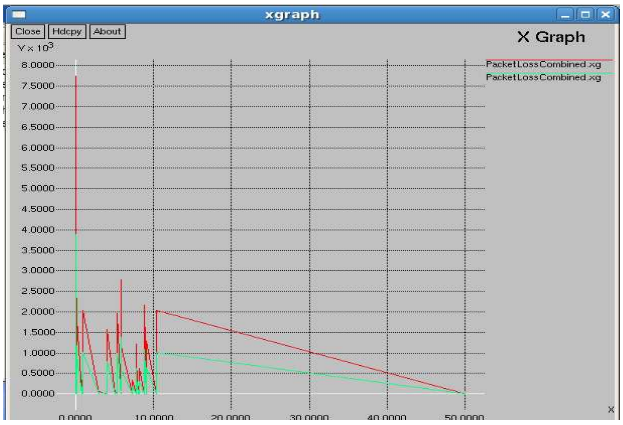


a) Initial condition

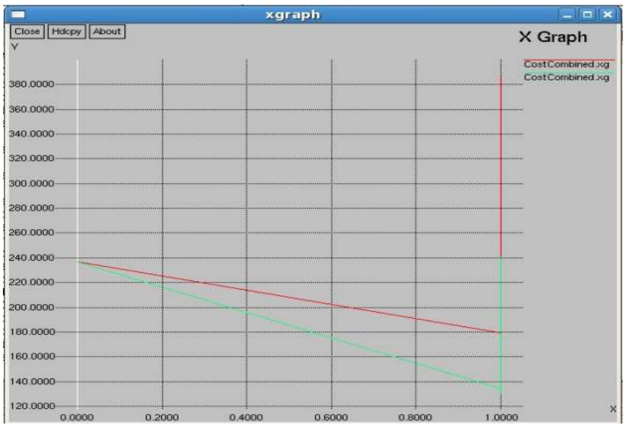


b) In communication

Fig 1: Nodes in a network



c) Compared Packet loss



d) Compared Combined cost

Fig 2. Graph Scenario's

V. CONCLUSION

Efficient neighbor discovery scheme based on Cognitive Radio has been proposed and analyzed in this paper. The work can be easily extended to further reduce the Network load involved in the process. To summarize, in this paper, we presented a distributed deterministic neighbor discovery algorithm for a heterogeneous cognitive radio network that allows multiple nodes to advertise simultaneously without interfering with each other and terminate the algorithm when all neighbors have been discovered. Performance of work is analyzed and simulation is conducted to verify the performance. It will be useful for the applications that needs to configure rapidly on deployment.

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