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Algorithms for the Discovery of Topology in Cognitive Radio Adhoc Network for Dynamic Route Optimization: A Study

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Abstract: Cognitive Radio Ad Hoc Networks (CRAHNs) constitute a viable solution to solve the current problems of inefficiency in the spectrum allocation and to deploy highly reconfigurable and self-organizing wireless networks. CRAHNs will automatically detect available channels in wireless spectrum. It can also be called as software defined radio with a cognitive engine brain. Cognitive Radio (CR) devices are envisaged to utilize the spectrum in an opportunistic way by dynamically accessing different licensed portions of the spectrum. However the phenomena of channel fading and primary cum secondary interference in cognitive radio networks does not guarantee application demands to be achieved continuously over time. The limited available spectrum and the inadequacy in the spectrum usage necessitate a new communication standard to utilize the existing wireless spectrum opportunistically. Mechanisms are available to provide better efficiency in utilizing the existing cognitive network. The frequencies used are utilized to the maximum extent without any interference. This paper aims in discussing the topology discover methods for Dynamic Route Optimization in Cognitive Radio.

Keywords: Cognitive Radio Ad Hoc Network, Topology, Topology Discovery Algorithm, Information Exchange, Discovery of Clusters, Mobile Agent

I. Introduction

An Adhoc Network is a collection of wireless mobile hosts forming a temporary network without the aid of any established infrastructure or centralized administration. Each node is considered to be alike here. It is needed to introduce some intelligence to the Adhoc networks in order to improve their throughput efficiency. The concept of Cognitive Radio (CR) has been employed to achieve this. CR enabled devices are 'clever' and can listen to the surrounding wireless environment and can select the appropriate frequency band, modulation scheme or specific power level as per the requirement. In this way an ability of self decision making can be incorporated in the wireless Adhoc networks. The frequency spectrum is a limited resource for wireless communications and may become congested owing to a need to accommodate the diverse types of air interface used in next generation wireless networks. This spectrum if utilized in an efficient manner, can lead to better utilization of the network. Wireless technology has enabled the development of increasingly diverse applications and devices resulting in an exponential growth in usage and services. These advancements made the radio frequency spectrum a scarce resource, and consequently, its efficient use is of the ultimate importance. To cope with the growing demand, network design focused on increasing the spectral efficiency by making use of advancement in Cognitive Radio technology. Cognitive Radio can reduce the spectrum shortage problem by enabling unlicensed users equipped with Cognitive Radios to reuse and share the licensed spectrum bands. Using the fact that a Cognitive Radio is capable of sensing the environmental conditions and automatically adapting its operating parameters in order to enhance network performance. The paper is organized as follows: The Section II gives an introduction about the Cognitive Radio (CR). The Section III describes the existing techniques in CR for Topology Discovery in Dynamic Route Optimization. Section IV concludes the results.

II. Cognitive Radio

A Cognitive Radio is a kind of two-way radio that automatically changes its transmission or reception parameters, in a way where the entire wireless communication network of which it is a node communicates efficiently, while avoiding interference with licensed or licensed exempt users. This alteration of parameters is based on the active monitoring of several factors in the external and the internal radio environment, such as radio frequency spectrum, user behaviour and network state. The Figure 1 shows a sample CR network.

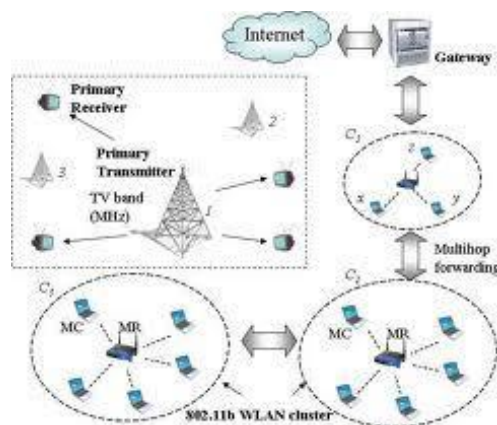


Figure 1: A Sample CR Network

Regulatory bodies in various countries (including the Federal Communications Commission in the United States, and Ofcom in the United Kingdom) found that most of the radio frequency spectrum was inefficiently utilized. For example, cellular network bands are overloaded in most parts of the world, but many other frequency bands, such as military, amateur radio and paging frequencies are not. Independent studies performed in some countries confirmed that observation, and concluded that spectrum utilization depends strongly on time and place [4]. Moreover, fixed spectrum allocation prevents rarely used frequencies (those assigned to specific services) from being used by unlicensed users, even when their transmissions would not interfere at all with the assigned service. This was the reason for allowing unlicensed users to utilize licensed bands whenever it would not cause any interference (by avoiding them whenever legitimate user presence is sensed). This paradigm for wireless communication is known as cognitive radio. Since the spectrum present is limited, all users cannot be allowed to access this network. Hence users are divided into two basic categories.

Primary Users: Since the spectrum present is limited, all users cannot be allowed to access this network of any other unlicensed users. Primary users do not need any modification or additional functions for coexistence

Secondary Users or Unlicensed Users: They access the licensed spectrum as a visitor, by opportunistically transmitting on the spectrum holes.

III. Comparison of the Existing Techniques for finding Topology in CR for Dynamic Route Optimization

Topology Discovery Algorithm is used for wireless Adhoc network. In a static Adhoc network, it collects neighbor by sending HELLO messages to its neighbors. Each node periodically reports its local topology information to the central topology manager. This scheme is based on the assumption that all the nodes within network know the address of the topology manager, and all the nodes within the network share same network prefix [7]. It employs HELLO and REPORT messages. HELLO message is for neighbor detection and link sensing. Local topology information is send to topology central manager through REPORT messages. Due to congestion some messages may be lost. In such case, congestion is considered to be only cause for message lost. Performance of the scheme is evaluated by using four metrics namely overhead, throughput loss, completeness and speed. In mobile Adhoc network accuracy and speed is only measured due to the restriction in the simulation environment.

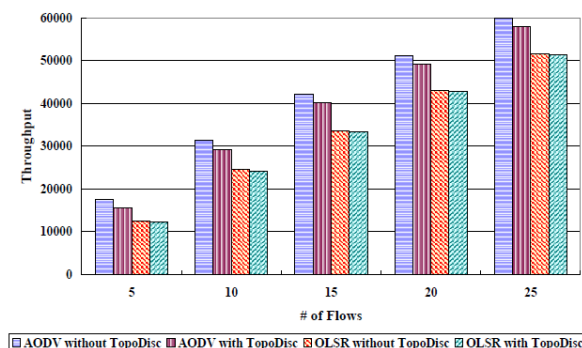


Figure 2: Throughput for CBR Traffic

The Figure 2 explains how the throughput loss is maintained by using the Topology Discovery Algorithm. Similar case of result is found when the other metrics namely overhead, completeness and speed are measured.

Topology discovery is found to be a time consuming job when done manually in large network. “NON-ANT” mobile based topology discovering system, which is a combination of reactive and proactive system, is proposed. This solves a number of problems faced by “ANT” based system, like need for predefined IP range, loss of agents, reactive and proactive systems. It divides the network nodes into two hierarchical groups namely cluster head and cluster member based on the type of agent that reside in them [8]. This system used less bandwidth when compared with “ANT” based approach. The network bandwidth usage of both approaches is calculated as

$$\text{Mobile Agent Approach: } u = (83 + (n - 2) * 6)$$

$$\text{Agent less approach: } u = ((6 * (n - 1)) + (6 * (n - 2)))$$

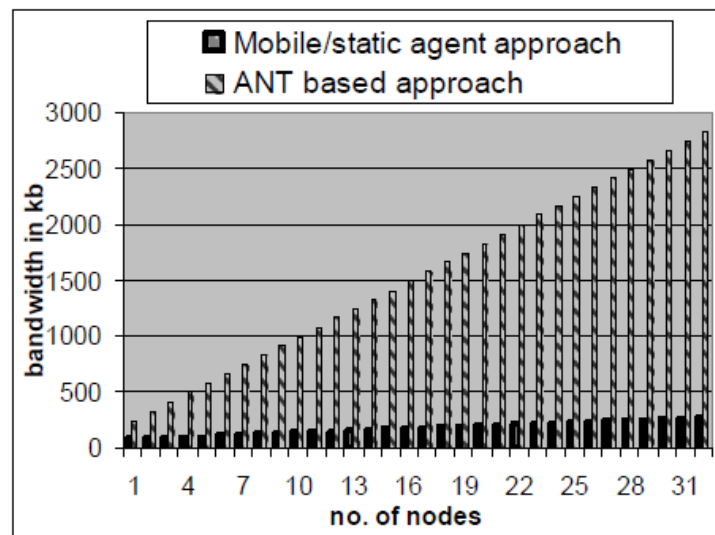


Figure 3: Comparison of Mobile Agent Based Approach and ANT Based Approach

The Figure 3 shows the comparison of the mobile agent based approach and ANT based approach based on the bandwidth usage. It is observed that the bandwidth usage of mobile agent based is less when compared with ANT based approach.

Weighted Topology Discovery Algorithm uses color based approach for partitioning the network into clusters. The topology is defined in two phases namely Information Exchange and Discovery of clusters in network. In Information Exchange phase, all nodes broadcast a hello message with their Mac ID and their position. After transferring this information all the nodes calculate their weights and again a broadcast is generated. Now all the nodes know the weights of their neighbors. In Cluster Finder phase, all those nodes that have their weights better than all their neighbors propagate their discovery request called "CLUSTERFINDER" and change their color to black means it has become the cluster heads. Ties are broken on the bases of node ID. All nodes which receive this message become gray. After this they will propagate this request to their neighbors after a certain delay that equals to inverse of their weights. Now those farther nodes that receive the message become Dark Gray. Weights of the nodes decide that which node should become the Clusterhead. The Dark Gray nodes compare their weights with their neighbors. The comparison does not include those nodes whose status has become gray or black. The Dark Gray Node with the best weight will become the cluster head and turns in to black. The newly formed cluster head informs neighbors for becoming the cluster head. All Dark Gray and white nodes that receive this message turn gray [9]. All white nodes that have become gray will propagate the Discovery request and algorithm moves to the start of Cluster Discovery Phase. The algorithm does not finish until all the nodes become a part of at least one cluster.

A mobile agent based system that allows for real time topology discovery of the network. As opposed to many such mobile agent based systems that utilize “Ant” based algorithms, our system makes efficient use of the limited network resources of the Adhoc network by restricting the mobility of the agents. The mobile agent uses its mobility only to move to a new node after which it turns into a stationary agent. Mobile agents are agents that can physically travel across a network, and perform tasks on machines that provide agent hosting capability. This allows processes to migrate from computer to computer, or processes to split into multiple instances that execute on different machines, and to return to their point of origin. Unlike remote procedure calls, where a process invokes procedures of a remote host, process migration allows executable code to travel and interact with databases, file systems, information services and other agents. Mobile Agents server as a very practical solution for topology discovery in an environment where the topology changes very frequently [10]. Due to the

decentralized characteristics of Adhoc network, it is essential that the topology discovery system is not centralized like traditional topology discovery system. In addition to being decentralized the topology discovery system also has to be “intelligent”.

```
<?xml version='1.0' encoding='UTF-8' ?>
- <tXML generator='1' fileID='2006-02-28T11:00:26' timestamp='2006-02-28T11:00:26-08:00'
  <link id='0' node1='1' node2='2' />
  <link id='2' node1='1' node2='3' />
  <link id='3' node1='2' node2='4' />
  <link id='4' node1='4' node2='5' />
</tXML>
```

Figure 4: Topology Information XML

The Figure 4 shows how the topology information is passed in XML format. This allows the agent to query the xml file in an efficient way rather than parsing through a plain text file. The platform that an agent originates is called home platform and is assumed as a trusted environment for that agent.

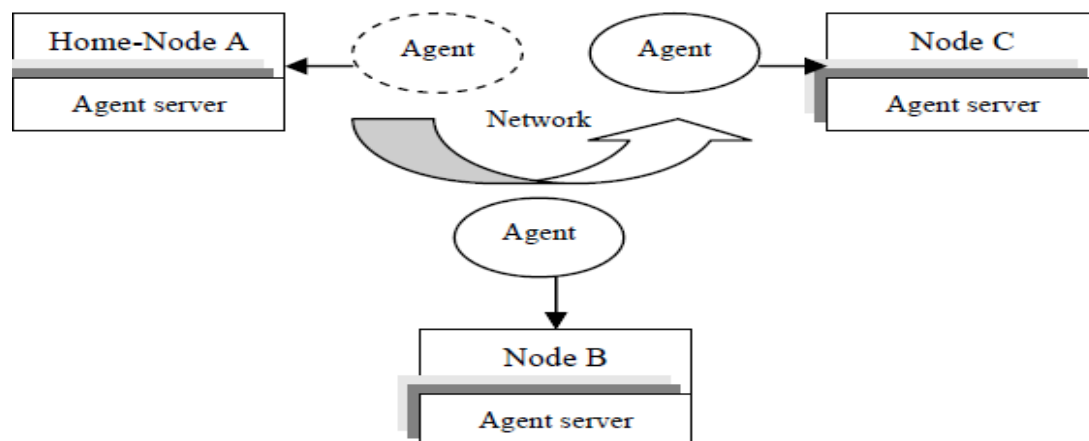


Figure 5: Mobile Agent System

The Figure 5 shows a mobile agent system. Each mobile node will run an agent server that provides the basic functionality for static and mobile agents, such as migration, communication, and security. Possibly, the agent server will be written in Java language due to its object-orientation nature, object serialization and remote method invocation techniques, and enhanced security. Static agents will be resident on mobile hosts and will be continuously running. These agents will be mainly responsible for the following operations: maintain a routing table; decide the best path to route network traffic based on information found on the routing table; and monitoring system's resources in terms of memory capacity, processing capabilities, network performance, cost, and so on. On the other hand, mobile agents will be responsible for the following operations: collect information generated from static agents; update routing tables on mobile hosts; and discovering new routes. They must also inform static agents; and other mobile agents for changes in the network. Static agents will maintain routing tables continuously, decide the best path dynamically, and monitor system's resources periodically. Mobile agents will collect information from static agents periodically, update routing tables periodically, and communicate with static agents and other mobile agents when necessary. Figure 6 illustrates the model with four mobile hosts, four static agents, and two mobile agents.

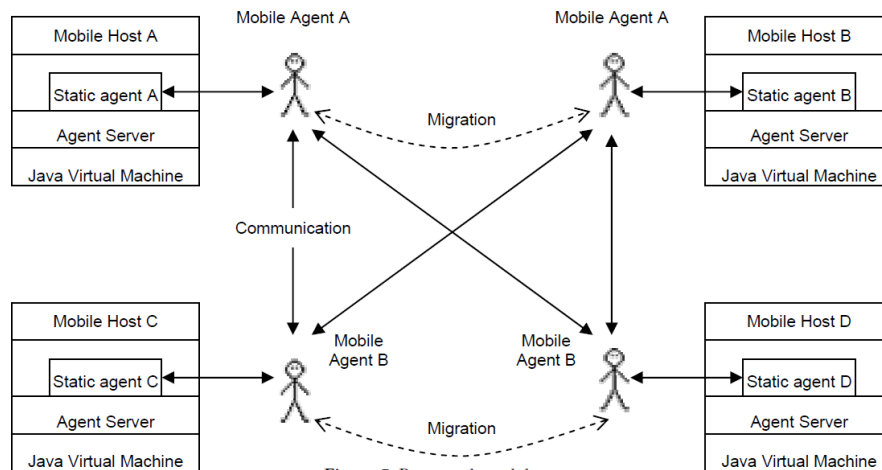


Figure 6: The proposed model

IV. Conclusion

The Topology Discovery Algorithm is used for efficient topology discovery in the case of static network. In the Adhoc network, all the nodes in the network will be in mobility. In such a network employment of Mobile agent for the task of topology discover in Adhoc network will yield a good result. But if multiple mobile agents are employed, collision in the network may occur. To avoid that and to prevent bandwidth loss, a single Mobile Agent along with Weighted Topology Algorithm which is based on color approach is suggested. Further research is suggested in that direction for finding best topology discovery algorithm in Adhoc network for dynamic route optimization in Cognitive Radio.

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