A Comparative Study of Routing Protocols in Cognitive Radio Networks

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ABSTRACT

Cognitive Radio Networks, comprise of cognitive, spectrum adaptive devices which are capable of changing their parameters, taking into consideration the radio environment so as to utilize the spectrum efficiently as well as to provide dynamic utilization to the secondary users. For this, an effective route setup becomes a dire necessity so as to provide efficient transmission in a highly congested environment. This paper focuses on some of the obstructions during the establishment of route from sender to destination node. This paper also provides insight on some of the used protocols in the field of cognitive networks used to effectively setting up of routes by taking into consideration the different features for discovery of nodes providing minimal path for efficient transmission.

Keyword: - *Cognitive Radio Networks; routing environment; radio spectrum; location-aided routing; challenges in routing*

1. INTRODUCTION

Current wireless networks are regulated by governmental agencies mainly according to a fixed spectrum assignment policy. The usage of licensed spectrum is quite uneven and depends heavily on the specific wireless technologies. Recent studies by the Federal Communications Commission (FCC) highlight that many spectrum bands allocated through static assignment policies are used only in bounded geographical areas or over limited periods of time, and that the average utilization of such bands varies between 15% and 85%[1].

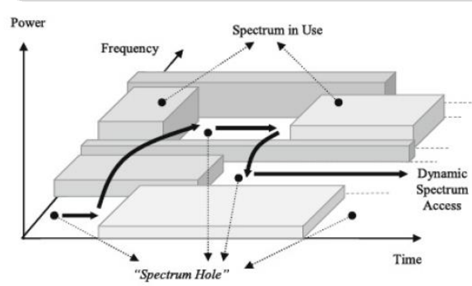

Fig.1: Spectrum-Hole Concept[1]

To address this situation, the notion of dynamic spectrum access (DSA) has been proposed. With DSA, unlicensed users may use licensed spectrum bands opportunistically in a dynamic and non-interfering manner. Resulting so-called Cognitive Radio (CR) transceivers have the capability of sensing a wide spectrum range, dynamically identify currently unused spectrum blocks for data communications, and intelligently access the unoccupied spectrum called Spectrum Opportunities.

The potentials of multi-hop CRNs needs to be realized which can open up new and unexplored service possibilities enabling a wide range of communication applications. The cognitive concept can be applied to different scenarios of multihop wireless networks including Cognitive Wireless Mesh Networks featuring a semi-static network infrastructure and Cognitive radio Ad Hoc Networks (CRAHNs) characterized by a completely self-configuring architecture, composed of CR users which communicate with each other in a peer to peer fashion through ad hoc connections.

In this paper, we focus on the issues related to the design and maintenance of routes in multi-hop CRNs. The purpose describes the most common approaches to routing in CRNs, clearly highlighting their design and their strengths/drawbacks.

2. ROUTING CHALLENGES IN MULTIHOP CRNs

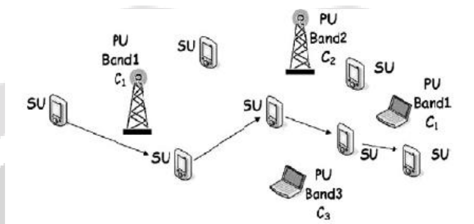

Fig.2: Information Routing in Multi-hop CRNs[8]

The network model [9] taken for reference shown in fig.2 describes secondary devices sharing different spectrum bands along with primary users. The PUs are assumed to be stationary while the SUs are considered to be mobile. Here, the problem of routing in multi-hop CRNs lays emphasis on the creation and the maintenance of wireless multi-hop paths among SUs by deciding both the relay nodes and the spectrum to be used on each link of the path. Such problem exhibits similarities with routing in multi-channel, multi-hop ad hoc networks and mesh networks, but with the additional challenge of having to deal with the simultaneous transmissions of the PUs which dynamically change the SOPs availability.

The main challenges for routing information in CRNs include:

2.1 SPECTRUM AWARENESS:

Designing solutions for efficient routing in multi-hop Cognitive Radio Networks requires a tight coupling between the routing module(s) and the spectrum management functionalities such that the routing module(s) can remain continuously aware of the surrounding physical environment to take more accurate decisions with regards to spectrum management.

2.2 SETTING UP OF QUALITY ROUTES:

In dynamically varying environment, the route setup needs to be redefined in CR scenario. The topology of multi-hop CRNs is highly influenced by PUs' behavior, and classical ways of measuring/ assessing the quality of end-to-end routes (nominal bandwidth, throughput, delay, energy efficiency and fairness) requires to be coupled with novel measures on path stability, spectrum availability/PU presence.

2.3. MAINTAINING/REPAIRING ROUTES:

The sudden appearance of a PU in a given location may render a given channel unusable in a given area, thus resulting in unpredictable route failures. This require frequent path rerouting either in terms of nodes or used channels.

3. APPROACH TO ROUTING PROTOCOLS

Commonly used routing protocols in the field of cognitive radio networks DORP, LASAR, LAUNCH and SEARCH.

3.1 Joint on-demand routing and spectrum assignment in cognitive radio networks

The delay based metric described in this model [14] have been used for evaluating the effectiveness of routes. They also utilised path selection algorithm for minimization of switching delay, queuing delay and back-off delay for the considered route.

The delay of nodes is formulated with the help of following equation:

$$D_{node} = D_{switching} + D_{queueing} + D_{backoff}$$ [8]

where $D_{switching}$, $D_{queueing}$ and $D_{backoff}$ are delays caused by frequency band switching, other flows transmissions and interference within a frequency band.

They have develop metrics and mechanism of spectrum assignment with full consideration of all possible delays during a multi-hop transmission through Cognitive Radio Network.

3.2 LAUNCH Protocol

LAUNCH protocol [13] handles Primary users when they are active and also selects the routes that are expected to be more stable. This is accomplished by the observation of a CR user over a period of time. This means even if a route is currently promising but it will be of less preference due to primary user's activity. LAUNCH prefers stable routes over short-lived ones.

LAUNCH uses a delay-based metric that selects the neighbour that satisfies two conditions:

1) It is closer to the destination than the current node (greedy forwarding criterion)

2) It has the lowest expected delay from the current node based on route stability (minimum delay criterion).

The proposed metric estimates the delay (T) between the two nodes as:

$$T=(T_{prop}+ T_{switch})/(1-P_{active})$$ [13]

Where T_{prop} is the propagation time between the two nodes which is calculated as the summation of the propagation time between the current node and its neighbor plus the propagation time between the neighbor and the destination. T_{switch} is the channel switching time which is a function of the difference of frequencies between the channels the source and destination nodes are currently working on and the channel which they will use.

3.3 LASAR Protocol

The LASAR protocol [1] exploits the geographical location information and discover the local spectrum access opportunities that improves performance at each hop. The secondary user uses location information and channel usage characteristics to select the next relay node in the network.

In this route setup design, the secondary user selects a data channel from a pool of available channels. It confirms whether the channel is free or is being occupied by a primary user. If a PU is being detected on that channel, it will leave that channel and will select another channel. It will then broadcast sensing invitation message specifying the parameters of channel in Common Control Channel so that other SUs make this channel busy to avoid interference. The sender will then broadcast RREQ specifying the parameters such as node ID, location and distribution parameters of PUs for the system model. Each neighboring node will then reply with RREP message containing propagation and switching delay between itself and destination node and distance gain it can offer to reach destination. Based on this, it will calculate Dynamic Transport Throughput and will select the node offering maximum DTT as its next relay node. Then the sender will start data transmission and will wait for acknowledgement signal from receiver.

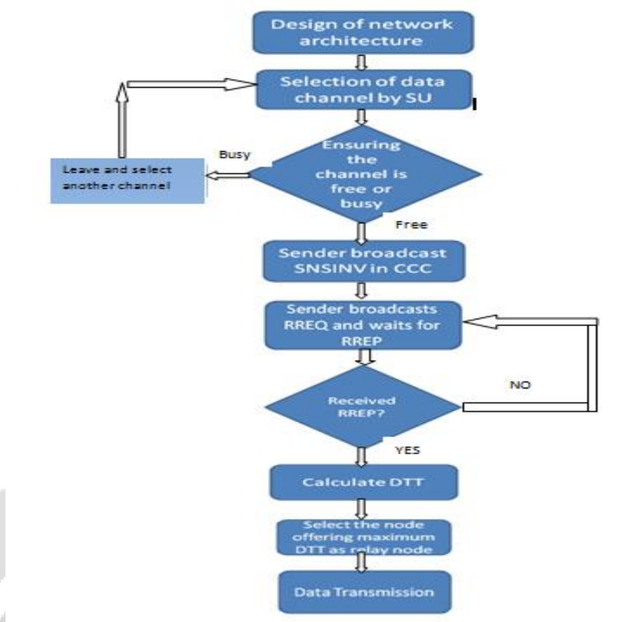

Fig. 3: Establishing route with the help of DTT[1]

3.4 SEARCH Protocol

In [8], the SEARCH routing protocol is designed taking into account the routing and channel selection decisions while avoiding regions of PU activity. SEARCH routing protocol is focuses on geographic forwarding principle. SEARCH mainly works on following two concepts:

PU activity awareness: In CR network, route must be constructed to avoid region affected by active PU. When PU activity affect region, SEARCH provides hybrid solution, it first uses greedy geographic routing on each channel to reach destination by identifying and circumventing PU activity region. The path information from different channels is combined at destination in series of optimization steps to decide on optimal end-to-end route in a computationally efficient way.

CR user mobility: For each node, through periodic beacons, updates its one-hop neighbors about it current location SEARCH ensures performance as well as less interference in cognitive radio network.

4. COMPARATIVE ANALYSIS OF PROTOCOLS

Routing Protocol	Feature
LASAR Protocol	Captures channel Usage characteristics & location information to select the best route
LAUNCH Protocol	Routing metric takes into account, the PUs activity, distributed calculations at neighbour & channel locking mechanism to achieve route stability
OCR Protocol	Exploits the geographic location information & discover the local spectrum access to improve transmission power over each hop
SEARCH Protocol	Builds run time forwarding mesh & offers a set of candidate routes to the destination
GPSR Protocol	Makes greedy decisions using information of router's neighbours in the network topology.

Table 1: Analysis of Routing Protocols

5. Conclusion and Future Work

In this paper, CR networks are reviewed and the problems associated with the routing of networks. The various routing protocols in cognitive radio networks has been briefly described here which comprised of DORP, LASAR, LAUNCH and SEARCH protocol. All these protocols make use of location information to design the routing parameters of the network. A new mechanism can be constituted with the help of LASAR protocol taking the mobility of the node into account.

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