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A Study: On Routing Schemes in Cognitive Radio Network

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ABSTRACT: Cognitive Radio (CR) technology is used to solve the spectrum scarcity problem in wireless networks, by using the existing wireless spectrum when they are not in use. CR technology allows sharing of licensed spectrum band in opportunistic and non interfering manner. However it should be aware of spectrum availability and Primary User (PU) activities. Routing and spectrum management are the main challenges in Cognitive Radio Network.. The main idea behind this concept is to use an appropriate routing protocol for cognitive network which becomes a major necessity now days. As the available radio frequency for wireless communication gets lesser day by day because of licensing, so we need to have some way to use these frequencies in a more efficient manner. Routing is a fundamental issue to consider when dealing with cognitive radio networks. Geographical concepts like location server is also challenging task to improve the routing problem .Here we focused on the potential routing approaches that can be employed in adaptive wireless networks.

KEYWORDS

Cognitive Radio Network , Spectrum Hole, Spectrum Sensing, Spectrum Sharing, Routing, Location server .

I. INTRODUCTION

Current wireless networks have fixed spectrum assigned by governmental policies. Where most of the portion of spectrum is used irregularly in few spaces because of that most amount of spectrum remains unutilized. The use licensed spectrum is quite uneven and depends on specific wireless technologies, their commercial success in market. According to recent studies by Federal Communications Commission (FCC) utilization of assigned spectrum varies in the range from 15% to 85%. Dynamic Spectrum Access (DSA) is introduced to solve spectrum usage inefficiency problem. DSA introduced policy based intelligent radios known as Cognitive Radios.

A ‘‘Cognitive Radio’’ is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. Cognitive radio networks provide high bandwidth to mobile users through heterogeneous wireless architectures and dynamic spectrum access techniques. Thus DSA enables cognitive users to use existing spectrum efficiently without disturbing primary user activities. Cognitive radio techniques allows to use or share spectrum opportunistically. Cognitive Radio technology allows users to detect available portion of spectrum as well as primary user’s presence, to select best channel, to share the channel with other users and to free the channel whenever primary user is detected. Cognitive radio has 2 main characteristics.

1) Cognitive Capability: It is ability of radio technology to sense the radio environment. It captures the temporal and spatial variations in radio environment and avoids interference to primary user.

2) Reconfigurability: Once radio environment gets captured, reconfigurability helps cognitive radio to program dynamically according to radio environment.

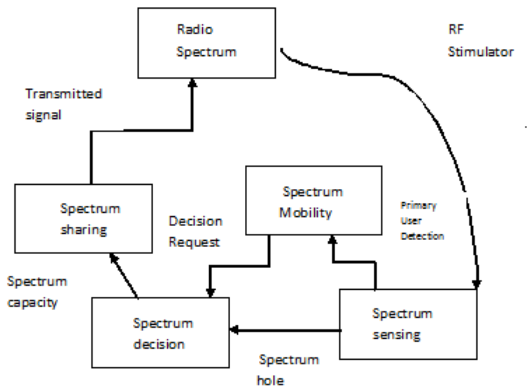

Figure 1: Cognitive radio cycle

To exploit under-utilized portions of the spectrum, known as *white spaces* or *spectrum holes*, the report motivates the need for a new generation of smart, programmable radios that are capable of interference sensing, channel state learning, and dynamic spectrum access. In the most common design considered today, *cognitive radios* (CRs) must transparently coexist with licensed users having obviously more priority on the licensed spectrum bands. In fact, CR can exploit the licensed bands either during the absence of their legacy users or by judiciously computing their transmission power in order to benefit from the underutilized portion of the spectrum.

The main idea behind this work is to use an appropriate routing protocol for cognitive network which becomes a major necessity now a days. As the available radio frequency for wireless

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communication gets lesser day by day because of licensing, so we need to have some way to use these frequencies in a more efficient manner. But since the topology of ad-hoc network changes dynamically so our cognitive ad-hoc network should be capable to cope up with dynamic network topology as well as diverse quality of service. And also proper routing protocol should be there so that an efficient routing can be done apart from maintaining QoS.
On local observation of CR users but also on statistical behavior of the PUs.

The remaining part of the paper is organized as follows: In section II we describe the difference between classical routing in wireless network and routing in cognitive radio network. In section III a survey is based on spectrum aware, geographical routing concept. So in this paper we explain existing work in cognitive radio network by considering the routing metrics like delay, throughput, and different methodologies for spectrum aware routing.. In section IV we showing the discussion and future direction and in section V we concluded the paper.

II Classical Routing Vs CRN Routing:

Routing is the process of selecting paths in a network along which to send network traffic. It is a the process of moving a packet of data from source to destination. The routing process usually directs forwarding on the basis of routing table which maintain a record of the routes to various network destinations. Thus, constructing routing tables, which are held in the router's memory, is very important for efficient routing. Most routing algorithms use only one network path at a time. Multipath routing techniques enable the use of multiple alternative paths.
In CRN routing the spectrum (channel) as well as node will change in the routing process, channel mobility and the nodes will change here. The process of moving packets across a network from one host to another host is called as routing. Cognitive network routing is different from wireless network routing. In cognitive radio network, routing is combination of traditional routing and spectrum management since spectrum availability varies from node to node with respect to time and location. Spectrum availability is also affected by the primary user activities. Now we will see below the major challenges of routing in cognitive radio network (CRN).

1. Spectrum availability: Routing module must be aware of spectrum availability which is achieved by monitoring spectral environment.
2. Primary User Activity Awareness: Cognitive radio network topology is affected by primary user activities as well as by route quality measurements such as delay, bandwidth, throughput, energy efficiency which should be considered with spectrum availability.
3. Route Maintenance: Primary user activities may results in frequent route rerouting which in turn will degrade the network performance. Thus effective signaling procedures are required for convenient routing in cognitive radio network.
4. Lack of CCC (Common Control Channel): In traditional routing protocols, specific functionalities such as neighbor discovery, route discovery and route establishment are done through local or global broadcast messages. In cognitive radio network, due to lack of CCC broadcasting becomes a major problem.
5. Intermittent Connectivity: In cognitive radio network, due to spectrum availability and primary user activities reachable nodes may change frequently. Thus, network connectivity in cognitive radio network depends on spectrum availability. This challenge can be solved by using time and space based solutions with respect to channels.

III. Cognitive Routing Protocols:

1. An Efficient Location Server for an Ad Hoc Network

In [3] three current location service, Grid Location Service (GLS) , Simple Location Service (SLS) , and Reactive Location Service (RLS) are introduced.
Grid Location service: In GLS, a node chooses a set of node in the network (i.e.,location servers) to maintain the node's current location. Nodes that require the location of a node query the node's
location servers.
Simple Location Service : In SLS, a node periodically transmits its location table to its neighbors. Thus, a node in the network learns the location of all other nodes in the network. Here each location packet (LP) updates location tables, contains the location of several nodes, the speed of each of nodes, and the time the LP was transmitted. The rate a mobile node transmits LPs adapts
according to location change:

$$\left(\frac{Trange}{\propto}\right) * \left(\frac{1}{v}\right) = \frac{Trange}{\propto v}$$

where *Trange* is the transmission range of the node, v □ is the average velocity of the node, and □ is a constant optimized through simulation is a scaling factor.

Reactive Location Service : RLS is a reactive location service that queries location information on an as needed basis.

2. An improved Map-based Location Service for Vehicular Ad Hoc Networks

In [2] a distributed hierarchical location service called Density aware Map-Based Location Service (DMBLS) for Vehicular adhoc Networks. DMBLS makes use of the street digital maps and the traffic density information to define a three level-hierarchy of locations servers.The location service uses a density aware server selection policy which selects servers at high density regions of a city. DMBLS, for vehicular urban environments, based on the traffic density. In this, they have assume that each vehicle knows its own geographic position and the use of the Global Positioning System (GPS).
Updating Location Information : Due to the high mobility, the vehicles positions keep changing very fast and therefore, the location server should be informed to update the information it stores. the location information are valid for a period *T* equal to the time required for the vehicle to reach the next waypoint plus a threshold time Tc and it can be predicted by the following formula:

$$T = Dint / Savg+Tc$$

Where *Dint* is the distance between the current intersection and the next intersection and *Savg* corresponds to the average speed of the vehicle. *Tc* represents the time spent by the vehicle near the intersection before it moves away with a distance *R* equal to the transmission range.

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

This section describes the Joint on-demand routing and spectrum assignment in cognitive radio networks [5]. The delay based metric have used evaluating the effectiveness of routes. They have also used here path selection algorithm for minimization of

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switching delay, queuing delay and back-off delay for the considered route.
Formulation of Delay on nodes : The below equation is used for calculating the delay at a node :

Dnode = Dswitching + Dqueueing + Dbackoff

where Dswitching, Dqueueing and Dbackoff 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.

4. SEARCH: A Routing Protocol for Mobile Cognitive Radio Ad-hoc Networks

In [5] the SEARCH routing protocol is designed. This protocol makes routing and channel selection decisions while avoiding regions of PU activity. It also considers a host of nodal mobility cases using predictive Kalman filtering.
SEARCH routing protocol is designed on geographic forwarding principle. In cognitive radio network, route is constructed at network layer must not affect primary user's transmission and thus must be aware of spectrum availability. The frequency changing PU activity and mobility of CR user make the problem of maintaining optimal routes in Ad-Hoc cognitive radio network challenging. 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: Cognitive user mobility results into frequent route disconnections. Thus 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.

5. Spectrum and Energy Aware routing protocol for Cognitive Radio networks

In [8] SER i.e. spectrum-aware and energy-efficient routing protocol is proposed.The basic operations of the proposed SER protocol include route discovery, data transmission, and route maintenance.

A. Routing Algorithm:
The route request (RREQ) broadcast procedure is based on DSR protocol. When the source CR user has packets to send to the destination CR user, it will initiate a route discovery process by broadcasting a spectrum aware RREQ message on the CCC to all of its neighbors.
For selecting the energy-efficient path, they had consider maximal minimal nodal residual energy with lower hop count as routing metric. Initially, at the source CR user, the value of minimum residual nodal energy, *mEres* equals the initial energy of the battery. To avoid CR users having very poor energy in a route; intermediate CR users should have a threshold energy, *Eth*. CR users receive the RREQ packet, they compare their own residual battery energy, *Eres* with the *mEres* and update accordingly in order to keep the value of *mEres* lowest among all the CR users in this route. This will ensure the route that has the minimal nodal residual battery energy. In the proposed protocol, an intermediate CR user *v* starts a timer whenever it receives the first RREQ. After receiving the first RREQ packet, destination CR user waits for a time period to get more RREQs before it makes route reply. Destination CR user then computes route utility using (1) and selects the route using (2).

$$Uk = \frac{mEres.k}{HCk}, \quad \forall k; \qquad (1)$$

$$P = \max\{Uk\}, \quad \forall k: \qquad (2)$$

where *Uk* is the route utility of path *k = 1, 2, ..., K,* the number of received RREQ by the destination. *Uk* is used to evaluate the selected routes to find the maximum value of *P* for which the value of *mEres* is maximized and *HCk* is minimized. Maximum value of *mEres* ensures that the selected path has high energy *i.e.* energy-efficient path; on the other hand, the smaller hop count gives the packet transmission with comparatively low delay. Destination CR user then reply to the source CR user with route reply (RREP) packet through CCC. Finally, after receiving the RREP packet by the source CR user, the data transmission begins. In addition, local route recovery (RREC) and route error (RERR) based scheme is used for route maintenance.

6. Spectrum-Aware routing protocol for cognitive Ad-hoc network

The [6] SARP protocol consist of two parts. One is the intelligent multi-interface selection function (MISF) which is used to assign an appropriate interface to a route to efficiently allocate the channels. The other one is the intelligent multi-path selection function (MPSF) which is used to select an appropriate path to route packets. This routing protocol considers both the spectrum and space.

Intelligent multi-interface selection function: The purpose of MISF is to let SARP assign the appropriate interface to a route to increase the performance of the network. It uses the delay of the RREQ packets as the metric to assign the appropriate interface to a route.

Intelligent multi-path selection function: MPSF uses the throughput increment as the metric to select the path. The throughput increment as the predicted throughput after a new application joins minus the current throughput. The destination nodes should select the path with the largest throughput increment.

7. Distributed Routing and spectrum Allocation algorithm with cooperation in cognitive wireless Mesh Network

In [7] this DRSAC-W algorithm is proposed. Routing and spectrum allocation is an important issue. DRSAC-W, a distributed routing and spectrum allocation algorithm with cooperation and DRSAC-WO , a distributed routing and spectrum allocation algorithm without cooperation are proposed in this paper. In order to show the decrease in average end-to-end delay.

Network Model: They have adopt a simple undirected graph G=(V,E) model of the cognitive wireless mesh network. V represents the set of CR-Mesh router and CR-Mesh gateways. E represent the set of wireless links.

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Problem Description : They had study the problem under the heterogeneous available channels condition and the route is constructed from source node to destination node There main aim to minimize the average end-to-end delay.
The average end to end delay is computed with the following :

$$\text{Delay}(si,di) = \sum_{(u.v)\in Path(si,di)} D^k \, x(u,v) = k$$

Delay*(si,di)* represents the average end to end delay of path(si,di), Path(si,di) represent the path from source node si to destination node dj. D^k represents the delay of the channel k. K is the set of available channel. x(u,v) is allocation channel of wireless link(u,v).

IV. Discussion and Future Direction:

1. DORP: In joint on-demand routing and spectrum assignment paper DORP protocol is proposed. This uses path selection algorithm for routing. The above protocol provides the better adaptability and derives paths with much lower cumulative delay. Though it includes low end to end delay and average throughput and also medium overhead in the networks.

2. SEARCH: A distributed routing protocol for mobile CR networks. This approach jointly optimizes the path and channel decisions so that the end-to-end latency is minimized. SERACH includes high throughput, average overhead and delay in the networks.

3. SER : A Spectrum and Energy Aware on demand protocol for routing in ognitive adio networks. It combines the integration of spectrum and route discovery. This protocol balances the traffic load among different CR users according to their nodal residual battery energy. Because of this it provides lower end to end delay, high throughput and average overhead.

4. SARP :Spectrum-Aware routing protocol for cognitive Ad-hoc network includes intelligent multi-interface selection function that uses the delay of the RREQ packets as a metric to assign the interface to a route and an intelligent multi-path selection function that uses the throughput increment as the metric to select the path to route packet, Effect of this SARP contains high throughput , very low overhead and delay.

5. DRSAC-W: A Distributed Routing and spectrum Allocation algorithm with cooperation and distributed routing and spectrum allocation algorithm without cooperation in cognitive wireless mesh network includes high throughput and decreasing overhead and end to end delay.

V. CONCLUSION

CR networks are envisaged to solve the problem of spectrum scarcity by making efficient and opportunistic use of frequencies reserved for the use of licensed users of the bands. To realize the goals of truly ubiquitous spectrum-aware communication, the CR devices need to incorporate the different spectrum related functionalities. The discussions provided in this survey strongly advocate cooperative spectrum-aware communication protocols that consider the spectrum management functionalities. SEARCH, a distributed routing protocol for mobile CR networks. This approach jointly optimizes the path and channel decisions so that the end-to-end path latency is minimized. Joint on-demand routing and spectrum assignment in cognitive radio networks provides better adaptability to the multiflow environment and derives paths with much lower cumulative delay. The main challenges of cognitive radio network is routing are awareness of primary user activities, selection of quality routes and maintenance of selected routes. Here different approaches are discussed for finding solutions of routing problems. Discussion on these approaches provides open view towards the routing challenges in cognitive radio network. Different routing measurements are provided to cognitive radio network to compute and analyze performance of proposed routing solutions.

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