INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ENGINEERING, SCIENCE & MANAGEMENT

ROUTING SCHEMES IN COGNITIVE RADIO AD-HOC NETWORK

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Abstract: Cognitive radio (CR) is a promising technology geared to solve the spectrum scarcity problem by opportunistically identifying the vacant portions of the spectrum and transmitting in them, while ensuring that the licensed or primary users (PUs) of the spectrum are not affected. The routing schemes can be classified based on spectrum decision, PU awareness, where the CR users have the ability to identify the locations where PUs are present and allow the routes to avoid them and re-configurability, where the route can be adapted with local spectrum changes or by selecting a different set of forwarding nodes altogether.
Unlike classical ad-hoc network, where the channel is decided beforehand, cognitive radio network do not form predefined channel for transmission so hereby, we are learning multi-hop routing algorithms wherein the hops learn about routing path information from their neighbors.
The idea is to present or categorize multi-hop routing schemes in ad-hoc cognitive radio network in order to handle dynamism.
In Cognitive Radio Ad-Hoc Networks, the available spectrum bands are distributed over a wide frequency range, which vary over time and space. Thus, each user shows different spectrum availability according to the primary user (PU) activity. As opposed to this, classical ad-hoc networks generally operate on a pre-decided channel that remains unchanged with time. In routing multi hop cognitive network, hops are learning information from neighbors and then find the route by learning the dynamism.

Key words: **Adhoc networks, computers.**

I. INTRODUCTION

Cognitive radio (CR) is a promising technology geared to solve the spectrum scarcity problem by opportunistically identifying the vacant portions of the spectrum and transmitting in them, while ensuring that the licensed or primary users (PUs) of the spectrum are not affected. This necessitates adapting to the dynamically changing spectrum resource, learning about the spectrum occupancy, making decisions on the quality of the available spectrum resource, including its expected duration of use, probability of disruption caused by the PUs, among others. Thus, CR networks help to make efficient use of the available spectrum by using bands.

Comparison of Classical ad-hoc networks with cognitive radio ad-hoc networks

The changing spectrum environment and the importance of protecting the transmission of the licensed users of the spectrum mainly differentiate classical ad-hoc networks from CRAHNs. These unique features of CRAHNs compared to classical ad-hoc networks are as follows:

- **Choice of transmission spectrum:** In CRAHNs, the available spectrum bands are distributed over a wide frequency range, which vary over time and space. Thus, each user shows different spectrum availability according to the primary user (PU) activity. As opposed to this, classical ad-hoc networks generally operate on a pre-decided channel that remains unchanged with time.
- **Topology control:** Ad-hoc networks lack centralized support, and hence must rely on local coordination to gather topology information. In classical ad-hoc networks, this is easily accomplished by periodic beacon messages on the channel. However, in CRAHNs, as the licensed spectrum opportunity exists over large range of frequencies, sending beacons over all the possible channels is not feasible. Thus, CRAHNs are highly probable to have incomplete topology information, which leads in an increase in collisions among CR users as well as interference to the PUs.
- **Multi-hop/multi-spectrum transmission:** The end-to-end route in the CRAHN consists of multiple hops having different channels according to the spectrum availability. Thus, CRAHNs require collaboration between routing and spectrum allocation in establishing these routes. Moreover, the spectrum switches on the links are frequent based on PU arrivals. As opposed to classical ad-hoc networks, maintaining end-to-end QoS involves not only the traffic load, but also how many different channels and possibly spectrum bands are used in the path, the number of PU induced spectrum change events, consideration of periodic spectrum sensing functions, among others.

II. WORKING OF ADHOC NETWORKS.

Computer Network

A computer network is a system of interconnected computers and peripheral devices.
Collection of two or more computers that are interconnected with each other to perform data communication using the data communication protocol through communication media (wired or wireless), so that computers can share information, data, programs and use of a hardware together.
For example, it may connect computers, printers, scanners and cameras.
There are two types of network

1. Wired network
2. Wireless network

2.1.1 Wired network

These networks are generally connected with the help of wires and cables. Generally the cables being used in this type of networks are CAT5 or CAT6 cables. The connection is usually established with the help of physical devices like Switches and Hubs in between to increase the strength of the connection. These networks are usually more efficient, less expensive and much faster than wireless networks. Once the connection is set there is a very little chance of getting disconnected.

2.1.2 Wireless network

Wireless network is a network set up by using radio signal frequency to communicate among computers and other network devices. Sometimes it's also referred to as WiFi network or WLAN.

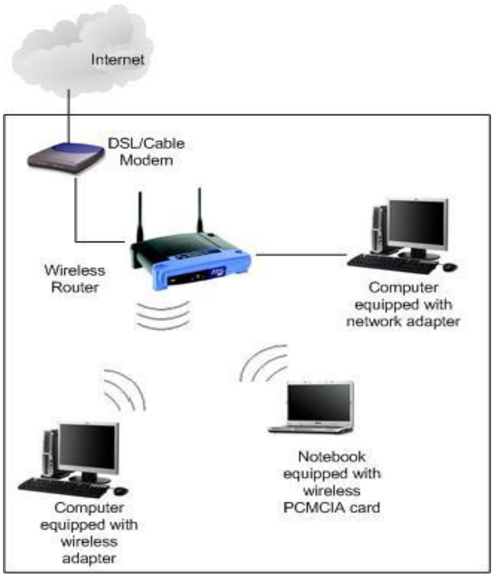

Figure 2.1- Wireless network

This network is getting popular nowadays due to easy to setup feature and no cabling involved. You can connect computers anywhere in your home without the need for wires.

2.2 Types of wireless network

There are two types of wireless network.

1. Infrastructure based wireless network
2. Infrastructure less wireless network

2.2.1 Infrastructure based wireless network

This kind of network consists of a fixed infrastructure.

E.g. cellular network

2.2.2 Infrastructure less wireless network

This kind of network do not consists of a fixed infrastructure. It is a collection of mobile nodes that are dynamically and arbitrarily located in such a manner that the interconnections between nodes are capable of changing on a continual basis.

E.g. ad-hoc network

2.3 Ad-hoc network

A wireless ad-hoc network is a decentralized type of wireless network. The network is ad-hoc because it does not rely on a preexisting infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. Instead, each node participates in routing by forwarding data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity. In addition to the classic routing, ad-hoc networks can use flooding for forwarding the data

2.3.1 Challenges in ad-hoc network

1. Lack of Infrastructure or centralized control. So the key management becomes difficult.

2. Dynamic topology makes it challenging to design sophisticated & secure routing protocols.
3. Communication through radio waves makes it difficult to prevent eavesdropping.
4. Vulnerabilities of routing mechanism due to non-cooperation of nodes.

2.4 Cognitive radio ad-hoc network

Cognitive radio (CR) technology is envisaged to solve the problems in wireless networks resulting from the limited available spectrum and the inefficiency in the spectrum usage by exploiting the existing wireless spectrum opportunistically. CR networks, equipped with the intrinsic capabilities of the cognitive radio, will provide an ultimate spectrum aware communication paradigm in wireless communications. CR networks, however, impose unique challenges due to the high fluctuation in the available spectrum as well as diverse quality-of-service (QoS) requirements. Specifically, in cognitive radio ad-hoc networks (CRAHNs), the distributed multi-hop architecture, the dynamic network topology, and the time and location varying spectrum availability are some of the key distinguishing factors.

The basic idea of CR networks is that the unlicensed devices (also called cognitive radio users or secondary users) need to vacate the band once the licensed device (also known as a primary user like UHF TV and public safety broadcast stations) is detected. CR networks, however, impose unique challenges due to the high fluctuation in the available spectrum as well as diverse quality of- service (QoS) requirements. These challenges necessitate novel design techniques that simultaneously address a wide range of communication problems spanning several layers of the protocol stack.

2.4.1 Characteristics of cognitive radio

Cognitive radio technology is the key technology that enables a CRAHN to use spectrum in a dynamic manner. The term, cognitive radio, can formally be defined as follows[8]:

A ‘‘**Cognitive Radio**’’ is a radio that can change its transmitter parameters based on interaction with the environment in which it operates.

From this definition, two main characteristics of the cognitive radio can be defined as follows

- **Cognitive capability:** Cognitive capability refers to the ability of the radio technology to capture or sense the information from its radio environment. This capability cannot simply be realized by monitoring the power in some frequency bands of interest but more sophisticated techniques, such as autonomous learning and action decision are required in order to capture the temporal and spatial variations in the radio environment and avoid interference to other users. Through this capability, the portions of the spectrum that are unused at a specific time or location can be identified. Consequently, the best spectrum and appropriate operating parameters can be selected.
- **Reconfigurability:** The cognitive capability provides spectrum awareness whereas reconfigurability enables the radio to be dynamically programmed according to the radio environment. More specifically, the cognitive radio can be programmed to transmit and receive on a variety of frequencies and to use different transmission access technologies supported by its hardware design

The ultimate objective of the cognitive radio is to obtain the best available spectrum through cognitive capability and reconfigurability as described before. Since most of the spectrum is already assigned, the most important challenge is to share the licensed spectrum without interfering with the transmission of other licensed users as illustrated in Fig. 3.2. The cognitive radio enables the usage of temporarily unused spectrum, which is referred to as spectrum hole or white space. If this band is further utilized by a licensed user, the cognitive radio moves to another spectrum hole or stays in the same band, altering its transmission power level or modulation scheme to avoid interference as shown in Fig. 2.2.

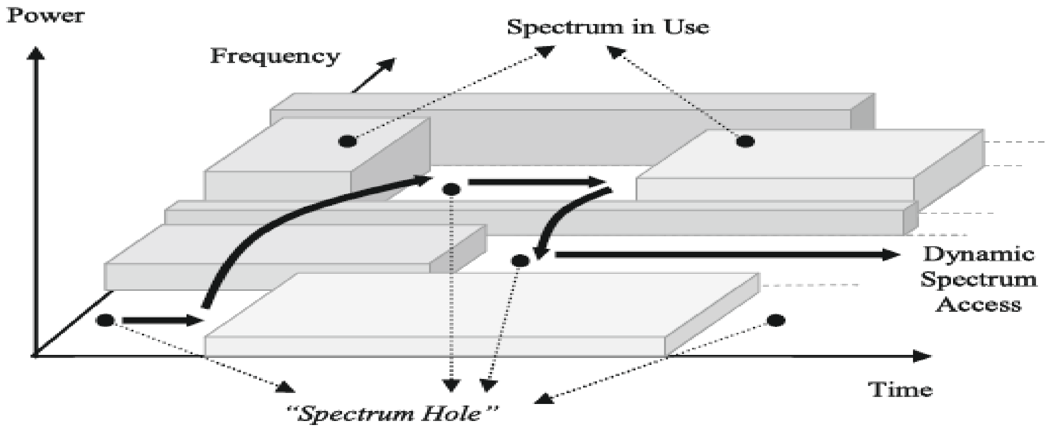

Figure 2.2 Spectrum hole concept.

2.4.2 Cognitive Radio Ad-Hoc Network architecture

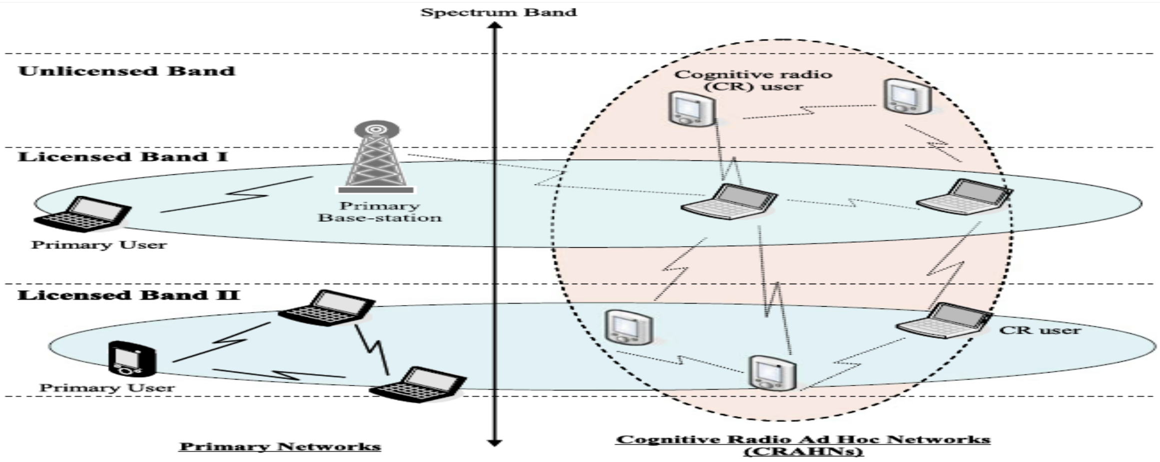

Figure 2.3 - The CRAHN architecture

The components of the cognitive radio ad-hoc network (CRAHN) architecture, as shown in Fig. 2.3, can be classified in two groups as the primary network and the CR network components.

The primary network is referred to as an existing network, where the primary users (PUs) have a license to operate in a certain spectrum band. If primary networks have an infrastructure support, the operations of the PUs are controlled through primary base stations. Due to their priority in spectrum access, the PUs should not be affected by unlicensed users. The CR network (or secondary network) does not have a license to operate in a desired band. Hence, additional functionality is required for CR users (or secondary user) to share the licensed spectrum band. Also, CR users are mobile and can communicate with each other in a multi-hop manner on both licensed and unlicensed spectrum bands.

In CRAHNs, each user needs to have all CR capabilities and is responsible for determining its actions based on the local observation, as shown in Fig. 3.4. Since the CR user cannot predict the influence of its actions on the entire network with its local observation, cooperation schemes are essential, where the observed information can be exchanged among devices to broaden the knowledge on the network.

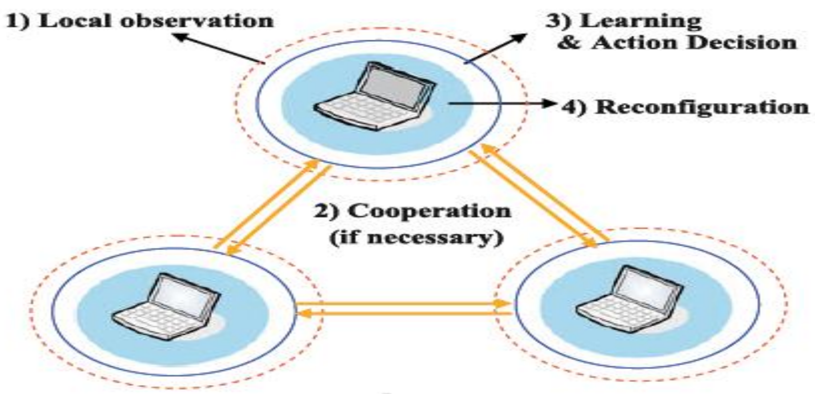

Figure 2.4 Cognitive Radio Ad-Hoc Network

2.4.3 Spectrum management framework for CRAHN

In order to adapt to dynamic spectrum environment, the CRAHN necessitates the spectrum-aware operations, which form a cognitive cycle. As shown in Fig. 3.5, the steps of the cognitive cycle consist of four spectrum management functions: spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility. To implement CRAHNs, each function needs to be incorporated into the classical layering protocol.

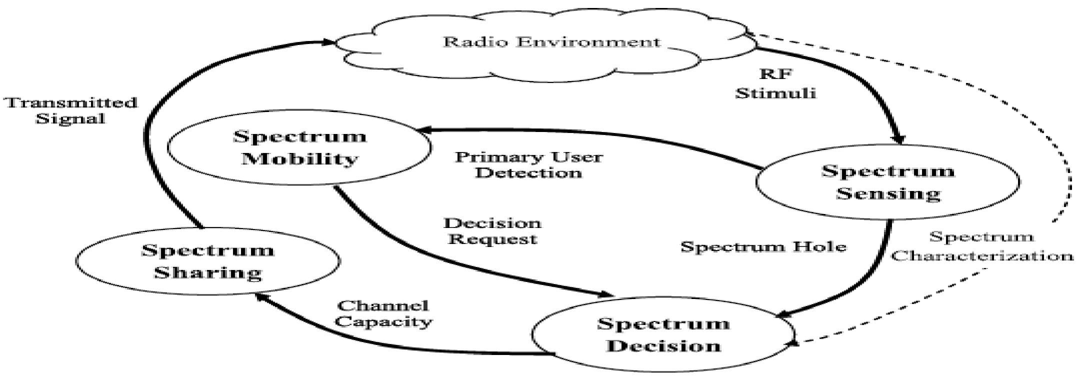

Figure 2.5 The cognitive radio cycle

The following are the main features of spectrum management functions [1]:

- **Spectrum sensing:** A CR user can be allocated to only an unused portion of the spectrum. Therefore, a CR user should monitor the available spectrum bands, and then detect spectrum holes. Spectrum sensing is a basic functionality in CR networks, and hence it is closely related to other spectrum management functions as well as layering protocols to provide information on spectrum availability.

- **Spectrum decision:** Once the available spectrums are identified, it is essential that the CR users select the most appropriate band according to their QoS requirements. It

is important to characterize the spectrum band in terms of both radio environment and the statistical behaviors of the PUs. In order to design a decision algorithm that incorporates dynamic spectrum characteristics, a priori information regarding the PU activity needs to be obtained. Furthermore, in CRAHNs, spectrum decision involves jointly undertaking spectrum selection and route formation.

- **Spectrum sharing:** Since there may be multiple CR users trying to access the spectrum, their transmissions should be coordinated to prevent collisions in overlapping portions of the spectrum. Spectrum sharing provides the capability to share the spectrum resource opportunistically with multiple CR users which includes
 resource allocation to avoid interference caused to the primary network.

- **Spectrum mobility:** If a PU is detected in the specific portion of the spectrum in use, CR users should vacate the spectrum immediately and continue their communications in another vacant portion of the spectrum. For this, either a new spectrum must be chosen or the affected links may be circumvented entirely. Thus, spectrum mobility necessitates a spectrum handoff scheme to detect the link failure and to switch the current transmission to a new route or a new spectrum band with minimum quality degradation. This requires collaborating with spectrum sensing, neighbor discovery in a link layer, and routing protocols. Furthermore, this functionality needs a connection management scheme to sustain the performance of upper layer protocols by mitigating the influence of spectrum switching.

To overcome the drawback caused by the limited knowledge of the network, all of spectrum management functions are based on cooperative operations where CR users determine their actions based on the observed information exchanged with their neighbors.

2.5 Common control channel

The common control channel (CCC) is used for supporting the transmission coordination and spectrum related information exchange between the CR users. It facilitates neighbor discovery, helps in spectrum sensing coordination, control signaling and exchange of local measurements between the CR users. The operation of the CCC is different from the data transmission over the licensed band

There are different design approaches that may be followed for establishing and using the CCC. The two main approaches are in-band and out-of-band CCC, depending on whether the control channel shares the data channel or uses a dedicated spectrum, respectively.

2.5.1 In-band CCC

The licensed spectrum used for ongoing data transmission band may be used to transmit the control messages. In this case, the CCC operation is only for a specific purpose and for a temporary duration. Moreover, each node pair may use a different channel for communication. As the CCC is the same as the channel used for data, the extent of coverage of the CCC is local, i.e. unique to the corresponding node pair. The advantage of this approach is that a separate dedicated transceiver is not needed for the CCC.

2.5.2 Out-of-band CCC

Out-of-band signaling (through a licensed channel reserved for CCC use or by using the unlicensed band) minimizes the CCC disruptions caused by PU activity. In this case, the spectrum reservation for the CCC may either be made for a short duration, or there may be a permanent assignment. As the data and the control signaling are separate, more than one transceiver may be needed for dedicated CCC monitoring. For single radio devices, the cost of switching between the data band and the CCC, and the associated deaf period when the CCC is not sensed, must be accounted for in the protocol design.

II. 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 spectrum-aware communication, the CR devices need to incorporate the spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility functionalities. The main challenge in CRAHNs is to integrate these functions in the layers of the protocol stack, so that the CR users can communicate reliably in a distributed manner, over a multi- hop multi-spectrum environment, without any infrastructure support. In routing multi hop cognitive network, hops are learning information from neighbors and then find the route by learning the dynamism. Routing in CRN is a challenging task due the diversity in the available channels and data rates.

Cognitive radio networks have many applications in the military, where the military personnel have a strong need for security, protection of the communication in hostile environment and disaster recovery arenas to set up emergency networks

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 ISSN : 2394-1766