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An Intelligent Routing Model using Multi-Radio Diversity for Cognitive Radio Ad-Hoc Networks

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ABSTRACT: The demand for radio spectrum is expected to grow rapidly with the rapid growth of wireless communication in the near future. However, radio spectrum is a limited resource and it is already very crowded. The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically. As it is difficult to accommodate more wireless applications within this limited resource, effective utilization of the unused wireless spectrum is a challenge from spectrum management perspective. To deal with the problems of spectrum congestion and spectrum under-utilization, cognitive radio (CR) has been recently proposed as the solution to current low usage of licensed spectrum problem. The main function for the cognitive radio is detecting unused spectrum, sharing the spectrum without harmful interference with other users and capturing the best scheduling the spectrum. Cognitive radio networks (CRNs) can make full use of spectrum resources of heterogeneous wireless architectures via dynamic spectrum access techniques. However, routing in CRNs impose challenges due to the fluctuating nature of the available spectrum. To study routing algorithm a model that can simulate CRNs routing protocol needs defining. In this paper, an Intelligent Routing Model (IRM) for cognitive radio ad-hoc networks is proposed and implemented in NS2. The performance of the proposed model is validated by observing improvement in overall network throughput and channel utilization of available spectrum.

KEYWORDS: CR, CRNs, dynamic spectrum access, routing, NS2

I.INTRODUCTION

With increase demand of wireless operated electronic gadgets, there is tremendous research taken place in the fields like wireless communication, signal processing, VLSI. So, lots of wireless communication technologies have been deployed in personal area network to wide area network to fulfil users need. This has increased the use of radio spectrum. Thus radio spectrum is one of the most heavily used resources. The recent radio spectrum measurements show that the fixed spectrum allocation policy is not suitable for current wireless system [1]. Moreover, most of the licensed bands assigned for licensed users are under-utilized, many portions of the radio spectrum are not utilized for a significant period of time or in particular areas, while unlicensed bands used to operate by various well-known wireless technologies, such as Wi-Fi, cordless phones, Bluetooth, NFC (Near Field Communication), and so on, are always crowded, approved by Federal Communications Commission (FCC)'s experiment results [2]. Cognitive radio (CR) [3][4][5] is a important technology for future wireless communications and to solve the problems of limited availability of spectrum and spectrum underutilization as well as to address the increasing congestion in the unlicensed bands by enabling unlicensed users to opportunistically access the vacant portions of the spectrum bands, referred to as Spectrum Opportunities (SOP) [5], which is always statistically underutilized by licensed users (also known as primary users: PUs). CR networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. This goal can be realized only through dynamic and efficient spectrum management techniques. CR networks, however, impose unique challenges due to the high fluctuation in the available spectrum, as well as the diverse quality of service (QoS) requirements of various applications.

In order to address these challenges, each CR user in the CR network must:

- Determine which portions of the spectrum are available

- Select the best available channel
- Coordinate access to this channel with other users
- Vacate the channel when a licensed user is detected [3]

These functionalities of cognitive radio networks enable spectrum-aware communication protocols. However, the dynamic use of the spectrum causes adverse effects on the performance of conventional communication protocols, which were developed considering a fixed frequency band for communication. The ultimate objective of the cognitive radio is to obtain the best available spectrum through cognitive capability and Reconfigurability. 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. 1. The cognitive radio enables the usage of temporally unused spectrum, which is referred to as spectrum hole or white space [4].

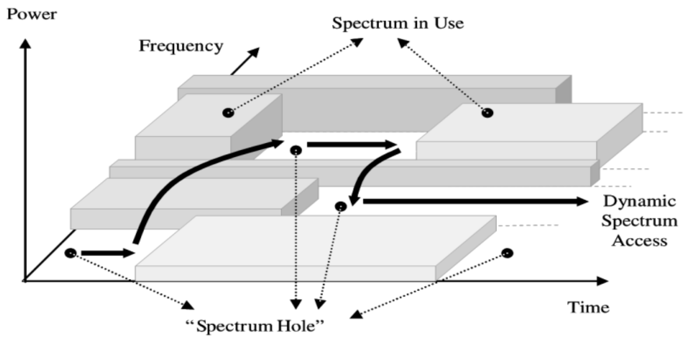

Fig. 1 Spectrum Hole Concept [3].

In this paper, the new routing model for CRN routing is based on Network Simulator 2 (NS2), which is one of the most popular network simulators. NS2 provides many radio models, such as 802.11, 802.16, 802.15.3, 802.15.4, which can be used for cognitive radio network simulations.

The rest of the paper is organized as follows. Section II briefly describes the background and presents problem analysis in CRN routing. Section III shows the proposed design and modification in TCL script in NS2. Comparative results are obtained in terms of the throughput for validation of the proposed model and shown in Section IV. Finally the paper is concluded in Section V.

II.BACKGROUND AND PROBLEM ANALYSIS

Background

The architecture of a CRN can be either infrastructure based or infrastructure less. In an infrastructure less CRN, the unlicensed users communicate with each other directly (i.e. in a peer-to-peer fashion) without requiring any base station. The communication can be either single-hop or multi-hop. For multi-hop communications, some unlicensed users can temporarily assume the role of relay stations as revealed in Fig. 2.

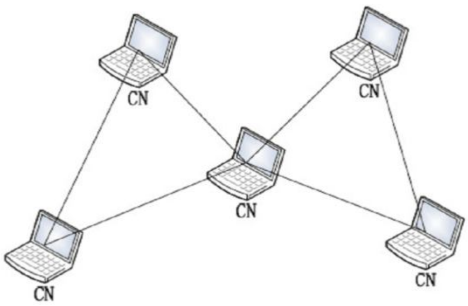

Fig. 2 Ad-hoc cognitive radio networks [6].

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The two main characteristics considered in CRN are cognitive capability [7] and fluctuating nature of the available spectrum.

Cognitive capability: The portions of the spectrum that are unused at a specific time or location can be identified according to the real time environment, as shown in Fig. 1. A CR allows a cognitive user to access a spectrum hole unoccupied by a primary user (PU) and improve the spectrum utilization while reducing the whitespaces in the spectrum. Therefore, the best spectrum can be selected, shared with other users, and exploited without interference with the licensed user.

Spectrum Fluctuation: The available spectrum will be different during the entire communication process. A licensed spectrum may be used by the PUs at some times, but at other times, it is idle. Through the cognitive capability, the secondary user (SU) finds the spectrum that is available at the moment, and then is listed as the available spectrum. When the SUs use the idle licensed communication with other users, the PUs appears and need to use the licensed spectrum. The available set of spectrum for second uses is changed with the appearance of PUs. That's the fluctuating nature of available spectrum.

Problem Analysis

In view of the characteristics that are mentioned in background, they cause some problems for route selection. Here the main problems considered are namely, spectrum awareness, variability of available spectrum and the complexity of spectrum selection.

Spectrum Awareness: In a dynamic CRN, the PUs may use the channels for intermittent durations causing the need to change the routing paths. At such times, the routing protocol is faced with two options, i.e., change the physical regions through which the existing path passes or switch the channel altogether [8]. At this time, the routing protocol may: (i) switch channels within the same spectrum band, (ii) switch spectrum bands altogether, (iii) circumvent the affected region on the same channel, or (iv) continue along the shortest path in the same channel by adapting its transmission, if this path intersects regions of PU activity. Thus, there is a need to design new routing protocols that considers the spectrum sensing function, spectrum decision, MAC layer spectrum access technology and end-to-end performance requirements.

Variability: The set of available spectrum is dynamic due to the effects of PUs. The set of neighbors will be changed once the set of available channel is changed. If the routing protocol doesn't know the change, some problems in routing selection can be observed. As shown in Fig. 3, the red broken line is S1 and the green real line is S2. A is communicating with B in spectrum of S1, and in the meanwhile the primary users also need to use the S1.But the routing layer does not know the behavior of PU and sends the data to B in S1 all the same. In fact, A should just use S2 to send the data. According to this example, the routing layer must know about the information of MAC layer, or the routing results are not dependent.

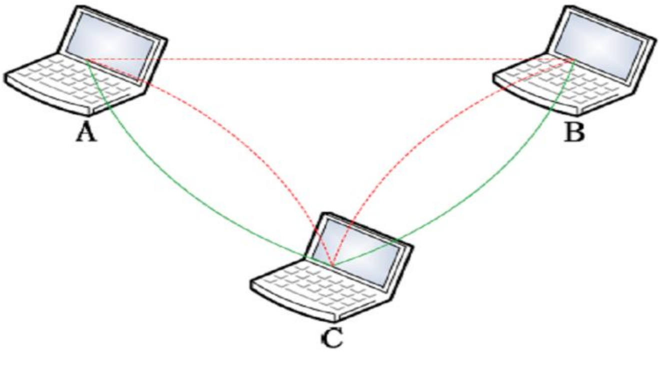

Fig. 3 Effects of dynamic spectrum [9].

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Complexity: In CR networks, some control information need to broadcast. Meanwhile, we need to reduce the redundant of network. With the requirements, we should choose a common channel [10] that, just one times, all nodes can receive the information from. However, the transmit scope and set of neighbors with different spectrum not the same, if we just use one control spectrum for nodes to exchange the routing information, sometimes, it may be not feasible. For example, Node X has A, B and C spectrum, Y has A, B, and Z has A, C. The scope of transmission is Rc > Rb > Ra. Three nodes all have the A spectrum, and we think A can be selected as the common channel. But, in fact, as the scope of transmission, the Node Z and Node X are not in the scope of spectrum A, so they can't communicate with A spectrum. This is the complexity problem when we select the available spectrum.

III. DESIGN OF INTELLIGENT ROUTING MODEL

In accordance with the discussion in Section II, the problems exists in CRN like the ability for finding the spectrum opportunities is addressed [11].Variability and complexity are the major issues in route selection and this leads to define the basic requirements for our model. First the routing agent must check the available channel for distinguishing between primary and secondary user (SU), then MAC switches spectrum and collaborates with the routing agent. The proposed Routing Model is shown in Fig.4.

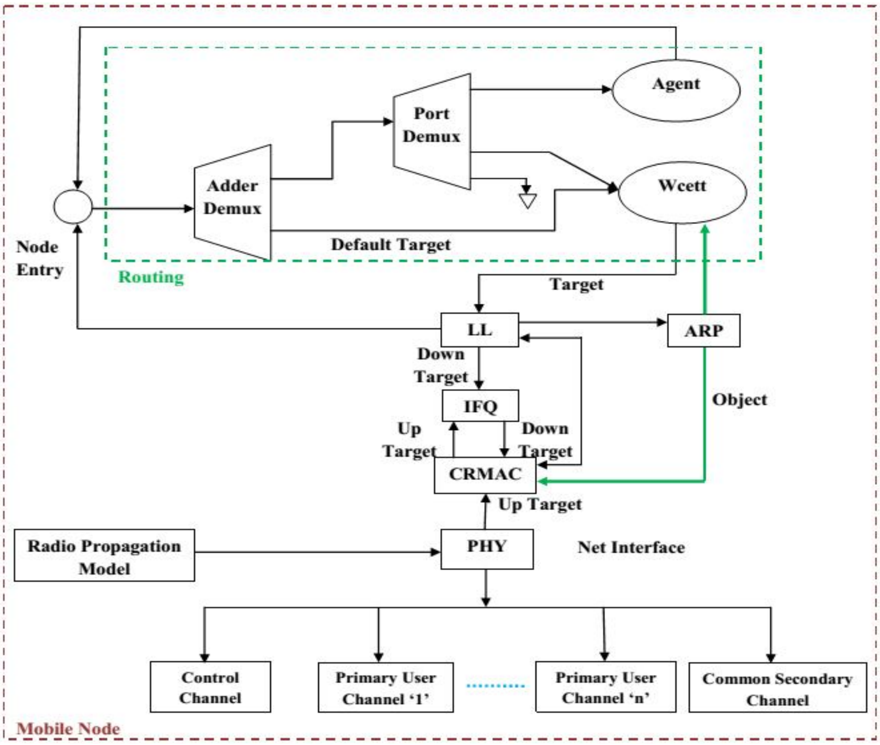

Fig. 4 Intelligent Routing Model (IRM).

Model Description

IRM model is designed to support the routing in CRN. As our proposed model supports multiple channels, we represent channel as spectrum. And channel id is used for channel assignment. We introduced cross layer design approach in our model [12]. Routing agent is used to identify the user. Using primary and secondary user tables, we distinguish between PU and SU. The routing protocol requires channel information transferred by CRMAC. In routing agent we amend the adhoc WCETT routing protocol, and take variability of the spectrum into account.

In the IRM model, we used mac type as Mac/CRMac which is the main part of our design. As shown in Fig. 4, CRMac collaborates with routing agent, out of available channels when RT agent selects available channel (spectrum) , it assign and switches the channels based on control information for the communication. For addressing the cross layer issue the CRMac transfers the channel information to RT agent, which helps the RT agent to identify the channel if it is used or free. Thus RT agent owns the cognitive capability. In the proposed model there is 'n+2' channels, out of which first channel is used as a control channel and last channel is used as a common secondary channel. The remaining channels are Primary User channels available according to the secondary user. The Primary User channels in a secondary user can be varied according to the user specification.

The Common Secondary Channel is used when all the Primary User Channels are busy. Suppose when 2 secondary users are transmitting data between them using a primary user channel and suddenly the Primary User starts using that channel, so now the secondary users has to vacate that channel and to continue data transmission between the secondary users they have to wait until that channel is available. This waiting can be avoided with the use of a Common Secondary Channel. Thus this will help in real time operations.

Modifications in NS2

- We make tcl script wir2.tcl by modifying ns-lib.tcl to support multichannel configuration. Wireless scenario is created and multichannel is supported by trace-all and namtrace-all-wireless to support the scenario scripts. Mobile nodes are formed by changing nodeconfig and create-wireless-node.
- Modify in file ns-mobilenode.tcl to assemble the single component into the compound component of Mobile Node in Fig.4.
- Each mobile node is associated with a channel. The down target of MAC is CRMac and all the channels are connected to CRMac.
- Channel {h,cc} is used for channel assignment and switching by learning and reasoning capability.
- CRMac {h,cc} is used for service request and service respond, it also defines a new class and points to MAC and channel entries.
- Wcett{h,cc} is used for routing and multichannel assignment. Once the mobile node of multi-channel and multi-interface structures is configured with TCL script, association of the node with multiple channels is followed. Two arrays of pointers are defined and added into mobile-node{h,cc}. These instances of array are used within the channel.cc file to manage the corresponding node lists.
- Timers for each assigned channels are set by modifying the mac-timers {h,cc} and mac 802_11{h,cc}. It also used to find the channel id and defines that which timer used for the channel.
- Ad-hoc routing Aodv protocol is modified and wcett protocol is used where variability of the channel is taken in to consideration.

IV. SIMULATION RESULTS

We created a wireless scenario over a 1000m x 1000m grid to exploit the use of the common secondary channel. There are 8 wireless nodes in which 4 nodes are PU and 4 nodes are SU. There are 2 primary user channels and a common secondary channel. Here the IRM model is compared with DSMCRN model [6]. The channel in CR in the DSMCRN model only contains the available spectrum. It doesn't have a common secondary channel. Hence when PU uses its spectrum the SU has to wait until the channel is available. Total three cbr flows are set for PU and SU communications. The packet size is fixed at 512. The toolsetdest is used to make the node movement random in the scenario with respect to the simulation time. The tool cbrgen is used to create the file of cbr that includes the type of cbr and rate of sending. We write the script wir2.tcl and analyze the trace file. Simulation results show comparative performance of the IRM model with the DSMCRN model.

For examining the performance of the IRM model, obtained results are compared with the existing DSMCRN model result. Fig. 5 illustrates the overall throughput performance. Increase in throughput is observed in IRM model as compared to the other. Due to the ability of CR in IRM model, when the SU finds the licensed spectrum is busy, they will use the common secondary channel. It is also believed that, due to cognitive ability the IRM model has shown the increase in overall network performance by utilizing the available spectrum opportunities, and is validated through increased throughput.

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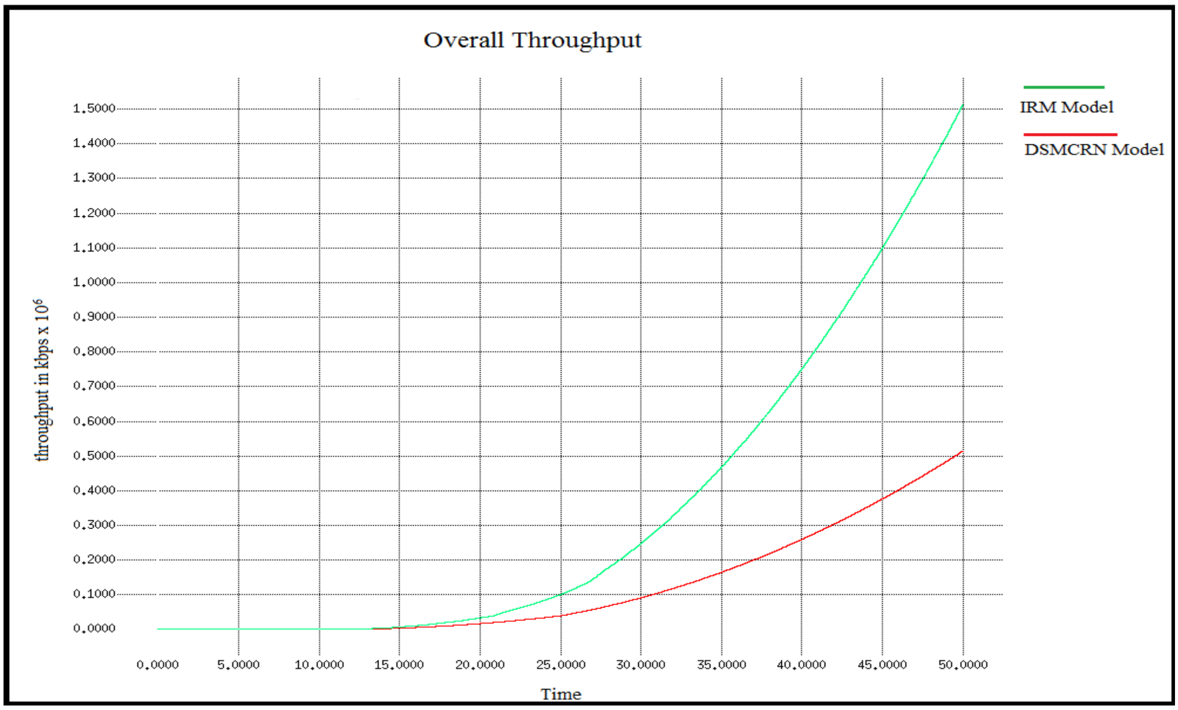

Fig. 5 IRM Vs DSMCRN

V.CONCLUSION

In this paper a new Intelligent Routing Model for addressing the issue of routing is proposed and implemented in NS2 which can be used for routing protocol simulation in cognitive radio networks. The performance of the IRM model is investigated and validated through simulation results compared to the existing DSMCRN model. It is observed that the proposed model shown drastic improvement in throughput with the effective utilization of the available channels. It is proved that, IRM model gives comparatively better results than the existing models.

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