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Spectrum Aware On-Demand Routing in Cognitive Radio Networks

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ABSTRACT

When a cognitive radio (CR) device changes its operation frequency, it experiences a hardware switching delay to tune to its new frequency before it can fully utilize it. This delay in general depends on the wideness between the two frequency bands. When the range of frequencies that the cognitive radio network (CRN) operates in is narrow, this delay difference might be negligible. But the CRNs of the future are envisioned to operate in a wide range of frequency bands. So the spectrum allocation and scheduling algorithms designed for CRNs have to take into account different delays that occur while switching to different frequency bands. The dependence of the switching delay on the wideness between the old and new central frequencies is unique to the dynamic spectrum access paradigm since other wireless technologies typically operate in a narrower bandwidth. In the proposed work a model is presented for spectrum aware on-demand routing in cognitive radio networks.

Keywords : Cognitive Radio Networks, Spectrum aware on-demand routing, Cognitive radio network(CRN), spectrum allocation.

I. INTRODUCTION

Cognitive Radio (CR) is an emerging technology in the wireless communication. CR nodes have the capability to change its transmission or reception efficiently without interfering with licensed users. The network formed with CR nodes communicating with each other is called Cognitive Radio Network (CRN).

In order to make good use of the unutilized bands, devices with cognitive capabilities can be Networked to create Cognitive Radio Network, in which there are two types of users sharing a common spectrum portion but with different rules: Primary Users (PUs) have the priority in spectrum utilization within the band they have licensed, and Secondary Users (SUs) must opportunistically access the spectrum without interfering with PUs.

Cognitive radio (CR) is a key promising technology for future wireless communications and mobile computing proposed to solve the problems of spectrum scarcity and spectrum underutilization as well as address the increasing congestion in the unlicensed bands by enabling unlicensed users (also called CR users or secondary users: SUs) to opportunistically access the vacant portions of the spectrum bands, referred as Spectrum Opportunities (SOP), which is always statistically underutilized by licensed users (also known as primary users: PUs) while ensuring that the interference to the licensed users is below an acceptable threshold level.

In order to use the licensed spectrum band, SUs must have atleast one cognitive radio transceiver. With the cognitive radio transceivers, SUs search for vacant spectrum, called spectrum opportunity, by conducting spectrum sensing. Since PUs have the authority to use the licensed spectrum band, SUs must not interrupt the transmissions of PUs by performing reconfiguration of transmission parameters or moving to other vacant spectrum bands. This creates dynamic use of spectrum bands, where the SUs are able to switch among different spectrums.

II. METHODS AND MATERIAL

A. CHALLENGES FOR ROUTING IN CRN:

The channel availability and data rates are varying continuously in case of CRNs, especially in case of multi hop CRNs. To design a routing scheme for such CRNs is a challenging job. CR users can access multiple available channels simultaneously, due to which overall network performance is increased and interference on the primary users is decreased. For this feature of CRNs the conventional routing metrics such as hope count, congestion, etc, are not sufficient for routing decision in CRNs. Some challenges for routing in CRN are listed below

1. Link Availability

Cognitive Radio Networks uses the licensed band in an opportunistic manner for communication among the CR nodes, using DSA (Dynamic Spectrum Access). These licensed bands are available to CR nodes for communication, only when these are not used by primary users. Thus we can say that the channel availability is based on geography as well as time. This random channel availability forms random CRN topology, even if all CR nodes are static, not mentioned mobile nature of CRN.

2. Unidirectional Links

In wireless networking unidirectional links are rare but in case of CRN , the CR nodes may get the opportunity of transmission in one time duration and there is no guarantee of opportunity for transmission from the another direction. Thus in the true sense it can be said that CRN differs from other wireless networks, at the network layer.

3. Heterogeneity

CRN is generally formed by heterogeneous wireless networks, which is not the case with the typical wireless ad hoc or sensor networks. Inter-system handover is usually required for routing in such heterogeneous wireless networks. Also the links are available for extremely short duration, hence successful networking lies in cooperative relaying among such heterogeneous wireless networks.

4. Deafness Problem

Deafness problem is nothing but switching of relay nodes among the available channel set whenever the presence of primary user is detected. This activity causes extra delay in CRNs communications.

5. Security issues

Enabling of CRNs at the price of losing security is a debatable issue. Short duration of available channel is not a sufficient for CR user or node to get secure certificate.

B. ROUTING IN CRAHNS

A number of works propose routing protocols for cognitive radio networks, ranging from making an adaptation of existing routing protocols to constructing completely new routing protocols to fulfill the characteristics of cognitive radio networks (CRNs). In CRNs, nodes can work on different and unlicensed frequency bands whenever available. They have route maintenance procedures that can be used to solve frequent connectivity changes in cognitive wireless networks. The routing protocols in CRAHNs should satisfy requirements for both CRNs and MANETs. AODV is an on-demand routing protocol used in MANETs and support the properties of dynamic topology, self-organizing, self-configuring, and mobility . Applying this routing protocol directly to cognitive radio networks is not viable, due to its poor performance in the dynamic spectrum utilization environment. Therefore, suitable modifications are necessary in AODV for its adaptation to CRN scenario.

Spectrum-aware On-Demand routing protocol (SORP)

SORP is an on demand routing protocol that is neither based on centralized spectrum allocation nor multi-channel. The nature of this protocol is due to lack of shared information. The routing technique proposed by Cheng is to select best suitable RF bands for each node along the route. The RF band selection is based on minimum cumulative delay. The switching and back-off delay causedby both the path itself and the intersecting flow are the judging parameters for calculating cumulative delay of the path. They proposed a spectrum aware on demand framework for routing and multi-flow multi-frequency scheduling for RF band selection. They slightly modified Ad hoc on demand distance vector routing (AODV) to incorporate the inconsistency of spectrum opportunity. They made some assumptions for their routing technique, as follow: To form a common control channel each node contains a traditional wireless interface in addition to the CR transceiver. Each node is able to provide spectrum sensing information to routing protocol through cross layer design. For route discovery SORP inherits the basic procedures of AODV with modified Route Request (RREQ).In SORP Spectrum Opportunity (SOP) information is piggybacked by RREQ messages. SOP information is piggybacked only when the node finds intersection between the RREQ and its own. Thus destination node receives the SOP distribution of all the nodes along the path and it assigns RF band to its CR transceiver accordingly. This RF band information is sent back to the source node as well intermediate nodes through Route Reply (RREP) message. All the nodes along the path assign the RF band according to the received RREP.

Advantages and Overhead:

This routing technique overcomes the inconsistency of SOPs. It selects best path on the basis of the total delay along the path. It selects the RF band with joint interaction of routing and scheduling. Therefore path cumulative based RF band selection introduces both switching and back off delay.

Proposed System

The proposed channel quality prediction mechanism captures the idle state duration of the channel and the spectrum sensing accuracy of the SUs. Than provides more high quality transmission opportunities and higher successful transmission rates at shorter spectrum waiting times for dynamic spectrum access. The proposed system works in following modules :

Primary User

Primary user has a license to operate in a certain spectrum band. This access can be only controlled by its base-station and should not be affected by the operations of any other unauthorized user.

Primary Base-Station:

Primary base-station is a fixed infrastructure network component which has a spectrum license. In principle, the primary base-station does not have any cognitive radio capability for sharing spectrum with cognitive radio users. However, primary base-station may be required to have both legacy and cognitive radio protocols for the primary network access of cognitive radio users.

Cognitive Radio User:

Cognitive radio user has no spectrum license. Hence, the spectrum access is allowed only in an opportunistic manner. Capabilities of the cognitive radio user include spectrum sensing, spectrum decision, spectrum handoff and cognitive radio MAC/routing/transport protocols. The cognitive radio user is assumed to have the capabilities to communicate with not only the base-station but also other cognitive radio users.

Cognitive Radio Base-Station

Cognitive radio base-station is a fixed infrastructure component with cognitive radio capabilities. Cognitive radio base-station provides single hop connection to cognitive radio users without spectrum access license.

Algorithm Steps:

1. First each node N will discover its 1-hop neighbors for all channels.
2. After calculating 1-hop neighbors, each node will calculate its 2-hop neighbors from the list of 1-hop neighbors for all the channels (it will not add those which are already its 1-hop neighbors).
3. Then each node will check for PU activity on all channels.
4. After checking PU activity, nodes will calculate channel quality for all available idle channels.
5. After calculating channel quality, each node will assign the first best channel to its first interface and second best channel to its second interface.
6. Reconfiguration: If PU nodes arrive at the assigned channel then only the effected nodes will repeat the algorithm by following steps 1-5, while the channel assignment for rest of the nodes will remain the same.

Channel Quality Prediction

We employ two metrics to evaluate the channel quality. The first one is the spectrum sensing accuracy of the secondary user on the primary channel, which has influence on the spectrum utilization efficiency of the secondary user; the second one is the expected duration of the idle state, which implies the channel availability to the secondary user. We design a channel quality metric MQ, which takes into account both the spectrum sensing accuracy and the expected channel idle duration time.

Spectrum Selection

A novel algorithm that solves efficiently the problem of spectrum sharing and user scheduling in a cognitive downlink MIMO system. We design a low complexity greedy algorithm. Following, we add the well-known proportional fairness to the proposed algorithm in order to ensure time-based fairness and to resolve efficiently the fairness/sum rate tradeoff.

Evaluation

Computer simulations show that the proposed algorithm is able to achieve near-optimal performances with low computational complexity. We also compare our proposed method with the corresponding constant switching delay-based algorithm and demonstrate that our suggestion of taking into account the different hardware delays while switching to different frequency bands is essential for scheduling in CRNs.

III. RESULTS AND DISCUSSION

The following are the snapshots of the proposed system

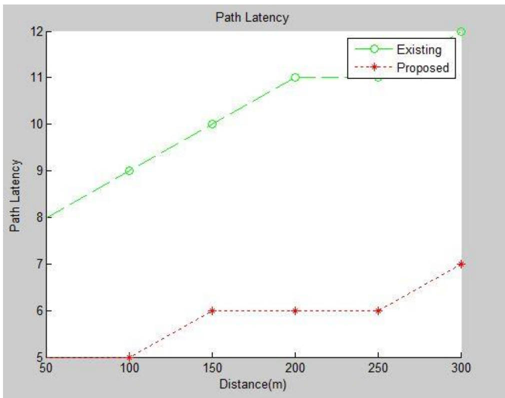

Figure 1. Comparison of Path latencies

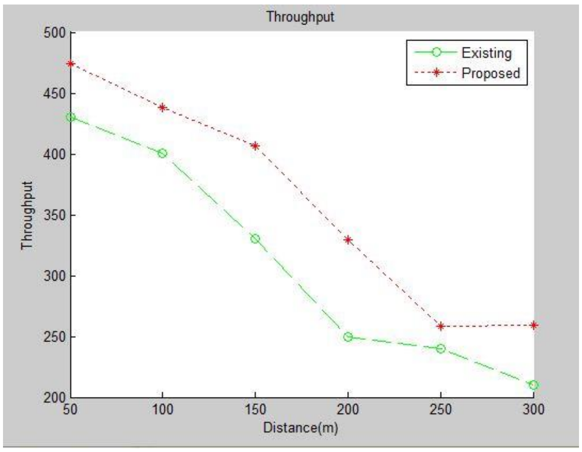

Figure 2. Throughput

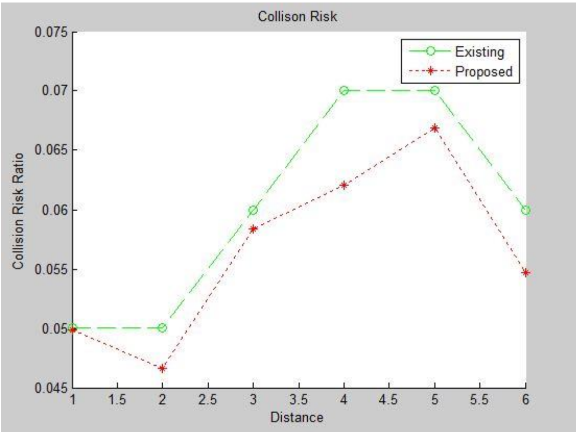

Figure 3. Collision Rate

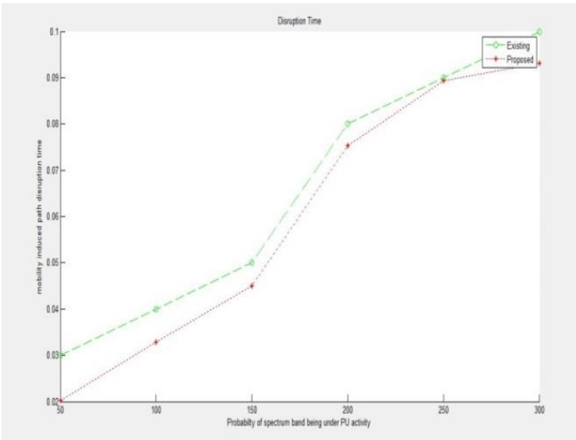

Figure 1. Disruption time

Considering IEEE 802.22 as the standard reference for cellular network mechanisms and channel assignment schemes for cooperative and non-cooperative CR devices along with their pros and cons. An experimental study and comparison with a random channel assignment demonstrate that a robust and efficient channel assignment scheme is a critical feature in CRNs.

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