Comparison of MAC Protocols in Cognitive Radio

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Abstract

Cognitive radio (CR) transceiver can sense, is aware of its operational environment and can dynamically and autonomously adjusts its radio operating parameters accordingly. When a primary user (PU) appears, CR-MAC protocol enables secondary users (SUs) to utilize multiple channels by switching channels dynamically. In this paper, performance of CR-MAC i.e. contention based MAC & collision free MAC is evaluated and compared on the basis of average throughput, average end to end delay, routing overhead and packet delivery ratio.

Keywords- Cognitive Radio Network, Cognitive Radio MAC.

1. Introduction

Radio spectrum is one of the scarcest and valuable resources in wireless communications. An unlicensed band such as Industrial, Scientific and Medical (ISM) has become over-crowded, with rapid increase of the wireless applications and products. It has been also found that the allocated spectrum is underutilized because of the static allocation of the spectrum [1]. Regulatory authorities strictly controlled the radio spectrum allocation through licensing processes. Most countries have their own regulatory bodies, though regional regulators do exist. In the U.S regulation is done by the Federal Communications Commission (FCC) [2].

In order to better utilize the licensed spectrum, the FCC has recently suggested a new policy for dynamically allocating the spectrum. Thus, the discrepancy between spectrum allocation and spectrum use suggests that this spectrum shortage could be overcome by allowing more flexible usage of a spectrum. Radios could find and adapt to any immediate local spectrum available is known as flexibility. To overcome spectrum scarcity, licensed spectrum bands need to be utilized more intelligently.

A new class of radios that is able to reliably sense the spectral environment over a wide bandwidth detects the presence or absence of primary users and use the spectrum only if the communication does not interfere with primary users is defined by term cognitive radio (CR). CR has become an attractive research topic nowadays, it efficiently utilize the unused spectrum [3]. This approach is enabled by software-defined radio frequency spectrum.

In this paper remaining part of the paper is organised as follows. In section 2 cognitive radio network is discussed. Section 3 discusses the CR MAC protocols. Section 4 presents the simulation setup and performance evaluation. Finally, this paper is concluded in section 5.

2. Cognitive Radio Network

The concept of the CR technique is that cognitive radio nodes (CR nodes) can temporarily borrow unoccupied channels from primary users (PUs) without interfering with PUs. Opportunistic use of spectrum requires SUs sensing the spectrum before transmitting data. Spectrum sensing or channel sensing techniques are used to decide whether at a given time the channel is being used by PUs or not. The parts of spectrum not being used by PUs are available to SUs and are called white/spectrum holes or available channels. Cognitive Radio transceiver automatically detects available channels in wireless spectrum and accordingly changes its transmission or reception parameters such as frequency range, modulation type or maximum output power [4].

The main features of cognitive radio include ability to recognize their communication environment and independently adapt the parameters of their communication scheme to maximize the quality of service for the secondary users while minimizing the interference to the primary users. Several spectrum sensing techniques have been explored in the literature. Usually spectrum sensing techniques are available in Physical layer, but in order to increase sensing reliability there has to be coordination between MAC layer & Network layer. For channel access between wireless nodes, a Cognitive Medium Access Control (CR-MAC) protocol is necessary. MAC protocol of IEEE 802.11 standards are designed for single channel, only it allows the use of multiple channels available at PHY layer. A single channel MAC protocol does not work well in a multichannel environment, because of the multichannel hidden terminal problem (MHTP). For data transmission a data channel selected by a Tx -Rx pair may not be known to the neighbours, therefore, there is always a possibility that the same data channel can be selected by one or more neighbours for transmission, resulting in collision. This phenomenon in multi-channel networks is termed as MHTP [6]. Cognitive Radio multi-channel MAC protocol extensions with IEEE 802.11 enables a node to operate in multiple channels in order to improve network-wide throughput. CR-MAC protocol enables secondary users (SUs) to utilize multiple channels by switching channels dynamically, which increases network throughput [5].

3. CR MAC Protocols

CR-MAC protocol allows SUs to identify and use the unused frequency spectrum in a way that minimize the level of interference to the PUs. Especially when the network is highly congested, this scheme improves network throughput significantly [6].

CR-MAC includes two key concepts the rendezvous channel (RC), and the backup channel (BC). RC is used for node coordination and Primary user (PU) detection. BC provides a choice of alternate spectrum bands in case of the appearance of a PU. In CR-MAC, each channel is divided into consecutive superframes composed of slotted beacon period (BP) followed by a data transmission period (DTP). To determine the vacant spectrum resource, each CR user scans all the available spectrum bands. If it hears a beacon, in these bands, then it may choose to join that specific band and also set the global RC to the band specified in the beacon. The start time of a superframe is determined by the beginning of a BP, also provides quiet period (QP) coordination for incumbent detection. The first two slot of the BP are known as the signalling slots, and are used for new devices joining this channel. Each device on that channel sends its own beacon during the BP at its designated beacon slot, from the third slot onwards. For data communication, beacons contain information about scheduled QPs, spectrum measurements, and multi-channel reservation. Node undergoes PUs detection during QP with DTP. To determine a suitable BC for a given channel, nodes perform in-band and out-of-band measurements via QPs [7].

The CR users periodically tune to the RC and transmit their beacons. If they need to establish a new data spectrum band, this is communicated over these beacons. Any spectrum change that occurs in CR-MAC must first be announced by the CR users over the RC, before using that band.

In this section overview of two types of MAC i.e. contention based & collision free MAC, is given [8].

3.1. Contention based MAC:

In contention based MAC, each node randomly selects a channel from a predefined channel list. Since each node is not aware of what channel is being used by other node, collision is still existed for this random channel selection. The channel information selected by each node is passed to PHY layer through the packet header.

CR-MAC choose transmission power and channel selection (TC), it will send down the information through the multi-channel support functional block as shown in Figure 1. MAC layer is only aware of a single channel, before the multi-channel support functional block is introduced. MAC analyses interference, traffic information of a node associated with a particular channel, based on which channel is selected and routing is established. Traffic information, interference information and communication information (TICC) to the upper layer through the information block will be given by physical layer.

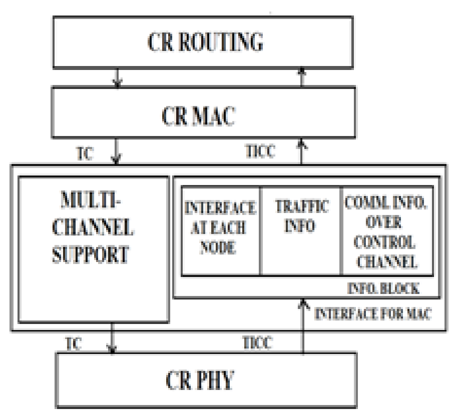

Figure 1 High level design for interface to contention based MAC

3.2. Collision free MAC:

In collision free MAC, operation is divided into two phases. In the first phase, each node sends out strategy packet with preferred receiving channel. If there is an empty channel available, then it is selected as the preferred receiving channel. If there is no empty channel, node shares the channel with the node that is furthest away from it so that there is no interference. In the second phase, node will use the channel selected during the first phase to send and receive data.

Intelligent based and schedule based MAC require negotiation about channel decision and transmission parameters. Most of the current intelligent based and schedule based MAC are negotiated over common control channel. Each node runs a DSA algorithm to calculate its transmission power. After DSA makes the decision, which includes the transmission power and Channel selection (TC), it will send down the information according the multi-channel support functional block as shown in Figure 2. The physical layer will provide the traffic information, interference information over data channel (TIC) to the upper layer through the information block.

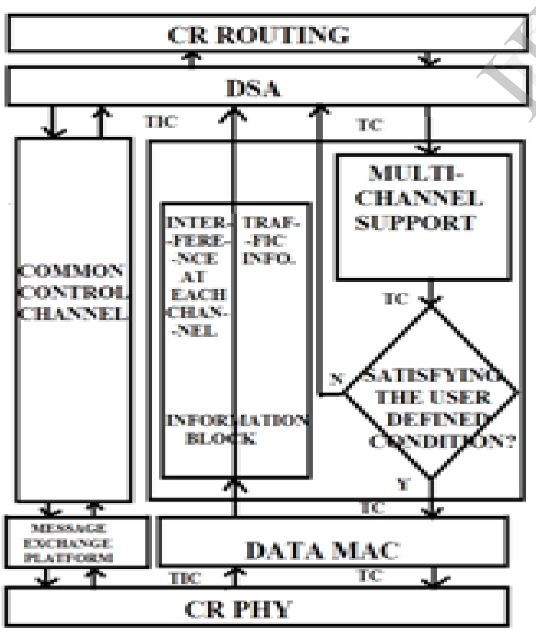

Figure 2 High level design for interface to Intelligent Based MAC/Scheduled Based MAC

4. Simulation Setup & Performance Evaluation

In this section, the performance comparison of contention based (maccon is used as MAC type) and collision free MAC (macng is used as MAC type) is presented. Evaluate the performances by carrying out the multiple simulations with increasing the number of channels via Network Simulator-2 (ns-2.31) [9], based on the Cognitive Radio Cognitive Network (CRCN) simulator [8].

Average throughput, average end-end delay, routing overheads and packet delivery ratio are used for evaluating the performance of contention based & collision free MAC.

In this paper, simulations are carried out with specific topology and traffic file where 6 nodes are created in 10 x 10m^2. IEEE 802.11 standard based network is used with FTP as the traffic source. Here, 3 pairs of nodes are transmitting simultaneously. Each node randomly selects a channel from a predefined channel list. All the simulation is run for 50 seconds. Simulations parameters are summarized in the Table I.

Table 1. Simulation parameters

Parameter	Values
Topology	10 x10 m^2
Number of Nodes	6
Traffic type	FTP
Packet Size	512 bytes
Simulation duration	50 seconds
Max connection	3
Routing protocol	AODV
Transport layer	TCP

The graphical representations of the results are shown in Figure 3, 4, 5 & 6. When only one channel per node is available it behaves as ordinary 802.11 MAC.

In figure 3, the contention based & collision free MAC protocol for average throughput is evaluated. Average throughput of collision free MAC for channel 1, 2 and 3 are 1395.06kb/s, 1693.59kb/s and 2135.10kb/s respectively. Average throughput of contention based MAC for channel 1, 2 and 3 are 1395.06kb/s, 1405.63kb/s and 1494.33kb/s respectively. So from the Figure 3, it can be noticed that the average throughput of collision free MAC protocol is very high as compare to that of contention based MAC, as the number of channel increases the average throughput also increases.

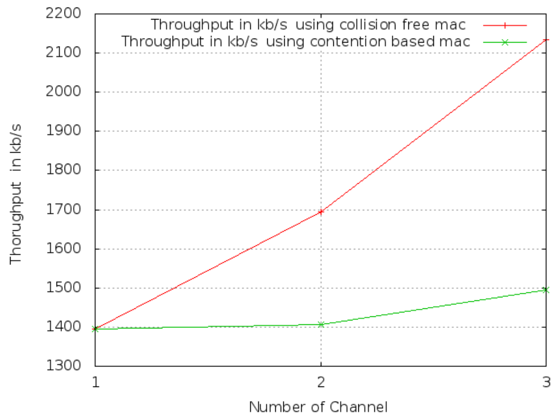

Figure 3. Number of channels Vs Average Throughput in kb/s

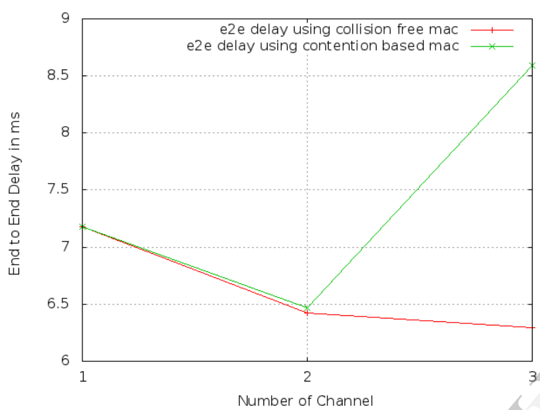

Figure 4. Number of channels Vs Average end-end Delay in ms

In Figure 4&5 the contention based & collision free MAC protocol for average end to end delay and routing overheads are evaluated. Average end to end delay of collision free MAC for channel 1, 2 and 3 are 7.18188ms, 6.41964ms and 6.29531ms respectively. Average end to end delay of contention based MAC for channel 1, 2 and 3 are 7.18188ms, 6.46964ms and 8.5885ms respectively.

Routing overhead of collision free MAC for channel 1, 2 and 3 are 14.2645, 13.5104 and 12.1816 respectively. Routing overhead of contention based MAC for channel 1, 2 and 3 are 14.2645, 13.5835 and 14.9277 respectively.

So, from the Figure 4 & 5 it can be noticed that the average end to end delay and routing overhead of collision free MAC protocol is low as compare to that of contention based MAC.

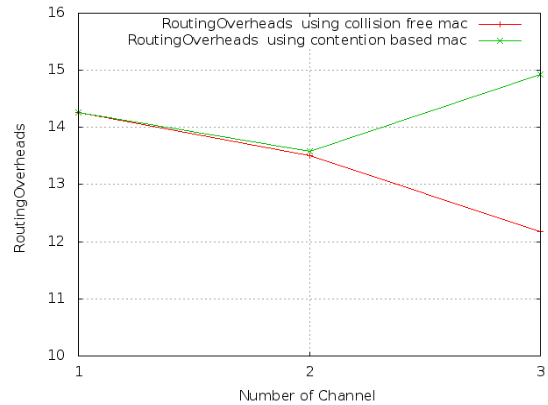

Figure 5. Number of channels Vs Routing Overhead

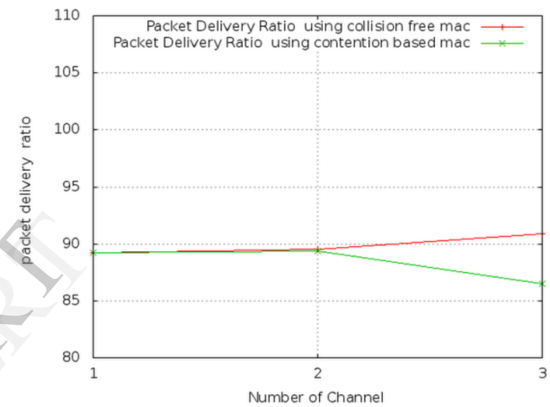

Figure 6. Number of channels Vs Packet Delivery Ratio

In Figure 6, the contention based & collision free MAC protocol for packet delivery ratio is evaluated. Packet delivery ratio of collision free MAC for channel 1, 2 and 3 are 89.2082, 89.5028 and 90.8473 respectively. Packet delivery ratio of contention based MAC for channel 1, 2 and 3 are 89.2082, 89.3972 and 86.5118 respectively. From the Figure 6, it can be noticed that the packet delivery ratio of collision free MAC protocol is high as compare to that of contention based MAC.

5. Conclusion

In cognitive radio when the primary user is not using channel at any instant of time then that channel is temporarily available to the secondary user. In this paper the performance of contention based & collision free MAC in a multichannel CRN is evaluated using the CRCN simulator patch in ns2 and compared. So from the above graphs on the basis of average throughput, average end-end delay, routing overhead and packet delivery ratio, it is evaluated that the performance of collision free MAC is better than that of contention based MAC protocol. Throughput is increased greatly with increase in number of channels.

6. References

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