A Survey on CR MAC Protocols for Dynamic Bandwidth Assignment and Energy Efficiency

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Abstract- Cognitive radio is the solution to the RF spectrum underutilization problem resulting from static spectrum policies. It is been noted that there is a lot of unused spectrum known as 'white spaces' even in commercial broadband and mobile network frequency bands. Cognitive radios can sense and adapt to their environment, utilize the white spaces and improve the spectrum utilization. Medium Access Protocol MAC in Cognitive Radio networks refers to the policy that controls how a secondary user should access a licensed spectrum band. Various MAC protocols are proposed to improve the performance of CR networks. This paper overviews the MAC protocol used to improve energy efficiency and bandwidth allocation process of CR networks.

Keywords – MAC Protocol, CR networks, Primary users, Secondary users.

I. Introduction

As communication field is growing day by day, high capacity and broadband wireless communication systems have been developed, and much more frequency spectrum will be required in near future. In particular, the frequency band less than 6GHz is suitable for mobile communications because of its relatively small propagation loss in mobile environments. However, most of the frequency bands less than 6GHz are already occupied by the various existing wireless systems[1], and it is extremely difficult to secure a newly available frequency band for new wireless systems. On the other hand, it was reported that average spectrum utilization efficiency is not very high because the frequency bands licensed to the existing systems are not well-utilized in terms of space and time. This temporally unused frequency spectrum is called "white space."

Cognitive radio is a technology that observes outside radio environments and adaptively transmits and receives information according to the observed results. A cognitive Radio system may be defined as a radio system that has the capability to obtain knowledge from and become aware of its environment (the service environment and the user preferences). A CR system dynamically[2] and automatically adjusts its behavior and operating parameters to serve the specific needs of the user in the best way within the current environment.

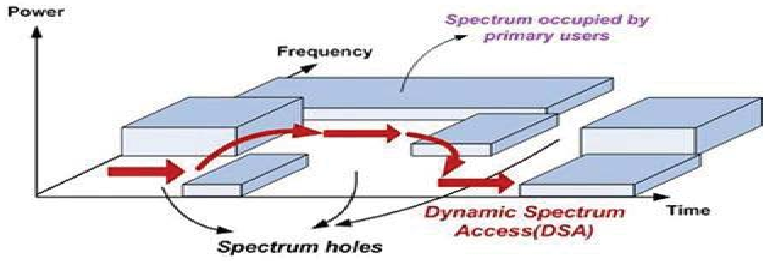

Figure 1. Spectrum hole (white spaces) in Licensed portions of spectrum.

One of the most important components of the cognitive radio[2] concept is the ability to measure, sense, learn, and be aware of the parameters related to the radio channel characteristics, availability of spectrum and power, radio's operating environment, user requirements and available networks (infrastructures) and nodes, local policies and other operating restrictions.

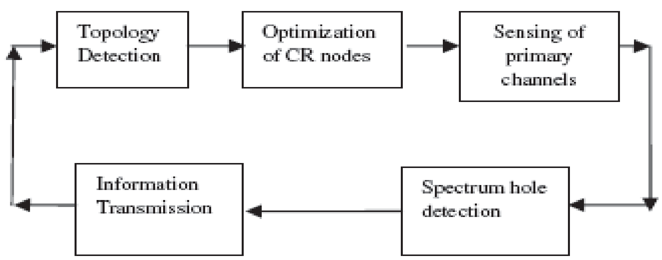

Figure 2. Block diagram of cognitive radio flow

In cognitive radio terminology primary users can be defined as the users having higher priority. They have legacy rights on the usage of a specific part of the spectrum. On the other hand, secondary users, which have lower priority, exploit this spectrum in such a way that they do not cause interference to primary users. Therefore, secondary users need to have cognitive radio capabilities, such as sensing the spectrum reliably to check whether it is being used by a primary user and to change the radio parameters to exploit the unused part of the spectrum.

Spectrum sensing, an essential component of CR technology involves

A. Identify spectrum holes(white space)

B. When the spectrum hole is used by the secondary users, detect the onset primary transmission.

CR will improve the spectrum utilization in wireless communication system and include various

other applications as Global Systen for Mobile Communication networks, satellite communication, military purpose, public safety and next generation technologies. . For new wireless applications there is a scarcity of available spectrum because of static spectrum allocation. With limited spectrum , the wireless systems will be congested because of higher traffic demands. Today the condition about the spectrum allocation is congestion in wireless spectrum and in the other side statistically assigned spectrum is underutilized as usage of spectrum mainly depend on time and space. CR users are designed with high intelligency which will enable to adopt the characteristics of the operating wireless environment. We assumed CR MAC protocol to operate over 802.11 network and access the unused spectrum in opportunistic manner.

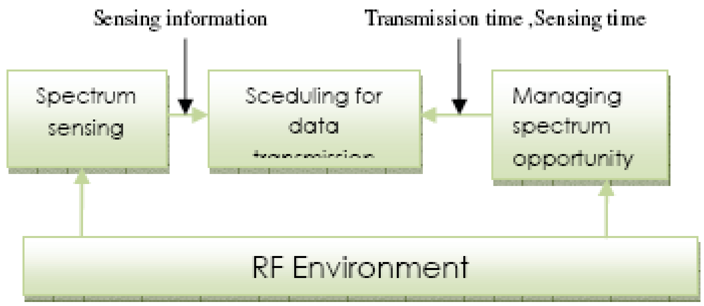

Figure 3. Architecture of CR MAC Protocol

CR MAC protocols for cognitive users are designed for using unused data channels by primary users. The function of CR MAC protocol over 802.11 network, is to search the spectrum hole and use that vacant channel until the primary user claim it again. If the primary uers are detected in between CRUs transmissions, CRUs need to vacant that data channel immediately and jump to any other vacant data channel in a random manner. This paper focuses on different CR MAC protocol designing methods for energy efficiency, dynamic bandwidth assignment. Uni MAC and ABi MAC protocols are designed to increase the throughput by allocating bandwidth dynamically and EECR is the protocol designed to increase efficiency by energy consumption methods.

II. Proposed Algorithm

A. Uni MAC Protocol –

Uni-MAC[3] protocol is a modified CR MAC protocol proposes a Smart Channel Selection Scheme which decides the Channel Hopping Order (CHO) for selecting vacant data channel instead of randomly selection in case of normal CR MAC protocol. CRU pair decides the channel hopping order by selecting most idle channel first and the busiest channel last in the list. By exchanging control packets REQ_{CR} Request to CR and $GRANT_{CR}$ Grant to send CR on contol channel, a pair of CRU sender and receiver performs the Bandwidth Negotiation Procedure(BNP). After the BNP the CRU pair which want to communicate switches synchronously to the first data channel as indicated by CHO. If the data channel is vacant, CRUs can transmit their data through this channel using RTS-CTS handshake. But before that CRU pair need o check the data channel is clear for predefined channel sensing period. If data channel is not clear for that period, CRU pair need to switch synchronously to the next data channel indicated by CHO and repeat the channel sensing and switching actions until an idle channel is found. If data channel is clear for the predefined channel sensing period, the CRU pair transmit TXOP packets with round of packet transmission which includes RTS-CTS- DATA-ACK.

TXOP is a predefined network parameter denoting the number of transmission opportunities of any CRU sender which limit monopoly of any CRU sender over a data channel. For every round of packet transmission, CRU decrement the TXOP counter by 1. Thus CRU pair can transmit till TXOP is 1. Uni- MAC also provides a check on primary user in between the CRU transmission. It defines a Suspend control packet for CRU sender in between every complete round of packet transmission where CRU pair would go silent for a predefined quiet period(QP). During QP, if any packet transmission is overheard, the CRUs assum that PUs are returning to the channel and they switch to the next data channel indicated by CHO . Thus Uni-MAC provides enhanced data transmission and channel evacuation approach and hence increases the efficiency. But this protocol is not capable in delivering internet applications with bidirectional packet transmission and variable data packet size

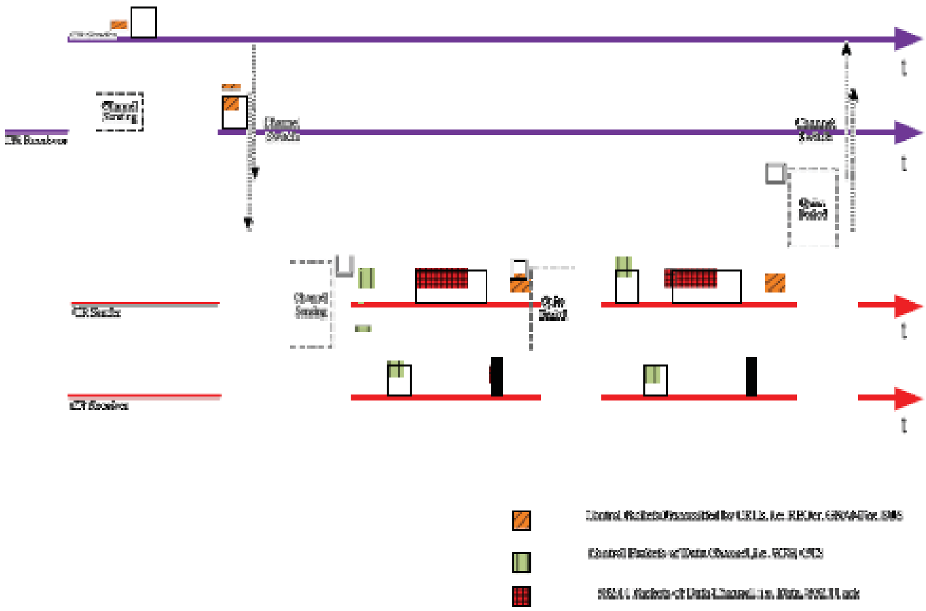

Figure 4. Illustration of Message Exchanges on a Data Channel of Uni-MAC when Txop=2 [4]

B. ABi MAC protocol

ABi MAC[4] protocol is the advancement of UNi MAC protocol. The drawback of Uni MAC that fixed number of packets can be transmitted prescribed by the protocol through TXOP. ABi MAC designed in such a way that it can support many network cases as unidirectional, bidirectional with variable packet size. The main objective of ABi MAC is to allocate bandwidth to the CRUs in a more dynamic manner with Dynamic Bandwidth Assignment (DBA) and Smart Transaction Interval Settings (STIS) which are the modifications over Uni MAC.

In Uni MAC TXOP packet is placing the limit for the number of packet transmissions by each CR users. ABi MAC define MAX_PACKET instead of TXOP which gives the idea of the maximum number packets that is allowable to be transmitted by a CRU pair when both CRUs are on the data channel. By defining various cases of packet transmission through DBA, ABi MAC provides very high flexibility in allocating the bandwidth to the CRU pair regardless of their traffic condition.

By defining parameters like

BDs : Number of packets to be transmitted by CRU sender,

BDr : Number of packets to be received by CRU receiver,

NPRs : Number of packets to be received from the sender,

NPRr : Number of packets to be received from the receiver

ABi can support (1) a uni-directional traffic flow from the CR sender to the CR receiver, (2) a bi-directional traffic flow where both the CRU sender and the CR receiver have the same number of packets to send in their queues, and (3) a bi- directional traffic flow where the CRU sender and the CR receiver have unequal numbers of packets to send in their queues. In case (3), the CRU pair will swap their sender/receiver identities on the data channel when the CR sender has transmitted all packets in its queue but the CR receiver still has packets to send in its queue. At this moment, the bi- directional traffic flow temporarily degenerates to a uni- directional traffic flow. With the other modification of STIS, TI is carried in the control packets provide the neighbouring Primary Users with the correct timing information when bi directional bandwidth reservation is needed. For bandwidth reservation, RTS and CTS two way handshaking is adopted in IEEE802.11. With this process TI is carried in the RTS packets to indicate how long a sender wants to hold the medium. In return, the

CTS packet echoing the expected duration of transmission. All the other nodes hearing this transaction will set their Network Allocation Vector (NAV) according to the TI overheard packets.

To sum up, through the proposed DBA, the ABi- MAC can maximize the achievable throughputs in a CRN by minimizing the frequency and overhead of EECR-MAC protocol[5] is a multichannel MAC protocol, which uses frame aggregation and back up data channel schemes to reduce the communication overhead and hence increases energy efficiency. When cognitive users are transmitting on primary data channel and if Primary User interferes, the back up channel is used to continue with the data transmission between the cognitive users.

1) *Frame aggregation:*

When there is transmission between the same pair of sender and receiver, then the frames of these nodes can be into a single frame so that control overhead is reduced. Without frame aggregation, each frame carries its own header and footer control information like source address, destination address etc which is not needed if the same pair of nodes are communicating. If these frames are aggregated and intead of each header and footer , one bit is added in the header which carries information about the number of frames that are aggregated to the receiver.CRUs switching from the control channel to the data Channel and vice versa in presence of bi-directional flows. Also, through the STIS, the ABi-MAC can broadcast correct information of TI to all neighboring nodes of a CRU pair to avoid unnecessary packet collisions.

C. EECR MAC PROTOCOL

The limitation of battery lifetime has been a critical issue for the advancement of mobile computing.Different types of power saving techniques are used to provide energy conserving mechanisms. Major issues in CR networks are power saving, security,dynamic bandwidth allocation and QoS. Energy efficiency is a major challenge in CR adhoc networks. In adhoc networks since there is no cenral controller, all the CR users communicate with each other directly. To prevent failurs of network, battery life of nodes should be increased minimizing energy consumption.

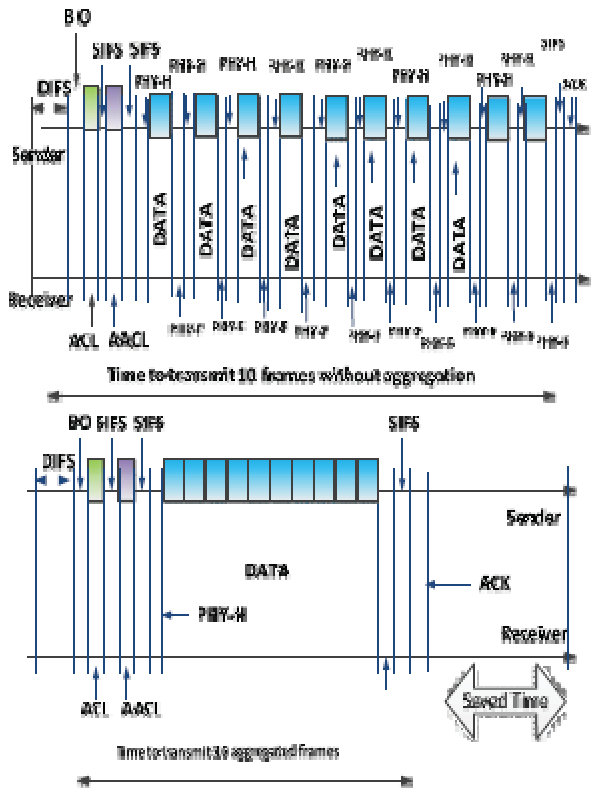

Figure 5. Without and with aggregated frames[6]

Some rules need to be followed by cognitive users for selection of data and control channel over IEEE802.11. All the cognitive users should launch available control channel list in dedicated control channel for CR users. Also each CR node has to verify that whether the channel is available for its data transfer. Hence CR nodes are continuously scanning for available channel list from other nodes. Availability of the channel need to be launched in the dedicated control channel. If other node acknowledges available channel list with AACL means these two nodes can communicate with each other. But this pair should see that there is atleast two data channels free as one can use for data transmission and second can be used as a back up channel in case of primary user claims for the channel.

The data channel where the data transmission is done by the CR users is called Primary Common Data Channel(PCDC) and the data channel kept reserved for back up is called Back up Common Data Channel. It is important for the CR users to check that if PU claims for the PCDC and if PU claims then CR nodes should move to BCDC. If PU claims on BCDC also then the nodes need to go back to the scanning stage and start the process again. Thus with BCDC, nodes get the opportunity to continue the communication even if PU claims on PCDC, without going back to initial scanning stage again. This method increases throughput and saves the time and energy. EECR-MAC protocol allows the aggregation of frames between cognitive nodes when transferring the data on primary data channel. If primary user claims in between, then remaining communication are continued on the backup data channel. In EECR-MAC protocol frames from single destination are aggregated where multiple frames merge into a single frame for transmission between the same pair of sender and receiver.

III. CONCLUSION

Uni-MAC provides enhanced data transmission and channel evacuation approach and hence increases the efficiency. But this protocol is not capable in delivering internet applications with bidirectional packet transmission and variable data packet size.

To sum up, through the proposed DBA, the ABi- MAC can maximize the achievable throughputs in a CRN by minimizing the frequency and overhead of CRUs switching from the control channel to the data channel and vice versa in presence of bi-directional flows. Also, through the STIS, the ABi-MAC can broadcast correct information of TI to all neighboring nodes of a CRU pair to avoid unnecessary packet collisions.
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