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RC-MAC (Relay-assisted Cognitive MAC) Protocol for Coghopnet: A Relay Assisted Cognitive Radio Ad Hoc Network

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Cognitive Radio (CR),defined as an intelligent radio which can adapt based its context, has come up to avoid spectrum scarcity and improve the utilization of underutilized spectrum bands. CRs must sense the spectrum holes and communicate in the sensed holes without interfering the licensed Primary Users(PUs) of the bands. Lack of infrastructure backbone in CR adhoc networks necessitates each user to have all CR capabilities for determining its actions based on local observations. The challenge is to identify the presence of PUs over a wide range of spectrum at a particular time and specific geographic location. In CR networks, the important functions of Medium Access Control(MAC) protocols are, identifying the available spectrum resource through spectrum sensing, deciding on the optimal sensing and transmission times, coordinating with the other users for spectrum access,deciding how long the optimal sensing and transmission durations must be and deciding the searching order of bands to minimize the required time for detecting holes.With relaying, seamless data transmission,data quality and correctness are enhanced.We have designed a new protocol RC-MAC(Relay-assisted Cognitive-MAC) for the relay-assisted CR adhoc network named as Coghopnet and discussed elaborately.With multihop relay we enhance coverage, throughput and system capacity.

Keywords:cognitive radio, ad hoc networks,spectrum holes,relay, MAC protocols

1. INTRODUCTION

The radio electromagnetic spectrum being a precious natural resource has to be utilized efficiently. Today's wireless networks are regulated by a fixed spectrum assignment policy, i.e. the spectrum is regulated by governmental agencies and is assigned to license holders or services on a long term basis for large geographical regions. Also, a large portion of the assigned spectrum is used sporadically.The spectrum usage is concentrated on certain portions of the spectrum while a significant amount of the spectrum remains unutilized[1].

According to the report published by the Federal Communications Commission (FCC) prepared by Spectrum-Policy Task Force it is found that, "In many bands, spectrum access is a more significant problem than physical scarcity of spectrum, in large part due to legacy command-and-control regulation that limits the ability of potential spectrum users to obtain such access".

A spectrum hole is a band of frequencies assigned to a primary user, but, at a particular time and specific geographic location, the band is not being utilized by that user.Spectrum utilization can be improved significantly by making it possible for a secondary user (who is not being serviced) to access a spectrum hole unoccupied by the primary user at the right location and the time in question.

2. LITERATURE REVIEW

2.1 Cognitive Radio

The cognitive radio, built on a software-defined radio, is defined [2] as an intelligent wireless communication system that is aware of its environment and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency and modulation strategy) in real-time, with two primary objectives in mind:

- Highly reliable communication whenever and wherever needed;
- Efficient utilization of the radio spectrum.

The two main characteristics of the cognitive radio are defined[3,4] as Cognitive capability

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andReconfigurability.Cognitive capability refers to the ability of the radio technology to capture or sense the information from its radio environment. Reconfigurability enables the radio to be dynamically programmed according to the radio environment[5].

Fig.1 shows the basic cognitive cycle[6].

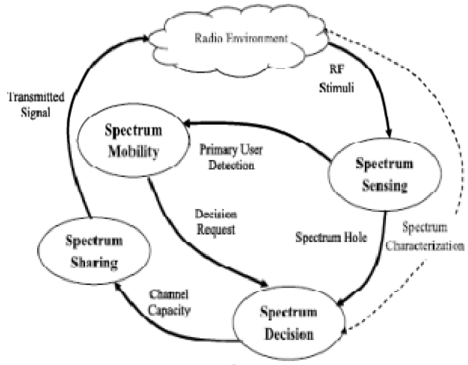

Fig.1. The cognitive radio cycle

2.2 Cognitive Radio Ad Hoc Network

According to the network architecture[6], Akyildiz *et al.*(2009) cognitive radio (CR) networks are classified as the infrastructure-based CR network and theCognitive Radio Ad-Hoc Networks (CRAHNs). In the infrastructure-based CR networks, the observations and analysis performed by each CR user feeds the central CR base-station, so that it can make decisions on how to avoid interfering with primary networks. [8] discussed about a method, Wireless sensor networks utilize large numbers of wireless sensor nodes to collect information from their sensing terrain. Wireless sensor nodes are battery-powered devices. Energy saving is always crucial to the lifetime of a wireless sensor network. Recently, many algorithms are proposed to tackle the energy saving problem in wireless sensor networks. There are strong needs to develop wireless sensor networks algorithms with optimization priorities biased to aspects besides energy saving. In this project, a delay-aware data collection network structure for wireless sensor networks is proposed based on Multi hop Cluster Network. The objective of the proposed network structure is to determine delays in the data collection processes. The path with minimized delay through which the data can be transmitted from source to destination is also determined. AODV protocol is used to route the data packets from the source to destination.

According to this decision, each CR user reconfigures its communication parameters, as shown in Fig.2a. In Cognitive Radio Ad-Hoc Networks (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.2b. 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.

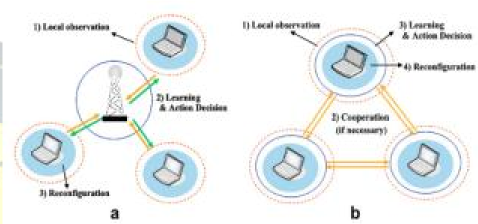

Fig.2. Comparison between CR capabilities for: (a) infrastructure-based CR networks and (b) CRAHNs

2.3Medium Access Control Protocols For Cognitive Radio Networks

In Cognitive Radio (CR) networks, identifying the available spectrum resource through spectrum sensing, deciding on the optimal sensing and transmission times, and coordinating with the other users for spectrum access are the important functions of the Medium Access Control (MAC) protocols[7,8].

A general framework of the spectrum functions and the inter-layer coupling is shown in Fig.3 by Claudia and Kaushik[9].

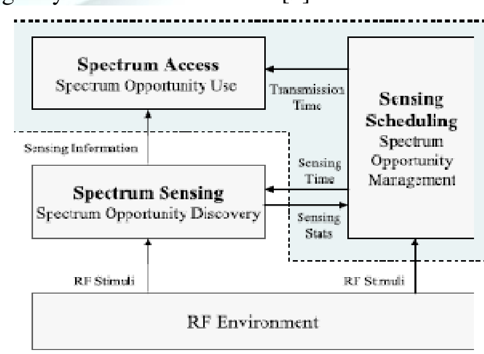

Fig.3. Spectrum functions at the CR MAC

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3. SYSTEM DESCRIPTION

3.1 Cognitive Relay Network

In 2009, Letaief and Zhang[10,11] considered a cognitive wireless relay network consisting of a source node that intends to communicate with a destination node aided by a total number of K relay nodes and assumed that each cognitive relay node is within the transmission range of one PU node. It is also assumed that more than one CR node can share the radio spectrum within one PU operating range when the PU is inactive. Furthermore assumed that each PU operates in a wide-band channel consisting of a number of non overlapping frequency bands f1, f2, . . fN, where N denotes the total number of frequency bands in the bandwidth of PUs. Each cognitive relay first gets the spectrum map of its local channel environment by spectrum sensing. The number of available bands varies from one relay to another in cognitive relay networks.

3.2 Cognitive Transmissions with Multiple Relays

CR users in a CR ad hoc network can communicate with each other in a multihop manner.

Reasons to use the relaying concept in CR ad hoc network are

- to enhance or maintain the data quality. Since data travelling over a long distance is subjected to degradation, use relay nodes to transmit data without degradation.
- to provide correctness of data. Consider two paths are available to transmit a message from Source to Destination where one is a direct path and another is an indirect path. If the direct path is prone to change the content of the message and not the indirect path, then the indirect path is selected to transmit the message using relaying is preferred.

3.3. Coghopnet

Hop (Relay) nodes are the intermediate nodes that connect the source (S) and the destination (D).

This work explores the feasibility of relaying in a CR ad hoc network. The relayed path selection can be based on multiple considerations.

When multiple paths exist between S and D,

(i) The path with minimum number of hops, i.e., the shortest distance path can be selected.

(ii) The path with lowest connection cost with respect to the total power required and the number of hops required can be selected.

(iii) The path where the hop nodes are less likely to move away can be selected.

(iv) The path with hop nodes having sufficient battery power can be selected.

(v) The path with relay nodes having sufficient memory and computational capacity (sensing capability) can be selected.

(vi) The path with hop nodes having high link stability can be selected where the link stability can be decided based on the high number of beacons it has received.

(vii) The path with hop nodes having the capability to inform its upstream and downstream nodes in case of link failure can be selected, so that S and D are informed about the link failure and unnecessary information stored in the buffer can be cleared by all the involved nodes.

(viii) The path with hop nodes that are not already in heavy traffic can be selected, so that the load can be distributed and balanced.

(ix) The path with hop nodes that can deliver the real time data packets within the given time delay constraints to satisfy the QoS requirements can be selected.

(x) The path with hop nodes having the history of high packet delivery ratio can be selected for the successful deliverance of the information.

3.4Coghopnet: A Relay-Assisted Cognitive Radio Ad Hoc Network

Coghopnet with relay assistance is used

- To compensate for path loss of transmitted data - Relay nodes can amplify and forward data to maintain the power levels of the transmitted stream.
- To provide redundancy for transmitted data - In the presence of severe channel degradation of data stream the relayed path between the source and the destination will be preferred over the direct path.

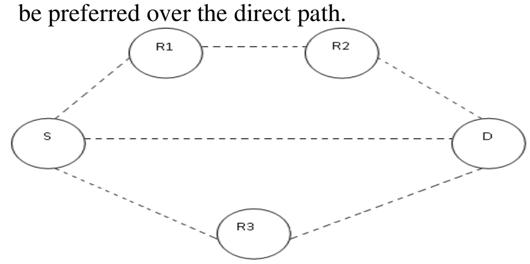

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Fig.4. A sample cognitive radio ad hoc network with S as source, D as destination and R1, R2 and R3 as relay nodes.

3.6The Signaling Flows Of Coghopnet:

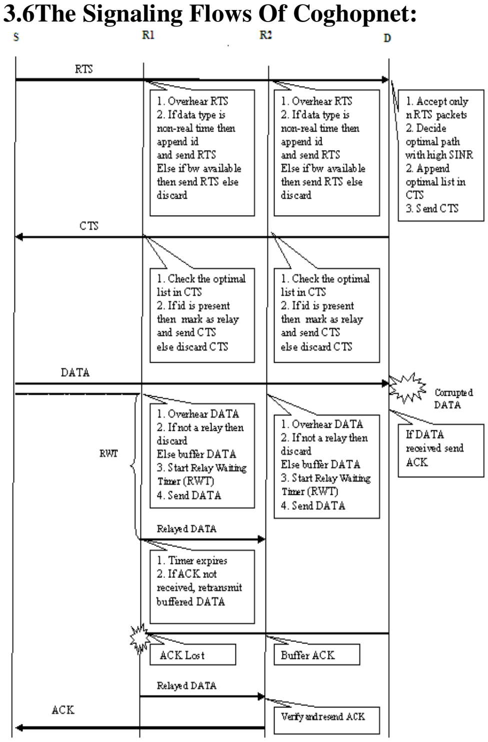

Fig.5. The signaling flows of Coghopnet

4. IMPLEMENTATION

4.1 Benefits Of Coghopnet

(i) Seamless transmission can be realized.
Without cognitive relay, S will send data to D directly when the S-D channel is not utilized by the PUs. If the PU returns over to the channel, s should stop its transmission immediately so as not to cause interference to the primary system.With multiple relay nodes, the transmission in the cognitive relay network does not necessarily stop even when some PUs are operating again.This is because there is always at least one available band in the cognitive relays that can be utilized as a relay channel to continue data transmission.
(ii)The network access opportunity is greatly improved by utilizing a large number of cognitive relays while supporting seamless data transmission.

4.2 STEPS IN RC-MAC Protocol

A new algorithm for Coghopnet is proposed here.

1. When S wants to send data to D, S starts sensing.
2. When the medium is free, it sends an RTS packet mentioning its id, destination id, duration of transmission, the type of data to be transmitted (non-real time data or real time data) and for real time data, the required bandwidth is also included.
3. All nodes within the transmission range of S will hear the RTS packet.
4. If the data type is non-real time then scenario 1
   Else scenario 2.

Scenario 1 for non-real time data (not considering bandwidth requirement):

5.1.1. The node receiving RTS append its id to it and broadcasts the RTS packet.

5.1.2. This step continues till it reaches D.

5.1.3. D checks the Received Signal Strength (RSS) and Signal-to-Interference Ratio (SIR) of RTS packets obtained for the same request from S through different nodes.

5.1.4. The RTS received with high SINR is considered as the stable link and CTS includes the id list with it, so when the nodes see its id in the CTS packet, it marks itself as a relay node and forwards the packet else discards the packet.

Scenario 2 for real time data:

5.2.1. Since the required bandwidth is mentioned in the RTS packet, the node receiving it checks if the required bandwidth is available.

5.2.2. If available, it appends its id and forwards the RTS packet, else it just drops the RTS packet.

5.2.3. These steps continue till it reaches D.

5.2.4. D receiving the RTS knows that the required bandwidth is actually available through the corresponding link.

5.2.5. The RTS received with high SINR is considered as the stable link and CTSincludes the id list with it, so when the nodes see its id in the CTS packet, it marks itself as a relay node and forwards the packet else discards the packet.

Signal to Interference plus Noise Ratio

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(SINR) is the ratio of the received strength of the desired signal to the received strength of undesired signals (noise and interference).

6. On receiving the CTS packet, S knows the optimal path and using it, S starts transmitting the data.
7. Every relay node buffers these packets, sets a relay waiting timer (based on the expected transmission time mentioned in RTS and the no. of relay nodes present in the optimal path) and transmits the packets to the next node.
8. D on receiving the data sends an acknowledgement packet.
9. When a relay node receives the ACK packet before the timer goes off, it frees the buffer and stores and sends the ACK to the next node.
10. If the timer goes off and ACK is yet to be received, the buffered data is resent.
11. The transmission gets over when S receives the ACK packet.

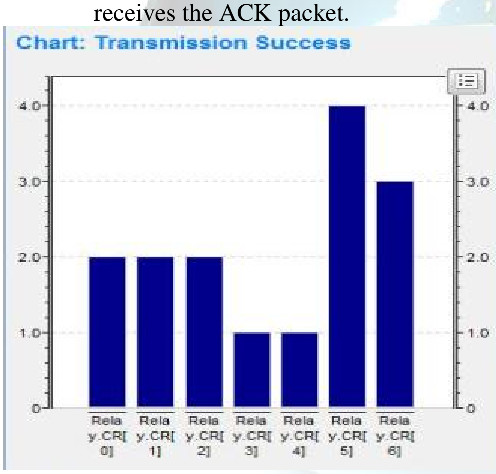

Fig.6. Transmission Success of Coghopnet with 7 CR nodes and 16 channels.

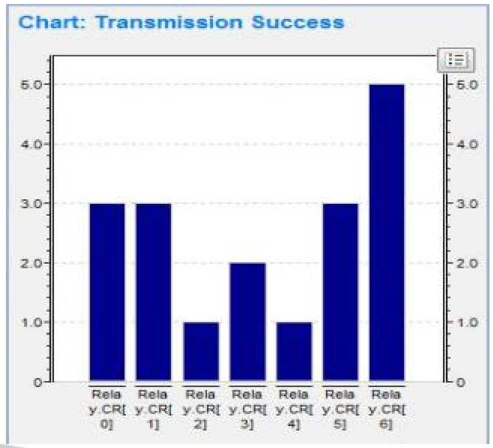

Fig.7.Transmission Success of Coghopnet with 7 CR nodes and 50 channels.

Advantages of RC-MAC Protocol

(i) Effects of shadowing and fading are eliminated by the use of relay nodes.
(ii) Hidden terminal problem is solved by using RTS/CTS communication by the relay nodes.
(iii) S sends data only through the high quality i.e. stable link thus reducing the probability of packet dropping due to poor links.
(iv) Destination-controlled relay selection minimizes overhead.
(v) CTS is sent back through the optimal path avoiding unnecessary control overhead. It avoids broadcasting of CTS packets by all nodes.
(vi) Efficient notification is done by piggybagging the relay path in CTS packet.
(vii) In scenario 1, all available neighbour nodes are candidate nodes for relaying. But the final decision is made by D. This eliminates processing done by every node before forwarding RTS packet.
(viii) In scenario 2, only eligible nodes availing the required bandwidth forwards the RTS packet thus are reducing a lot of control overhead. But it requires that every node has to verify for the availability of bandwidth before sending the RTS packet. This helps in efficient real time data transmission.
(ix) Buffering of data helps to retransmit data in case of packet loss, hence efficiently utilizing the available bandwidth.

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(x) Buffering the ACK packet helps when ACK packet is lost. Because when an ACK packet is lost, the node may think the data was not transmitted successfully and starts retransmitting data. The receiving node which has freed the data already must check for the corresponding ACK. If present the ACK packet can be retransmitted else must buffer the data and continue transmitting the data.

(xi) This protocol has two scenarios based on the data type thus adapting well to the required transmission.

5. CONCLUSION AND FUTURE ENHANCEMENT

In this paper, the Relay-assisted Cognitive-MAC Protocol namely RC-MAC protocol for the Cognitive Radio Ad Hoc Networks has been designed and discussed elaborately. Relays eliminate the hidden terminal problem. Also the dynamic spectrum can be fully utilized through a number of cognitive relay nodes that can support seamless data service for cognitive users. Though the best-relay selection is an attractive relay protocol for cognitive radio networks due to its spectrum efficiency compared with the best-relay transmission in traditional wireless networks, cognitive radio networks face an additional challenging issue, i.e., mutual interference between the primary and the cognitive users, especially in a relay network scenario. From this work it is found that with multihop relay using RC-MAC protocol the coverage, throughput and system capacity of the cognitive ad hoc network is enhanced. For future enhancement more features can be added to this protocol to make it a much more efficient one. The concept of probability of being free for a longer time for a channel can be used to select the candidate along with the noise level consideration. Also prioritizing the CR users and channel allocation for transmission can be started with the highest priority CR User.

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