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RESEARCH ARTICLE

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A SECURED AND EFFICIENT BROADCASTING MODEL FOR COGNITIVE RADIO AD HOC NETWORKS (CRAHN)

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ABSTRACT

Cognitive radio networks are innovative approach to wireless engineering in which radios are designed with an unprecedented level of intelligence and agility. Cognitive radio technology is envisaged to solve the problems in wireless networks resulting from limited available spectrum and the inefficiency in the spectrum usage by exploiting existing wireless network opportunistically. Cognitive radio views the radio spectrum in deeper detail and identifies unused gap to transmit the signals. Unlicensed users in Cognitive radio ad hoc network may obtain different available channels which are dedicated to licensed users depending on the traffic and locations. Control information is usually propagated as broadcasts to the adjacent nodes in wireless ad hoc networks. But the problem in this approach is control information may be delivered to unauthorized users who are available in the network. In this paper, an efficient communication model is proposed to address this challenge. This proposed model can be applied to any broadcast protocol with Cognitive radio network topology. This model deals with identification of authorized users in the network to transfer the control information. Also, it proposes a security algorithm to validate authority of users who are in the network and establishes transmission of control information between source and destination. This selective broadcasting approach reduces the network traffic and increases the security of the control information.

Keywords: Cognitive Radio Ad hoc Network, Authorized users, Broadcasting, Privacy policies, Control Information, Non-uniform channel availability

INTRODUCTION

In Today's world, the usage of wireless devices are increasing rapidly which leads to demand in radio spectrum for communication. As per Federal Communications Commission (FCC), most of the radio spectrum for wireless communications has been already allocated for licensed users. Only limited spectrum is available for unlicensed users which lead to spectrum scarcity [1]. Cognitive Radio (CR) technology has been introduced to solve this problem and it is using dynamic spectrum access [2]. By using CR technology, unlicensed users (Secondary users) can form a CR ad hoc network and perform their communication by accessing licensed channels which are not used by licensed users (Primary users). In the below diagram, spectrum band has been classified as Unlicensed band and Licensed band. Primary users will use licensed band and the spectrum is dedicated to use for primary users. Secondary user (Ad hoc user) will use unlicensed band for communication. Due to spectrum scarcity, cognitive radio technology has been introduced which will establish communication in both licensed and unlicensed bands [3].

A Cognitive radio will sense for available spectrum within its coverage area. Once spectrum has been identified, it will validate how long the spectrum can be accessible by Cognitive user. Control information (like Channel availability, routing information) and some emergency messages will be broadcast to other nodes in the network. Each node will validate the information and rebroadcast the information to its neighbor nodes. In this way all the nodes in the ad hoc network will receive control information [4]. Such control information exchange is crucial for the realization of most networking protocols. Control information may be some important information and it should not be accessible by unknown users. So, broadcast is an important operation in CR ad hoc networks [5].

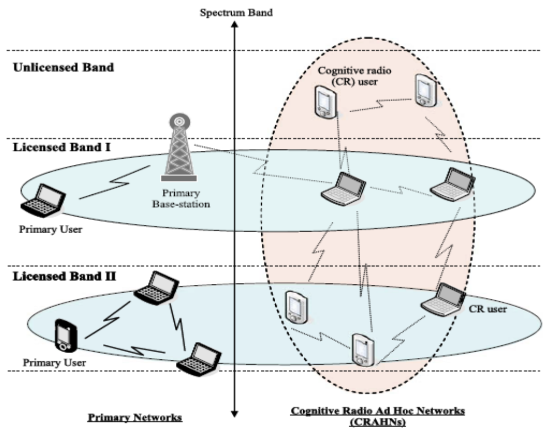

Fig (1). Cognitive Radio Ad hoc networks

Even though broadcasting issues has been addressed for traditional mobile ad hoc networks (MANETs) [6]-[10], still research is going on for broadcasting in CR ad hoc networks. Few papers addressing broadcasting issues which are mainly focusing on broadcast protocol designs [11]-[15].

The proposed model describes a way of broadcasting in an efficient manner. This proposed model can be applied to any broadcast protocol with cognitive radio network technology. It deals with identification of authorized users in ad hoc network to transfer control information. As control information is more secure in cognitive radio network, CR node has to determine the corresponding receivers for the control information from its neighbor routing table. Also, we are proposing security policies which validate authority of users who are present in the network and establish transmission between Sender and receiver nodes. The purpose of selective broadcasting approach is to reduce network traffic and to increase security of control information.

Cognitive Radio Ad Hoc Network Formation

System Architecture

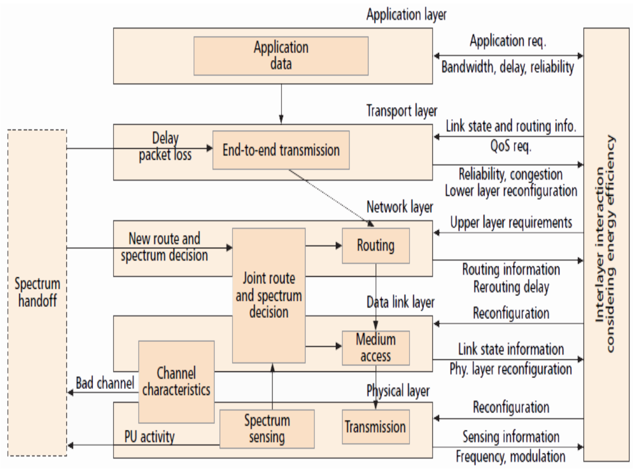

Fig (2). Cognitive radio node architecture

Cognitive radio network is an infrastructure less network. It does not have central network authority. The above diagram represents Cognitive radio node architecture. A Cognitive radio node will perform below list of operations.

i. Spectrum sensing
ii. Spectrum decision
iii. Spectrum sharing
iv. Spectrum mobility

Physical layer of Cognitive radio node will perform Spectrum sensing activity. Generally, most of the frequencies are allocated for licensed users, only few of them are allocated to unlicensed users (ISM bands 900 MHz to 2.4 GHz). Due to spectrum scarcity, Cognitive radio node will search for under-utilized licensed band which are already allocated for licensed users. Once the spectrum has been identified, the spectrum details have been communicated to upper layer. Data link layer and Network layer will perform spectrum decision operation. It will validate the spectrum details and verifies the period of time for which the given spectrum is under-utilized. Finally spectrum details will be shared to neighbor CR users to perform their communication in the available channel. In case the spectrum is utilized by primary user then, CR node will perform spectrum handoff process in which it will switch from one available spectrum to another. By this way, CR node can establish communication to its neighbor nodes by reducing delay in communication.

Ad hoc Network Formation

A CR Node will sense for its neighbors within its coverage area. If neighbor has been identified then, it will send a request to connect with the neighbor node. Once connection has been established, CR Node can able to perform communication with its neighbors.

Consider a Graph G (V, E) where V refers number of nodes in the network and E refers number of edges. v_s is a source node which will search for neighbor nodes. v_1, v_2 and v_3 are neighbor nodes which are present within the coverage area of v_s. Hence node v_s will send a request to establish a connection to its neighbor nodes v_1, v_2 and v_3. Neighbor nodes will validate the request and send an acknowledgement to source node v_s to indicate the acceptance of the connection request. Nodes v_4 and v_5 are outside the coverage area of node v_s. Hence, node v_s can communicate to v_4 and v_5 via node v_3.

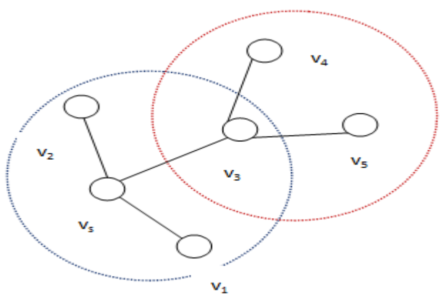

Fig (3). Ad hoc network formation

Each node will maintain routing information which consists of neighbor details and the path to communicate to its neighbors. Once the connection has been established, each node will share its routing information to its neighbors and it will update its routing table accordingly.

Algorithm 1: Ad hoc network formation

Consider a network G (V, E) with source node V_s

Step 1: Source node V_s sends its request to establish connection to its neighbor nodes.

$V_s \rightarrow V_i$

Step 2 : If neighbor nodes accepted the request then, it will provide confirmation response to source node.

$V_s \leftarrow V_{i\,;}$

$E_s \leftarrow E_{i\,;}$

Step 3 : Once connection has been established, source node will update its routing information.

if $RC_s > R_i$ (D) then

R_s (N,H,D) $\leftarrow$ R_i (N,H,D);

else

R_s(N,H,D) $\leftarrow$ R_i (N,H,D) = invalid

Where, N – Neighbor node

H – Next hop

D – Distance

Step 4 : Similarly, it will share its routing information to its neighbor nodes.

Message Broadcasting

Identifying Authorized Users

A Cognitive Radio node will form an ad hoc network initially. Then, it can establish a communication to its neighbor nodes. In existing system, control information is broadcasted to all of its neighbors as it should not be. Because control information contains important details which is secured and it should not be shared to unauthorized users. To overcome this problem, we introduce a concept of identifying authorized users.

In this case source node will prepare control information that needs to be transmitted. Also, it will validate its neighbor details to identify authorized CR nodes to which the information has to be delivered. CR node will maintain routing table which contains neighbor details like IP address, routing information etc. From which it will gather corresponding IP addresses to which the message has to be transmitted and append these receiver addresses along with the message.

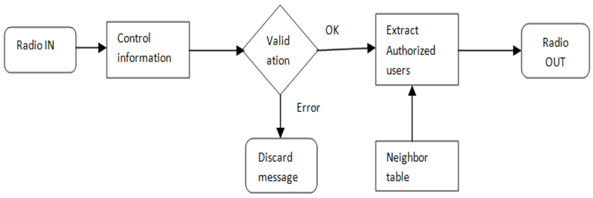

Fig (4). Authorized user identification

A CR node either it will receive control information or generate a new control information. If it receives any control information then, it will validate the control information. If any error occurs then, the message will be discarded. Once validation completed, it determines what type of control information it is. For example, it may have channel information, delay information, node failure information etc. Based on the type of message, it will extract authorized user details from its neighbor table. Those authorized users addresses will be added along with the control message and then it will be broadcasted to neighbor nodes.

Broadcasting Messages

Broadcasting is an important operation in Cognitive Radio ad hoc networks. A Broadcasting message consists of Sender address, Receiver address, control information, routing information and security information. A message will be broadcasted to all of the neighbor nodes and neighbors will rebroadcast the message to its neighbors. Likewise, a message will be transmitted to all the nodes in the ad hoc network. This method leads to network traffic as all the nodes may not require the control information has been transmitted. To prevent this problem, we are introducing selective broadcasting method.

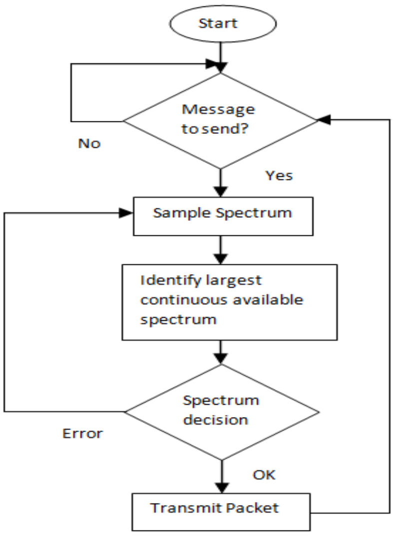

Fig (5). Message Broadcasting

In Selective broadcasting, source node will identify the authorized users to transmit the control information. For each message authorized user may vary based on the information present in the message. Hence, source node has to identify authorized user for each transmission of control information. While broadcasting the control information it will append sender address and receiver addresses (list of authorized users) along with the message. Each node which is receiving the message will validate the control information and add authorized users in the message and then rebroadcast the message to its neighbors. In this way all the nodes in the ad hoc network will transmit and receive control information in an efficient manner. As the nodes which are unauthorized to receive control information does not aware of the broadcasting messages as it will not be a part of recipient. It will reduce the traffic of network as information has been broadcasted to selective users instead of all users in the network.

Fig (5) represents the way of broadcasting messages. CR node will check if any new messages have to be broadcasted. If so, it will check for spectrum availability. CR sensor will be sensing the available spectrum in the network and taking samples to compare along with other spectrums. Finally it will identify the largest continuous available spectrum which can be utilized to establish communication. CR node will make a decision whether the given spectrum can be used for broadcasting. If so, it will broadcast message in that spectrum. Otherwise, it will check other available spectrum for message transmission.

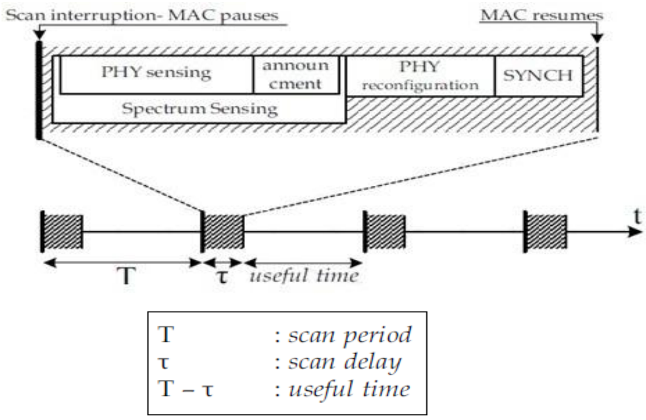

Fig (6). Spectrum scanning

CR terminal performs scanning periodically with a scan period T shown in Fig(6). The mechanism of spectrum sensing, measurement announcement, physical layer reconfiguration and synchronization affects total τ duration. The remaining period T-τ is considered as useful time in which CR node will establish communication. Till the next scan period, the identified spectrum holes are treated as single channel, common for all participating CR terminals and the MAC performs the communications functions.

Broadcasting of messages consists of three way handshaking mechanism in the form of rts-cts-data-ack. Fig(7) represents the broadcasting of messages to other CR nodes. In Fig(a), transmitter node send rts signal to perform communication. Receiver will acknowledge the request and sends cts signal to transmitter. Then transmitter will deliver data to receiver. Once receiver receives the entire data it will send ack signal to transmitter. In this case, scan interruption has not occurred. In Fig(b), scan interruption happens while sending cts signal to transmitter. Once scan delay is completed, receiver node will send cts signal to sender. In Fig(c), scan interruption happens while transmitting data. So, sender will fragment the data and then transmit to receiver. Network allocation vector (NAV) defines the time period for which the medium is expected to be busy due to current transmission.

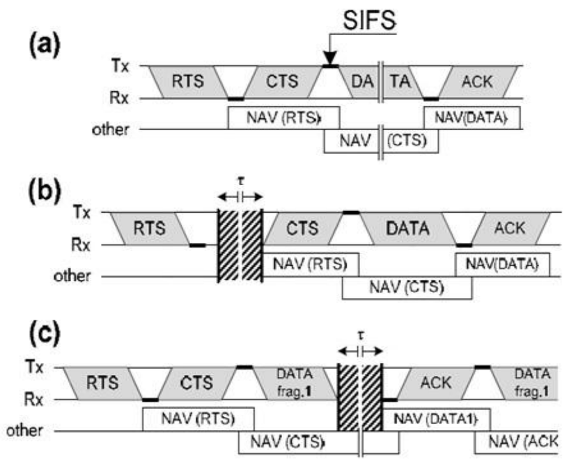

Fig (7). Message Broadcasting (a). No Scan procedure interruption (b). Interruption at cts packet transmission (c). Interruption at data transmission forcing data fragmentation

Successful packet transmission time has been calculated as follows.

$E[t_s] = RTS + CTS + 3.E[t_{SIFS}] + E[t_{DATA}] + ACK + E[t_\tau]$

Privacy Policies

As messages are transmitted in ad hoc network there might be a possibility of security attacks. Any unauthorized user may track the communication and identify the message. So, to transmit messages in a secured manner we introduce privacy policies. Privacy policy will depend upon applicable law and to address requirements across geographical boundaries and legal jurisdictions. Most countries have their own legislation and guidelines of who needs to be covered, what information can be collected, and what it can be used for.

Message Encryption

Each Cognitive Radio has privacy wall which will do encryption and decryption of messages using RSA public key cryptography method. Sender's message will be encrypted with Sender's private key using RSA Algorithm. Finally the encrypted message will be broadcasted to neighbor nodes. RSA Encryption algorithm has represented below.

Algorithm 2 : RSA Encryption

Input: RSA public key (n,e), Plain text m ∈ [0, n-1]
Output: Cipher text c
begin
1. Compute $c = m^e \bmod n$
2. Return c.
End

Message Decryption

Message decryption module in receiver will decrypt the message which was encrypted by sender. Once message has been received, receiver's privacy wall will decrypt the message with sender's public key. Receiver will validate the message and if required it will rebroadcast the message to its neighbors by encrypting the message with its own private key. RSA Decryption algorithm has represented below.

Algorithm 3 : RSA Decryption

Input: Public key (n,e),Private key d, Cipher text c
Output: Plain text m
begin
1. Compute $m = c^d \bmod n$
2. Return m.

End

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Performance Evaluation

The proposed model has been tested and compared with the existing system. It clearly shows that the proposed model saves energy of each cognitive radio node and it increases the success rate of transmission.

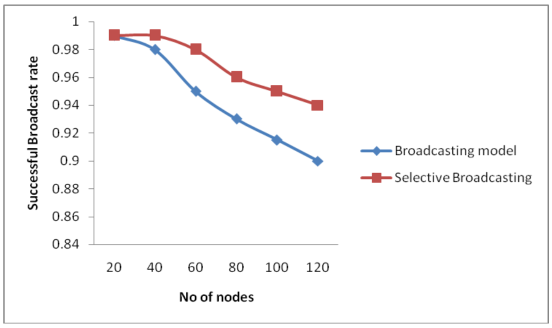

Fig (8). Results of successful broadcast rate versus number of nodes

The above chart represents the comparison between existing broadcasting model with proposed solution. In this case, a successful broadcast rate will be higher when the communication has been established with minimal number of nodes. Whenever the transmission node count gets increased, the success rate has been reduced due to several factors like channel unavailability, collission etc. As the existing model broadcasts messages to all of its neighbor nodes without validating authority of its neighbors. The proposed model describes the way of selective broadcasting in which the message will be transmitted to selective nodes which will increase the success rate of broadcasting.

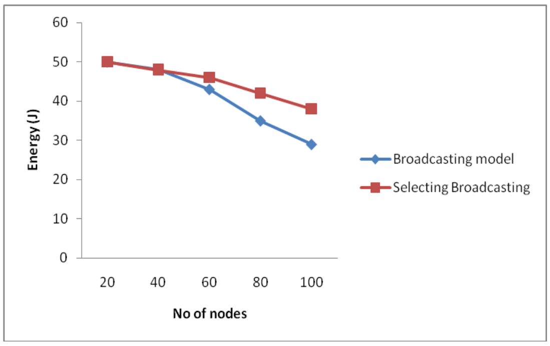

Fig (9). Results of energy consumption versus number of nodes

The above figure compares number of nodes along with energy consumption to transmit the messages. In existing broadcasting model, messages are broadcasted to all the neighbor nodes which lead to more energy consumption as the communication happening frequently. The proposed model transmits messages to selective users which saves energy of each cognitive radio node and increases the life of each node. As shown in Fig (9), if communication has been established with in less number of nodes then, there will not be a big difference between existing and proposed model. But, while adding more number of nodes, energy spent has been minimal when compare to the existing communication model.

Conclusion

In this paper, we introduced secure and energy efficient broadcasting model for cognitive radio ad hoc networks. In Existing broadcasting model, messages are broadcasted to all the neighbor nodes which may increase the network traffic. The proposed approach shows that, messages are broadcasted only to authorized users which reduce the network traffic. The energy spent for each message transmission is more in traditional broadcasting network. By using this selective broadcasting approach, energy consumption has been reduced. Also, messages are transmitted in a secure manner by following security policies.

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