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# Spectrum and Delay Efficient Routing Protocol for Mobile Cognitive Ad-Hoc Networks

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***Abstract*: The ad hoc mobile cognitive network is an advanced network technology for the Federal Communications Commission (FCC) problem of frequency deficiency. Cognitive radio networks are cognitive networks that select their network parameters based on the network environment. In a cognitive radio network, two users, the primary and the secondary or the cognitive user, gain access to the spectrum available to communicate with each other when the primary user accesses the spectrum. The secondary user should leave the spectrum and use the spectrum for the spectrum if the spectral hole is available for transmission. Therefore, routing in cognitive networks is a challenge and a challenge in mobile cognitive networks because of node mobility, the primary user interface, and the lack of spectrum. A delay minimized routing protocol is proposed for minimum delay route selection between the source and destination, which is improved version of AODV. The numerical and ns2 simulation results for the proposed protocol significantly state that delay minimized routing protocol (DMR) is better in terms of average end-to-end delay and average throughput.***

***Index Terms: Primary users (PU), delay minimized routing protocol (DMR), spectrum, cognitive radio networks, cognitive users, Mobile Cognitive Ad-Hoc Networks, Federal Communication Commission(FCC), Dynamic Spectrum Access(DSA).***

## I. INTRODUCTION

Cognitive Radio Network (CRN) is a novel technology used by the Federal Communications Commission (FCC) to conquer the spectrum shortage crisis in current wireless networks. Cognitive radio networks consist of a network consisting of primary and secondary users using networks based on Dynamic Frequency Access (DSA).

There are two types of user, the licensed user (primary user) and the unlicensed user (secondary user). The unlicensed user is not authorized if the licensed user accesses the spectrum. Therefore, the secondary user must recognize the presence of the primary user. The spectrum has to be realized from time to time. Dynamic nature, therefore, the spectral holes generated by the primary user are dynamic, so the cognitive user uses DSA. Cognitive radio networks are a challenge when using DSA routing.

### A. categorization of cognitive radio networks

The Cognitive Radio Network (CRN) is less infrastructural and infrastructural, it has a fixed structure in the infrastructure network, such as the primary user of the base station, the secondary user, etc., and it has no fixed structure in the low-grade infrastructure network.

### B. Central and Decentralized Network

A centralized network is a network consisting of a base station for central and primary users. Decentralized network is a network without a central base station and a secondary user for communication with users and users. Static and dynamic networks are fixed locations of static network base stations, primary users, and secondary users. However, in ad hoc dynamic networks, the status of primary and secondary users changes (mobility is nature).

### B. Cognitive radio networks routing

Cognitive radio network routing is depend on the knowledge existing in the network along with the nodes of the spectrum. There are two types of routing solutions for cognitive radio networks: one is the knowledge path for the entire spectrum and the other is the knowledge route for the local spectrum.

Home Spectrum information Routing provides minimal power routing, minimum delay-based routing, maximum throughput-based routing, geographic routing, and class-based routing. This paper is structured as follows: Section I contains the Introduction to Cognitive Radio Networks (CRN). Section II contains the related work of the routing protocols in CNR. Section III contains the problem of DMR. Section IV contains the proposed system model and routing algorithm from DMR, Section V contains numerical results from DMR, Section VI describes the performance evaluation, and Section VII is Completed Research with future directions.

## II. RELATED WORK

### A. The Routing Protocol for Cognitive Radio Ad Hoc Networks (ROPCORN)

The ROPCORN protocol is an on-demand routing protocol designed to transport data across CRNs using link modeling. The main idea is to design a link cost metric based on the history of the use of its spectrum and the inverse of its immediate position.

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It aired the packet with the following cast and the primary user was unaffected. ROPCORN is based on the RACON protocol, which uses buffers at intermediate nodes and does not have sufficient overhead for spectrum availability and load estimation. The optimal path choice depends on the spatial or temporal localization of the link disconnection.

### B. Search the routing protocol

This demand is based on a routing protocol based on geographic routing and an improved version of AODV and follows greedy forwarding and PU avoidance for US channel-path optimization algorithms to find the best path. SERC operates and chooses two ways to avoid PA operational area to handle overhead routing due to SERC, RERP, root error and ROP messages.

### C. Link Prediction -based Adaptive Routing

Adaptive routing with prediction of link availability is based on link-availability estimation. Link-availability estimation measures basic user functionality and consumer movability. It reduces routing power consumption and reduces delay by increasing network performance. This link is working by predicting the availability of channel and topology control.

### D. Joint channel assignment and routing

The joint channel assignment and routing technique operates based on an estimation algorithm that uses delay estimation and conflict probability and link stability estimation. This is in demand routing protocol, which allows the user to routing with the traditional values of the AODV type and identify the route with minimum delay.

### E. Adaptive Delay Tolerant Routing Protocol (ADTRP)

The coherent sequence of mobile topology and the communication topology of interest is found in the ADTRP algorithm, which is the global minimum number of transitions from one instance of topology to another. The algorithm uses the average lifetime of the mobile graph in a consistent sequence for the communication topology and is easy to use for the static sequence of any communication topology, so it has better throughput, better packet delivery ratio, and reduced beetle. Drop down and reduce the delay.

### F. STOD-RP: A Spectrum-Tree Based On-Demand Routing Protocol

STOD-RP is an on-demand routing protocol designed to reduce control overhead and reduce end-of-the-end delay and is a basic tree-on-demand distance vector (AODV) protocol, an extension of which is used in the spectrum tree. Address, spectrum determination, and path selection can be used effectively for this root matrix. A fast and efficient spectrum-compatible path retrieval method is used when the path is damaged.

## III. PROPOSED SYSTEM MODEL AND ROUTING ALGORITHM

The system has 8 secondary users with q cognitive radios and traditional wireless interface and cache to store packet. There are three primary users with three channels c1, c2, and c3. All nodes uses the same transmit power and two ways of symmetrical connection. Each node is assigned an identical bandwidth. Due to the mobility, the time is serialized as discrete time slots. In each time slots the topology of network is fixed with available channels.

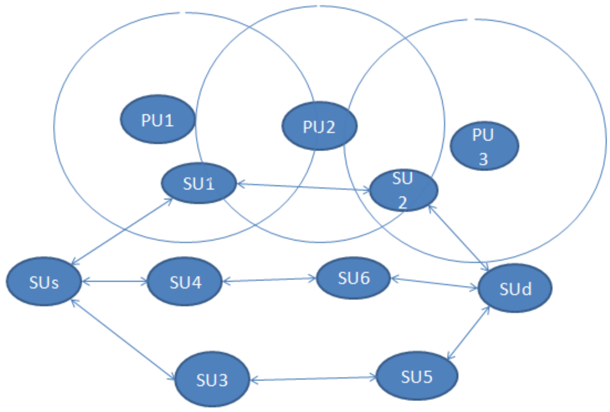


**Fig:1. Joint routing and channal assignment**

### A. Heuristic Algorithm

The algorithm is used to find the best promising solutions, but they do not guarantee, they will find the finest, so they can be measured estimated and correct algorithms. In general, find the best answer and they are fast and easy to find. Sometimes these algorithms may be perfect, which means they actually find the best solution, but the algorithm is still called heuristic until the best solution is proved. The greed method is used in the heuristic algorithm, but tends to ignore or suppress some of the demands of the problem in order to make the algorithm easier and faster.

- Transmission Time is the amount of time form the beginning until the end of a message transmission.
- Media Access Time is the time taken the packet to access the available channel or link.
- Maximal Lifetime is the time period of availability of the current link, if there is no change in the speed.

### B. Heuristic values Delay

$$D^{f^k}_{e^c_{u,v}} = EMAT^c_{v,u} + ETT^c_{v,u} \qquad (1)$$

C. Expected Transmission Time (ETT)

$$ETT^c_{v,u} = ETX^c_{v,u} * \left(T^{c,DATA}_{v,u} + T^{c,ACK}_{v,u}\right) \qquad (2)$$

$$ETX^c_{v,u} = \frac{1}{1-P^c_{v,u}} \qquad (3)$$

D. Expected Media Access Time (EMAT)

$$EMAT^c_{v,u} = D^c_{\sum v,u} * slot \qquad (4)$$

$$D^c_{\sum v,u} = \frac{1}{2}\left(\frac{1}{1-P^c_{v,u}} + \frac{W_0}{1-r*P^c_{v,u}}\right) - 1 \qquad (5)$$

E. Expected Maximal Lifetime (EMLT)

$$EMLT^c_{v,u} = MLT^c_{v,u} * P\left(MLT^c_{v,u}\right) \qquad (6)$$

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**Table :1. Notations**

| | |
|---|---|
| $e_{u,v}$ | A link from SUs $v$ to $u$ |
| $e^c_{u,\ v}\ e^c_{u,v}$ | A link-channel pair (i.e., $e_{u,v}$ is assigned channel $c$) |
| $f^k$ | The $k^{th}$ dataflow $f^k = (s_k, d_k)(1 \le k \le K)$ where $s_k$ and $d_k$ are source and destination nodes of $f^k$ |
| P | Collision probability |
| $D^c_{\sum v,u}$ | The average number of waiting time slots for a link channel $e^c_{u,v}$ |
| $W_0\, W_0$ | The initial contention window size. |
| $ETX^c_{v,u}$ | The expected times that a given packet is transmitted from $v$ to $u$ on a channel $c$. |
| $T^{c,ACK}_{v,u}$ | The time of transmitting a ACK packet over a link channel |
| $T^{c,DATA}_{v,u}$ | The time of transmitting a data packet over a link channel |
| R | the back-off algorithm constant |
| $D^{f_k}_{e^c_{u,v}}$ | Delay of $f^k$ over a link $e_{u,v}$ and a channel $c$ |
| $P^c_{v,u}$ | The collision probability of a link channel $e^c_{u,v}\ e^c_{u,\ v}$ |
| $MLT^c_{v,u}$ | Maximal Lifetime of a link channel $e^c_{u,v}\ \ e^c_{u,\ v}$ |
| $ETT^c_{v,u}$ | Expected Transmission Time (ETT) of a link channel $e^c_{u,v}$ |
| $EMAT^c_{v,u}$ | Expected Media Access Time (EMAT) of a link channel $e^c_{u,v}$ $e^c_{u,\ v}$ |
| $EMAT^c_{v,u}$ | Expected Maximal Lifetime of a link channel $e^c_{u,v}\ \ e^c_{u,\ v}$ |

### F. Algorithm for minimum delay routing protocol

**Step 1**: Let each node have two route tables with minimum delay of the node to all next Hop nodes to zero and cache to store data packet
**Step 2**: If the node is source node the RREQ packet is dropped and set minimum delay to infinite and channel is zero
**Step 3**: For every channel form node to next Hop node calculate the minimum delay and Expected maximal lifetime of a channel and stored in table 2
**Step 4**: If the Expected maximal lifetime of a channel “c” is greater than the packet delay + minimum delay and calculated minimum delay is less than the minimum delay between the nodes in the network
**Step 5**: Then minimum delay is calculate, the minimum delay and “c” is the channel to use.
**Step 6**: Packet delay is replaced to calculated minimum delay. If the calculated minimum delay is smaller than the packet delays in the route table this node. Then
**Step 7**: This node will replace the route table 1 with new reverse route from this node to source.
**Step 8**: If this node has route to destination in its route table 1 or this node is destination then it makes RREP packet and send along with a current reverse route. Otherwise it broadcast RREQ.
**Step 9**: When the node receives an RREP packet form a node then it gets route form table 1 to source and destination.
**Step 10**: If the node is source node and the minimum delay in RREP packet is lower than destination route, then source node update its route table.
**Step 11**: If this node is not the source then it updates its route table 1 to destination route and copy the route in route table 2. After that this node forward the RREP packet to the next hop using source route.

### G. Algorithm for Local Route Repair while data transfer

When a route fails at link channel then the packets is stored in the cache with the pervious Hop count and send to other route which is in table 2, with route error packet. When neighbour receives the route error packet it perform route repair as follows
**Step 1**: This node checks its route table 1 if it found a route to destination it removes that route
**Step 2**: If there is still an active route to the destination node in the route table 2 then this node sends the packet with error response packet with same state information of the packet to route node and minimum delay routing protocol will be executed for that node form Step 4 on words
**Step 3**: If there is no active route is present then route error packet will be broadcasted in source route.
**Step 4**: The node which receives will perform Local Route Repair.
**Step 5**: If the route error packet reaches the source node. Then minimum delay routing protocol will be executed once again.

## IV. NUMERICAL RESULTS

The system has 8 secondary users with q cognitive radios and traditional wireless interface and cache to store packet.
3 primary users with 3 channels c1, c2, c3.
PU1==c1, PU2==c2 and PU3==c3
SU1, SU2, SU3, SU4, SU5, SU6, SUs, SUd.
SUs use c1, c2 and c3 channels SU1, SU4and SU3.
Delay= SUs and SU4 = 104 ms
Delay= SU4 and SU6 = 92 ms
Delay= SU6 and SUd = 104 ms
Delay= SUs and SU = 92 ms
Delay= SU3 and SU5 = 92 ms
Delay= SU5 and SUd = 92 ms
By taking the routed presented in base paper for the topology
The routes are PATH 1= Sus- SU1- SU2- SUd
PATH 2= Sus- SU4- SU6- SUd
PATH 3= Sus- SU3- SU5- SUd
Each SU has two tables
The tables are of the form

| Destination | Next | Delay |
|---|---|---|
| SUs | SUs | 104 |

PATH 2 is not in use because it has primary user interface and dint have channel to communicate
Delay of PATH 2=104+92+104=300 ms
Delay of PATH 3=92+92+92=276 ms
So PATH 3 is used for communication.
The PATH 2 is stored in stored in all SU's table 2
The PATH 3 is stored in table 1
Consider Route error is occurred at node SU5

Then packet is stored in cache, after that is has route to SU3. SU3 checks for connection then it dint find any connection then it send back to SU's SU is source so it performs entire minimum delay routing protocol and find PATH 2 for transmission of data.

The numerical calculations show that the delay minimized routing protocol user caches to the nodes so that it is to minimized the route repair process when link failures is occurred while data transmission is going on..

## V. SIMULATION AND PERFORMANCE EVALUATION

Ns2.31 with CRCN patch is used to simulated the DMR protocol. Ns2 is the network simulator – 2 which is open source for network related simulations ns3 is the latest among several versions. Though they are several versions in ns2 only ns2.31 with Ubuntu 16 and with additional patch crcn-ns-2.31-ubuntu10_i386.deb is used to simulate the Cognitive radio networks.

The simulation is conducted taking 10 Secondary users and 2 Primary users as topology and taking CAODV, WCETT and DMR routing protocols, calculated average throughput and average end-to-end delay.

**Table: 2. Simulation parameters**

| | |
|---|---|
| Channel type | Wireless Channel |
| Radio-propagation model | Two Ray Ground |
| Network interface type | Wireless Phy |
| MAC type | 802_11 |
| Interface queue type | Queue/Drop Tail/Pri Queue |
| link layer type | LL |
| Antenna model | Antenna/Omni Antenna |
| Max packet in Queue | 50 |
| Bandwidth | 11 mbps |
| No of PUs | 2 |
| No of SUs | 8 |
| No of data flows | 2 |
| No of channels | 2 |
| Transmission range | 125 m |
| Interference range | 250 m |
| Window size | 256 |
| Length of slot | $50*10^6$ |
| Maximal speed | 10 m/s |
| Packet sending | Poisson distribution |
| Pause time | 5 sec |
| Transport layer | TCP/UDP |
| Packet size | 512 |
| Data generation | FTP |
| Power of nodes | Identical power |
| Bit rate | 1 mbps |
| Time of simulation | 100 sec |
| Ns2.31 | CRCN patch |

Estimate the DMR protocol by comparing the CAODV and WCETT (weighted cumulative expected transmission time) protocols. Cognitive ad-hoc on-demand distance vector (CAODV) routing protocol

1. The PU's operational area is avoided during the route creation and packet discovery process
2. Implementing a combined route and channel option to reduce route costs.
3. Multichannel communication is provided to improve overall performance.

The WCETT (weighted cumulative expected transmission time) protocol is similar to the AODV protocol. Metric based routing uses a weighted cumulative metric to select the best path between the source and destination node.

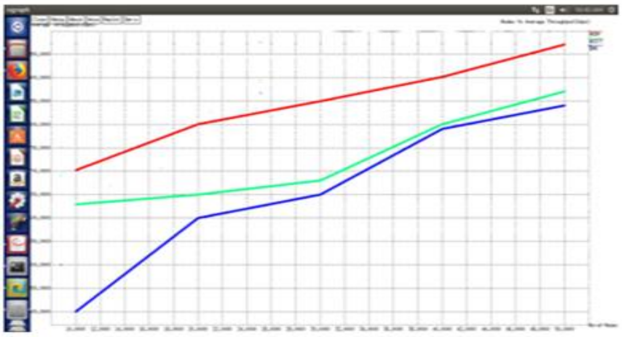

**Fig: 2. Nodes Vs Average Throughput**

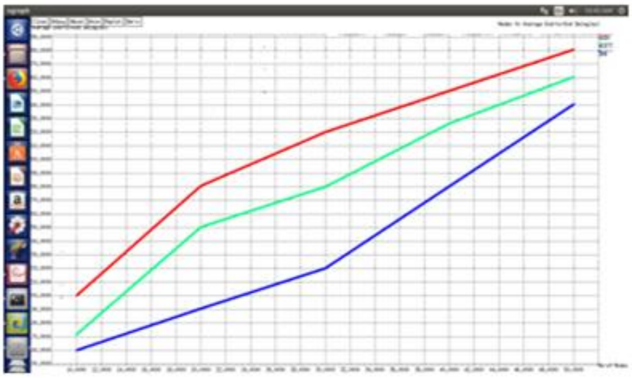

**Fig: 3. Nodes Vs Average End-to-End Delay**

Using different number of SU's to test the CAODV, WCETT and DMR, the fig: 2 and fig: 3 average delays and average throughput rate increases as the SU's increased. But DMR gives the low delay and high throughput among three protocols.

## VI. CONCLUSION

Routing is challenging problems in cognitive networks and node mobility is very challenging in mobile cognitive networks due to lack of primary user interface and spectrum. The conclusion of this paper is that each protocol is designed to overcome some problem in the network, which is for many problems and for a single problem such as performance improvement, minimized end-to-end delay, overall throughput increasing and so on. There are more protocols or improved versions of protocols for increasing problems and recruitments. The simulation results for the proposed protocol significantly state that, delay minimized routing protocol (DMR) is better in terms of average end-to-end delay and average throughput when compared with other protocols like CAODV and WCETT routing protocols.

The future work of this paper is to incorporate machine learning algorithms to predict the flow of primary user data in networks which is used in minimized delay in network and implement it in matlab2017.

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