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An Implementation of Optimum Routing Strategy in Cognitive Radio Network

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***Abstract* – The growth in demand of wireless devices and multimedia applications has led to increase in spectrum usage and put a of limitations on the use of available radio spectrum that is limited and precious resource. Many survey of spectrum utilization shows that entire spectrum is not used all times, so many of the radio spectrum is underutilized. One of the credible solutions to overcome this shortcoming is by the usage of Cognitive Radios (CR). The Cognitive Radio has spectrum sensing capabilities and thus can improve spectrum usage. The ad hoc network employing CR are termed as Cognitive Radio Ad Hoc Networks (CRAHN). To establish a route between a pair of nodes in CRAHN, a routing protocol is needed. Various routing strategies have been proposed based on performance metrics such as delay, power, hop count and spectrum awareness. Optimum routing Protocol is proposed using all the above metrics. The routing strategy is implemented in MATLAB-7.10..**

Index Terms – CRN, CRAHNs, MTPR, Shortest path routing, Optimum routing strategy

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1. INTRODUCTION

Wireless communication created a revolution in our lives. New wireless devices are capable of offering higher data rates and providing innovative services. All wireless devices require frequency spectrum for their operation. Licensed and unlicensed spectrum is available for different wireless services. Licensed spectrum is used for specific service while the unlicensed spectrum (Industrial, Scientific and Medical (ISM) radio bands) are freely available for wireless services and research purposes. But due to exponential increase in demand and usage of wireless devices the unlicensed spectrum becomes scarce resource. Static frequency spectrum policy is in appropriate because in static policy bandwidth in unlicensed bands is becoming scarce and for licensed bands it is either underutilized or unoccupied. The solution to the problem of scarcity and underutilization of frequency band is dynamic spectrum access (DSA) [15] .Cognitive radio is a key technology that enables the cognitive radio network in a dynamic manner. Thus cognitive radio can be defined as one of the most promising technologies for wireless ad-hoc network is Cognitive Radios (CR). The Cognitive radios (CR) [6] are intelligent radios that detect the free spectrum dynamically which is called Dynamic Spectrum Access

The CR resolve the channel access method, spectrum use and spectrum scarcity problem. In this CR Radios Frequency (RF) is optimized as well as minimizing the interference between users. Thus in CRAHNs [8], transceiver changed its transmission parameters (bandwidth) according to changing environment. Thus CR intelligently detect which communication channels are available and instantly moves in to vacant channels while avoiding the occupied ones. Thus CR can be defined as

"A "cognitive Radio" [6] is an intelligent radio that can change its transmitter parameter by sensing the environment in which it operates."

Devices having cognitive radio capability called cognitive radio devices and together they form the network called COGNITIVE RADIO NETWORKs (CRNs). In CRN there are two types of users: PU (Primary user) and SU (secondary user):

- Primary Users: In CRN the primary users (PUs) have a license to operate in a certain spectrum band and have the priority in spectrum utilization.
- Secondary Users: The secondary users are unlicensed users which are not allocated to any band. These users use the spectrum band opportunistically.

Paper Outline: The rest of the paper is organized as follows. Section II discusses the overview of the various routing strategies in CRN. Section III describes the Optimum routing strategy. Section IV gives the setup parameters and implementation results. Section V gives the conclusion followed by future work and references.

2. Routing Protocols in CRNs: The Literature Review

For effective routing in Cognitive radio network routing strategies [7] can be categorize in to two main classes based on the spectrum awareness:

- Full spectrum knowledge
- Local spectrum knowledge

In full spectrum knowledge [7] [9] scheme, nodes in CRNs have full knowledge about the availability of spectrum while in local knowledge based scheme, nodes do not have a full knowledge of the spectrum availability. Each SU has its own spectrum availability knowledge.

In former case theoretical tools are used to designed efficient routes, differentiating on the basis of which kind of theoretical tool is used to steer the route design. The subclass encompasses all solutions based on graph abstraction of CRNs. Example of this routing strategy are Routing through layered graph, Routing through colored graph etc. The routing scheme using local spectrum knowledge [7] [9] can be classified in three subclasses that is Minimal power routing, Delay based routing, and Throughput based routing. The categorization of routing schemes is shown in Fig. 1.

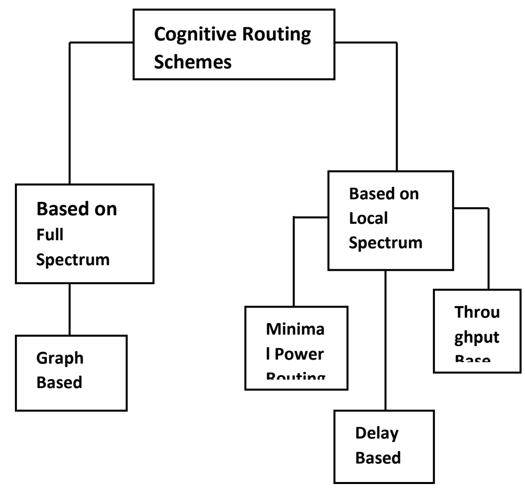

Figure. 1 Classification of Routing Strategy in CRNs

Since CRAHNs consists of multiple hops and have dynamic topology, various routing strategies are developed by various researchers for stable communication between source and destination.

The dynamic use [14] of spectrum band creates adverse effects on network performance if the same communication protocols are used, which were developed for fixed frequency band. There for new protocols should be developed appropriately to suit the cognitive radio environment. Various routing schemes have been proposed for cognitive radio ad-hoc network based on performance metric. But all the routing protocols developed for cognitive radio evaluate their performance using single performance metric. For example in Delay aware routing scheme consider different types of delays only e.g. switching delay, back off delay and queuing delay while power aware routing scheme tries to minimize the total power consumption [17] between source and destination.

Thus the entire routing schemes consider only single performance metric for routing. So a hybrid protocol is needed that take End to End delay, Transmission power consumption and hop count performance metric in to consideration.

3. Proposed Optimum Routing Strategy

The proposed Optimum routing strategy tries to find an intermediate path in between Minimum Total Power Routing (MTPR) and shortest path routing protocol since MTPR [2] protocol tries to minimize power loss of the overall path but results in high value of delay and hop count therefore, results in congestion in the network. On the other hand shortest path routing strategy has high value of transmission loss but has lower value of delay and hop count. Therefore a intermediate path is find out between MTPR and shortest path routing. In addition, the performance parameters such as spectrum, delay and power are also taken into consideration so that the overall performance is improved.

A. Objectives

The main objectives of Optimum routing strategy is as follows:

- The hop count should not be too high as MTPR and not too low as shortest path since reliability of a path depends on it.
- The end to end delay must be optimum.
- The packet delivery ratio should improve.
- Prefer a PU node whenever possible as it increases the network reliability.

4. Implementation Of Optimum Routing Strategy

4.1. Simulations Setup Parameters

The following parameters are considers for the implementation of Optimum Routing Strategy:

4.1.1 Performance Metrics

The following performance metrics were taken into consideration:

- Hop Count: Defined as the number of intermediate hops from source to the destination.
- Packet delivery ratio (PDR): Defined as the ratio of total packet received at the destination to the total number of packets sent.
- End-to-End Delay: Time taken for a packet to reach from source to destination.

4.1.2 Setup Parameters

The set up parameters for simulation purpose are as follows (see Table I)

Area	1500 * 1500
Transmission range	400
Node (SU)	24-36
Node (PU)	16
Position of SUs	Random
Position of PUs	Fixed
Max velocity	15 m/sec
Pause time	0 sec
No. of iteration	25
Source	Choose randomly from SU
Destination	Choose randomly from SU
Weight-age parameter	0.5
Weight-age parameter	0.5
No of channels per node	4
Simulation time	20 sec
Mobility model	Random walk

Table 1 Setup Parameters

4.2. Inputs Metrics for Simulation

Following Input metrics have been consider in our implementation for performance of optimum routing strategy

- Power (P) :The transmission cost for a path is calculated using the following formula:

(1) $P= a*d^4+ b$

Where the value of α is 0.01 and β is taken as 0 .

- Cost function: For selecting the route for transmission cost function is calculated for each route. The path having minimum cost function value is chosen for transmission. The cost function is defined as follows:

(2) $Cost\ Function = a* (EED) + b* P$

Where ‘a’ and ‘b’ are weighted parameters, chosen according to simulations. For example if R0 be the source and Rn is the destination and the R1, R2, R3, R4 – Rn denotes the intermediate nodes between source and destination which forms the route or path for transmission. The route from source to destination will be represented by Csd = { R0, R1, R2, R3, R4 – Rn }. The C(Ri, Rj) represents a cost function required over a route (Ri, Rj). Total Cost Function formula is:

(3) $$Cost\ (Csd) = \sum_{i=0}^{N-1} Cost\ (Ri, R(i+1))$$

The path having optimum value of cost function is selected as a transmission path from source to destination.

- End-to-End Delay (EED): The delay which include switching delay, back off delay and path delay are considered for 1

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Deploy Secondary Nodes (N)

Hop Count = 0;

PDR= 0;

Reachability = 0;

End to End Delay = 0;

TPL = 0;

For ( source (S) = 1:1:n)

    If ( path exists (S-D))

        Hop Count = Hop count+
                    size(path);

        End to End Delay= End to End

delay+Pathdelay()
        +switching delay
            delay + back off
            delay();

        PDR = PDR + Send data();

    End

  End

End

PDR = (PDR) / Reachability;

Hop count = Hop count / Reachability;

End to End Delay= End to End Delay /
Reachability
```

Figure 2.Algorithm to Calculate the Performance Metric for CRN

4.3. Implementation Results With Analysis

4.3.1 . Snapshot

For implementation an experiment is performed having K number of nodes with 400 m transmission range. The primary and secondary nodes are randomly deployed in a simulation region of 1500 * 1500 m2. The scenario of the simulation process is shown in Fig. 4.2. The red numbered dots represents the Primary users (PU) which are fixed in this simulation result. The blue numbered dots represent the Secondary users (SU) whose position is not fixed. The Yellow line shows the path from source to destination for the optimum routing strategy while the path with magenta lining represent the MTPR path and the path with green lining is of shortest path routing protocol.

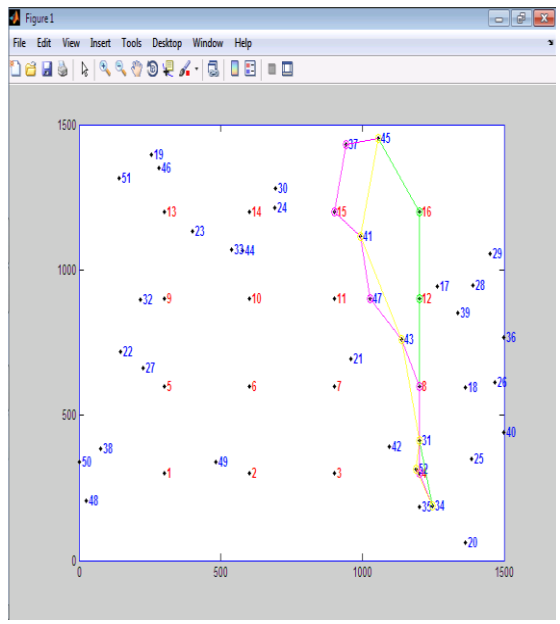

Figure. 3 Snapshot for Simulation Process

4.3.2 Impact On PDR

The PDR value for all three approaches is shown in Fig. 5. Following interferences can be drawn:

- Since our proposed strategy takes into account the delay and spectrum factor. Therefore, the value of PDR is quite high for the proposed methodology.

More is the number of intermediate nodes lesser will be the reliability. Therefore, the value of PDR is quite high for shortest path routing in comparison to MTPR

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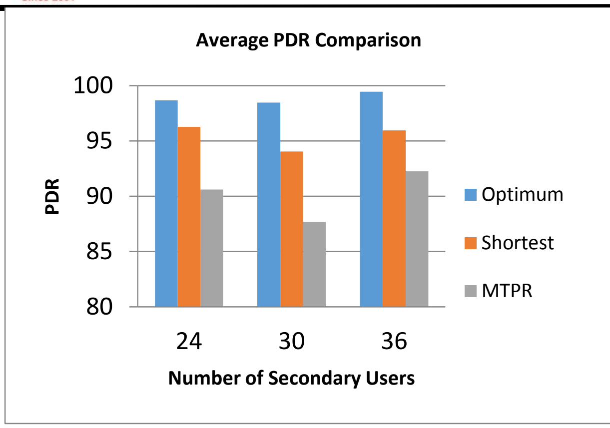

Figure 4. Impact on PDR

4.3.3 Impact on Hop Count Value

The hop count value for all three approaches is shown in Fig. 6. Following analysis can be drawn as follows:

The hop count value for the optimum routing strategy is in between MTPR and shortest path routing.

When secondary users are increases, the value of hop count increases marginally.

When PU node is preferred for the transmission between source and destination the intermediate SU hop are reduced significantly because PU offer greater transmission range therefore reliability of the network increases.

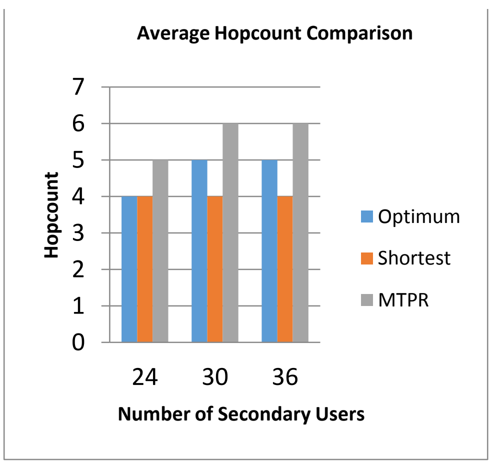

Figure. 5 Impacts on Hop Count

4.3.4 Impact on End To End Delay

The end to end delay value for all the three approaches is shown in Fig. 7. Following important analysis can be drawn as follows:

Since optimum routing strategy consider the delay and spectrum factor. Therefore the delay for the optimum routing strategy is quite low as compared to MTPR and shortest path routing strategies.

If there are more number of intermediate nodes in the transmission path there will be high delay at each end. In MTPR there are maximum number of intermediate nodes for transmission there for this routing strategy have high end to end delay in comparison to shortest path routing.

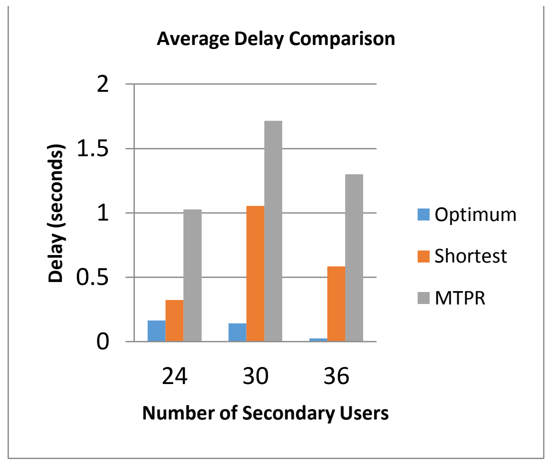

Figure. 7 Impact of End to End Delay

5. CONCLUSIONS

The Optimum routing strategy is compared with the MTPR and shortest path routing. The result shows that packet delivery ratio as well as the delay parameter improved for the Optimum routing scheme in comparison to shortest path and MTPR routing scheme.In implemented routing strategy various routes have been traversed for finding best route which include primary user. So future scope is to reduce the number of route traversed for selecting the best route. Only one route is calculated in first iteration which includes primary users.The overall comparison for optimum routing scheme in comparison to MTPR and shortest path routing scheme is sown in Table II

Protocols → / Parameters ↓	MTPR	Shortest Path routing	Optimum Routing
Hop Count	High	Low	Medium
End to End Delay	High	Medium	Low
PDR	Low	Medium	High

Table 2 comparison

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