Performance Evaluation of Shortest Path Routing Strategy using Cognitive Radios

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Abstract

To have an efficient and successful communication in ad hoc networks, the use of Cognitive Radios (CR) has gained popularity in the recent past. These radios have spectrum sensing capabilities and thus can easily switch to free spectrum band. The use of such type of radios not only improves the routing performance but at the same time improves the overall throughput of the network. To show the same, we implement shortest path routing strategy in MATLAB-7.01. The routing scheme uses two types of radios one with spectrum sensing capability such as cognitive radios and the other which doesn't. The following performance metrics such as Packet Delivery Ratio (PDR), Delay, Success Ratio and Hop count are taken into consideration for measuring the efficiency. The result shows that a node having spectrum sensing capability outperforms the other one.

Keywords: Cognitive radio, Dijkstra Algorithm, Routing Protocol.

1. Introduction

Ad hoc network is a wireless self-configuring network that aims at providing communication between distant nodes where we don't have pre initialized infrastructure [1-2]. The communication in such network is multi-hop in nature to save battery power. These networks have several limitation such as: limited battery power, security and bandwidth. One of the major issues that is addressed [3-5] in recent past is the type of radios used for communication. The radios used aren't capable of sensing the free spectrum availability due to which their packets are dropped by the other nodes as shown in Fig. 1. It shows an ad hoc network having Primary User (PU) and Secondary User (SU). The PUs are the ones that uses spectrum at their will while SUs are dependent upon PUs for the purpose of communication. Figure shows two paths one marked with green arrows is the shortest one but is only available for 10 seconds while the other path is not the shortest one but is free for 60 seconds. Thus, it now depends upon how much time we need the connection to sustain. If we want to sustain the route for less than 10 seconds than it is best to use the shortest path otherwise we should use the spectrum before the communication process starts. Due to the problem discussed above Cognitive Radio (CR) were proposed for ad hoc network leading to the development of Cognitive Radio Ad Hoc Network (CRAHN).

The CRAHN [6-7] basically consists of two users, PU and SU. The nodes of these networks employ radio's having cognitive abilities which includes determining its location, or even altering transmission parameters and its characteristics [8-9]. Fig. 2 shows the CRAHN that takes spectrum knowledge into consideration before communication and helps the routing protocol to find the best shortest spectrum aware routing strategy [10-11]. The route shown in green colour is the optimum one since the communication requirement of SU is of more than 10 seconds.

Figure 1. Ad hoc Radio

Figure 2. Cognitive Radio
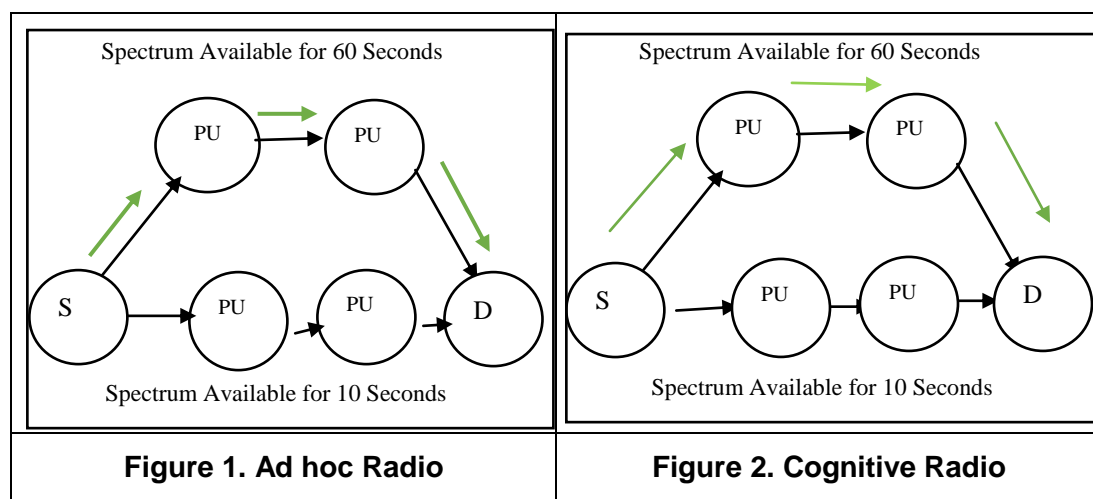
In this paper, we try to compare the efficiency of two networks on the basis of radios used. We will refer two types of Radios in the upcoming text:

Ad hoc Radios: These nodes doesn't have spectrum sensing capability.

Cognitive Radios: These radios possess spectrum sensing capability and are able to switch to free spectrum band when required.

The paper has been organized as follows: Protocol under consideration, Experimental Set-Up, Results, Analysis and Conclusion. The below given figure 1(a) shows the data being dropped when the channel used by Primary user (PU) is busy and figure 1(b) shows the data being forwarded by Primary User when its channel is not in use.

2. Protocol under Consideration

The flowchart in Fig. 3, shown below takes input: *Secondary User Concentration (SU), Transmission Range (TR), Primary User (PU) concentration* and gives an output of *Avg_PDR, Avg_hopcount, Delay* for 25 iterations. In figure 4, in addition to these inputs, channel information is also taken. First of all the algorithm distributes number of nodes randomly and we initialise time (t) =0. We select Source (S) and Destination (D) and algorithm finds the neighbouring nodes and calculates distance between them and stores them in a matrix (M) which is then used by *Dijkstra ()* function to find the shortest path between source(S) and destination (D). Also, *Random Walk Mobility Model* is used to add mobility to the nodes. Time is incremented after each iteration by adding step size to time until time (t) is less than simulation time (T). Here, Step size is a constant by which time increments by a fixed amount (Step size= 0.2 msec) in an iteration and Simulation time (T) is the total time needed to complete a simulation process and which in our case is taken as 100 sec.

3. Experimental Set-Up

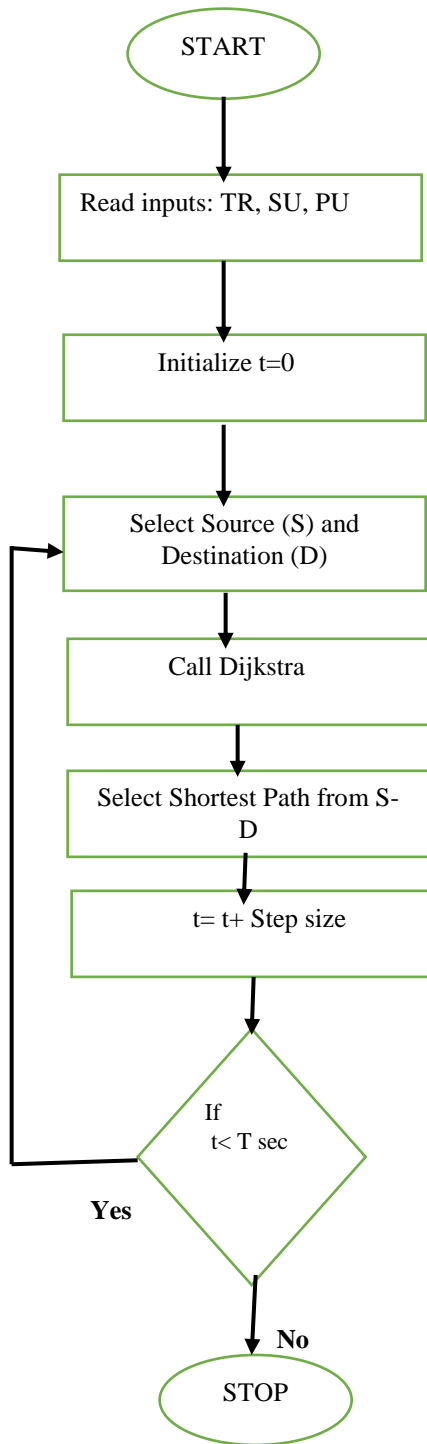This section provides detailed set up parameters, performance metrics and tools used in our experiment.
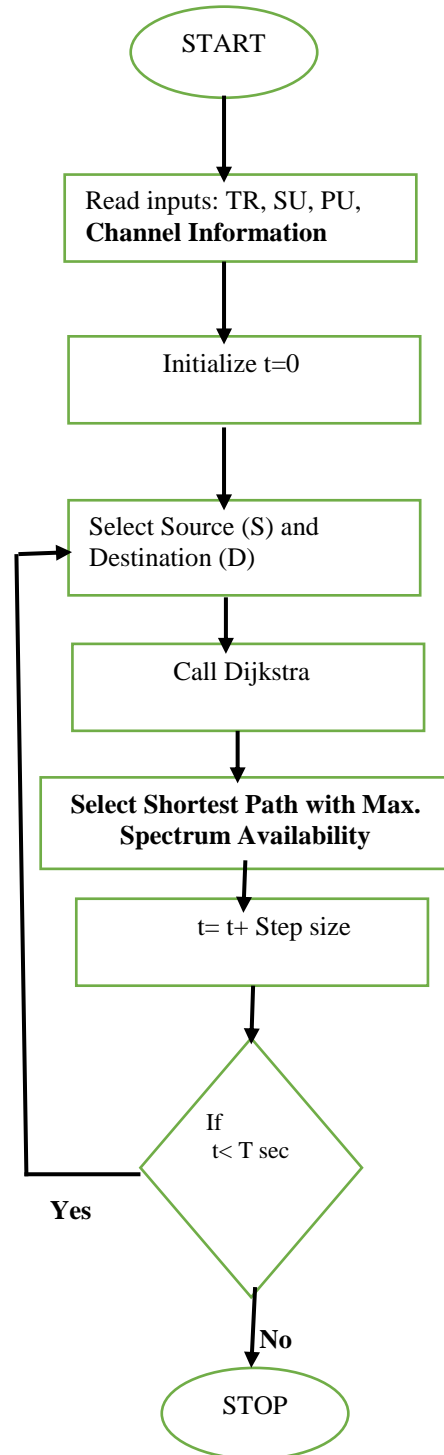
Figure 3. *Ad hoc* **Radio**

Figure 4. Cognitive Radio

3.1. Set-up Parameters

Table 1 Shows Set-up Parameters used in our Experiment.

Table:1 Set-up Parameters

Number of SU nodes	24,30,36
Shape	Square(1500 X 1500)
Deployment of Nodes (SU)	Random
Mobility models	Random way Point
Routing algorithm used	Dijkstra
Transmission Range	400
Number of Iteration	25
Position of PUs	Fixed
Simulation time (T)	100 sec.
Max Speed of SUs	15 Km/hr
Number of PUs	16

3.2. Performance Metrics Used

The following performance metrics were used in our experiment:
Packet Delivery Ratio(PDR) – It is the ratio of total packets delivered to the source to the total number of packets transmitted
Hop Count- Defined as the number of intermediate hops from source to destination.
Delay–It is the total time taken by data packet to reach from source to destination.
Success Rate – It is defined as the percentage of number of successful routes formed to the number of routes requested.

3.3. Tools Used

MATLAB- 7.01 was used for our experimental analysis due to its following key features:
The basic data element is a matrix. A simple integer is a matrix of one row and one column. Several mathematical operations such as cross products, inverse matrices, determinants, *etc* that can work on arrays or matrices can be built in MATLAB. Plotting of data is easy and we can change sizes, colours, scales, *etc* by using graphical interactive tools. Vectorized operations, *i.e*, one command is needed for adding two arrays, instead of, for and while loop. Functionality of MATLAB is expanded by addition of toolboxes. Most of the mathematical functions are readily available in MATLAB which can greatly reduced the complexity of the program. Also, Functions made in MATLAB can be used to return multiple values.

3.4. Snapshots

Fig. 5 shows the snapshot of the simulation process. The red dots are PUs while the blue dots are SUs. The path marked in green colour shows the shortest path from source (Node 48) to destination (Node 32) while the pink path shows the shortest path spectrum aware routing protocol.
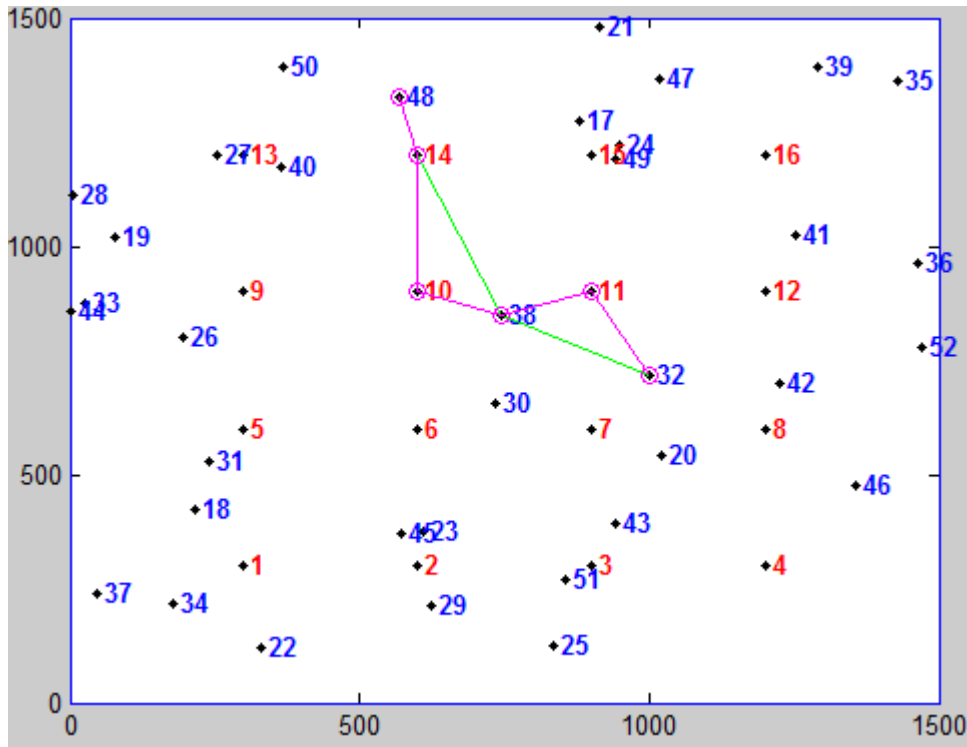
Figure 5. Snapshot of the Simulation Process

4. Results

This section provides the function used to calculate the result and impact of Ad hoc and Cognitive Radios on PDR, Delay, Hop count, success rate by varying the concentration of SUs.

4.1. Function Used to Calculate Result:-

The function shortest () takes Transmission Range (TR), Secondary users (SU), Primary Users (PU) as inputs and gives Avg_PDR, Avg_hop count, Avg_Delay as outputs. First, we initialise PDR, Hop Count, Delay, all to zero. Loop is then used to perform N (25) number of iterations. PDR (P) and Hop Count (Count) are the outcomes of shortest path routing protocol algorithm. PDR and Hop count are calculated by adding P to PDR and count to Hop count respectively with each iteration and their average is calculated by dividing the total PDR and total Hop count to the number of iterations (N). Avg_Delay is calculated by incrementing delay with each iteration and dividing the total delay to the number of iterations (N).

function [Avg_PDR, Avg_hop count,Delay]= shortest(TR, SU, PU)

{

PDR=0;

Hop Count=0;

Delay=0;

for (i=1 to N)

{

*[P,Count]=Routing protocol (S,D,TR,M);*

PDR= PDR+ P;

Increment delay;

Hop count= Hop count + Count;

}

Avg_PDR= PDR/N;

Avg_hop count= Hop count/N;

Delay= Total Delay/N;

Return (1);

}

4.2. Impact on PDR

Figure 6 shows the impact of ad hoc radios and cognitive radios on PDR values. The following inference can be drawn:

- The PDR value is much more in case of shortest path that employs CR than in case of shortest path with Ad hoc Radio.

- Also, there are very minute changes in the value of PDR in case of shortest path that employs CR than in case of shortest path that employ Ad hoc Radio.

- The reason for the aforesaid being that in latter case, the dropping of data packets is more since it doesn't take into consideration the spectrum of route formation. Hence, the value of PDR for shortest path having Cognitive Radios is much high.
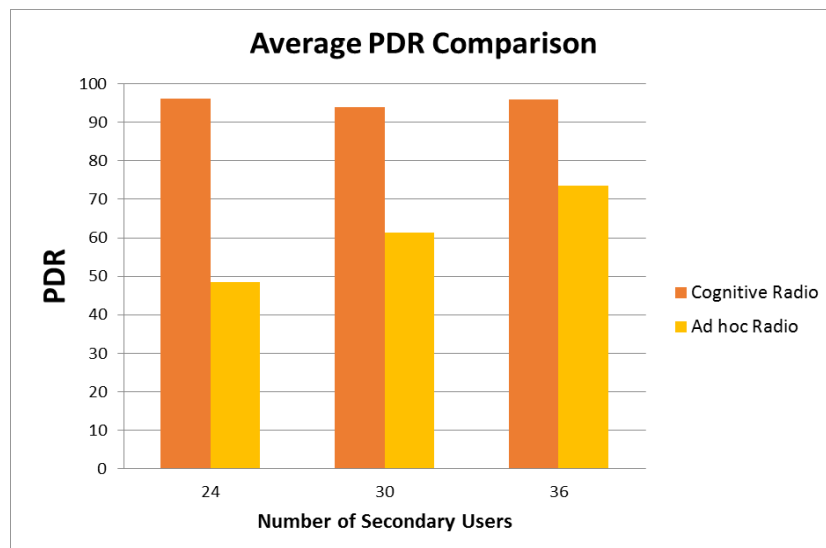
Figure 6. Impact on PDR

4.2. Impact on Hop Count and Delay

Fig. 7 and Fig. 8 shows the impact of Ad hoc and Cognitive Radio on hop count and Delay respectively. The Hop count and Delay value is more in case of shortest path that employs CR than in case of shortest path that employs Ad hoc Radio. Reason being, in case of CR, spectrum information is taken into account before

communication and hence, the path may not be the shortest but will have less chances of link failure at any given instant of time.
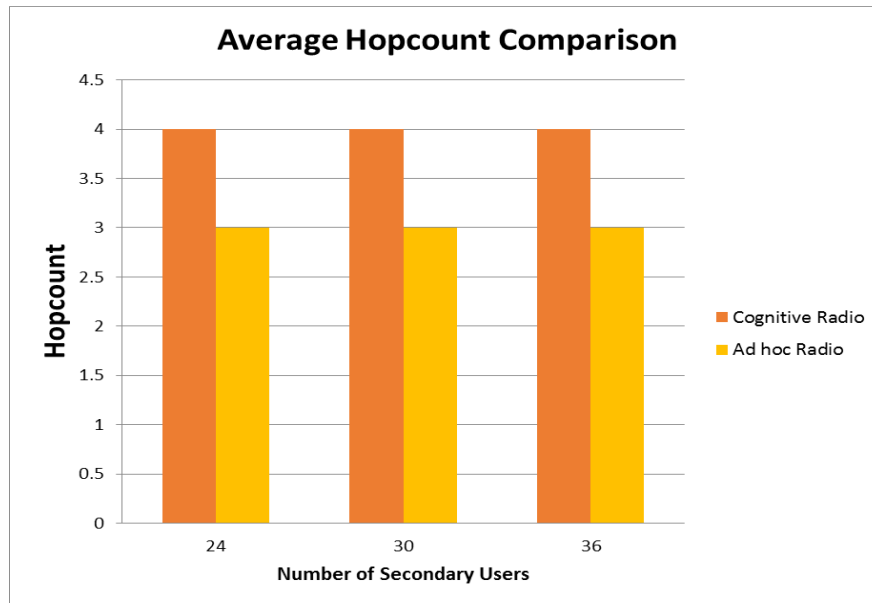

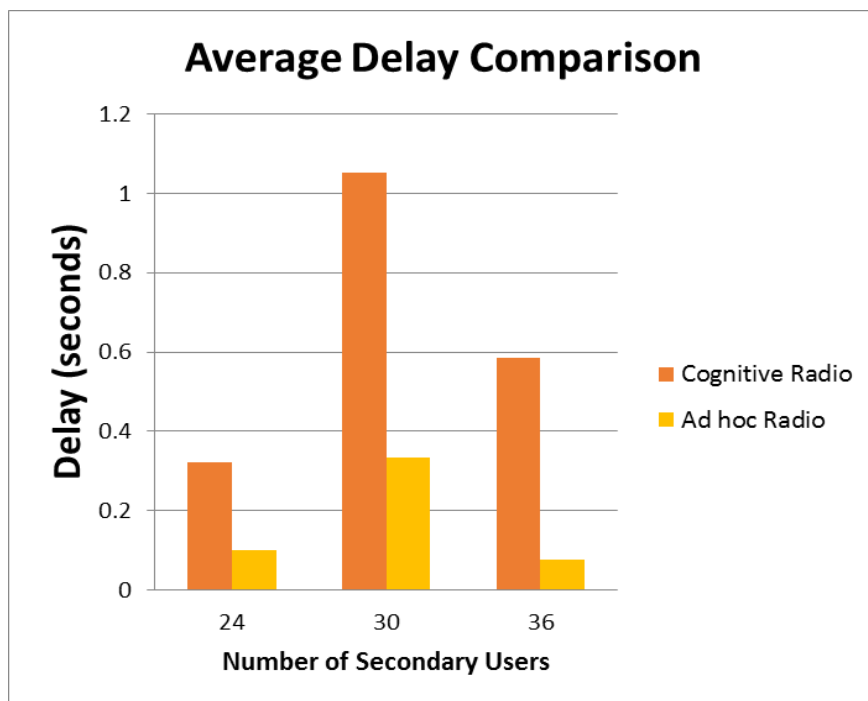**Figure 7. Impact on Hop Count**

Figure 8. Impact on Delay

4.3. Impact on Success Rate

Figure 9 shows the impact of Ad hoc and Cognitive Radio on Success rate. The following inference can be drawn:

- The success rate is high in case of shortest path that employs CR than in case of shortest path that employs Ad hoc Radio.

- The reason for lesser efficiency of Ad hoc Radio is that it has more chances of link failure than Cognitive Radio.
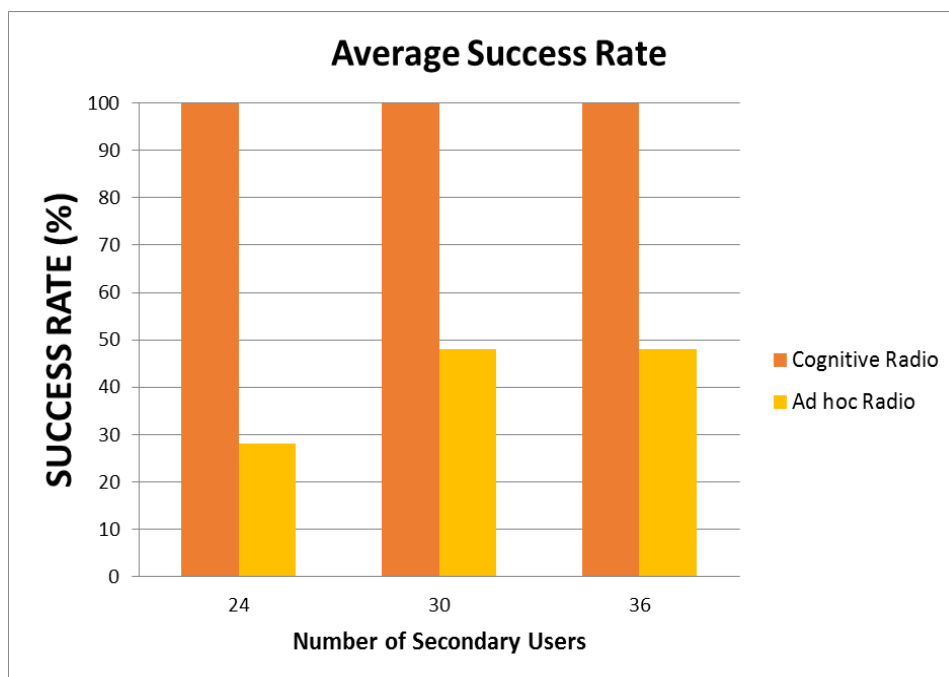

Figure 10. Impact on Success Rate

5. Conclusion

This paper is an effort to describe the performance evaluation of shortest path routing strategy for Cognitive Radio. Under written outcomes of the paper may prove to be beneficial for researchers.

- Average Packet Delivery Ratio (PDR) is much more with Cognitive radios.
- Average Hop Count is more and so is average Delay.
- Success rate is also high.

Table 2. Overall Comparison

Parameters ⟍ Protocols →	Shortest Path Spectrum Aware	Shortest Path Spectrum Unaware
PDR	High	Low
Hop Count	High	Low
Delay	High	Low
Success Rate	High	Low

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