Towards Realistic Performance Evaluation of Delay Tolerant Network

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Abstract: - Delay Tolerant Network (DTN) is a type of wireless ad hoc network in which route is established between a pair of nodes in spite of having long delays and frequent route ruptures. To ensure successful communication in such an environment a robust routing protocol is used the performance of which depends upon various factors such as transmission range, processing capability, transmission delays, bandwidth and the environment. Many researchers have evaluated the performance of routing protocol in an idealistic environment and only few have made an effort to evaluate its performance for realistic environment. This paper is an effort to evaluate the efficacy of DTN in realistic as well as idealistic conditions by designing a simulator in MATLAB-7.0. To make the scenario realistic, obstacles of different shapes, types and numbers were introduced in the simulation region. The results show that the performance of routing protocol vary significantly by changing the environment i.e. the results for idealistic scenario cannot be applied for realistic scenario.

Key-Words: - Routing, Realistic Environment, Simulation.

1 Introduction

A DTN [1-3] is a wireless ad hoc network consisting of mobile nodes having intermittent connectivity between a pair of nodes. As the name implies the network has high end to end delay. Researchers have made valuable efforts in designing routing protocol for these networks, the main purpose of which is to establish a path between a pair of nodes. The performance of routing protocols for DTN [4-7] depends upon various factors as follows:

• Intermittent connectivity: The nodes in DTN [8] are mobile and may move in and out of periphery of the simulation region. As a result there are frequent disruptions in connectivity established by routing protocols leading to degradation in performance.

• Availability of Network Resources: Availability of the network resources such as bandwidth [9], process capability and residual battery power [10] influence the performance of routing protocols to a great extent.

• Storage Capacity [11]: As the mechanism used for data transfer is of store and forward type, the storage capacity or buffer size [12] of the relay node need to be quite high so as to have good performance of network.

• Environment: The environment may contain obstacles of different shapes, types and number. Moreover the shape of the simulation region (i.e rectangular, circular or elliptical shape) also affects the performance of the network [13].

Various researchers have made a valuable contribution in evaluating the performance of DTN in ideal conditions i.e. in absence of obstacles. This paper also evaluates the same but by making scenario realistic by incorporating obstacles such as mountains or rivers in the simulation region. Thus the main objectives of the paper are:

• To evaluate the performance of routing protocols of DTN having cyclic nodes.

• To make the simulations as realistic as possible.

• To compare and analyze the variance in performance metrics in realistic and idealistic environment.

To fulfill all these objectives a simulator was designed in MATLAB-7.01.The simulator distributes the nodes randomly in a simulation region along with cyclic nodes and obstacles. A path is established using shortest path routing strategy and evaluation of various performance metrics is done.

The rest of the paper is organized as follows: Section 2 provides motivation and problem identification. Section 3 gives the algorithm and simulation set up parameters. Section 4 provides the impact of realistic scenario on DTN. Section 5 present the conclusion followed by the references.

2 Literature Survey and Problem Identification

The literature contains papers that discuss the impact of routing protocols on DTN performance in idealistic environment as follows:

Cong Liu [17] studied the performance of DTN in terms of Packet Delivery Ratio (PDR) and propagation delay. It was found that due to frequent network disconnections in DTN, the propagation delay become very large as a result of this the PDR reduces significantly.

Another effort in this direction was made by Zhensheng Zhang [18]. It was found that using routing protocols for DTN designed for MANET result in significant drop in network performance.

Xiao Chen [19] studied reliability of delivered data for DTN as a performance metric to evaluate the network performance. It was discovered that the flood forwarding approach makes the routing cost quite high.

Yukun Yao [20] worked on the information exchange between nodes in DTN having same transmit power. He analyzed that DTN is an energy consuming network. He emphasised the need of energy-efficient power control mechanism for DTN.

Qinghua Li [1] researched the impact of selfish nodes on DTN and proposed a Social Selfishness Aware Routing algorithm to allow user selfishness. This approach was successful in improving the packet delivery ratio with low transmission cost but the results obtained do not consider the practical aspect of applications.

To study the impact of routing protocols various routing strategies have been proposed and simulated in an idealistic environment (in absence of obstacle), but how these strategies work in presence of obstacle is still an issue. Recently Shailender Gupta et. al. [21] carried out a comprehensive study on MANET performance in presence of obstacle which motivated us to carry out the same task for DTN networks also.

3. Experiments Performed

3.1 The Experimental work performed

To carry out comprehensive study of the impact of obstacles on DTN performance four different experiments were conducted which are as under:

3.1.1 Experiment 1

Evaluation of impact on performance of DTN nodes with different shapes of obstacle.

3.1.2 Experiment 2

Evaluation of impact on performance of DTN nodes with different types of obstacle (river or transparent type and mountain or opaque type).

3.1.3 Experiment 3

Evaluation of impact on performance of DTN nodes by varying number of obstacles.

3.2 Performance metrics

The following parameters are evaluated for DTN:

3.2.1 Hop count: defined as the number of intermediate nodes required to establish the path from source to destination [22].

3.2.2 Probability of reachability (PoR): defined as fraction of possible reachable routes to all possible routes that may physically exist between every pair of source and destination [23].

3.2.3 Packet delivery ratio (PDR): defined as the number of packets received by the destination to the total number of packets sent by the source [24].

3.2.4 Path optimality: defined as the ratio of total distance travelled in realistic environment to the distance travelled in the idealistic environment having no obstacle [24].

3.3 Algorithm

The algorithm to calculate the various performance metrics is shown as under. Total forty nodes (N=40) were deployed and k % of nodes defined as DTN nodes [25]. To calculate the value of PoR a variable called count is used to find the total no of paths that exists between all S-D pairs. If the path exists between S-D pair the value of count variable is incremented by 1. For calculating the value of average hop count the Cum_Hop_count variable is used (initialized to zero). If path exists between pair of S-D then again check if path is intersected by an obstacle or not. If the path is not intersecting by the obstacle then the value of hop count is added to Cum_Hop_count variable otherwise next destination is searched. This process is repeated for all combinations of S-D pairs. For calculating PDR the source sends 100 packets using procedure send_data() between every S-D pair and returns successfully packets received by destination. A variable called Cum_Data_packet is used to find cumulative value of packet received by destination. Path_length contain the distance between source and destination through intermediate nodes. The average hop count, PoR and packet delivery ratio are calculated by using formula given in algorithm.

Algorithm 1: To calculate various performance metrics

```
Total Nodes N = 40;
count = Cum_Data_Packets = Cum_hop_count =0;
for i=1 to 39
    for j=i+1 to40
      If (S-D path exists)
       If (path intersect obstacle)
        Continue;
     else
   Cum_Data Packets = Cum_Data Packets +Send data( );
    Cum_hop_count = Cum_hop_count + Hop_count;
    Cum_path_length=Cum_path_length+path_length;
    Count++;
   end
   end
   end
end
PDR = Cum_Data Packets /count;
PoR = 2 * Count / N / (N-1);
Hop Count = Cum_hop_count/count;
```

3.4 Set up parameters

The Table 1 shows the values of set up parameters used for simulation purpose.

Table 1: Set up parameters

Set up parameter	Value
Inner region dimension	1500x1500 sq units
Outer region dimension	2500x2500 sq units
Numbers of nodes	40
Transmission range	275 m
Mobility model	Random Walk
Speed of Ad-hoc nodes	25m/s
Placement of nodes	Random
Obstacle shape	Square ,Circle
Speed of DTN nodes	5m/s
Routing algorithm	Dijkstra's Shortest Path
Packet transmission interval	1sec
Packet size	512 bytes
Number of packet sent	100
Obstacle type	Mountain, River
Area of obstacle	112500 sq units

4 Impact of Realistic Scenario

4.1 Experiment 1

Fig.1 and Fig.2 show the snapshots of the simulation process having different shapes of the obstacle (circle and square respectively) in green colour. Nodes in red colour are the cyclic ones that move periodically in and out of inner region and nodes in black colour are non cyclic ones and are constrained to move in the inner region. Green line shows the path of communication between an S-D pair involving intermediate nodes. The obstacles constitute 5 percent of the inner area that obstruct the node movement as well as direct communication path between two nodes.

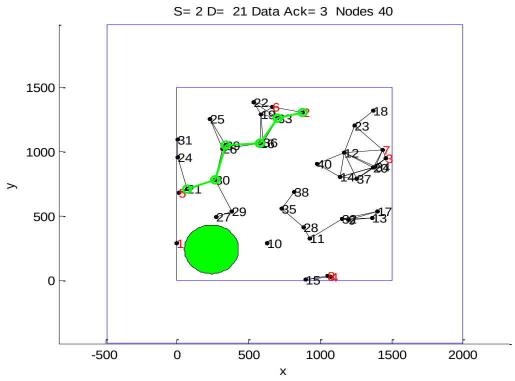

Fig.1 Snapshot of the network with circular shape obstacle.

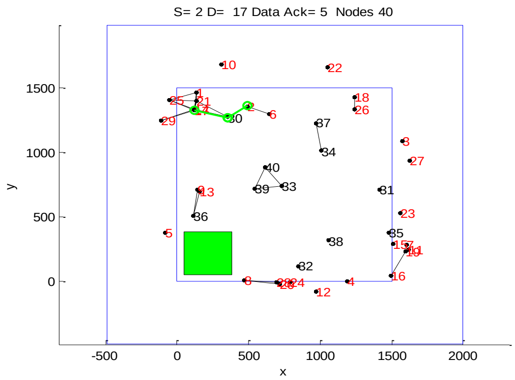

Fig.2 Snapshot of the network with square shape obstacle.

4.1.1 Result of experiment 1:

4.1.1.1 Impact on hop count

Fig.1 shows the impact of varying shape of obstacle and cyclic node concentration on hop count [14]. The following inferences can be drawn:

• As the percentage of cyclic node increases, the number of intermediate nodes decreases both for idealistic and realistic environment which results in decrease in hop count consistently.

• For circular shaped obstacle the value of hop count is smaller as compared with the square shaped of obstacle.

• From the graph it may also be inferred that realistic results are quite different from ideal ones.

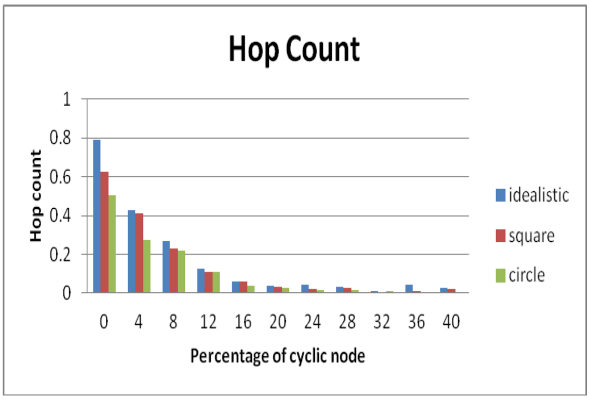

Fig.3 Impact of shape of obstacle on Hop count

4.1.1.2 Impact on packet delivery ratio (PDR)

Fig.4 shows the impact on packet delivery ratio for idealistic and realistic scenario by varying shape of the obstacles and by changing cyclic node concentration. The following inferences can be made:

• As the percentage of cyclic node increases the number of intermediate nodes decreases resulting in low value of packet delivery ratio decreases consistently.

• The number of packets transferred between the nodes is reduced due to presence of obstacle showing that realistic scenario results are quite different from idealistic ones.

• The reduction in packet delivery ratio for circular shape of obstacle is more as compared to square shaped obstacle.

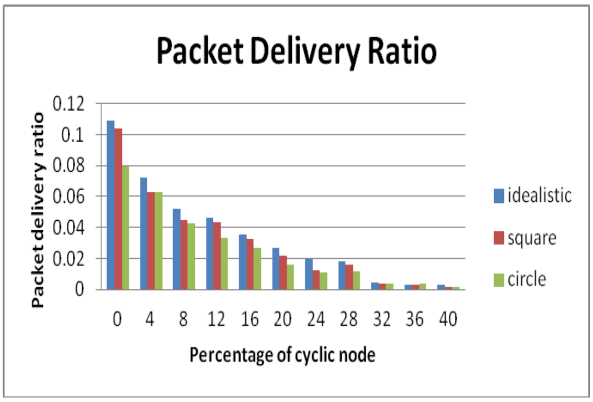

Fig.4 Impact of shape of obstacle on packet delivery ratio.

4.1.1.3 Impact on probability of reachability (PoR)

Fig.5 shows the impact on PoR in presence obstacles and cyclic nodes. The following inferences can be made:

• PoR decreases consistently as the percentage of cyclic nodes increases from 0 to 40 % due to reduction in overall number of intermediate nodes.

• The decrease in PoR value in presence of obstacles is more compared to idealistic scenario and it is highest for circular shaped obstacle.

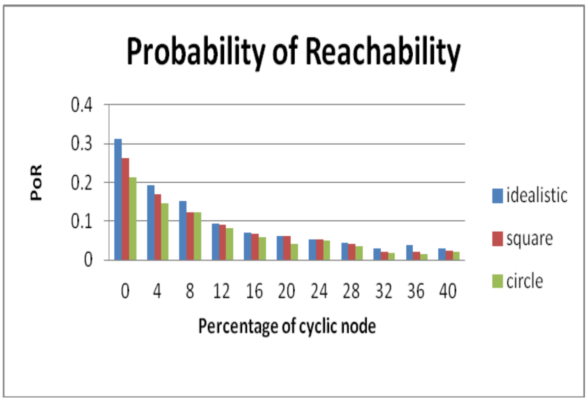

Fig.5 Impact of shape of obstacle on PoR

4.1.1.4 Impact on Path optimality

Fig.6 shows the comparison of path optimality for idealistic and realistic environment having different shaped obstacle and for different cyclic nodes concentration.

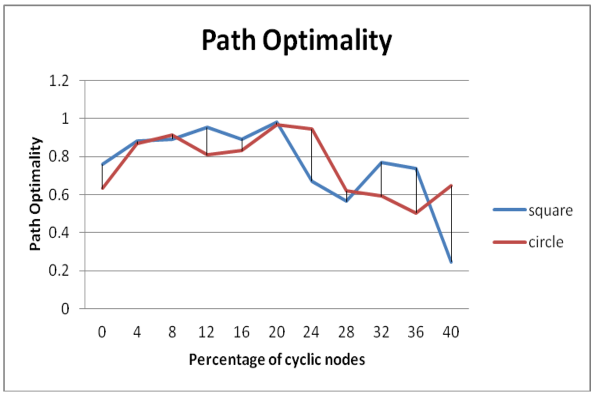

Fig.6 Impact of shape of obstacle on path optimality.

The following inferences can be made:

• The value of path optimality goes on decreasing as the percentage of cyclic nodes increases.

• The fall in path optimality value is slightly more for circular shaped obstacle compared to square shaped obstacle.

4.1.2 Analysis of experiment 1

The analysis of experiment 1 is carried out using Fig.7 and Fig.8. The double headed arrows indicate the direction of motion of cyclic nodes. The cyclic nodes follow the trajectory which is perpendicular to diameter (D) as shown in the Fig.7. Therefore the maximum obstruction in case of circular obstacle will be due to diameter (D). On the same lines the maximum obstruction caused by square shaped obstacle is equal to side (L) of square (Fig.8). Since the value of D is high as compared to value of L, the obstruction provided by the circle to the node movement is higher. This accounts for smaller value of hop count for circular obstacle which in turn results in smaller value of PDR and reachability and Path optimality for circular shaped obstacle.

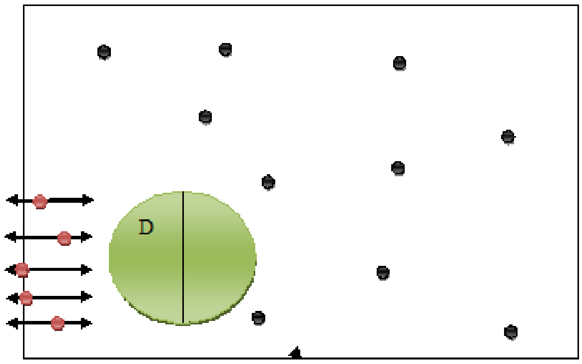

Fig.7 circle shaped obstacle.

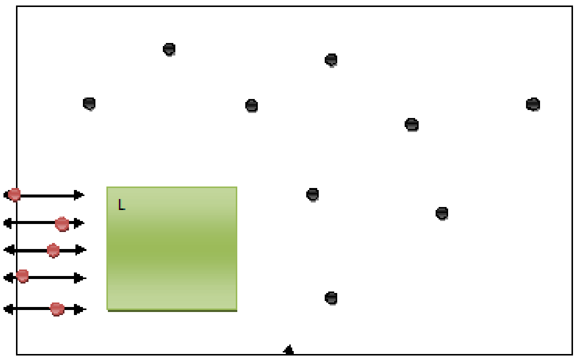

Fig.8 square shaped obstacle.

4.2 Experiment 2

In this experiment [15] two types of Obstacles are used i.e. mountain and river. Mountain not only restricts the node movement but also obstruct the direct transmissions path between nodes. The river type obstacle on the other hand obstructs the node movement only. Fig.9 and Fig.10 shows the snapshots of the simulation process having both mountain and river type of obstacles.

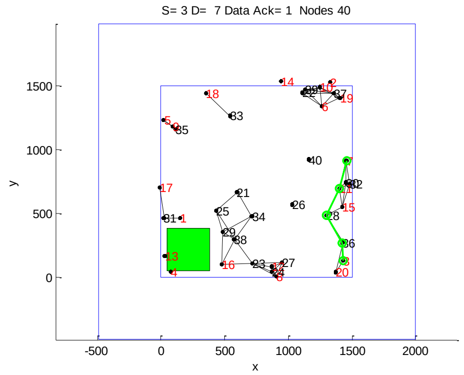

Fig.9 Snapshot having mountain type of obstacle.

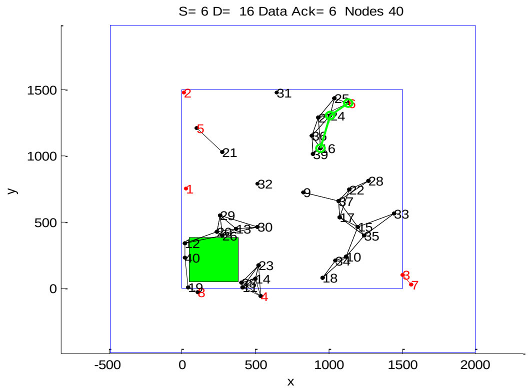

Fig.10 Snapshot having river type of obstacle.

4.2.1 Result of experiment 2:

4.2.1.1 Impact on hop count

Fig.11 shows the results of hop count for idealistic and realistic condition with varying concentration of cyclic nodes. The following inferences can be made:

• The value of hop count goes on decreasing for realistic and idealistic scenario with increase in percentage of cyclic node.

• The value of hop count is lower in realistic scenario in comparison to its value in idealistic scenario.

• For the mountain type obstacle the value of hop count is lesser in comparison to the value of hop count having river type of obstacle.

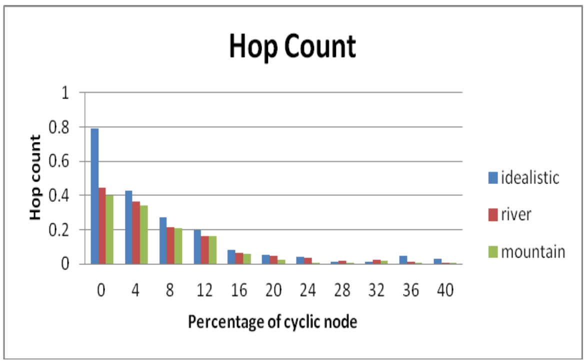

Fig.11 Impact of obstacle type on hop count

4.2.1.2 Impact on probability of reachability (PoR)

Fig.12 shows the impact of obstacle type on reachability for idealistic and realistic environment. The following inferences can be made:

• With increase in the concentration of cyclic nodes the value of reachability decreases both for idealistic and realistic environment.

• The value of PoR in presence of obstacles is quite low in comparison to its value in idealistic condition.

• The fall in value of PoR for mountain type obstacle is more compared to fall in value of river type obstacle.

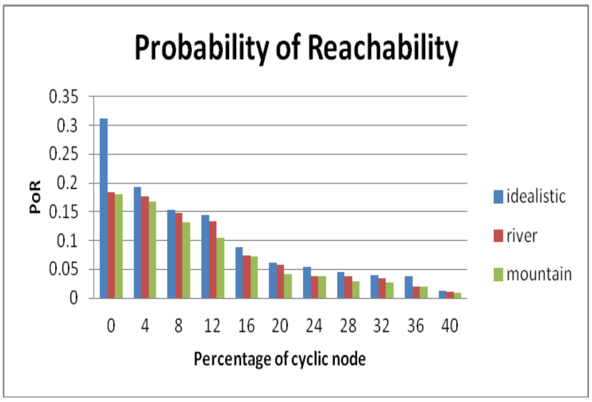

Fig.12 Impact of obstacle type on PoR

4.2.1.3 Impact on packet delivery ratio (PDR)

Fig.13 shows the impact of packet delivery ratio for idealistic and realistic environment. The following inferences can be made:

• With increase in the concentration of cyclic nodes the value of packet delivery ratio decreases both for idealistic and realistic environment.

• The value of PDR is quite low in comparison to its value in absence of obstacle.

• The value of PDR for mountain type obstacle is lesser when compared to river type obstacle.

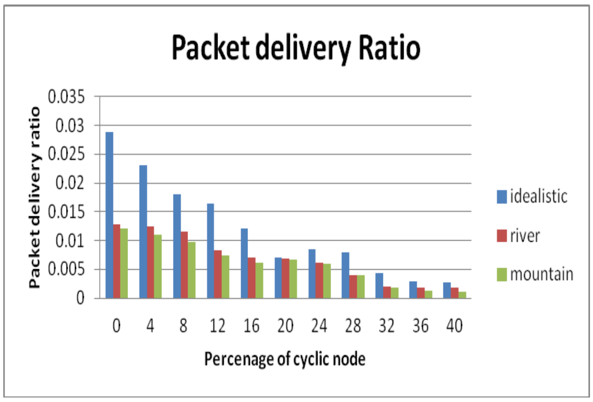

Fig.13 Impact of obstacle type on packet delivery ratio.

4.2.1.4 Impact on Path optimality

Fig.14 shows the impact of obstacle type on the value of path optimality. The following inferences can be made:

• As the percentage of cyclic node increases path optimality decreases significantly.

• At 30 to 40 percentages of cyclic nodes, path optimality remains constant in river type of obstacle where as in case of mountain type obstacle it reduces further because the mountain obstacle hinders the communication, even if the nodes lie within the transmission range.

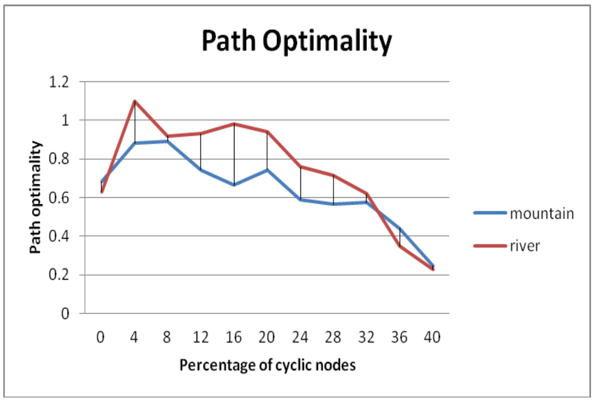

Fig.14 Impact of obstacle type on path optimality

4.2.2 Analysis of experiment 2

To analyse the cause of variation in performance of the mountain and river type obstacles based on the fact that both the obstacle types differ in way these treat the communication signal. The mountain type obstacle obstructs the node movement as well as hinder's the communication through it where as the river type only obstructs the node movement. Due to this difference the hop count, PoR and packet delivery ratio in an environment in case of river type obstacle is larger than the environments containing mountain type of obstacle.

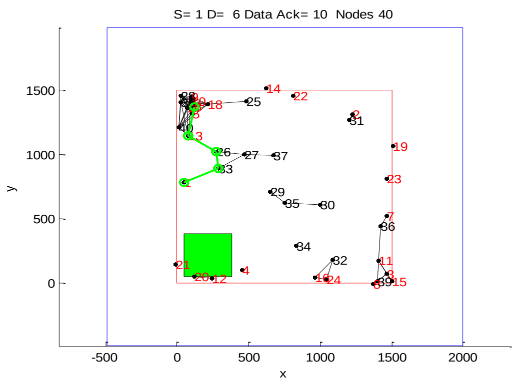

Fig.15 Snapshot with one obstacle.

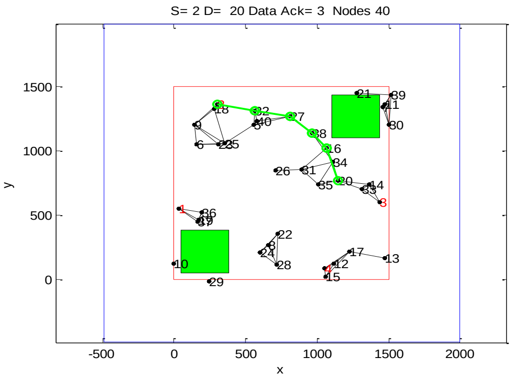

Fig.16 Snapshot with two obstacles.

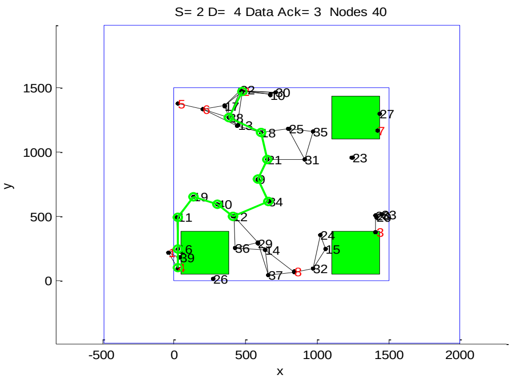

Fig.17 Snapshot with three obstacles.

4.3 Experiment 3

In experiment 3, the impact on performance metrics has been observed by varying the number of obstacles in the simulation region. One to three (mountain type) obstacles are placed in the simulation region. The snapshots of the simulation process are shown in Fig.15 – Fig.17.

4.3.1 Result of experiment 3:

4.3.1.1 Impact on hop count

Fig.18 shows the impact on hop count with variation in number of obstacle.

The following inferences can be made:

• As the percentage of cyclic nodes increases the value of hop count decreases consistently.

• For any value of cyclic node percentage, as the no of obstacles increases the fall in value of hop count increases further.

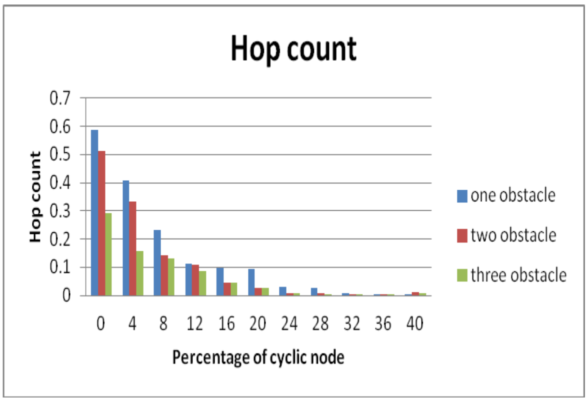

Fig.18 Impact of number of obstacle on hop count

4.3.1.2 Impact on probability of reachability (PoR)

Fig.19 shows the impact on PoR due to increase in the number of obstacles. The following inferences can be made:

• As the percentage of cyclic nodes increases the value of PoR decreases consistently.

• As the no of obstacles increases the fall in value of PoR increases further.

• When the percentage of cyclic node is more than 20, the value of PoR is very little affected by increase in the number of obstacles.

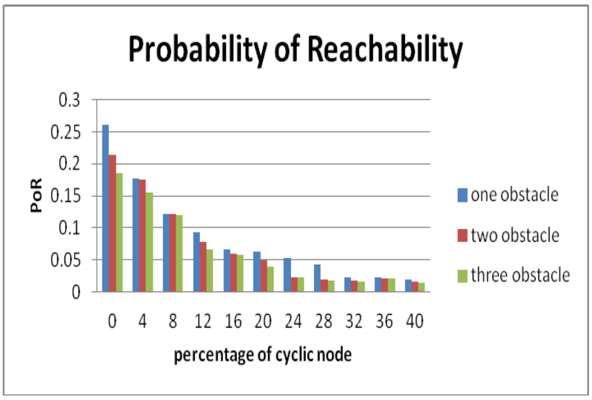

Fig.19 Impact of number of obstacle on PoR

4.3.1.3 Impact on packet delivery ratio (PDR)

Fig.20 shows the impact on packet delivery ratio with increase in number of obstacle.

The following inferences can be made:

• As the number of obstacle increases, it stifles the movement of nodes and reduces the possibilities of nodes coming within the transmission range of each other, thus increase in number of obstacles reduces the packet delivery ratio subsequently.

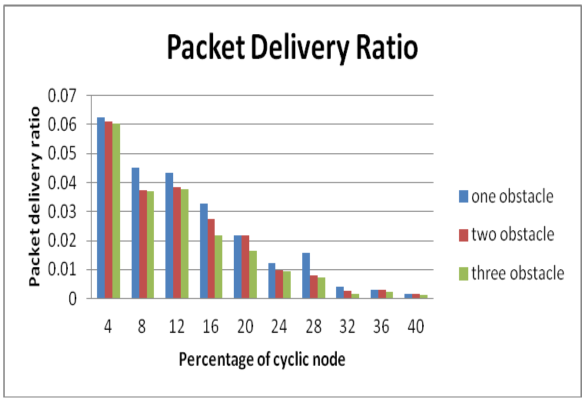

Fig.20 Impact of number of obstacle on packet delivery ratio.

4.3.1.4 Impact on Path optimality

Fig.21 shows the impact on path optimality due to the presence of obstacles. The following inferences can be made from the graph.

• As the percentage of cyclic nodes increases the value of Path optimality decreases.

• As the no of obstacles increases the fall in value of Path optimality is more.

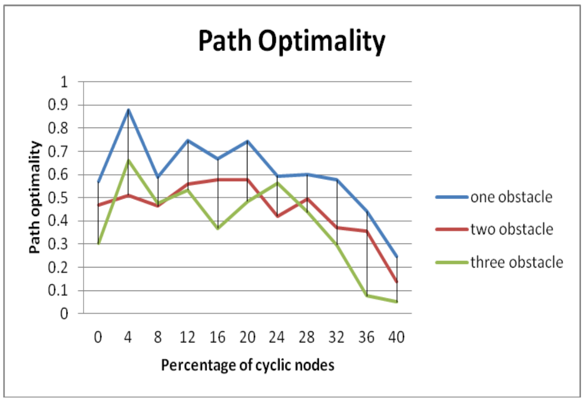

Fig.21 Impact of number of obstacle on path optimality.

4.3.2 Analysis of experiment 3

It was observed from the experiment 3 that with an increase in the number of obstacles deployed in the simulation region directly affect the performance of the Network. These results are expected since with increase in the number of obstacles the obstruction in node movement as well as signal hindrance increases. Therefore on increasing the number of obstacles the performance metrics i.e. hop count, PoR and packet delivery ratio degrade significantly.

4 Conclusion

In this paper an effort has been made to compare the performance of DTN in realistic and idealistic environment. Various strategies have been developed for DTN that are tested in idealistic condition having no obstacle. This paper considers the impact of obstacles on routing protocols performance of DTN. The following inference may be drawn:

• The results of idealistic scenario cannot be used for practical applications as can be seen from Table 2.

• The network performance decreases as the percentage of cyclic nodes increase in bath the case i.e. idealistic and realistic scenarios implying that if we want to see the trend then idealistic results can be used but in case of actual scenario the scene is quite different.

• Before deploying any routing protocol in DTN the geographical shape must be considered so as to decide which routing protocol is best suitable for the given environment.

The results can be very fruitful for researchers working in field of DTN network.

Table 2: Over all comparison

Performance Metrices		Experiment 1 Square-Circle	Experiment 2 Mountain-River	Experiment 3 One –Two-Three Obstacles	Idealistic
Hop count	Min Max	0.0077- 0.0038 0.6256- 0.5038	0.0026- 0.0064 0.4013- 0.4474	0.002-0.0013 -0.009 0.5872- 0.5103-0.2936	0.0128 0 .7897
PDR	Min Max	0.0018- 0.0017 0.1037-0.0794	0.0011- 0.0018 0.01205 -0.0128	0.0018-0.0015-0.0012 0.0625-0.0612-0.0604	0.0028 0.1088
PoR	Min Max	0.0205- .0141 0.2615-0.2141	0.0100- .0115 0.1802-0.1846	0.0196- 0.0154-0.0137 0.2615-0.2141-0.1859	0.0294 0.3115
Path Optimality	Min Max	0.24-0.50 0.97-0.96	0.24-0.22 0.89-1.1	0.24- 0.13-0.05 0.88- 0.57-0.66	

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