Towards Realistic Performance Evaluation of Delay Tolerant Network

Shailender Gupta[1], Bharat Bhushan[2], Sangeeta Sardana[3] and Neelam Malik[4]

YMCA University of Science and Technology, Faridabad, India
[1]shailender81@gmai1.com, [2]bhrts@yahoo.com, [3]sangeeta_dhall@yahoo.co.in, [4]malikneelam.2007@gmail.com

Abstract

Delay Tolerant Network (DTN) aims to provide communication between distant nodes in spite of high end to end delay and frequent disruptions in connectivity. For successful communication between a pair of nodes, a routing protocol is used. The performance of routing protocols for DTN depends upon various factors i.e. bandwidth, residual battery power processing capability and mobility of nodes. Out of these the most prominent factor is mobility. To show the impact of mobility of nodes in simulation various mobility models are used. This paper is an effort to evaluate the performance of routing protocol for DTN using Random Walk (RW) mobility model. Moreover to provide a realistic touch to the simulation environment, cyclic motion among k% of total nodes has been introduced. To carry out the above process, a simulator was designed in MATLAB-7.0. The results show that as the percentage of cyclic nodes increases, the performance of routing protocols decreases significantly.

Keywords:* N*etwork, Routing, Mobility models

1. Introduction

Delay Tolerant Networks [1] are characterized by the sporadic connectivity between their nodes and therefore lack stable end to end paths from source to destination. Due to frequent network connectivity disruptions, the topology is partially or intermittently connected at a given time. These frequent disconnections may occur due to propagation phenomenon, node mobility and low battery power. Propagation delays might be long due to effect of different environmental factors (*e.g.*, deep space, underwater *etc*).To ensure communication in such an environment a robust routing protocol is required which is a challenging task even today for researchers. One of the main factors affecting the performance of the a routing protocol [7] is the mobility [6] of the nodes *i.e.*, if the nodes of the networks are having high velocity the performance based on metrics such as Packet Delivery Ratio (PDR) [5], reachability and hop count deteriorates [9]. To study the impact of mobility on the performance of routing protocols mobility models are used.

The mobility models represent the unpredictable movement pattern of the nodes in wireless networks and give us an idea regarding their location, velocity and acceleration change over time. These models are used for simulation purpose in standard software tools such as NS-2, QualNet *etc*. In this paper we tried to find the impact of RW mobility model on the performance of shortest path routing protocol for DTN.

To make the scenario more realistic cyclic nodes [2] were added. A cyclic node is one which repeats its trajectory after a fixed interval of time such as patrolling by defence personnel, intra-planet satellite communication and skating tour[8] *etc*. The concentration of cyclic nodes was varied and its impact on the performance of routing protocols was observed and analysed.

The rest of the paper has been organised as follows: Section 2 discusses the random walk mobility model used in the simulation of DTN. Section 3 displays the Snapshot of the simulation region of the DTN network, the set up parameters used, performance matrices and algorithm. Simulation results are presented in Section 4. Finally, we conclude the paper in Section 5.

2. Random Walk Mobility Model

In this model [6] every node moves towards a new randomly chosen location by selecting random direction and speed from the predefined range and is independent from other nodes of the network. Whenever any node reaches the boundary, a new direction is chosen from pre-defined ranges and this is how the node remains in the periphery as shown in the Figure 1. The nodes A, B and C move randomly in the direction as indicated by arrows. When a node reaches the boundary, its direction changes randomly without alteration in the speed as shown in Figure 1.

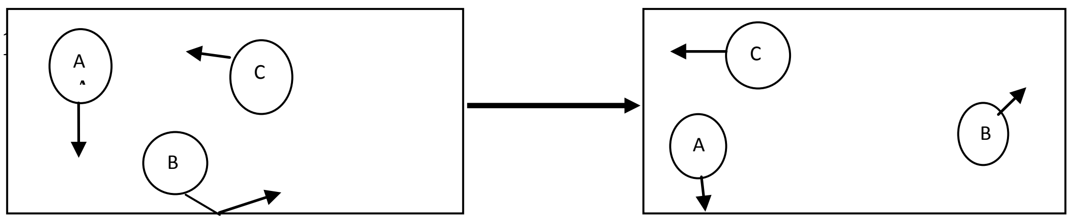

Figure 1. Cyclic and Random Walk

As mentioned earlier we introduced cyclic nodes in the simulation region to give the scenario a realistic touch. Therefore in the simulation few nodes were made to exhibit cyclic movement while other nodes observe random motion as shown in Figure 2. (*i.e.*, A, B are cyclic nodes while C is having random motion). As shown in the Figure 2(a) the node A starts sending data / control packets to node C through an intermediate node B. Cyclic nodes may move out of inner periphery but do not go outside the outer region. When the cyclic node B moves out from the inner periphery it drops the packet as shown in Figure 2(b).

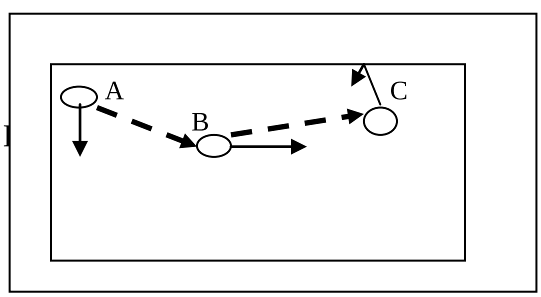

Figure 2(a). Connection Established

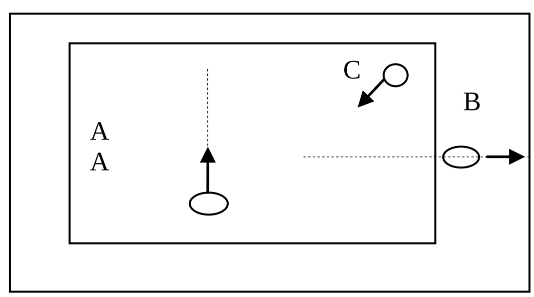

Figure 2 (b). Impact of Cyclic Node

3. Simulation Set up

For the implementation of the Routing protocol in DTN environment a simulator was designed in MATLAB in which a size of the region 1500 x 1500 sq. units called inner region was taken wherein 40 numbers of nodes were distributed randomly as shown in Figure 3. Another region called outer region of width of 1000 units is drawn around inner region. Dijkstra's shortest path algorithm is used to determine shortest route between a source (S) and destination (D) pair. Out of 40 nodes k% of nodes are chosen randomly for exhibiting cyclic motion. Figure 3(a) and Figure 3(b) show the snapshots of the simulation process with value of k ranging between 10% to 50%. The red dot represents the cyclic nodes and the green lines describe the shortest path for a given pair of source and destination. 100 data packets are transmitted between source and destination and Data Ack defines the no of packets acknowledged by destination.

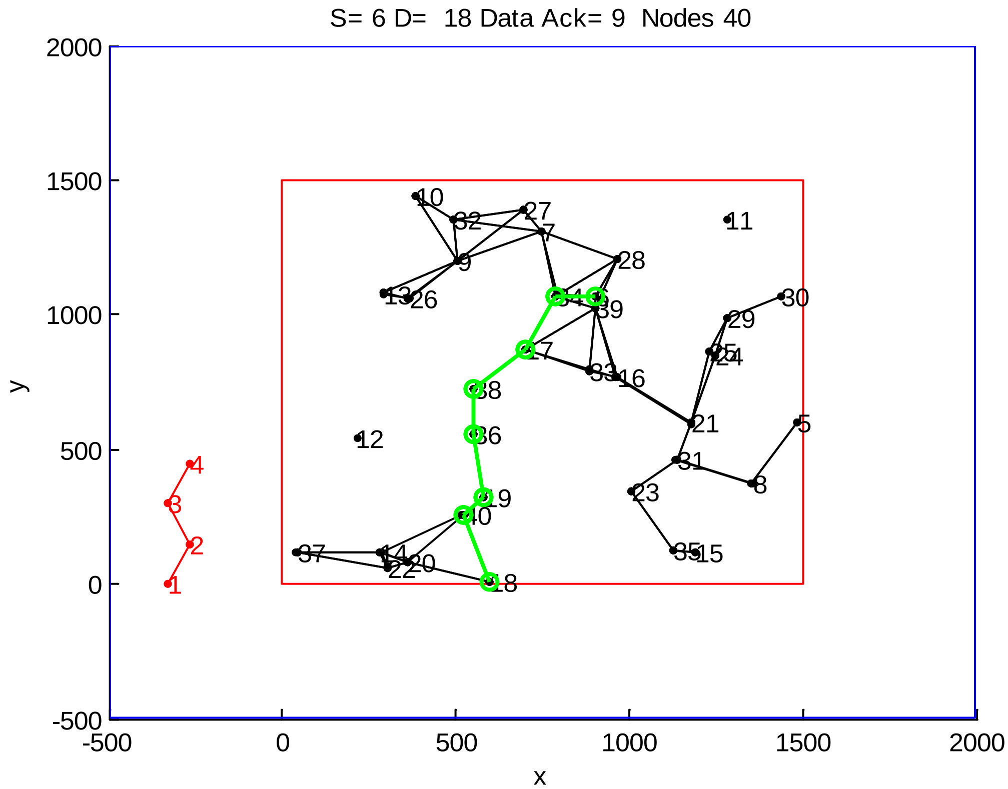

Figure 3(a). Ad Hoc Network With 10 % Concentration of Cyclic Node

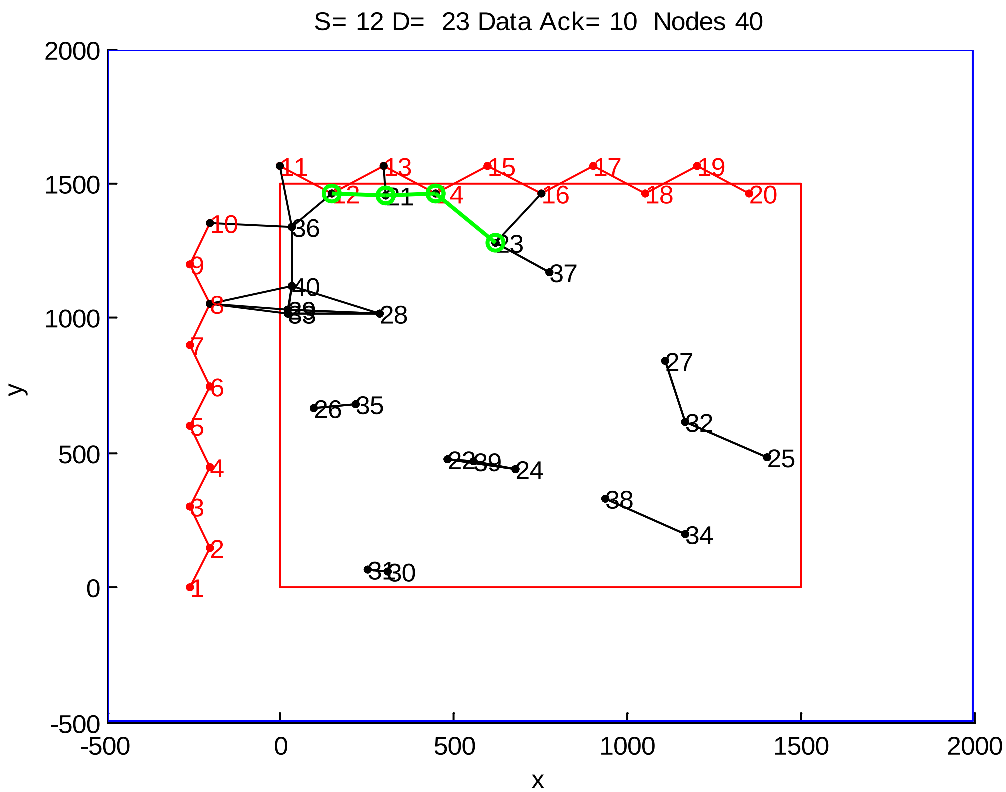

Figure 3(b). Ad Hoc Network With 50% Concentration of Cyclic Node

3.1. Performance Metrices

The parameters under which the performance of the DTN network is evaluated are as follows:

Hop count: defined as the number of successive nodes required to establish the path from source to destination.

Probability of Reachability: defined as fraction of possible reachable routes to all possible routes that may physically exist between every pair of source and destination.

Packet Delivery Ratio: defined as the number of packets received by the destination to the total number of packets sent by the source.

Path Optimality: defined as number of possible reachable path in DTN to ad hoc network for all source and destinations.

3.2. Set up Parameters

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

Table1: Set Up Parameters

Set up parameters	**Values**
Area (Inner) Area (Outer)	1500X1500 sq units 2500X2500 sq units
Numbers of nodes	40
Transmission Range	275 m
Mobility Model	Random Walk
Speed of Ad-hoc nodes	25m/s
Speed of DTN nodes	5m/s
Numbers of Iterations	10
Shape of Region	Square
Packet transmission interval	1sec
Packet Size	512 bytes
Number of packet sent	100

3.3. Algorithm Used

The algorithm to calculate the various performance metrics is shown as under. We used 40 nodes (N=40) and define k % of nodes as DTN nodes. To calculate the value of PoR we use a variable count to calculate the total no of paths existing between all SD pairs. If the path exists between SD 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 SD then the value of hop count is added to Cum_Hop_count variable. The process is repeated for all SD pairs. For calculating PDR the source sends 100 packets using proceure send_data() between every SD 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. The average hop count, PoR and PDR are calculated by using formula given in Algorithm.

```
Total Nodes N = 40; count = Cum_Data_Packets = Cum_hop_count =0;

for i=1 to N-1
    for j=i+1 to N
        If (S-D path exists)
            Cum_Data Packets = Cum_Data Packets +Send data( )
            Cum_hop_count = Cum_hop_count + Hop_count;
            Count++
        end
    end
end
PDR = 2 * Cum_Data Packets / N / (N-1);
                        PoR = 2 * Count / N / (N-1);
Hop Count = 2 * Cum_hop_count/N / (N-1);
```

4. Simulation Result

We discuss impact of varying cyclic nodes on various performance metrics as under:

4.1. Impact on Hop Count

Figure 4 shows the Hop Count comparison for DTN and ad hoc network. The following inference can be drawn:

- The hop count is nearly same when the number of DTN nodes is approximately 10% of the total number of nodes showing that there is no effect on the path length until 10% of DTN nodes.
- As the percentage of cyclic nodes increases beyond 10 %, the value of hop count decreases significantly for DTN. Since the failure in connectivity is directly proportional to concentration of DTN nodes. This shows that as the concentration of DTN nodes increases, the number of intermediate nodes in between given pair of SD decreases.
- In case of Ad hoc Network the average value of hop count does not vary significantly with change of cyclic nodes. This is due to the fact that cyclic nodes remain within inner region only.

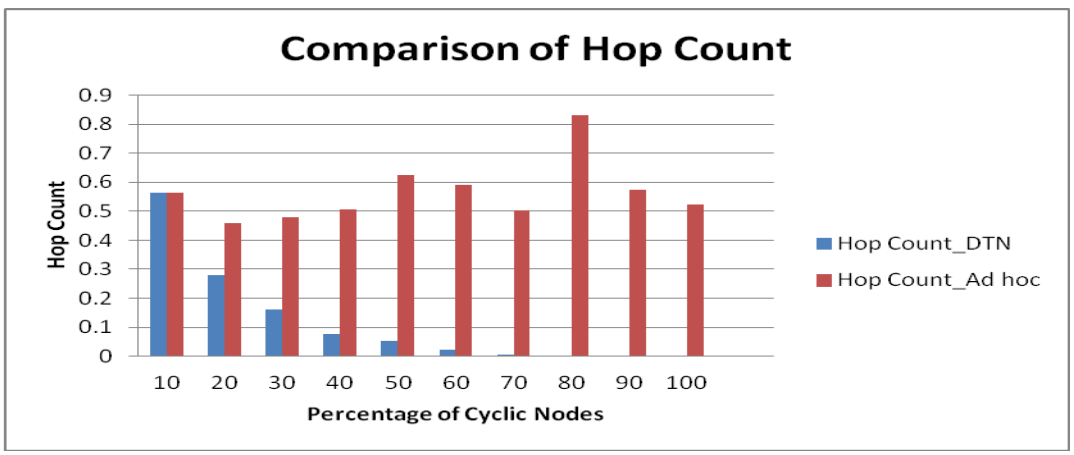

Figure 4. Hop Count in DTN and Ad Hoc Network

4.2. Impact on Probability of Reachability (PoR)

Figure 5 shows the comparison of PoR in ad hoc and DTN environments. The following observations were made from the results:

- The PoR follows a decreasing trend for DTN environment as percentage of cyclic nodes increase as shown but never falls to zero even at 100 % concentration of cyclic nodes. The reason behind the same is that even at 100 percentage concentration of DTN nodes the communication still prevails between neighboring nodes having zero hop count values (see Figure 4).
- For Ad hoc network no pattern is observed and the reason for the same has already been discussed.

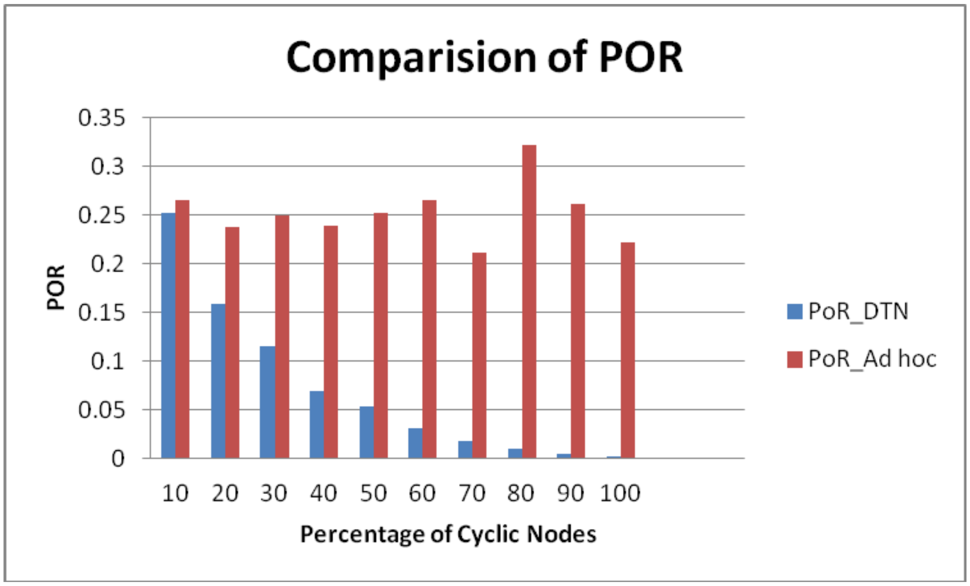

Figure 5. PoR in DTN and Ad Hoc Network

4.3. Impact on Packet Delivery Ratio (PDR)

Figure 6 shows the comparison of PDR for DTN and ad hoc network. The following inference may be drawn:

- For DTN the value of PDR decreases with increase of percentage of cyclic nodes. This is due to the fact that with increase in concentration of cyclic nodes the probability of connection rupture increases and hence the value of PDR decreases.
- The PDR for ad hoc network is always higher than that of DTN employing cyclic nodes even at low concentration levels (nearly 10 percentage).
- Even at 100 % concentration of cyclic nodes the PDR value doesn’t falls to zero. The reason for the same has already been discussed.
- PDR value for Ad hoc Network remains independent of cyclic nodes concentration due to the reason discussed above.

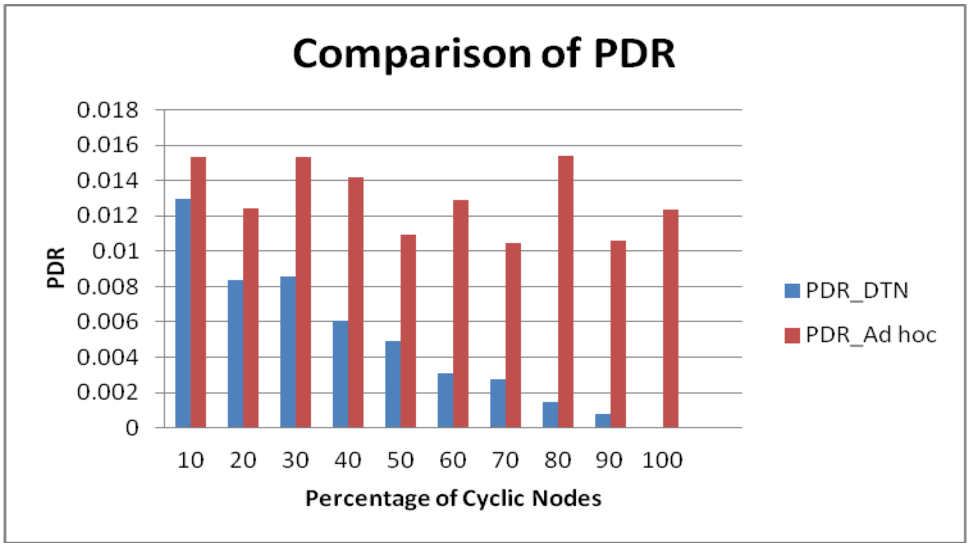

Figure 6. PDR in DTN and Ad Hoc Network

4.4. Impact on Path Optimality

Figure 7 shows the path optimality for DTN nodes. With increase in concentration of cyclic nodes concentration the path optimality follows a decreasing trend. This is due to the fact that with increasing cyclic node concentration the PoR value and hop count value goes on decreasing which results in fall of Path Optimality.

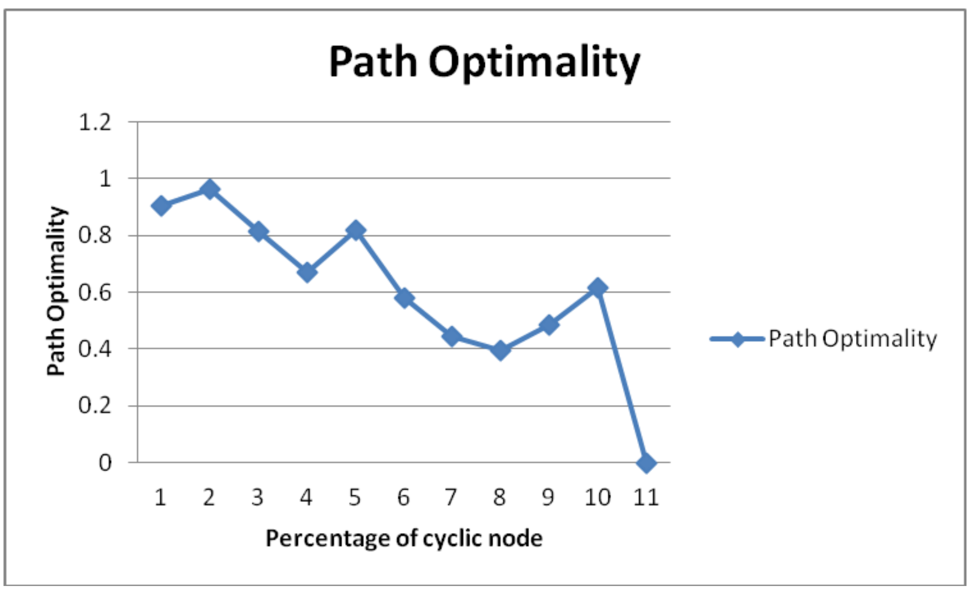

Figure 7. Path Optimality in DTN and Ad Hoc Network

Overall comparison of Ad-hoc and DTN environment: The Table 2 shows the comparison between Adhoc and DTN environment on the basis of performance metrics as the cyclic node concentration increases. We observe from the table that while the performance of the Ad-hoc environment is nearly constant for all performance metrics the performance of DTN environment decreases.

Table 2. Performance Comparison of Routing Protocols in Different Environment

Environment→ / Performance Metrics ↓	Ad hoc Environment	DTN Environment
PDR	Remains almost same	Decreases
Hop Count	Remains almost same	Decreases
PoR	Remains almost same	Decreases
Path Optimality	Constant	Decreases

5. Conclusions

Table 2 provides the overall conclusion of the above results that can be summarized as follows:

- In case of DTN the value of PDR and PoR decreases significantly with increase in percentage of cyclic nodes. This is due to increase in number of disruption from with increase in percentage of cyclic nodes.

- The Hop count and the path optimality also show the same trend as that of PDR and PoR. The reason for the same is that with increase in concentration of cyclic nodes the paths with higher number of intermediate nodes becomes unreliable.

The above results can be very fruitful for the researchers working in the field of delay tolerant networks.

References

[1] Q. Li, S. Zhu and G. Cao, "Routing in Socially Selfish Delay Tolerant Networks", Department Of Computer Science & Engineering, The Pennsylvania State University, University Park, IEEE INFOCOM, **(2010)**.

[2] E. Bulut, S. Cem Geyik and B. K. Szymanski, "Conditional Shortest Path Routing in Delay Tolerant Networks", Department Of Computer Science and Center for Pervasive Computing and Networking Rensselaer Polytechnic Institute', 110 8th Street, Troy, NY 12180, USA Bulute, Geyiks, **(2010)**.

[3] L. Yin, H.-M. Lu, Y.-D. Cao, J-M. Gao, "Cooperation in Delay Tolerant Network", School of Computer Science, Beijing Institute of Technology, Beijing, PRC, **(2010)** IEEE.

[4] V. Conan, J. Leguay and T. Friedman, "Fixed Point Opportunistic Routing in Delay Tolerant Network", **(2008)** January 10.

[5] A. Krifa, C. Barakat and T. Spyropoloulos, "Optimal Buffer Management Policies for Delay Tolerant Networks", IEEE SECON, **(2010)**.

[6] B. Divecha, A. Abraham, C. Grosan and S. Sanyal, "Impact of nodes mobility on MANET Routing protocols model", **(2011)**.

[7] Z. Zhang, "Routing in Intermittently Connected Mobile Ad Hoc Networks and Delay Tolerant Networks: Overview and Challenges", San Diego Research Center. 1st Quarter 2006 IEEE Communication The Electronic Magazine of Original Peer-Reviewed Survey Articles.

[8] P. U. Tournoux, J. Leguay, F. Benbadis, V. Conan, M. Amorim and J. Whitbeck, "The Accordion Phenomenon: Analysis, Characterization, and Impact on DTN Routing", proceeding of infocom, **(2009)**.

[9] S. Gupta, C. K. Nagpal and C. Singla, "Impact of Selfish NodeConcentration in Manets", International Journal of Wireless & Mobile Networks (IJWMN), vol. 3, no. 2, **(2011)** April.