Performance Measurement of Some Mobile Ad Hoc Network Routing Protocols

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Abstract

A mobile ad hoc network (MANET) is a wireless network that uses multi-hop peer to peer routing. A user can move anytime in an ad hoc scenario and, as a result, such a network needs to have routing protocols which can adopt dynamically changing topology. To accomplish this, a number of ad hoc routing protocols have been proposed and implemented such as, Ad hoc On-Demand Distance Vector routing (AODV), Fisheye State Routing (FSR) and Location-Aided Routing (LAR). This paper compares the major characteristics of these protocols such as, routing messages overhead, throughput and end to end delay using a parallel discrete event-driven simulator, GloMoSim. The experimental results show that FSR protocol has low control overhead compared with AODV and LAR. Regarding the throughput, AODV has a high throughput compared with the other considered protocols. Considering the end to end delay, LAR protocol shows better performance over FSR and AODV protocols.

Keywords: *Mobile Ad hoc networks (MANET), Ad hoc On-Demand Distance Vector routing (AODV), Fisheye State Routing (FSR) and Location-Aided Routing (LAR).*

1. Introduction

Mobile Ad hoc Network (MANET) is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration [3, 5 and 17]. In such a network, each mobile node operates not only as a host but also as a router, forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node participates in an ad hoc routing protocol that allows it to discover "multi-hop" paths through the network to any other node. Some examples of the possible uses of MANET include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield [1], and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake. The traditional routing protocols may not be suitable for MANETs since the network topology usually changes with time. Accordingly, there are new challenges for routing protocols in MANETs. Many different protocols have been proposed to solve the routing problem in MANETs. These protocols are usually based on the graph model which implies that the mobile nodes are aware of only their connectivity with the neighbors and not the relative locations. Hence the network topology may be represented as a graph with mobile nodes occupying the vertices. The nodes between which connectivity exists are connected by an edge in the graph. Edges may be directed in case the network link is physically asymmetric. Protocols can also be defined based on the geographic model in which each node is aware of the geographical location of itself and other nodes. Protocols with such a facility, which may be provided by many mechanisms like GPS, are known as location aware protocols. Another important class of protocols is the one in which the whole networking region is divided into zones. The routing problem now is two fold consisting of inter and intra zone routing but is far easier to handle. Such a mechanism is known as zone routing [6, 9, 13 and 14].

Routing protocols may be classified into two types based on the way the route information is generated and maintained. Table Driven protocols attempt to maintain up to date route information for all the destination routes in each node of a network by maintaining routing tables [4, 12 and 16]. Each node is required to maintain these tables and also to propagate periodic updates to keep all the tables current. The need to maintain tables and the updates are overheads on the networking and hence different protocols implement different strategies to consolidate the number of routing tables required to be maintained and the method to broadcast network updates. Source Initiated or On Demand Routing makes away with the need for any tables by finding routes as per requirements [18 and 20].

Whenever a node requires a route to another node, it initiates a route discovery process in the network, which returns the routes back. The discovered routes are cached and maintained till the route is required or the destination becomes inaccessible.

In this paper, GloMoSim Simulator 2.03 version is used to simulate three ad hoc routing protocols, that is, AODV, FSR and LAR. The commonly performance metrics supported by GloMoSim for these protocols are evaluated. Since these protocols have different characteristics, the comparison of all performance differentials is not always possible. However, the following system parameters are utilized for comparative study on the protocols:

- Routing messages overhead,
- Average end to end delay,
- Throughput

The rest of the paper is organized as follows. In the following section, we briefly review about a categorization of the prominent ad hoc routing protocols and give a short introduction about the three routing protocols compared in this paper. In Section 3, we present the performance metrics of our simulation. Section 4 describes our simulation environment. Section 5 presents the result of simulation. We draw our conclusions in Section 6 followed by recommendations for future work in this regard.

2. Ad Hoc Network Routing Protocols Studied

In this section, we briefly review the AODV, FSR and LAR protocols studied in our simulations.

2.1 The Ad Hoc On-demand Distance Vector Routing (AODV)

The Ad Hoc On-demand Distance Vector Routing (AODV) protocol is a reactive routing protocol for mobile ad hoc networks [2 and 15]. As a reactive routing protocol, only routing information about the active paths is needed to maintain. In AODV, routing information is maintained in routing tables at nodes. Every mobile node keeps a next-hop routing table, which contains the destinations to which it currently has a route. A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time. Moreover, AODV adopts the destination sequence number technique used by DSDV in an on-demand way [7].

2.2 Fisheye State Routing (FSR)

The Fisheye State Routing (FSR) is a proactive routing protocol based on Link State routing algorithm with effectively reduced overhead to maintain network topology information [8 and 11]. In proactive routing protocols, routing information to reach all the other nodes in a network is always maintained in the format of the routing table at every node. As indicated in its name, FSR utilizes a function similar to a fish eye. The eyes of fishes catch the pixels near the focal with high detail, and the detail decreases as the distance from the focal point increases. Similar to fish eyes, FSR maintains the accurate distance and path quality information about the immediate neighboring nodes, and with the progressive detail as the distance increase.

2.3 Location-Aided Routing (LAR)

The Location-Aided Routing (LAR) is based on flooding algorithms. It attempts to reduce the routing overheads present in the traditional flooding algorithm by using location information. This protocol assumes that each node knows its location through a Global Positioning System (GPS). Two different LAR scheme were proposed in [10], the first scheme calculates a request zone which defines a boundary where the route request packets can travel to reach the required destination. The second method stores the coordinates of the destination in the route request packets. These packets can only travel in the direction was the relative distance to the destination becomes smaller as they travel from one hop to another. Both methods limit the control overhead transmitted through the network and hence conserve bandwidth. They will also determine the shortest path (in most cases) to the destination, since the route request packets travel away from the source and towards the destination. The disadvantage of this protocol is that each node is required to carry a GPS.

3. The performance Parameters

This section presents the performance parameters (metrics) used to evaluate the AODV, FSR and LAR protocols. The main performance parameters are routing message overhead, average end to end delay, and throughput.

3.1 Routing Message Overhead

Routing message overhead is calculated as the total number of control packets transmitted. The increase in the routing message overhead reduces the performance of the ad-hoc network as it consumes portions from the bandwidth available to transfer data between the nodes [18].

3.2 Average End to End Delay

A network’s end-to-end delay is defined as the average time interval between the generation and successful delivery of data packets for all nodes in the network, during a given period of time. Packets that are discarded or lost are not included in the calculation of this metric [18].

3.3 Throughput

A network’s end-to-end throughput is a measure of the network’s successful transmission rate, and is usually defined as the number of data packets successfully delivered to their final destination per unit of time. However, to convert this metric to a measure of data throughput or to compare it to other networks, the network’s packet size and the network’s number of nodes also has to be known.

This paper therefore defines a network's end-to-end throughput as the number of data bytes successfully delivered to their final destination per unit of time, divided by the number of nodes in the network [18].

4. Simulation Environment

To compare the performance of the three routing protocols described in section (2), simulation experiments were performed. In this section, experiment modeling, design and key observations from our simulation experiments are described in that order.

Simulations were carried out with the GloMoSim library [19] which is widely used in the academic research. The GloMoSim library is a scalable simulator for wireless network and it is built using the parallel discrete-event simulation capability provided by PARSEC. The numbers of nodes used in the simulation scenarios are 100, 200, and 300, with rectangular area sizes 1500×1000, 2000×1500, and 3000×2000 m^2, respectively. The nodes placed randomly within the simulation area. The radio propagation range for each node is 376 meters and channel capacity is 2Mb/s. Each simulation is executed for 300 seconds of simulation time. IEEE 802.11 MAC protocol was used in the experiments for the MAC layer. The sources used for the simulations are CBR (constant bit rate) sources. Twenty data sessions with randomly selected sources and destinations are used in the simulations. Each source transmits data packets at 4 packets/sec rate with packet size 512 bytes until the simulation run ends.

The mobility model used is the random waypoint model [12 and 20]. In this model, a node selects a random destination within the terrain range and moves towards it at a speed between the pre-defined minimum and maximum speed. Once the node arrives at the destination, it stays for a pause time. After being stationary for the pause time, it randomly selects another destination and speed and then resumes movement. The minimum and the maximum speed for the simulations are 0 m/s and 10 m/s, respectively. Simulation runs done on variance pause time values from 0 to 300 second. The simulations have been done on a PC Pentium IV, 2GHz processor and 3GB RAM.

5. Simulation results

The following subsections represent the results of the simulation scenarios. The 100 nodes scenario results will be introduced in subsection (5.1). The 200 nodes scenario results will be introduced in subsection (5.2). The 300 nodes scenario results will be introduced in subsection (5.3).

5.1 Scenario Results with 100 Nodes

This section presents the simulation results for the 100 nodes network simulation scenario on a rectangular area 1500 x 1000 m^2.

5.1.1 Routing Message Overhead

Figure 1, shows the routing message overhead resulted from each of AODV, FSR and LAR routing protocols. As can been seen in this Figure, LAR has lower routing message overhead compared with the AODV and FSR.

The pause time increases, the overhead resulted from FSR protocol tends to be zigzag. The overhead resulted from AODV protocol is increased between 0 and 60 sec and then decreases.

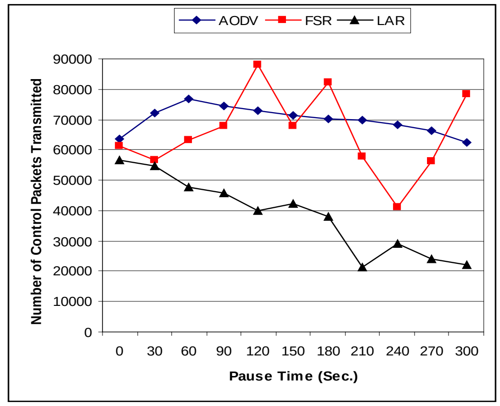

Fig. 1 Routing message overhead vs. pause time for 100 nodes

5.1.2 Average End to End Delay

Figure 2, illustrates the average end to end delay for the AODV, FSR and LAR routing protocols. The end to end delay of FSR protocol is closed to zero and increased to maximum value between pause time 200 and 300 sec. As can been seen in Figure 2 the end to end delay of the LAR protocol is decreased as the pause time is increased. For the AODV protocol, the delay is increased between pause time 0 and 100 sec and then decreased. The end to end delay of LAR protocol is better than AODV protocol.

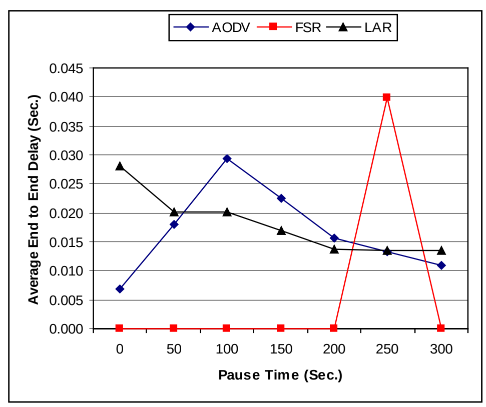

Fig. 2 Average End to End delay vs. pause time for 100 nodes

5.1.3 Throughput

Figure 3, demonstrates the throughput vs. pause time for the considered protocols. It is clear that AODV protocol has a good performance compared with both FSR and LAR.

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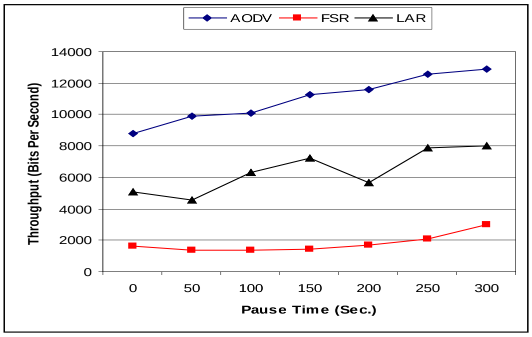

Fig. 3 Throughput vs. pause time for 100 nodes

5.2- 200 Nodes Scenario Results

This section presents the simulation results for the 200 nodes network simulation scenario on a rectangular area 2000 x 1500 m^2.

5.2.1 Routing Message Overhead

Figure 4, indicts the routing message overhead resulted from each of AODV, FSR and LAR routing protocols. The performance of these protocols is similar to the results obtained in the 100 nodes network simulation scenario. As shown in Figure 4, the overhead resulted from AODV protocol increases between 0 and 120 sec and then decreases. As in the 100 nodes network simulation scenario on a rectangular area 1500 x 1000 m^2, the overhead resulted from FSR protocol tends to be zigzag. Here LAR protocol is more advantageous as it gives minimum overheads.

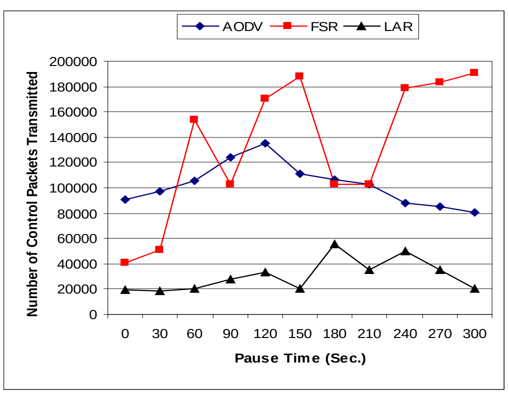

Fig. 4 Routing message overhead vs. pause time for 200 nodes

5.2.2 Average End to End Delay

Figure 5, depicts the average end to end delay for the AODV, FSR and LAR routing protocols. The end to end delay of FSR protocol is closed to zero and increased to maximum value between pause time 100 and 200 sec. The end to end delay of the LAR protocol is increased until the pause time 200 sec and then decreased. For the AODV protocol, the delay is increased between pause time 0 and 100 sec and then decreased.

5.2.3 Throughput

The throughput vs. pause time for the considered protocols is illustrated in Figure 6. It is clear that AODV protocol has a good performance compared with both FSR and LAR. The throughput of the LAR protocol decreases until pause time 100 and then increases.

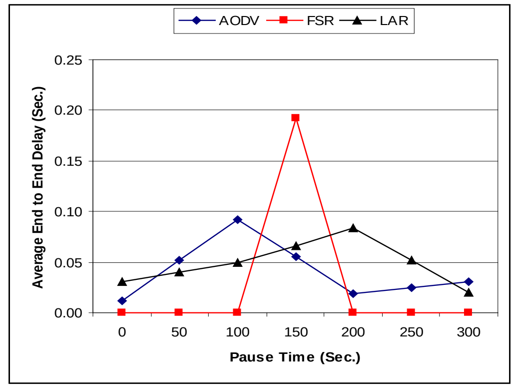

Fig. 5 Average End to End delay vs. pause time for 200 nodes

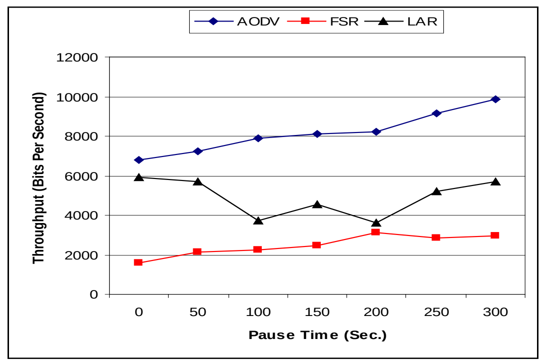

Fig. 6 Throughput vs. pause time for 200 nodes

5.3- 300 Nodes Scenario Results

This section presents the simulation results for the 300 nodes network simulation scenario on area 3000 x 2000 m^2.

5.3.1 Routing Message Overhead

Figure 7, illustrates the routing message overhead resulted from the three considered protocols. As the pause time increases, the number of control packets transmitted using FSR protocol increases. On the other hand the number of control packets transmitted using AODV protocol decreases. The overhead resulted from LAR protocol tends to be zigzag.

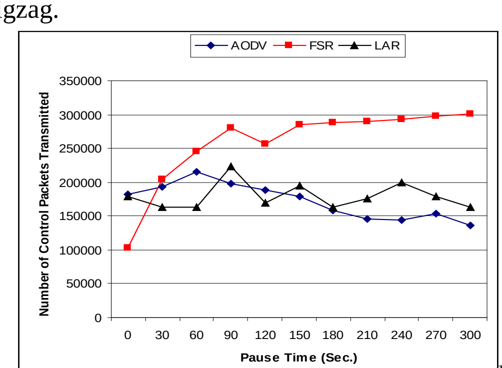

Fig. 7 Routing message overhead vs. pause time for 300 nodes

5.3.2 Average End to End Delay

Figure 8, demonstrates the average end to end delay for the AODV, FSR and LAR routing protocols. The end to end delay of FSR protocol is closed to zero all the simulation pause time. The end to end delay of the LAR protocol is increased until the pause time 250 sec and then decreased. For the AODV protocol, the delay is increased between pause time 0 and 100 sec and then decreased.

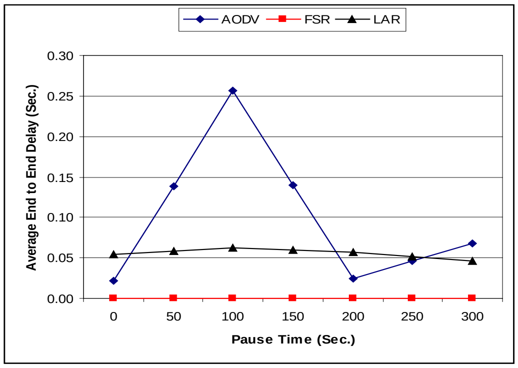

Fig. 8 Average End to End delay vs. pause time for 300 nodes

5.3.3 Throughput

Figure 9, present the throughput vs. pause time for the considered protocols. It is clear that AODV protocol has a good performance compared with both FSR and LAR.

Fig. 9 Throughput vs. pause time for 300 nodes

6. Conclusions and Future Works

6.1 Conclusions and Performance Summery

This paper attempts to determine how AODV, FSR, and LAR protocols perform under increased loads. We tested these protocols for three different scenarios (100, 200, and 300 nodes) on different rectangular areas (1500x1000, 2000x1500, and 3000x2000 m^2). The performance evaluation of these protocols is based on the well known GloMoSim simulator. The simulation characteristics used to evaluate the performance of these protocols are routing message overhead, end to end delay and throughput.

– *Routing Message Overhead*

The results of the simulation show that AODV and FSR impose a huge routing overhead compared with LAR, as shown in Figures 1, 4 and 7. This is not surprising due to, in proactive routing protocol all nodes are active and each node discovers route to other nodes in the network before the actual communication request. This leads to less time delay of route discovery during communication request, however the overhead cost is too high in this case. Moreover, as the number of nodes increases, the routing overhead clearly increases. For the FSR protocol, this problem caused by the rapid changes in network topology might overwhelm the network with control messages and flood large number route finding packets instead of buffering data packets for new route to be found and since more table updates are being sent.

– *Average End-to-End Delay*

From Figures 2, 5 and 8, It is clear that AODV gives average end to end delay higher than the other two protocols with high mobility due to its single path nature and inefficient manner to handle route failure. This is because when a node receives a route request for which it has the answer in its routing table, it immediately replies with the route rather than forwarding it to the destination. The source can now start to communicate with the destination. Moreover, as the number of nodes increases, the FSR protocol trends to be zero delay as shown in Figure 8. The reason for this due to the behavior of the FSR protocol, because the routes are available the moment they are needed. Also, each node consistently maintains an up-to-date route to every other node in the network, a source can simply check its routing table when it has data packets to send to some destination and begin packet transmission so, no delay occur.

– *Throughput*

This metric which we call the ratio of delivered packets is an important as it describes the loss rate that will be seen by the transport protocols, which in turn affects the maximum throughput that the network can support. Figures 3, 6 and 9 shows the number of bits received per second. For AODV, FSR and LAR packet delivery ratio is independent of offered traffic load. In case of AODV protocol when numbers of nodes increases, initially throughput increases as number of routes are available compared to FSR and LAR protocols. Regretfully FSR was not up to the task and it performed poorly throughout all the simulation sequences because increasing the overhead reduces the throughput.

6.2 Future Work

Recommendations for future studies that can improve the reliability of this kind of work include the following:

- This study included only one mobility model throughout the simulation. In the future work we plan to apply another mobility model may be affect on the measure performance parameters.

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protocols; routing protocols can be studied on different types of data traffic (application layer protocols) like http, ftp, telnet, and real time audio/video transmissions.

- There are several MAC protocols to be used in the simulation such as CSMA, MACA and IEEE 802.11; in this paper we applied IEEE 802.11 only. Different types of MAC may give different results for ad hoc routing protocols.
- Finally, since we used GloMoSim, our simulation was confined to three protocols, AODV, LAR, and FSR. Additional ad hoc network protocols, such as DSDV, TORA and so on could be added in GloMoSim for comprehensive performance evaluation.

7. References

[1] A. Rahman, S. Islam, A. Talevski, "Performance Measurement of Various Routing Protocols in Ad-hoc network", Proceedings of the International MultiConference of Engineers and Computer Scientists 2009 Vol I, IMECS 2009, March 18 - 20, , Hong Kong, 2009.

[2] C. Perkins, E. Belding-Royer, S. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing", Network Working Group, IETF RFC, RFC 3561, July 2003.

[3] D. B. Johnson, and D. A. Maltz, "Dynamic Source Routing in Ad-Hoc Wireless Networks", Mobile Computing, T. Imielinski and H. Korth, Eds., Kluwer, 1996, pp. 153–81.

[4] D. Lang, "On the Evaluation and Classification of Routing Protocols for Mobile Ad Hoc Networks ", PhD thesis, 2006.

[5] E. Ahvar, and M. Fathy, "Performance Evaluation of Routing Protocols For High Density Ad Hoc Networks based on Energy Consumption by GlomoSim Simulator", World Academy of Science, Engineering and Technology 29, 2007.

[6] F. Yongsheng, W. Xinyu and L. Shanping, "Performance comparison and analysis of routing strategies in Mobile ad hoc networks", International Conference on Computer Science and Software Engineering, 2008.

[7] G. He, "Destination-Sequenced Distance Vector (DSDV) Protocol", Networking Laboratory, Helsinki University of Technology, 2002.

[8] G. Pei, M. Gerla, and T. Chen, "Fisheye State Routing in Mobile Ad Hoc Networks", ICDCS Workshop on Wireless Networks and Mobile Computing, 2000.

[9] J. Hoebeke, I. Moerman, B. Dhoedt and P. Demeester, "An Overview of Mobile Ad Hoc Networks: Applications and Challenges", Department of Information Technology (INTEC) Ghent University – IMEC vzw, 2010.

[10] L. Blaˇzevi´c, J. Le Boudec and S. Giordano, "A Location Based Routing Method for Irregular Mobile Networks", EPFL-IC Report Number May 2003.

Fisheye state routing protocol (FSR) for ad hoc networks", Internet Draft, draft-ietf-manet-aodv-03.txt, work in progress, 2002.

[12] M. K. Kumar and R. S. Rajesh, "Performance Analysis of MANET Routing Protocols in Different Mobility Models", IJCSNS International Journal of Computer Science and Network 22 Security, VOL.9 No.2, Feb., 2009.

[13] P. Van Mieghem, "Data Communications Networking", Techne Press, Amsterdam, The Netherlands, 2006.

[14] S. Ahmed and M. S. Alam, "Performance Evaluation of Important Ad Hoc Network Protocols", EURASIP Journal on Wireless Communications and Networking, Volume 2006, Article ID 78645, Pages 1–11, 2006.

[15] S. Das, C. Perkins, E. Royer, "Ad hoc on demand distance vector (AODV) routing", Internet Draft, draft-ietf-manetaodv- 11.txt, work in progress, 2002.

[16] S. Rahayu Abdul Aziz, N. Adora Endut, S. Abdullah and M. Norazman Mior Daud, "Performance Evalution of AODV, DSR, and DYMO Routing Protocol in MANET", Conference on scientific & Social Research (CSSR), March 2009.

[17] S. S. Tyagi and R. K. Chauhan, "Performance Analysis of Proactive and Reactive Routing Protocols for Ad hoc Networks", International Journal of Computer Applications (0975 – 8887) Volume 1 – No. 14, 2010.

[18] T. H. Abd El-Nabi, "Modeling and Simulation of a Routing Protocol for Ad Hoc Networks Combining Queuing Network Anakysis and Ant Colony Algorithms", Phd Thesis, April 2005.

[19] The official GloMoSim Website, http://pcl.cs.ucla.edu/projects/glomosim/ 2010.

[20] V.C. Patil1, R. V. Biradar, R. R. Mudholkar and S. R. Sawant, "On-Demand Multipath Routing Protocols for Mobile Ad Hoc Networks Issues and Comparison", International Journal of Wireless Communication and Simulation Volume 2 Number 1, pp. 21–38, 2010.

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