Performance of MANET Routing Protocols considering Impact of Node Density under Different Traffic Patterns

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ABSTRACT
A mobile ad-hoc network has certain characteristics such as dynamic topology, limited bandwidth, and energy-constraint etc, which imposes new demand on the routing protocols. This work specially aims to study and investigate the performance of one proactive routing protocol-DSDV and two reactive protocols-AODV and DSR for mobile ad-hoc networks under both CBR and TCP traffic patterns using network simulator NS-2. Based on extensive simulations, we present a comparative analysis of these routing protocols covering performance metrics such as packet delivery ratio, average end-to-end delay, normalized routing load, and average jitter. We will investigate the effect of varying number of sources and node density on MANET routing protocols.

General Terms
Mobile Ad-hoc Networks Routing Protocols.

Keywords
MANET, DSDV, AODV, DSR, CBR, TCP

1. INTRODUCTION
Mobile Ad-hoc Networks (MANETs) [1][2][15] are self-creating, self-organizing, and self-administrating networks. There is no centralized administration or pre-existing infrastructure that takes care of the network management and existence. Mobile nodes are themselves responsible for establishing and maintaining connection between them. In such an environment, it is necessary for one mobile host to enlist the aids of other hosts in forwarding a packet to its destination, due to the limited range of each mobile host's wireless transmission. In this case, a multi-hop scenario occurs, in which the packets sent by the source host must be relayed by several intermediate hosts before reaching the destination host. Thus, robust and efficient operation in mobile wireless networks is supported by incorporating routing functionality into all the mobile nodes, in contrast to fixed network such as the Internet where only some nodes in the network perform the routing function. Thus, each mobile host in a MANET must function as a router to discover and maintain routes to other nodes in the network.

The benefits of ad-hoc networks over the traditional cellular systems are on-demand setup, fault tolerance, and unconstrained connectivity. Because of these benifits, the ad-hoc networks are used where wired network and mobile access is either unproductive or not feasible. In emergency search-and-rescue or military manoeuvrers, a temporary communication network also needs to be deployed immediately. In the above situations, a mobile ad-hoc network (MANET) [10] can be a better choice.

The main objective of ad-hoc routing protocols is to deliver data packets among mobile nodes efficiently without predetermined topology or centralized control. The various mobile ad-hoc routing protocols have been proposed and have their unique characteristics. Hence, in order to find out the most efficient routing protocol for the highly dynamic topology in ad-hoc networks, the behaviour of routing protocols has to be analyzed with varying node density and network load under different traffic patterns.

2. MOBILE AD-HOC ROUTING PROTOCOLS
There are two main approaches for routing process in ad-hoc networks. The first approach is a proactive approach which is table driven and attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. Proactive protocols present low latency, but high routing overhead, as the nodes periodically exchange control messages and routing-table information in order to keep up-to-date route to any active node in the network. The second approach is re-active, source-initiated or on-demand. Reactive protocols create routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. Reactive protocols do not maintain up-to-date routes to any destination in the network and do not generally exchange any periodic control messages. Thus, they present low routing overhead, but high latency as compared to proactive protocols. The DSDV is a proactive protocol and AODV, DSR, and TORA are reactive protocols. The mobile ad-hoc routing protocols considered in this study are described below.

2.1 Destination Sequenced Distance Vector (DSDV)
DSDV [3][11][14] is considered to be successor of Distance Vector in wired routing protocol and guarantees a loop free path to each destination. It is based on the Bellman-Ford algorithm for calculation of shortest path. For this protocol, every node maintains routing table which contains all available destinations with associated next hop towards destination, distance and destination sequence number. Destination sequence number presents improvement of DSDV routing protocol compared to distance vector routing, and it is used to distinguish stale routes from fresh ones and avoid formation of route loops.

In order to maintain the consistency in dynamic environment, each node periodically broadcasts its routing table to its neighbours. Broadcasting of the information is done in Network Protocol Data Units (NPDU) in two ways: full dump and incremental dump. Full dump requires multiple NPDUs, while incremental requires only one NPDU to fit in all the information, to minimize the number of control messages disseminated in the network. When an information packet is received from another node, node compares the sequence number with the available sequence number for that entry. If the sequence number is larger, entry will be updated with the routing information with the new sequence number, else if the information arrives with the same sequence number, metric entry will be required. If the number of hops is less than the previous entry, new information will be updated. Update is performed periodically or when significant change in routing table is detected since the last update. If network topology frequently changes, full dump will be carried out, since incremental dump will cause less traffic in stable network topology. When such updating takes place each update is broadcasted in the network, which leads to a heavy network load situation and affects the bandwidth. With more number of nodes, traffic load increases. DSDV takes into account only bidirectional links between nodes.

2.2 Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [11][12] is an on-demand routing protocol, which is based on the concept of source-based routing. DSR is a simple pure on-demand reactive protocol that does not periodically exchange any control packets. The main concept of the DSR protocol is "source routing", in which source nodes place the complete route that the packet must follow from a source to a destination in the header of a packet.

DSR applies two on-demand processes, route discovery and route maintenance. The route discovery process is used to discover new routes and maintain them in the cache of nodes. The route maintenance process detects link failures, then repair route or find alternate route. Each node "caches" the routes to any destination it has recently used, or discovered by overhearing its neighbour's transmission. When there is not such route, a route discovery process is initiated.

DSR applies on demand schemes for both route discovery and route maintenance. There by reducing network bandwidth overhead, conserving battery power and avoiding large routing updates throughout the mobile ad-hoc network. DSR is a loop free protocol and supports unidirectional links.

2.3 Ad-hoc On-demand Distance Vector (AODV)

Ad-hoc On-demand Distance Vector [11][13] is a reactive routing protocol, which mixes the properties of DSR and DSDV. Routes are discovered as on-demand basis and are maintained as long as they are required. Each node of AODV maintains a routing table but unlike the DSDV protocol it does not necessarily maintain route for any possible destination in network. However, its routing table maintains routing information for any route that has been recently used within a time interval; so a node is able to send data packets to any destination that exists in its routing table without flooding the network with new Route Request (ROUTE_REQ) messages.

Like DSDV it maintains a sequence number, which it increases each time it finds a change in the topology of its neighbourhood. This sequence number ensures that the most recent route is selected for execution of the route discovery. All routing packets carry these sequence numbers. AODV stores routing information as one entry per destination in contrast to DSR, which cashes multiple entries per destination. Without source routing, AODV relies on routing table entries to propagate an ROUTE_REPLY back to the source and, subsequently, to route data packets to the destination.

AODV supports for both unicast and multicast routing, and also supports both bidirectional and unidirectional links.

3. SIMULATION ENVIRONMENT

In this paper, we have taken two different scenarios. In the first scenario, traffic pattern type is taken as CBR and number of nodes has been varied for different number of sources and performance comparisons has been made among DSDV, AODV, and DSR protocols. In the second scenario, traffic pattern type is taken as TCP instead of CBR. The following table shows the chosen simulation parameters.

Table 1 Simulation Parameters for CBR / TCP Traffic Patterns (Varying node density)

Parameters	**Value**
Routing Protocols	DSDV,AODV, and DSR
Number of nodes	50, 75, 100, and 125
Maximum speed of nodes	20 m/sec.
Simulation area	1000 m X 1000m
Traffic pattern type	CBR or TCP
Packet size	512 bytes
Packet rate (only in CBR)	4 packets/sec.
Simulation time	500 seconds
Pause time	100 seconds

Performance Metrics

The following four performance metrics have been chosen to compare the three routing protocols:

Packet Delivery Ratio [3]: It is defined as the ratio of all the received data packets at the destinations to the number of data packets sent by all the sources.

End-to-End Delay [3]: The end-to-end delay is defined as the total time taken by a data packet in transmitting across a MANET from source to destination. It includes all possible delays in the network caused by route discovery latency, retransmission by the intermediate nodes, processing delay, queuing delay, and propagation delay.

Normalized Routing Load [3]: It is defined as the ratio of all routing control packets sent by all the sources to the number of received data packets at all the destinations.

Average Jitter [9]: In a stream of packets between a source node and destination node, the jitter of the packet number i is defined as the deviation of the difference in packet spacing at the receiver compared to the sender, for a pair of packets, if Si is the time packet i was sent from the sender, and Ri is the time it was received by the receiver, the jitter of packet i is given by: $J_i = | (R_{i+1} – S_{i+1}) – (R_i – S_i) |$

4. SIMULATION RESULTS AND PERFORMANCE COMPARISON

Performance of DSDV, AODV, and DSR protocols is evaluated under both CBR and TCP traffic pattern. Extensive simulation is done by using NS-2 simulator [4]-[7].

4.1 Packet Delivery Ratio

Packet delivery ratio of proactive routing protocols (DSDV) is less as compared to reactive routing protocols (AODV and DSR) either CBR (Fig. 1) or TCP (Fig. 2).

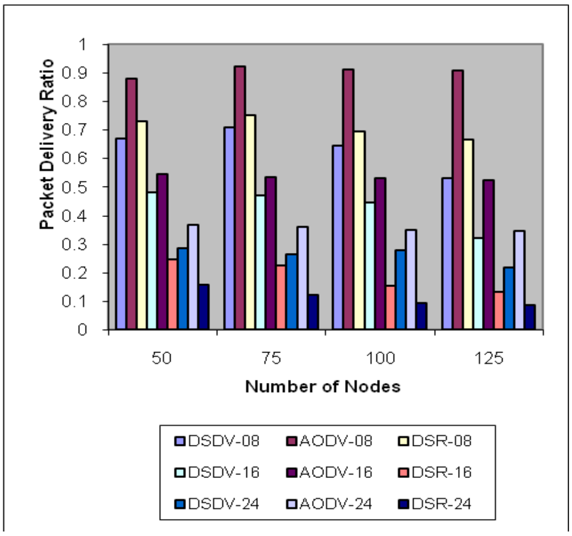

Fig. 1: Packet Delivery Ratio for CBR Traffic (Increasing number of nodes)

Above Fig.1 shows that at the less number of sources, AODV has the highest packet delivery ratio (around 90%) and DSR has packet delivery ratio (around 72%) and DSDV has the lowest packet delivery ratio (around 62%).

Packet delivery ratio of AODV protocol remains almost constant whereas packet delivery ratio of both DSR and DSDV degrades gradually when number of nodes increases.

As number of sources increases packet delivery ratio of these three protocol decreases, and packet delivery ratio of DSR become lowest among these three protocols.

Fig. 2 show that for TCP traffic, DSR performs better having packet delivery ratio around 99%, AODV has packet delivery ratio around 97% and DSDV has lower packet delivery ratio around 96% irrespective of number of nodes. The reason for this low packet delivery ratio of DSDV is due to its proactive nature which requires updating and maintaining all the routes in routing table.

As the number of sources increases, packet delivery ratio of all these protocol decreases very slowly in TCP traffic pattern as compared to CBR traffic pattern.

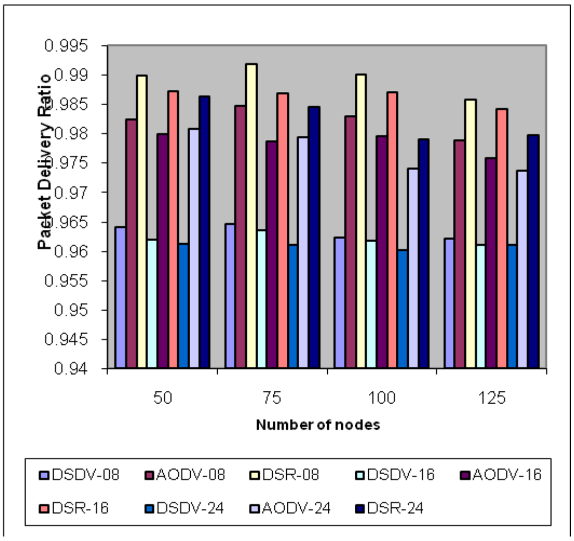

Fig. 2: Packet Delivery Ratio for TCP Traffic (Increasing number of nodes)

4.2 Average End-to-End Delay

Fig. 3 and Fig. 4 show that for both CBR and TCP traffic, DSR

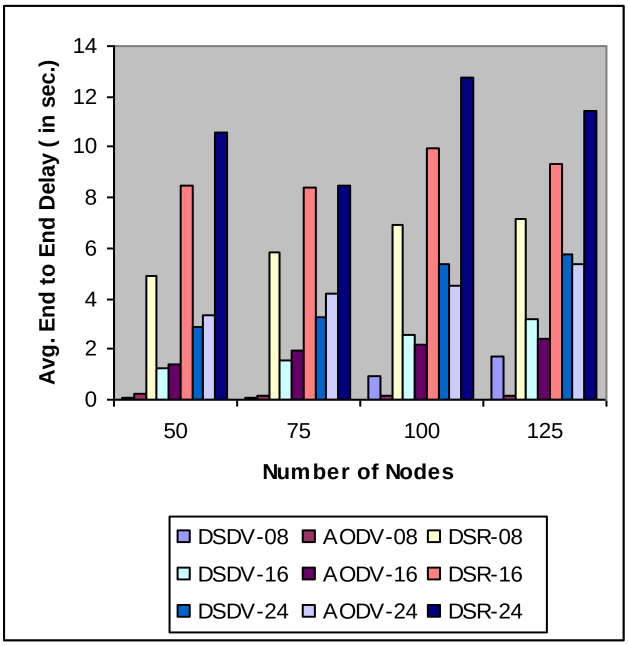

Fig. 3: Avg. End-to-End Delay for CBR Traffic (Increasing number of nodes)

protocol shows the maximum average end-to-end delay because DSR uses source routing. The AODV protocol has slightly higher average end-to-end delay than average end-to-end delay of DSDV protocol.

At the less number of nodes end-to-end delay of DSDV is lower than end-to-end delay of AODV. But when number of nodes increases, end-to-end delay of DSDV becomes higher than end-to-end delay of AODV.

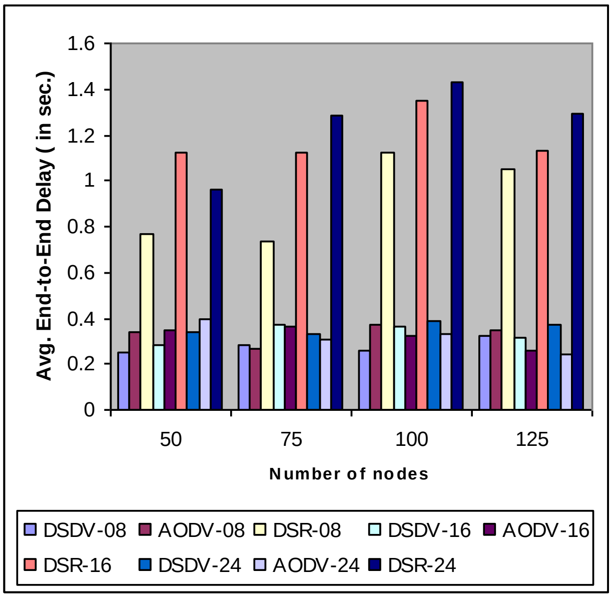

Fig. 4: Avg. End-to-End Delay for TCP Traffic (Increasing number of nodes)

As shown in Fig. 4, in case of TCP traffic pattern average end-to-end delay of DSDV and AODV is remains almost constant irrespective of number of nodes. The average end-to-end delay of DSR protocol initially increases with increase in number of nodes (up to 100 nodes), and then it degrades.

4.3 Normalized Routing Load

Fig. 5 shows that DSR has the lowest normalized routing load, which is almost independent from the number of nodes in the network. AODV has a higher normalized routing load than DSR. However, AODV scales well when the number of nodes in the network increases. DSDV has the highest normalized routing load. The normalized routing load of AODV and DSDV increases with increase in the number of nodes.

The normalized routing load of all these protocols is increases as number of sources increases.

As shown in Fig. 6, for TCP traffic AODV has the lowest normalized routing load, and then DSR and DSDV are in order. The DSDV has the highest normalized routing load. This is a direct result of the DSDV's proactive behaviour. Normalized routing load of these three protocols are increases as number of sources and number of nodes are increases.

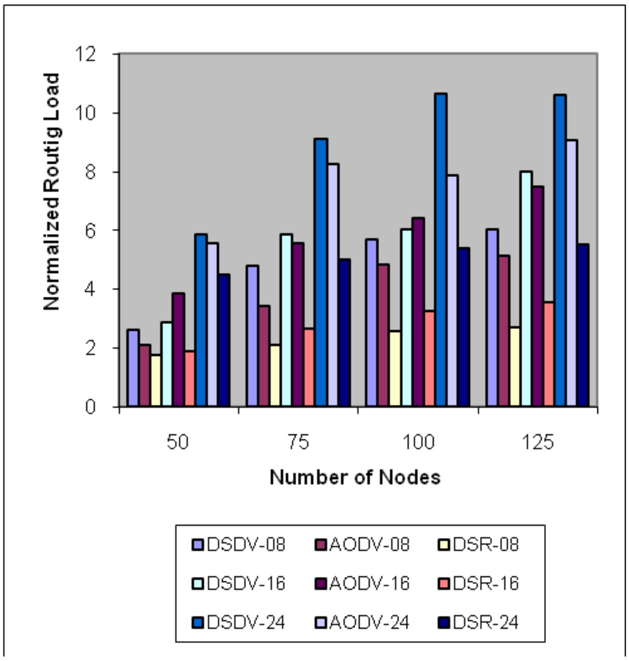

Fig. 5: NRL for CBR Traffic (Increasing number of nodes)

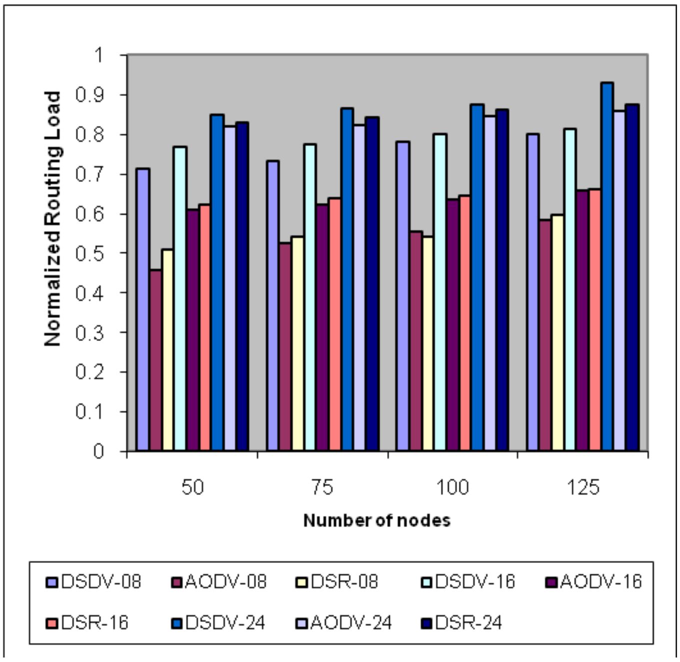

Fig. 6: NRL for TCP Traffic (Increasing number of nodes)

4.4 Average Jitter

Fig. 7 and Fig. 8 shows that for both CBR and TCP traffic, DSDV has the best (lowest) average jitter and then AODV and DSR are in order. The DSR has the highest average jitter. The average jitter of all these protocol is slightly increases as number of nodes increases.

In TCP traffic pattern, average jitter of these three protocols is better (lower) than average jitter of these protocols in CBR traffic pattern for the same value of simulation parameters.

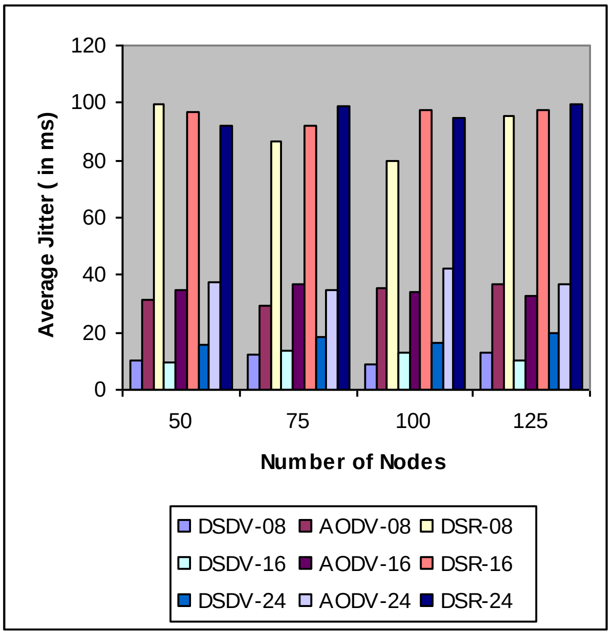

Fig. 7: Average Jitter for CBR Traffic (Increasing number of nodes)

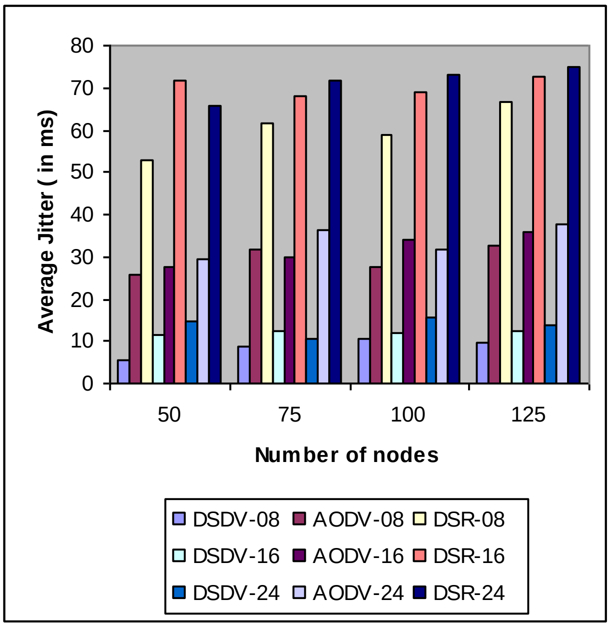

Fig. 8: Average Jitter for TCP Traffic (Increasing number of nodes)

As the number of sources increases, average jitter of all these protocol increases very slowly in TCP traffic pattern as compared to CBR traffic pattern.

5. CONCLUSIONS & FUTURE WORK

This study work was carried out using network simulator NS-2 to compare the performance of one proactive routing protocol DSDV and two reactive protocols AODV and DSR of MANETs under both CBR and TCP traffic patterns. The performance of these routing protocols was compared in terms of packet delivery ratio, average end-to-end delay, normalized routing load, and average jitter when number of sources and number of nodes varied.

Simulation results show that the overall performance of reactive protocols is better than proactive protocols. In case of CBR traffic, for performance metrics packet delivery ratio and average end-to-end delay AODV outperforms DSR. Packet delivery ratio of AODV protocol remains almost constant whereas packet delivery ratio of both DSR and DSDV degrades gradually when number of nodes increases. At large number of sources and high node density, DSR has the lowest packet delivery ratio amongst these three protocols. DSR protocol shows the maximum average end-to-end delay because DSR uses source routing. At the less number of nodes end-to-end delay of DSDV is lower than end-to-end delay of AODV. But when number of nodes increases, end-to-end delay of DSDV becomes higher than end-to-end delay of AODV.

In case of TCP traffic DSR perform better in term of packet delivery ratio. But AODV has lowest normalized routing load and it shows better performance for almost all performance metrics. Therefore AODV would be the right choice for robust scenario where traffic load is more and node density is high. For TCP traffic, value of all these performance metrics for all these protocols is better than in CBR traffic and all these metrics degrade very slowly as compared to CBR traffic when number of sources and node density increases.

As day-to-day new challenges come with new technology and advancement in the ad-hoc networks fields. So, in future more simulation can be done to investigate, the performance of routing protocols also with multimedia, and HTTP traffic under different mobility models using more advance network simulators.

6. REFERENCES

[1] Vasudha Arora and C. Rama Krishna, *"Performance Evaluation of Routing protocols for MANETs under Different Traffic Conditions"*, 2nd IEEE International Conference on Computer Engineering and Information Technology, 2010.

[2] Vikas Singla and Parveen Kakkar, *"Traffic Pattern based performance comparison of Reactive and Proactive Protocols of Mobile Ad-hoc Networks"*, International Journal of Computer Applications, Volume 5-No. 10, August 2010.

[3] Sabina Barakovie and Jasmina Barakovie, *"Comparative Performance Evaluation of Mobile Ad hoc Routing Protocols"*, MIPRO May 2010.

[4] *"The Network Simulator version 2"*, the source code of ns-allinone-2.34 can be downloaded from http://www.isi.edu/nsnam/ns/ns-build.html

[5] Kevin Fall, Kannan Varadhan, and the VINT project (May, 2010), available at http://www.isi.edu/nsnam/ns/ns-documentation.html

[6] Marc Gresis, *"Tutorial for the network simulator (ns-2)"*, available at http://www.isi.edu/nsnam/ns/tutorial/index.html

[7] NS by example available at http://nile.wpi.edu/NS

[8] Suresh Kumar, R K Rathy, and Diwakar Pandey, *"Traffic Pattern Based Performance Comparison of Two Reactive Routing Protocols for Ad Hoc Networks Using NS2"*, 2nd IEEE International Conference on Computer Engineering and Information Technology, 2009.

[9] Vahid Nazari Talooki and Jonathan Rodriguez, *"Jitter Based Comparisons for Routing Protocols in Mobile Ad hoc Networks"*, IEEE 2009.

[10] Yu-chee Tseng, Wen-Hua Liao, and Shih-Lin_Wu, *"Mobile Ad hoc Networks and Routing Protocols"*, Handbook ISBN-0-471-41902-8.

[11] Georgios Kiou Mourtzis, "Simulation and Evaluation of Routing Protocols for Mobile Ad hoc Networks", Master thesis in Computer Science and Engineering, Naval Postgraduate School, Monterey California, September, 2005.

[12] D.B Johnson, D.A Maltz, and Yih-Chun Hu., *"The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)"*, Internet draft (draft-ietf-manet-dsr-10.txt), 19 July 2004.

[13] C. Perkins E. Belding-Royer, and S.Das, *"Ad hoc On-Demand Distance Vector (AODV) Routing"*, RFC 3561, July2003.

[14] Perkins Charles E, Bhagwat Pravin, *"Highly dynamic Destination-Sequenced Distance-Vector routing"*, for mobile computers, Proc. of the SIGCOMM '94

[15] Baldev Ram Mali and N.C. Barwar, "Effect of Mobility on Performance of MANET Routing Protocols under Different Traffic Patterns", International Journal of Computer Applications, ISBN: 978-93-80864-99-3.