PERFORMANCE COMPARISON OF MULTIHOP WIRELESS MOBILE AH-HOC ROUTING PROTOCOLS

V.C .Patil (1) , Rajashree.V.Biradar (2) , Dr. R. R. Mudholkar (3) , Dr. S. R. Sawant (4)
(1) Department of Electronics and Communication Engineering, Bellari Institute of Technology and Management Bellary-583104, Karnataka,India.
patilvc@rediffmail.com
(2) Department of Information Science and Engineering, Bellari Institute of Technology and Management bellary-583104, Karnataka,India.
rajashreebiradar@yahoo.com.
(3) Department of Electronics Shivaji University, Kolhapur-416004, Maharasra ,India.
rrm_eln@unishivaji.ac.in
(4) Department of Electronics, Shivaji University, Kolhapur-416004, Maharasra , India
srms_eln@unishivaji.ac.in

ABSTRACT

As of date, wireless communication is one of the most demanding areas of research within networking, with many proposed, but unverified protocols. The success of the proposed protocols depends on the availability of robust implementations that enable both real-time test beds and non-real time simulations. Wireless ad-hoc network is a collection of mobile nodes forming a temporary network without the aid of any centralized administration or standard support services regularly available on conventional networks. Routing in wireless ad-hoc networks is nontrivial due to highly dynamic environment. In recent years several routing protocols targeted at mobile ad-hoc networks are being proposed and prominent among them are DSDV, AODV and DSR. The performance comparison of these protocols considering all the characteristics that should be possessed by routing protocols is the fundamental step towards the invention of new routing protocol. This paper does the detailed comprehensive analysis of routing protocols using ns2 simulator. All protocols are provided with identical traffic load and mobility patterns. Results indicate that the performance of DSR is the best among all routing protocols.

Keywords: AODV, DSR, DSDV, Ad-hoc network, Random way point model.

1 INTRODUCTION

Wireless networking is an emerging technology that allows users to access information and services electronically, regardless of their geographic position. Wireless networks can be infrastructure networks [5] or infrastructureless (Ad-hoc) networks. An Ad-hoc network [6] is a collection of mobile nodes which forms a temporary network without the aid of centralized administration or standard support devices regularly available in conventional networks. These nodes generally have a limited transmission range and, so, each node seeks the assistance of its neighboring nodes in forwarding packets and hence the nodes in an ad-hoc network can act as both routers and hosts, thus a node may forward packets between other nodes as well as run user applications.

By nature these types of networks are suitable for situations where either no fixed infrastructure exists or deploying network is not possible. Ad-hoc mobile networks have found many applications in various fields like military, emergency, conferencing and sensor networks. Each of these application areas has their specific requirements for routing protocols. Since the network nodes are mobile, an Ad-hoc network will typically have a dynamic topology which will have profound effects on network characteristics. Network nodes will often be battery powered, which limits the capacity of CPU, memory, and bandwidth. This will require network functions that are resource effective. Furthermore, the wireless (radio) media will also affect the behavior of the network due to fluctuating link bandwidths resulting from relatively high error rates. These unique features pose several new challenges in the design of wireless, ad-hoc networking protocols. Network functions such as routing, address allocation, authentication, and authorization must be designed to cope with a dynamic and volatile network topology.

In order to establish routes between nodes which are farther than a single hop, specially configured routing protocols are engaged. The unique feature of these protocols is their ability to trace routes in spite of a dynamic topology. Routing Protocols in Ad-hoc networks can be basically classified as Proactive (table driven) routing protocols and Reactive (on-demand) routing protocols [4].

In Proactive routing, routes to all destinations are computed a priori and link states are maintained in node's routing tables in order to compute routes in advance. In order to keep the information up to date, nodes need to update their information periodically. The main advantage of proactive routing is when a source needs to send packets to a destination, the route is already available, i.e., there is no latency. The disadvantages of proactive routing are some routes may never be used and dissemination of routing information will consume a lot of the scarce wireless network bandwidth when the link state and network topology change fast. (This is especially true in a wireless Ad-hoc network.)

In Reactive routing, protocols update routing information only when a routing requirement is presented. This implies that a route is built only when required. The main advantage of Reactive routing is that the precious bandwidth of wireless Ad-hoc networks is greatly saved. The main disadvantage of Reactive routing is if the topology of networks changes rapidly, a lot of update packets will be generated and disseminated over the network which will use a lot of precious bandwidth, and furthermore, may cause too much fluctuation of routes.

The rest of the paper is structured as follows. Protocol descriptions in section 2, Mobility metric in section 3, Simulation methodology in section 4, Performance evaluation metrics and results in section 5 and Conclusion in section 6.

2 PROTOCOL DESCRIPTIONS

This section gives short descriptions of the three ad-hoc routing protocols studied in this work.

2.1 Destination Sequenced Distance Vector – DSDV

DSDV [17,26] is a hop-by-hop distance vector routing protocol. DSDV is a Proactive routing protocol. This implies that each network node maintains a routing table that contains the next-hop for and number of hops to all reachable destinations. Periodical broadcasts of routing updates attempt to keep the routing table completely updated at all times. To guarantee loop-freedom, DSDV uses a concept of sequence numbers to indicate the freshness of a route. A route R is considered more favorable than R' if R has a greater sequence number or, if the routes have the same sequence number, R has lower hop-count. The sequence number for a route is set by the destination node and increased by one for every new originating route advertisement. When a node along a path detects a broken route to a destination D, it advertises its route to D with an infinite hop-count and a sequence number increased by one. Route loops can occur when incorrect routing information is present in the network after a change in the network topology, e.g., a broken link. DSDV uses triggered route updates when the topology changes. The transmission of updates is delayed to introduce a damping effect when the topology is changing rapidly. The parameter values used for DSDV in the simulations are given in Table 1 and are the same as in [1].

Table 1: DSDV Simulation parameters

Periodic route update interval	15s
Periodic updates missed before link declared broken	3
Route advertisement aggregation time	1s
Maximum packets buffered per node per destination	5

2.2 Ad-hoc On Demand Distance Vector –AODV

AODV [13,15,16] is a reactive routing protocol. That is, AODV requests a route only when needed and does not require nodes to maintain routes to destinations that are not communicating. The process of finding routes is referred to as the route acquisition. AODV uses sequence numbers in a way similar to DSDV to avoid routing loops and to indicate the freshness of a route.

Whenever a node needs to find a route to another node it broadcasts a Route Request (RREQ) message to all its neighbors. The RREQ message is flooded through the network until it reaches the destination or a node with a fresh route to the destination. On its way through the network, the RREQ message initiates creation of temporary route table entries for the reverse route in the nodes it passes. If the destination, or a route to it, is found, the route is made available by unicasting a Route Reply (RREP) message back to the source along the temporary reverse path of the received RREQ message. On its way back to the source, the RREP message initiates creation of routing table entries for the destination in intermediate nodes. Routing table entries expire after a certain time-out period.

Neighbors are detected by periodic HELLO messages (a special RREP message). If a node x does not receive HELLO messages from a neighbor y through which it sends traffic, that link is deemed broken and a link failure indication (a triggered RREP message) is sent to its active neighbors. The latter refers to the neighbors of x that were using the broken link between x and y. When the link failure messages eventually reach the affected sources, these can choose to either stop sending data or to request a new route by sending out new RREQ messages. The parameter values used in the simulations are given in Table 2.

Table 2: Parameter values for AODV

HELLO interval	15s
Active route time-out	300s
Route reply lifetime	300s
Allowed HELLO loss	2
Request retries	3
Time between retransmitted requests	3s
Time to hold packets awaiting routes	8s
Maximum rate for sending replies for a route	1/s

2.3 Dynamic Source Routing – DSR

Dynamic Source Routing [6,10,17,25] is a reactive routing protocol which uses source routing to deliver data packets. Headers of data packets carry the sequence of nodes through which the packet must pass. This means that intermediate nodes only need to keep track of their immediate neighbors in order to forward data packets. The source, on the other hand, needs to know the complete hop sequence to the destination.

As in AODV, the route acquisition procedure in DSR requests a route by flooding a Route Request packet. A node receiving a Route Request packet searches its route cache, where all its known routes are stored, for a route to the requested destination. If no route is found, it forwards the Route Request packet further on after having added its own address to the hop sequence stored in the Route Request packet. The Route Request packet propagates through the network until it reaches either the destination or a node with a route to the destination. If a route is found, a Route Reply packet containing the proper hop sequence for reaching the destination is unicasted back to the source node. DSR does not rely on bi-directional links since the Route Reply packet is sent to the source node either according to a route already stored in the route cache of the replying node, or by being piggybacked on a Route Request packet for the source node. However, bi-directional links are assumed throughout this study. Then the reverse path in the Route Request packet can be used by the Route Reply message. The DSR protocol has the advantage of being able to learn routes from the source routes in received packets.

To avoid unnecessarily flooding the network with Route Request messages, the route acquisition procedure first queries the neighboring nodes to see if a route is available in the immediate neighborhood. This is done by sending a first Route Request message with the hop limit set to zero, thus it will not be forwarded by the neighbors. If no response is obtained by this initial request, a new Route Request message is flooded over the entire network. The parameter values used in the DSR simulations are taken from [1] and are given in Table 3.

Table 3: Parameters for DSR.

Time between retransmitted requests	500 ms
Size of source route header carrying n ad dresses bytes	4n+4
Time-out for non propagating search	30 ms
Time to hold packets awaiting routes	30s
Maximum rate for sending replies for a route	1/s

3 MOBILITY METRIC

This section defines a mobility metric used in this simulation , henceforth referred to as mobility, intended to capture and quantify the kind of node motion relevant for an ad-hoc routing protocol[17][22]. Ad-hoc routing protocols must take action when the relative motion of nodes causes links to break or form and a mobility metric should thus be proportional to the number of such events. The metric should be independent of the particular network technology used. Therefore mobility metric is proposed which is geometric in the sense that the speed of a node in relation to other nodes is measured, while it is independent of any links formed between nodes in the network.

The study in [1] uses the pause time at waypoints in a random motion model as a mobility metric. This makes sense for the particular motion model used in that study but is too ad-hoc to be useful for generic motion models. For instance, the pause time metric is ill-defined when node motion is continuous or when nodes use different pause times. Moreover, the speed at which nodes move between way-points is also relevant for how often links break and form.

The mobility metric proposed here describes the mobility of a scenario with a single value M which is a function of the relative motion of the nodes taking part in a scenario. If l(n,t) is the position of node n at time t, the relative velocity v(x,y,t) between nodes x and y at time t is

$$v(x, y, t) = \frac{d}{dt}(l(x, t) - l(y, t)) \; . \qquad (1)$$

The mobility measure, M, between any pair (x, y) of nodes is defined as their absolute relative speed taken as an average over the time, T, the mobility is measured. The formula for obtaining M_{xy} is given below.

$$M_{xy} = \frac{1}{T} \int_{t_0 \le t \le t_0 + T} |v(x, y, t)| dt \qquad (2)$$

In order to arrive at the total mobility metric, M, for a scenario, the mobility measured in (2) is averaged over all node pairs, resulting in the following definition

$$M = \frac{1}{|x,y|}\sum_{x,y} M_{xy} = \frac{2}{n(n-1)}\sum_{x=1}^{n}\sum_{y=x+1}^{n} M_{xy}\,, \qquad (3)$$

where |x,y| is the number of distinct node pairs (x,y) and n is the number of nodes in the scenario. (Note that the second relation in (3) assumes nodes being numbered from 1 to n.) Hence, the mobility expresses the average relative speed between all nodes in the network. Consequently, the mobility for a group of nodes standing still, or moving in parallel at the same speed, is zero. For practical reasons a discrete version of the mobility formula is used when computing the mobility for the network scenarios in this study. M is approximated by summing the relative speeds over small time steps, 0.1 seconds. The distances are measured in meters which gives the mobility measure in meters per second. Alternatively, the distance could be normalized with the transmitting range of the nodes to compare systems with different radio coverage.

4 SIMULATION METHODOLOGY

4.1 Network Simulator

The entire simulations were carried out using ns 2.31 network simulator which is a discrete event driven simulator developed at UC Berkeley [8] as a part of the VINT project. The goal of NS2 is to support research and education in networking. It is suitable for designing new protocols, comparing different protocols and traffic evaluations. NS2 is developed as a collaborative environment. It is distributed as open source software. A large number of institutes and researchers use, maintain and develop NS2. NS2 Versions are available for Linux, Solaris, Windows and Mac OS X.

4.2 Structure Of NS2

NS2 [8,23,24] is built using object oriented language C++ and OTcl (object oriented variant of Tool Command Language). NS2 interprets the simulation scripts written in OTcl. The user writes his simulation as an OTcl script. Some parts of NS2 are written in C++ for efficiency reasons. The data path (written in C++) is separated from the control path (written in OTcl). Data path object are compiled and then made available to the OTcl interpreter through an OTcl linkage. Results obtained by ns2 (trace files) have to be processed further by other tools like Network Animator (NAM), perl, awk script etc.

The performance of ad-hoc network is found by varying the traffic load and mobility of nodes. Traffic generation models are used to study the effect of traffic load on the network and mobility generation models are used to study the effect of mobility of nodes. Table 4 provides all the simulation parameters.

Table 4: Simulation Parameters

Serial No.	Parameters	Value
1	Number of nodes	50
2	Simulation Time	200sec.
3	Area	500*500m^2
4	Max Speed	20 m/s
5	Traffic Source	CBR
6	Pause Time (sec)	0,20,30,40,100
7	Packet Size	512 Bytes
8	Packets Rate	4 Packets/s
9	Max Connections	10,20,30,40
10	Band Width	10Bbps
11	Delay	10 ms
12	Mobility model used	Random way point

4.3 Traffic Generation Models

Traffic-scenario generator script 'cbrgen.tcl' is used to create CBR traffic connections between wireless mobile nodes. To study the effect of traffic load on the network, various numbers of maximum connections were setup between the nodes with the traffic rate of 4 packets per seconds where each packet size was 512 bytes. A set of four traffic generation files corresponds to each routing protocols were used for each values of maximum connections to improve the accuracy of the results .

4.3 Mobility Generation Models

The movement scenario files used for each simulation are characterized by a pause time. To study the effect of mobility, the simulation is carried out with movement patterns generated for different pause times. Pause time of 0 seconds corresponds to continuous motion, and a pause time of 100 corresponds to almost no motion. A set of five movement scenario files corresponds to three routing protocols were used for each value of pause time. The 'setdest' program of NS-2 simulators used which generates node-movement files using the 'random waypoint algorithm'.

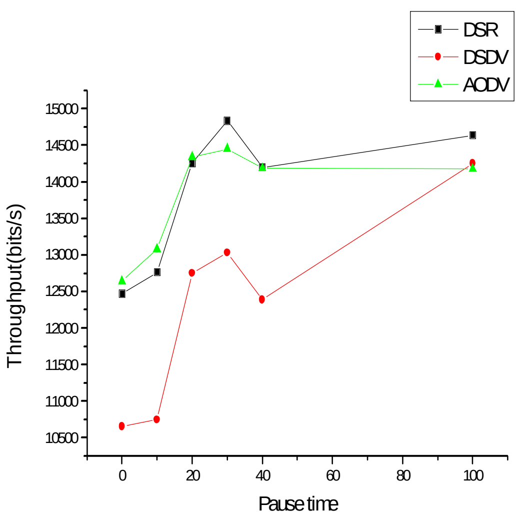
5 PERFORMANCE EVALUATION METRICS AND RESULTS

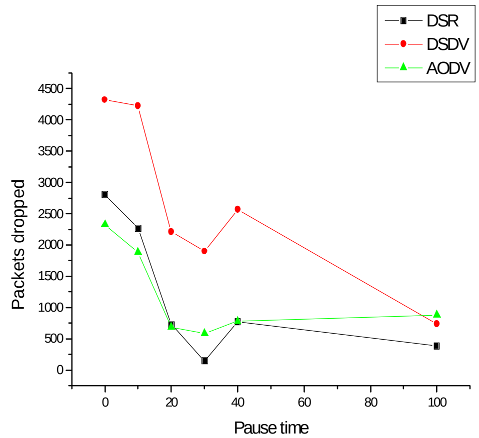
The following five important performance metrics are considered for evaluation of these routing protocols.

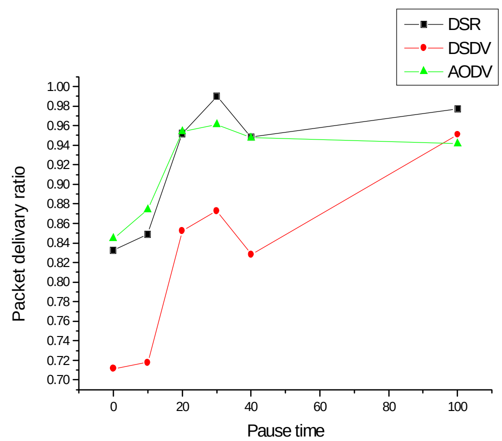
- **Throughput:** Throughput is the measure of how fast we can actually send through network. The number of packets delivered to the receiver provides the throughput of the network.
- **Packets dropped***:* Some of the packets generated by the source will get dropped in the network due to high mobility of the nodes, congestion of the network etc.
- **Packet delivery ratio:** The ratio of the data packets delivered to the destinations to those generated by the CBR sources.
- **Normalized routing overhead:** The number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission
- **Optimal path length:** It is the ratio of total forwarding times to the total number of received packets.

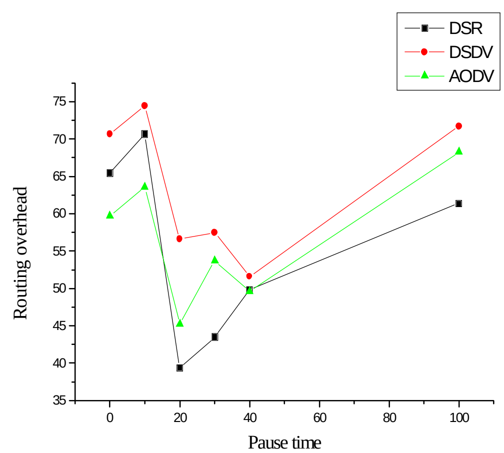
5.1 Results Of Simulation To Analyze The Effect Of Mobility

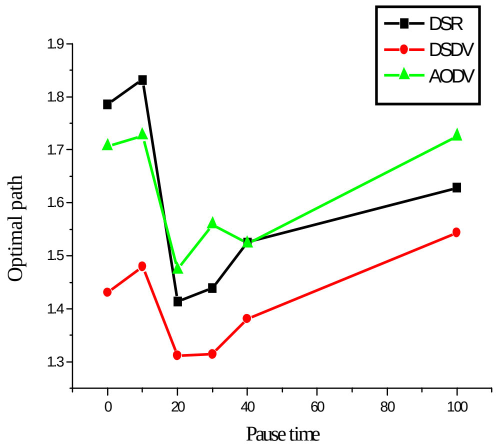
To analyze the effect of mobility, pause time was varied from 0 seconds (high mobility) to 100 seconds (no mobility).





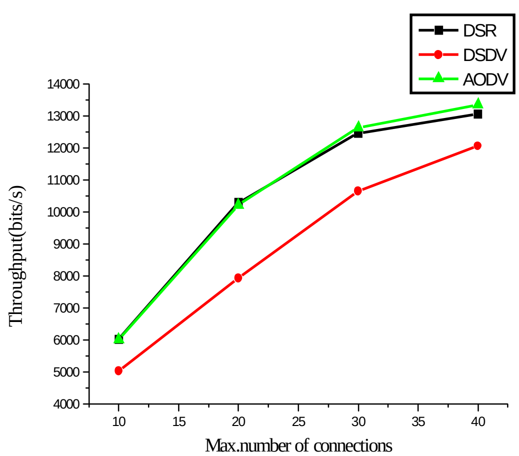


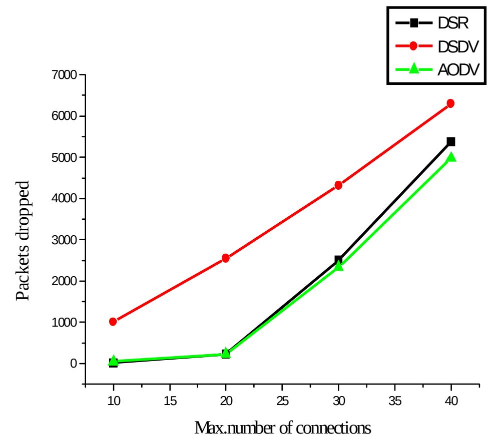


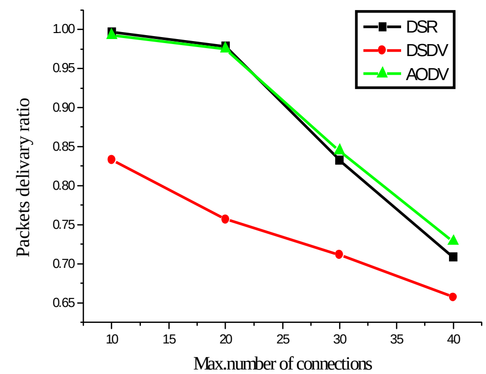


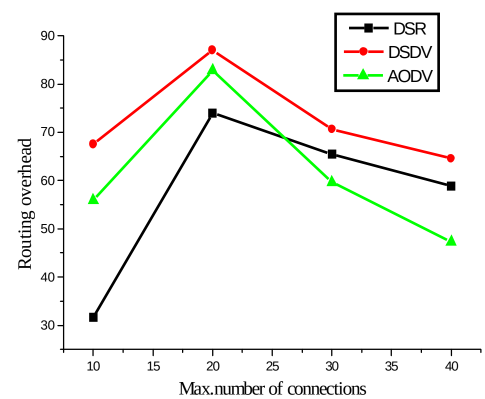
5.2 Results Of Simulation To Analyze The Effect Of Traffic Load.

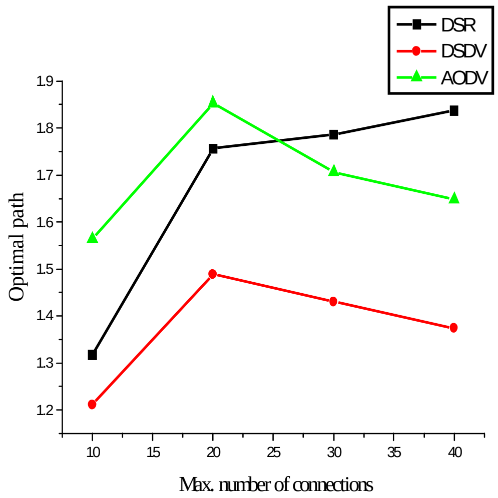
To study the effect of traffic load on the network, number of connections was varied as 10, 20, 30 and 40 connections. The network was simulated for high mobility scenario keeping the pause time 0 seconds.











5.3 Analysis Of Simulation Results

The simulation results bring out some important characteristic differences among these routing protocols. The presence of high mobility implies frequent link failures and each routing protocol reacts differently during link failures. The different basic working mechanism of these protocols leads to the differences in the performance. DSDV fails to converge at lower pause times hence performance of the protocol decreases as mobility increases. At higher rates of mobility (lower pause times), DSDV performs poorly dropping more number of packets. As DSDV maintains only one route per destination, each packet that the MAC layer is unable to deliver is dropped since there are no alternate routes. For DSR and AODV, packet delivery ratio is independent of offered traffic load, with both protocols delivering between 95% and 100% of the packets in all cases. The reason for having better packet delivery ratio of DSR and AODV is that both allow packets to stay in the send buffer for 30 seconds for route discovery and once the route is discovered, data packets are sent on that route to be delivered at the destination. If we see DSR and AODV deliver more packets at the destination as compared to DSDV because these two protocols try to provide some sort of guarantee for the packets to be delivered at the destination by compromising at the delay. Where as DSDV, try to drop the packets, if it is not possible to be delivered hence the lesser delay and lesser packet delivery ratio.

DSDV uses the table-driven approach of maintaining routing information. It is not as adaptive to the route changes that occur during high mobility. DSDV sends periodic routing updates at every 15 seconds in the network.. These periodic broadcasts increase routing load in the network. Hence for DSDV we will have more routing overhead irrespective of mobility and traffic load and this increases more if we simulate a network for longer duration as DSDV sends periodic updates at regular intervals. In contrast, the lazy approach used by the on-demand protocols, AODV and DSR to build the routing information as and when they are created make them more adaptive and result in better performance (high packet delivery fraction) and less routing load.

6 CONCLUSION

As it can be seen, there is large number of different kinds of routing protocols in mobile Ad-hoc networks. The use of a particular routing protocol in mobile Ad-hoc Network depends upon factors like size of the network, load, mobility requirements etc. This paper compares the performance of DSDV, AODV and DSR routing protocols for mobile Ad-hoc networks using NS-2 simulator.

In summary, it can be said that for robust scenario where mobility is high, nodes are dense, area is large, the amount of traffic is more and network is for longer period, AODV performs better among all studied routing protocols. For the normal situations where a network is of general nature with moderate traffic and moderate mobility DSR would be the right choice as it delivers more packets at the destination with lowest routing overheads. For low mobility and less number of nodes, DSDV is preferable. Results indicate that the performance of DSR which uses source routing is the best among all compared routing protocols.

REFERENCES

[1] J. Broch, D. A. Maltz, D. B. Johnson, Y. C. Hu, and J. Jetcheva: A Performance Comparison of Multi-Hop Wireless Ad-hoc Network Routing Protocols, In Proc. of the ACM/IEEE MobiCom (1998).

[2] P. Johansson, T. Larsson, N. Hedman, B. Mielczare, M. Degermark: Scenario-based performance analysis of routing protocols for mobile ad-hoc networks, In Proc. of the ACM/IEEE MobiCom. (August 1999).

[3] S Gowrishankar, T G Basavaraju and S. K. Sarkar: Effect of Random Mobility Models Pattern in Mobile Ad-hoc Networks, IJCSNS International Journal of Computer Science and Network Security, VOL.7 No.6, pp. 160-164 (2007).

[4] Smt Rajashree.V. Biradar & Prof V. C.Patil : Classification and Comparison of routing Techniques in Wireless Ad-hoc Networks, in the proceedings of international Symposium on Ad-hoc Ubiquitous Computing (ISHUC'06), pp. 7-11 (2006).

[5] Geetha Jayakumar and Gopinath Ganapathy : Performance Comparison of Mobile Ad-hoc

Network Routing Protocol, IJCSNS International Journal of Computer Science and Network Security, VOL.7 No.11(2007).

[6] S.R. Das, C.E. Perkins, and E.M. Royer: Performance comparison of two on-demand routing protocols for Ad-hoc networks, Nineteenth Annual Joint Conference of the IEEE Computer and Communications leties, pages 3–12 (2000).

[7] J.Geetha, and G. Gopinath, : Ad-hoc Mobile Wireless Networks Routing Protocols, A Review, Journal of Computer Science , pp. 574-582.(2007).

[8] 5th VNIT/NS Simulator Tutorial/Workshop slides and the NS Manual [2009].

[9] N.S. Yadav, and R.P.Yadav: Performance Comparison and Analysis of Table- Driven and On- Demand Routing Protocols for Mobile Ad-hoc Networks, International Journal of Information Technology, Vol.4, No. 2, pp 101-109(2007) .

[10] D. Johnson, D. Maltz, and Yih-Chun Hu: The Dynamic Source Routing Protocol for Mobile Ad-hoc Networks (DSR), (2004).

[11] K. Fall, and K.Vardhan, Eds :, Ns notes and documentation, available from http://www-mash.cd.berkeley.edu/ns/.

[12] S. Corson and J. Macker: Mobile Ad-hoc Networking (MANET) Routing Protocol Performance Issues and Evaluation Considerations, RFC 2501 MANET (1999).

[13] C. Perkins, E. Belding-Royer, and S.Das: Ad-hoc On-Demand Distance Vector (AODV) Routing, RFC 3561 (2003).

[14] I. Khider, Wang Furong, Yin Wei Hua, Sacko: Study on Indoor and Outdoor environment for Mobile Ad-hoc Network: Random Way point Mobility Model and Manhattan Mobility Model," International Conference on WiCom 2007 Volume-Issue, 21-25 Sept. 2007 pp. 1470 – 1474 (2007).

[15] Charles E. Perkins, Elizabeth M. Royer, Samir R. Das: Ad-hoc On-demand Distance Vector Routing, IETF Draft, 33 pages (October 1999).

[16]Charles E. Perkins: Ad-hoc On Demand Distance Ve tor (AODV) Routing, Internet draft, draft-ietf-manet aodv-02.txt (November 1998).

[17] Tony Larsson, Nicklas Hedman: Routing protocol in wireless Ad-hoc networks ,a simulation study ,a master thesis (1998) .

[18] S. Lee, W. Su, M. Gerla: On-Demand Multicast Routing Protocol (ODMRP) for Ad-hoc Networks , http://www.ietf.org/internet-drafts/draft-ietf-manet-odmrp-02.txt, IETF Internet Draft (January 2000).

[19] G. Anastasi, E.Borgia, M.Conti, E.Gregori, 2003: IEEE 802.11 Ad-hoc networks: performance measurements, icdcsw, p. 758, 23rd International Conference on Distributed Computing Systems Workshops ICDCSW (2003).

[20] Anastasi, G., E.Borgia, M.Conti, E.Gregori : IEEE 802.11 Ad-hoc networks: protocols, performance and open issues, Ad hoc Networking, IEEE Press Wiley, New York (2003).

[21] S. Marinoni, Performance of Wireless Ad-hoc Routing Protocols, A Simulation Study in Realistic Environments. Master's thesis, Helsinki University of Technology (May 2005).

[22] Hanbali, A. A. Kherani, R. Grenovelt, and E. A. P.Nain, Impact of mobility on the performance of relaying in Ad-hoc networks, In Proceedings of the IEEE INFOCOM, Barcelona, Spain.(2006).

[23] The CMU Monarch Project: The CMU Monarch Projects Wireless and Mobility Extensions to ns URL: http://www.monarch.cs.cmu.edu (1998).

[24] Marc Greis's tutorial web pages (originally at his web site, now at http://www.isi.edu/nsnam/ns/tutorial/)

[25] Elizabeth Belding Royer: Routing approaches in mobile Ad-hoc networks," in: S.Basagni, M.Conti,S.Giordano, I.Stojemenvoic (Eds), Ad-hoc Networking, IEEE Press Wiley, New York(2003).

[26] C. E. Perkins and P. Bhagwat. Highly dynamic destination sequence distance-vector routing (DSDV) for mobile computers. CM SIGCOMM'94, pages 234–244(October 1994).

[27] D. B. Johnson, D. A. Maltz, and Y.-C. Hu: The Dynamic Source Routing Protocol for Mobile Ad-hoc Networks, IETF Draft - MANET working group (2005).