Performance Evaluation of Routing Protocols, Mobility Models and Simulation in MANET

Sanjeev Shrivastava[1], Vivek Pargania[2]
Research Scholar M.Tech (CN)[1], Associate Professor[2]
Department of Computer Science Engineering
Bhilai Institute of Technology, Durg, India

Abstract : A mobile ad hoc network (MANET) consists of mobile wireless nodes and *is an infrastructure less and decentralized network which need a robust dynamic routing protocol*. The communication between these mobile nodes is carried out without any centralized control. MANET is a self organized and self configurable network where the mobile nodes move randomly. The mobile nodes can receive and forward packets as a router. Routing is a critical issue in MANET and hence the focus of this paper is the performance analysis of routing protocols. Many routing protocols for such networks have been proposed so far to find optimized routes from source to the destination and prominent among them are Dynamic Source Routing (DSR), Ad-hoc On-Demand Distance Vector (AODV), and Destination- Sequenced Distance Vector (DSDV) routing protocols. The performance comparison of these protocols should be considered as the primary step towards the invention of a new routing protocol. Over the last decade various routing protocols have been proposed for the mobile ad-hoc network and the most important among all of them are DSR, DSDV and AODV. This paper presents a performance comparison of proactive and reactive routing protocols DSR, DSDV and AODV based on mobility model and QoS metrics (packet delivery ratio, average end-to-end delay, throughput, and jitter), normalized routing overhead and normalized MAC overhead by using the NS-2 simulator. In this work, the performance comparison is conducted by varying mobility speed, a number of nodes and data rate. The main objective of this paper is to compare the performance of all the three routing protocols and then to make the observations about how the performance of these routing protocols can be improved. Performance of these routing protocols are compared on the basis of various parameters such as throughput, delay and packet delivery ratio. The comparison results show that AODV performs optimally well not the best among all the studied protocols.

KEYWORDS: Mobile Ad hoc Network (MANET), DSR, DSDV, AOD, NS-2 simulator, Mobility Model and QoS metrics

I. INTRODUCTION

Over the last epoch, academics have made various researches in the field of mobile computing especially MANETs. A Mobile ad-hoc network (MANETs) is a self-organized, haphazardly developed network and can easily adopt in working environment. MANET is the collection of wireless mobile nodes that can interact and communicate with each other, without having the unified and established infrastructure. MANETs have transformed the vision of getting connected “anywhere and at any time” in to the realism. MANETs are useful in numerous application areas such as: communication in the military operation, colleges and institutions, disaster regaining areas, law and order maintenance, traffic control areas, medical field, conferences and convocations etc. The Internet Engineering Task Force (IETF) created a MANET working group to deal with the challenges faced during the construction of the MANET routing protocols. These protocols are basically categorized in to three types such as: on demand (reactive), table-driven (proactive) and hybrid. One of the elementary goals of the mobile ad-hoc network is to establish precise and competent route between the mobile nodes so that communication between the sender and receiver is effective.

The mobility of mobile nodes plays a significant role in the performance of routing protocols. Routes between two communicating nodes may consist of multiple hops through other nodes in the network. Therefore, finding and maintaining routes in MANET is nontrivial. Several routing protocols have been developed for mobile ad hoc networks. Such protocols must deal with typical limitations of these networks which include low bandwidth, high power consumption, and high error rates. Figure 1 shows the categorization of these routing protocols the overhead is too high since a path which is not used for a long time is still maintained and updated. Examples include Destination-Sequenced Distance-Vector (DSDV) [1,2 3, 4, 5, 6, 7].

In Proactive (table driven) routing protocols, each node maintain one or more routing table which contain information about every other node in a network. Routing tables are updated by all the nodes in order to maintain a consistent and up to date view of the network. In table driven routing protocol, continuous broadcasting of messages is done in order to establish routes and maintain them. One of the basic advantages of proactive routing protocol is that route from source to destination is easily available without any overhead, as they are independent of traffic profiles. Various proactive routing protocols are: DSDV [1, 5, 6].

In reactive (on demand) routing protocol, creation of routes is done when it is required. When some packets are to be send from source to destination, it may invoke the route discovery mechanism to find the path to the destination. The route is valid, till the destination is reached or it is no longer be required in the future. Some of the reactive routing protocols are: DSR [1, 3], AODV [2, 3, 6, 7, 19, 20].

Each node in MANET maintains continuously the information required to properly route traffic. The three widely used routing protocols have been investigated and compared: Destination Sequenced Distance Vector (DSDV), Ad-hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR). MANETs are a kind of wireless ad-hoc network (WANET) that usually has a routable networking environment on top of a link layer ad hoc network. MANETs consist of a peer-to-peer, self-forming, self-healing network. Different protocols are then evaluated based on measures such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput, ability to scale, etc.[10, 11, 12, 13, 14, 15, 16, 17, 18].

II. CHALLENGES FACED BY THE MANETS

MANETs are very much different from the wireless network infrastructures. MANETs has to face various challenges in order to achieve best Quality of Service for the underlying network. Some of these challenges are unicast and multicast routing, topology changes dynamically, speed and network overhead, limited power supply and bandwidth, QoS and secure routing and scalable and energy efficient routing.

These challenges are faced at the different layers of MANETs shown in the Figure-1. It represents the layered architecture of the OSI model and entitled the challenges of MANETs regarding these layers.

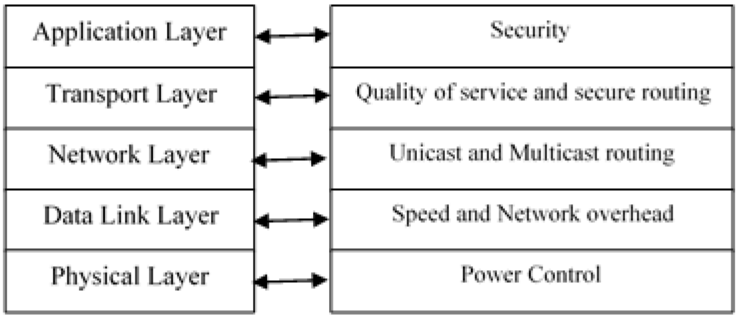


Figure-1: Challenges are faced at the different layers of MANETs

III. ROUTING PROTOCOLS

Dynamic Source Routing (DSR)- DSR is the reactive routing protocol which is able to manage MANETs without using the periodic table update messages like proactive routing protocols does. Specially, DSR are designed to make use in multi-hop wireless ad-hoc networks. Ad-hoc network enables the network to be self-organizing and self-configuring which means that there is no need of existing network infrastructure. This protocol basically focuses on the two different phases i.e. route discovery and route maintenance. In route discovery phase, source node sends the packet to the destination node. In route maintenance phase, protocol detects when the topology of the network has changed and decides if an alternative route has been used or the route discovery protocol must be started to find the new path. Route discovery and route maintenance phase only give responses when they receive the request [11, 17, 21].
Some of the advantages of DSR are it does not need the routing table for making the periodic updates, intermediate nodes are able to utilize the route cache information efficiently to reduce the control overhead and bandwidth saving because it does not require any HELLO messages. Disadvantages are DSR route maintenance protocol does not locally repair the broken link, it is only been efficient for less than 200 nodes in MANETs and there is small time delay if the beginning of the new connection takes place.

Destination- Sequenced Distance Vector Routing- The DSDV algorithm is basically the amendments made in distributed bellman ford algorithm, which provides loop free routes. It gives us the single path from source to destination using distance vector routing protocol. In order to reduce the amount of overhead in a network two types of updates packets are transferred i.e. full dump and incremental packet. Full dump broadcasting carry all the routing information while the incremental dump broadcasting will carry information that has changed since last full dump irrespective of the two types, broadcasting is done in the network protocol data unit(NPDU). Full dump requires multiple NPDU's whereas incremental dump requires one NPDU's to fit in all the information. Incremental update packets are sent more easily and frequently than the full dump packets. DSDV introduces the large amount of overhead to the network due to the requirement of periodic update messages. Hence, this protocol is not suitable for the large network because large portion of the network bandwidth is used for the updating of messages[2, 3, 4, 5, 6, 7, 8].

Management of the routing table- The routing table for each and every node consists of a list of all available nodes, their next hop to the destination, their metric and a sequence number generated by the destination node. With the help of the MANETs, routing table is used to send the data packets. Routing table can be kept consistent with the dynamically changing topology of ad-hoc network by periodically updating the routing table with some small changes in the network. Hence, mobile nodes provide their routing information by broadcasting the routing table update packet. The metric of the update packet starts with the initial value of one for one hop neighbors and goes on incremented with each forwarding node. The receiving node updates their routing tables if the sequence number of the update is greater than the current node or equal to the current node. Fluctuations in the routing table are minimized by delaying the advertisement of routes until we find the best route.

Changes in the topology- DSDV responds to the broken links by authorizing all the routes that contain this link. The routes are immediately assigned a metric as well as the incremented sequence number. Physical and data link layer components are used to detect the broken links or if the node does not receive broadcast packets from its neighbors node. Then, immediately the detecting node will broadcast an update packet and inform all the other nodes about the broadcasting mechanism. Route will again be reestablished when the routing table is broadcasted by the node.

Some advantages of DSDV are guarantees loop free path, count to infinity problem is reduced in DSDV, with incremental updates, we can avoid extra traffic and it maintain the best possible path instead of maintaining the multiple paths to the destination this reduces the amount of space in the routing table. Disadvantages are it does not support the multipath routing, difficult to determine the delay for the advertisement of routes and unnecessary advertising of routing information can result in the wastage of bandwidth.

Ad Hoc On Demand Distance Vector (AODV)- Basically AODV is the improvement of DSDV routing algorithm. It is collectively based on the combination of both DSDV and DSR. The main aim of AODV routing algorithm is to provide reliable and secure data transmission over the MANETs [2, 3, 6, 7, 11, 12, 13, 23]. In this routing protocol, route maintenance from one node to every other node is not considered in the network. Whereas in AODV, route are discovered only when they are needed as well as they are maintained only as long as they are required. The key steps used in the AODV algorithm are defined below:

Route creation process is initiated when the node wants to send the data packet to the destination node but does not find the valid route to send the packet. This process is initiated as such: when a particular node want to send the data packet to the destination node then, the routing table entries are checked in order to verify whether there exists a route between the source and destination or not. If the route exists, then the packet is forwarded to the next hop towards the destination. When the route does not exists, and then the route discovery process is initiated. AODV starts the route discovery process using the route request (RREQ) and route reply (RREP). The source node will create the route request packet(RREQ) containing its sequence number, its IP address , destination node sequence number, destination IP address and broadcasting ID. Whenever the source node initiates the RREQ, the broadcast ID is incremented each time. As the sequence number is used to identify the timeliness of each data packet and broadcast ID and the IP address identify the unique identifier for route request so that they can uniquely identify each of the request. The data packet sends the request using the RREQ message and gets back the reply in the form of RREP message if the route is discovered between the nodes. The source node sends the RREQ packet to its neighbors as well as set the timer in order to wait for the RREP message. In order to describe RREQ, reverse route entry is set up by the node in its routing table. This enables us to know how we can forward the route reply (RREP) to the source. Moreover, a time period is associated with the reverse route entry and if this route entry is not used within the given time period then only the route information is deleted. If in any case RREQ is lost during the transfer of packet then the source node again initiates route discovery mechanism.

Route maintenance- that has been created by the source node and destination node is being maintained as long as it is needed by the source node. Since nodes in the MANETs are mobile and if the source node is in the mobile state during the active session, it again restarts the route discovery mechanism in order to establish new routes from source to destination. Otherwise, if some of the intermediate node or the destination node is in the mobile state during the active session, then the nodes initiates the RERR message that affects the above neighbors and the nodes. As a result of which these nodes forward the RERR message to the predecessor nodes and can be continued until the source node is reached. When RERR is received by the source node, then the node stop sending the data or it can again start the route discovery mechanism by sending the RREQ message.

Some advantages of AODV are loop free routing, optional multicast and reduced control overhead. Disadvantages are bi-directional connection needed in order to detect a unidirectional link and delay caused by the route discovery process.

IV Simulation Environment and Parameters

In our simulating, the mobile ad-hoc network (MANET) nodes are set of mobile nodes, a Source, and Destination. Each MANET node has a capability of transferring the packet from one end to other which doesn't have a fixed route because the network is Dynamic which indicates that all the mobile nodes in the network are moving [20-22]. There are different parameters on which our System is designed. Our MANET network is a wireless channel with radio propagation model and MAC type Mac/802_11 the communication of the network is done in the Link Layer of the OSI model. The protocol used for routing is AODV, DSR, and DSDV. We have used to agents UDP (user datagram protocol) and TCP (Transmission control protocol). The applications used are FTP (File transfer protocol) and CBR (Constant bitrate) because of this two application establishment of the connection within the network is done. The simulations were performed using Network Simulator 2 (NS-2.35), particularly popular in the ad hoc networking community [23].Simulation parameters used in our simulation model are shown in Table-1.

Table-1 : Simulation parameters

Parameter	Value	Parameter	Value
Simulator	NS-2.35	Number of Mobile nodes	10 -100
Channel type	Channel/Wireless channel	Source Type	CBR (Constant bit rate)
Mac Type	Mac/ 802.11	Simulation Time	300 s
Network interface	Phy /Wireless Phy	Routing protocols	DSDV, AODV and DSR
Radio – propagation Type	Propagation / Two rays round wave	Number of connection	20 -30
Network queue Type	Queue / Drop tail	Data Rate	2-20 packet / second
Link Layer Tyoe	LL	Pause time	5 second
Antenna	Antenna / Omni Antenna	Packet Size	512
Maximum packet in ifq	50	Mobility Model	Random Waypoint
Area (M * M)	1000 * 1000	Transmission Range	250 m
Mobility Speed	0-20 m/s	-	-

Many papers proved that AODV and DSR have more advantages than DSDV in many performance metrics such as overhead, throughput, an end to end delay and packet delivered ratio (PDR). b. AODV has advantages than DSR and vice versa in some cases, for a performance comparison between those protocols.

Evaluation Metrics - Six metrics are used to evaluate our protocols, which are an end-to-end delay, Packet delivery ratio, Throughput, Jitter, normalized routing overhead, and Normalized MAC Overhead.

1) End-to-end delay is the average time delay for data packets to reach from the source node to the destination node. It includes processing, queuing and propagation delay of the link. The performance is better when packet end-to is low.
2) Packet delivery ratio (PDR) is the ratio between the number of packets transmitted by a traffic source and the number of packets received by a traffic sink; it represents the maximum throughput that the network can achieve. A high packet delivery ratio is desired in the study of performance metrics.
3) Throughput is the total packets successfully delivered to individual destinations over total time.
4) Jitter is the delay variation between each received data packets: The variation in the packet arrival time should be minimized to have better performance in Mobile Ad-hoc Networks.
5) Normalized Routing/Control Overhead Normalized Routing Overhead is defined as the number of routing packets "transmitted" per data packet "delivered" at the destination. The performance is better when routing overhead low.
6) Normalized MAC Overhead is defined as the fraction of all control packets (routing control packets, Clear-to-Send (CTS), Request-to-Send (RTS), Address Resolution Protocol (ARP), requests and replies, and MAC ACK total number of successfully received data packets.

V Results –

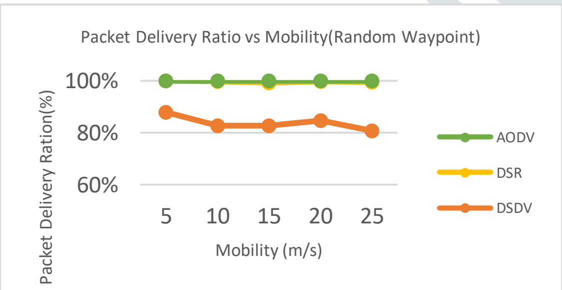
The simulation results are shown in the following section in the form of graphs. Graphs show a comparison between the three protocols on the basis of the above-mentioned metrics by varying mobility speed of the nodes, network size, and the load.

5.1 Varying the node speed or dynamic property of the network in the first set of simulations: The mobility speed of the nodes is varied. The nodes start with a low velocity of 5 m/s (18 km/h) and then the node velocity increases up to 20 m/s (72 km/h). The data rate is kept constant at10 packets/s (40.960 kbps) and the no. of nodes and connections are fixed at 50 and 20 respectively. Packet delivery ratio in Fig. (2a) shows the packet delivery ratio of the protocols AODV, DSR, and DSDV. AODV and DSR almost show the similar performance. Packet delivery ratio for the protocols decreases as speed increases. This is because, at higher speeds, link breakage may occur more frequently and therefore a packet loss fraction is increased. Although the packet delivery fraction of all the protocols decreases as speed increases, DSDV's packet delivery fraction decreases in a more rapid fashion due to its excessive channel usage by regular routing table updates.

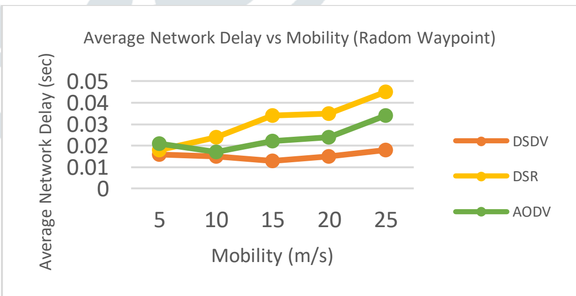
Furthermore, as mobility speed increases, more event-triggered updates are generated, resulting in even more packet delivery fraction decrease. This problem is not present in AODV, DSR since routes are generated only on-demand. Average end to end delay Fig. (2b) shows the average end to end delay of the three routing protocols. With the increase of movement speed, topology change may occur more frequently and thus the probability of broken links increases. Broken links may cause additional route recovery process and route discovery process. This leads to increase in average end-to-end delay of packets as the node speed increases. AODV protocol performs well for the dynamic network than DSR and DSDV on average end to end delay because it adopts both proactive and reactive features. In DSDV routing protocol, when the route break occurs in the network, the uplink and downlink nodes generate hello packets after waiting for the hello interval and the hello packets are propagated in the network with some delay (propagation delay). Moreover, some processing delay is also created due to the exchange and the updates of the routing tables at the nodes. Both these processing and the propagation delays are responsible for the increased end to end delay in case of DSDV. DSR end to end delay increases at high mobility speed because it suffers from stale route cache problem. Also, DSR is source path routing and when mobility is more in the network, less number of route replies is successfully received by the CBR sources. Throughput Again in the fig (2c), the throughput of AODV and DSR is more than DSDV because when the mobility speed of the node is increased, the throughput of DSDV decreases more as the node is busy in updating its routing table. DSR and AODV throughput is also decreased but its value is nominal. Jitter Figure (2d) shows the delay jitter of the three routing protocols. Jitter is dependent on delay as in jitter; variation of the packet arrival time is calculated in the network on the receiver side. That's why the jitter is almost in the same fashion for all the protocols like delay.

DSR has lower jitter on less speed because it utilizes the route information stored in the route cache for creating the connection but has more jitter variation above 10 m/s because, at higher speeds, the DSR node cache information is stale for the other nodes. Normalized Routing Overhead Figure (2e) shows the normalized routing load. DSDV has the best performance with an increase of the routing load at a higher mobility.

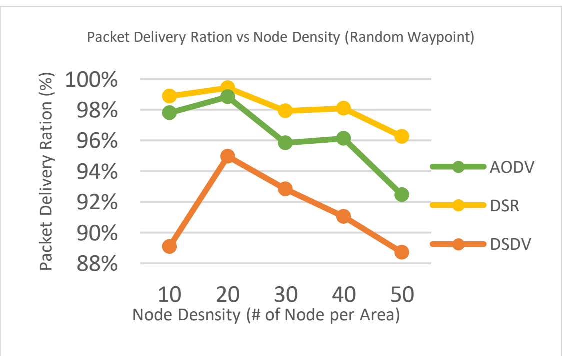
AODV routing overhead is more than DSR and DSDV because it generates more no. of control packets to find a fresh enough route to the destination node. It increases when nodes move at higher speeds. DSR has higher routing load than DSDV due to its source path routing and stale route cache problem at increased mobility. But actually, the control overhead is measured based on the size of control packets in terms of bytes in the network. Size of control packets (in bytes) generated by DSDV and DSR protocols is greater than AODV protocol and when the size of the control packets increases, then the packets need to be fragmented, and it is difficult to handle fragmented packets in the mobile ad hoc network. That's why DSR is not suitable for big ad hoc network. From this observation, it can be concluded that AODV protocol is best suitable for the dynamic network. Normalized MAC overhead Figure (2f) shows the normalized MAC overhead. AODV has higher normalized MAC load than DSR. DSDV is the most stable protocol in terms of the normalized MAC load in networks with varying mobility.



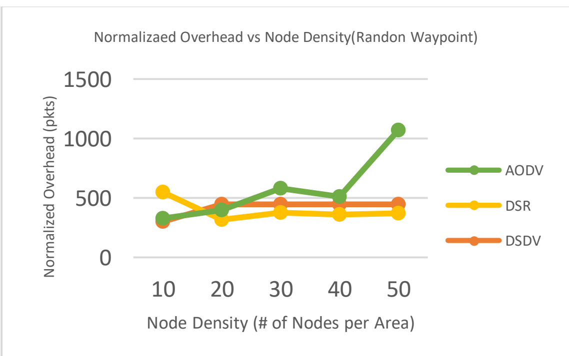
(a) Packet Delivery Ratio vs Mobility (Random Waypoint)



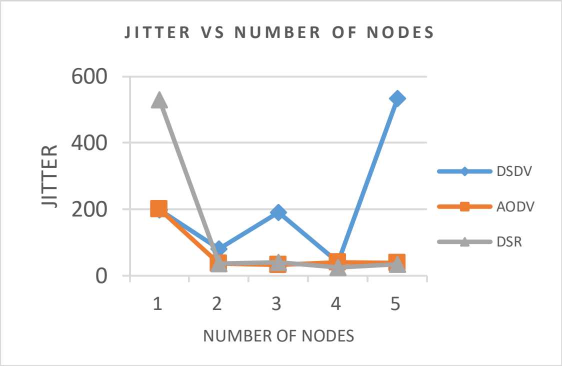
(b) Average Network Delay vs Mobility (Radom Waypoint)



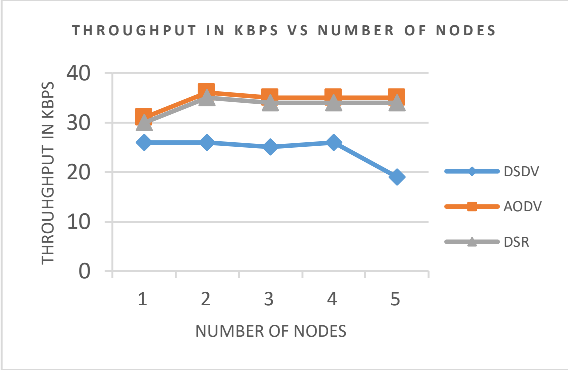
(c) Packet Delivery Ratio vs Node Density (Random Waypoint)



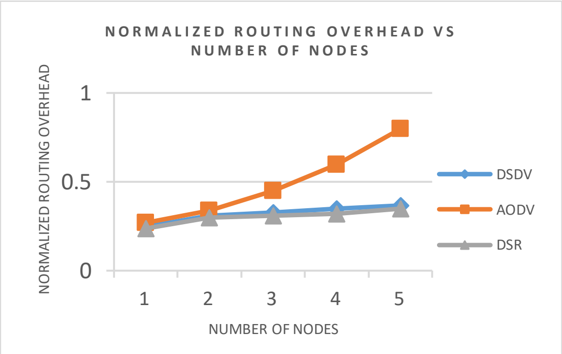
(d) Normalized Overhead Vs Node Density (Radom Waypoint)



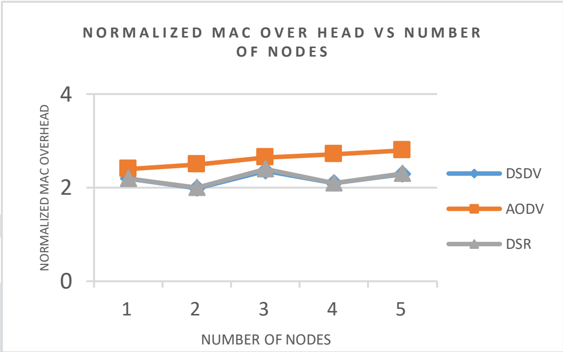
(e) Packet Jitter Vs. Number of Nodes



(f) Throughput in KBPS Vs Number of Nodes



(g) Normalized routing Overhead vs Number of Nodes



(h) Normalized Mac Overhead vs Number of Nodes

Figure-2: Varying the network size

VI. CONCLUSIONS

As it can be seen, there is a large number of different kinds of routing protocols in mobile ad-hoc networks, the use of a particular routing protocol in the mobile ad-hoc network depends upon the 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 the NS-2 simulator. The routing protocols have been compared on the basis of QoS metrics (packet delivery ratio, average end-to-end delay, throughput, jitter, normalized routing load and normalized MAC load by varying mobility speed of the nodes, network size, and the network load. Simulation results show that DSDV is a proactive routing protocol and is suitable for a limited number of nodes with low mobility due to the storage of routing information in the routing table at each node. Since DSR protocol uses source routing and route cache, byte overhead in each packet will increase whenever network topology changes.

Hence, DSR is preferable for moderate traffic with moderate mobility. For the robust scenario where mobility is high, nodes are dense, the amount of traffic is more, AODV performs better among all studied routing protocols. Thus from the simulation results, it can be concluded that for all types of networks, AODV performs optimally well not the best.

Though there are some disadvantages of this protocol, it is robust for use in mobile ad hoc networks. Our future work will include the modification to the basic AODV routing protocol so as to make it efficient in providing QoS and meet the challenges of mobile ad hoc networks.

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