Effect of Mobility on Performance of MANET Routing Protocols under Different Traffic Patterns

Baldev Ram Mali
Govt. Polytechnic College,
Jodhpur

N.C. Barwar
Jai Narain Vyas University,
Jodhpur, Rajasthan

ABSTRACT
The mobility of nodes in a mobile ad-hoc network results in frequent changes of network topology making routing in MANETs a challenging task. The primary objective of this work is 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 in terms of 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 mobility speed of nodes on MANET routing protocols. Here, NS-2 simulator is used for performing various simulations and awk scripts are used for analyzing the simulation results.

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

1. INTRODUCTION
Mobile Ad-hoc Networks (MANETs) [1][2] are autonomous self-organized networks without the aid of any established infrastructure or centralized administration (e.g., base stations or access points). Communication is done through wireless links among mobile hosts through their antennas. Due to concerns such as radio power limitation and channel utilization, a mobile host may not be able to communicate directly with other hosts in a single hop fashion. 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, each mobile host in a MANET must function as a router to discover and maintain routes to other nodes in the network.
In a Mobile Ad-hoc Network, nodes move arbitrarily, therefore the network may experience rapid and unpredictable topology changes. The topology of the mobile ad-hoc network depends on the transmission power of the nodes and the location of the mobile nodes, which may change with time. In general, Mobile Ad-hoc Networks are self-creating, self-organizing, and self-administrating networks.
Ad-hoc networks have several advantages compared to traditional cellular systems. These advantages include on demand setup, fault tolerance, and unconstrained connectivity. Mobile Ad-hoc Networks offer unique benefits and flexibility for a variety of situations and applications. Because of these features, 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.
A fundamental problem in ad-hoc networking is how to deliver data packets among mobile nodes efficiently without predetermined topology or centralized control, which is the main objective of ad hoc routing protocols. Dynamic topology, asymmetric links, routing overhead, and interference are challenges that make routing in mobile ad-hoc networks a difficult task. Moreover, bandwidth, energy and physical security are limited.
The various mobile ad-hoc routing protocols have been proposed and have their unique characteristics. Hence, in order to find out the most adaptive and efficient routing protocol for the highly dynamic topology in ad-hoc networks, the routing protocols behaviour has to be analysed with varying node mobility speed and network load under different traffic patterns.

2. MOBILE AD-HOC NETWORK 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)
Destination Sequenced Distance Vector [3] [13] is a loop free routing protocol in which the shortest-path calculation is based on the Bellman-Ford algorithm. Each node in the network maintains routing table which contains all available destinations with associated next hop towards destination, metric and destination sequence number. 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. The protocol has three main attributes: to avoid loops, to resolve the “count to infinity” problem, and to reduce high routing overhead.
Routing tables are updated by exchanging the information between mobile nodes. 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. DSDV takes into account only bidirectional links between nodes.

2.2 Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [11] is an on-demand routing protocol, which is based on the concept of source-based routing rather than table-based. This protocol is source-initiated rather than hop-by-hop. DSR is a simple reactive protocol, its key feature is that it is a pure on demand protocol, i.e. it does not employ any periodic exchange of packets. DSR does even employ beacon packets like some other on demand protocols. Consequently, 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.

Both route discovery and route maintenance mechanisms are implemented in an ad-hoc fashion and in the absence of any kind of periodic control messages. The main concept of the protocol is "source routing", in which nodes place the route that the packet must follow from a source to a destination in the header of a packet. 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. The protocol is designed for a MANET of up to two hundreds nodes with high mobility rates and is loop-free. Other important attribute of this protocol is its support for unidirectional links.

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

Ad-hoc On-demand Distance Vector [12] is a reactive routing protocol, 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. In this way, the designers of AODV tried to minimize the routing overhead in the network caused by the frequent generation of routing control messages.

AODV uses source and destination sequence numbers to avoid both "loops" and the "count to infinity" problems that may occur during the routing calculation process. All routing packets carry these sequence numbers.

AODV shares on-demand behaviour with DSR; however 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 has ability to interconnect nodes in a "Pure" MANET running AODV with other non-AODV routing domains, thus extending any network with fixed infrastructure to a network with both mobile wireless nodes and static nodes, e.g., Ethernet. 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 mobility speed 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 I
Simulation Parameters for CBR / TCP Traffic Pattern
(Varying mobility speed)

Parameters	Value
Routing Protocols	DSDV,AODV, and DSR
Number of nodes	50
Maximum speed of nodes	10,20,30,40 and 50 m/sec.
Simulation area	1000 m X 1000m
Traffic pattern type	CBR or TCP
Packet size	512 bytes
Packet rate	4 packets/sec.
Simulation time	500 seconds
Pause time	100 seconds

3.1 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 fraction of all routing control packets sent by all nodes over the number of received data packets at the destination nodes. This metric discloses how efficient the routing protocol is. Proactive protocols are expected to have a higher normalized routing load than reactive ones. The bigger this fraction is the less efficient the protocol.

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 mean deviation of the difference in packet spacing at the receiver compared to the sender, for a pair of packets, if S_i is the time packet i was sent from the sender, and R_i is the time it was received by the receiver, the jitter of packet i is given by: $\mathbf{J_i = |\,(R_{i+1} - S_{i+1}) - (R_i - S_i)\,|}$

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) in any kind traffic pattern i.e. either CBR (Fig. 1) or TCP (Fig. 2).

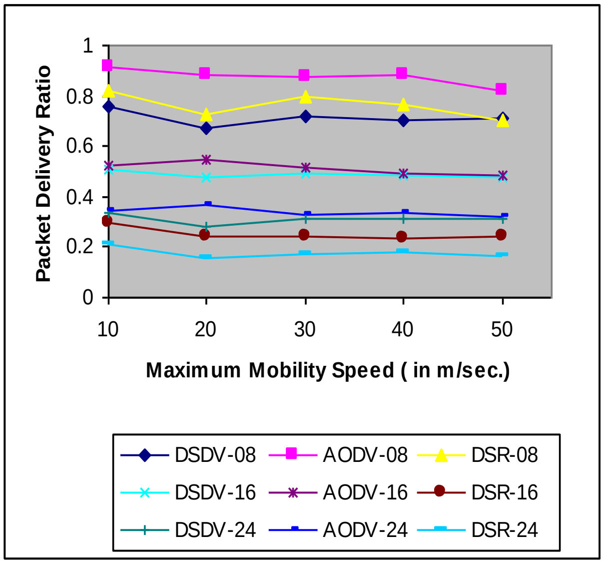

Fig. 1 Packet Delivery Ratio for CBR Traffic (Increasing mobility speed)

As shown in figure 1, it is observed that in this case of CBR traffic, with lower number of sources (08) and low mobility speed AODV has higher packet delivery ratio (approx. 90%), DSR has packet delivery ratio (approx. 80%) and DSDV has lowest value of packet delivery ratio (approx. 70%). But packet delivery ratio starts degrading gradually when there is increase in number of sources and mobility speed of nodes. At higher number of sources and high mobility speed DSR has lowest packet delivery ratio.

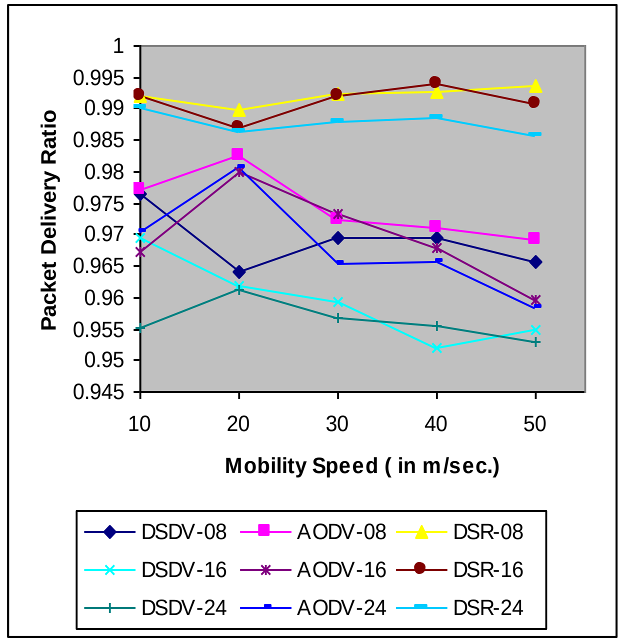

Fig. 2 Packet Delivery Ratio for TCP Traffic (Increasing mobility speed)

Fig. 2 depicts that for TCP traffic pattern, both DSR and AODV have higher packet delivery ratio approx. 99%, and 97% respectively. DSDV has lowest packet delivery ratio (approx. 96%) amongst these three protocols. 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. Packet delivery ratio of all these protocol slightly decreases as mobility speed increases when other parameters remain unchanged.

For TCP traffic pattern, packet delivery ratio of all these protocol is higher than packet delivery ratio of these protocols in CBR traffic pattern for the same value of simulation parameters. As the number of sources increases, packet delivery ratio of all these protocol decreases very slowly in TCP traffic as compared to CBR traffic.

4.2 Average End-to-End Delay

It is observed from the figure 3 that for CBR traffic, DSR 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 when number of sources is less. It increases as the number of sources and mobility speed increases.

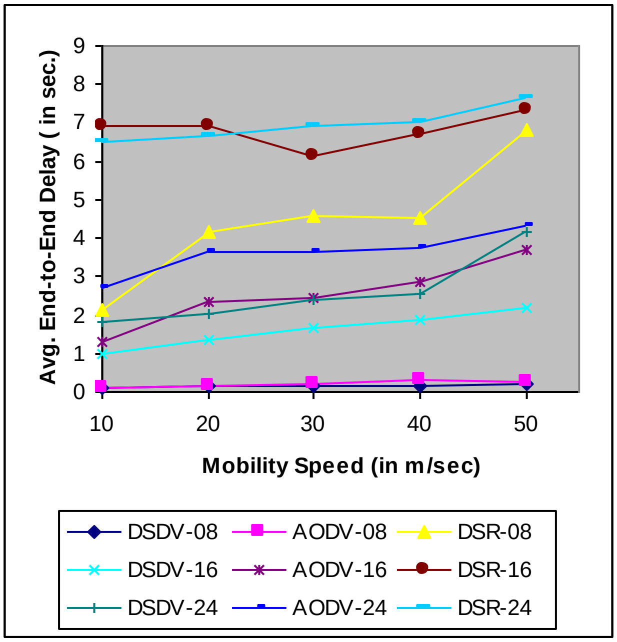

Fig. 3 Avg. End-to-End Delay for CBR Traffic (Increasing mobility speed)

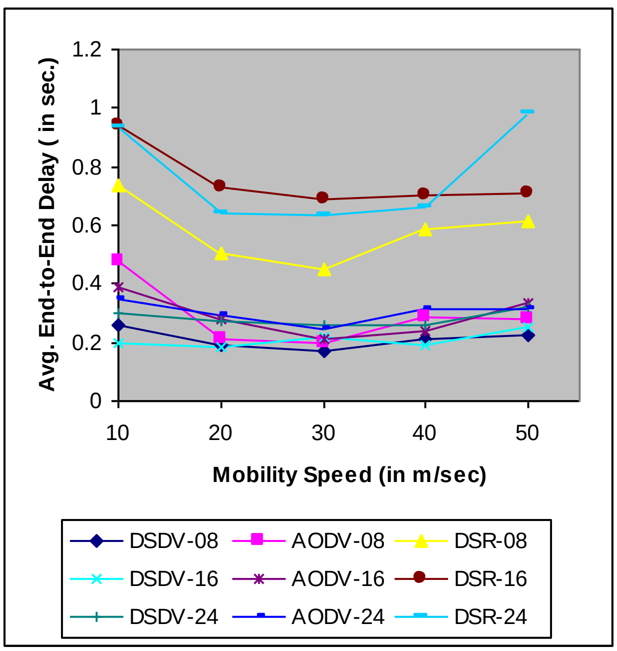

Fig. 4 Avg. End-to-End Delay for TCP Traffic (Increasing mobility speed)

As shown in figure 4, in case of TCP traffic average end-to-end delay of proactive routing protocol (DSDV) is less as compared to reactive routing protocols (AODV and DSR). The DSR 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. Initially end-to-end delay of all these protocols is decreases with increase in mobility speed (approx. up to 30 m/sec.), then it is increases with increase in mobility speed.

4.3 Normalized Routing Load

Fig. 5 shows that for CBR traffic, DSR has the lowest normalized routing load, and then AODV and DSDV are in order. The DSDV has the highest normalized routing load. This is a direct result of the DSDV's proactive behaviour.

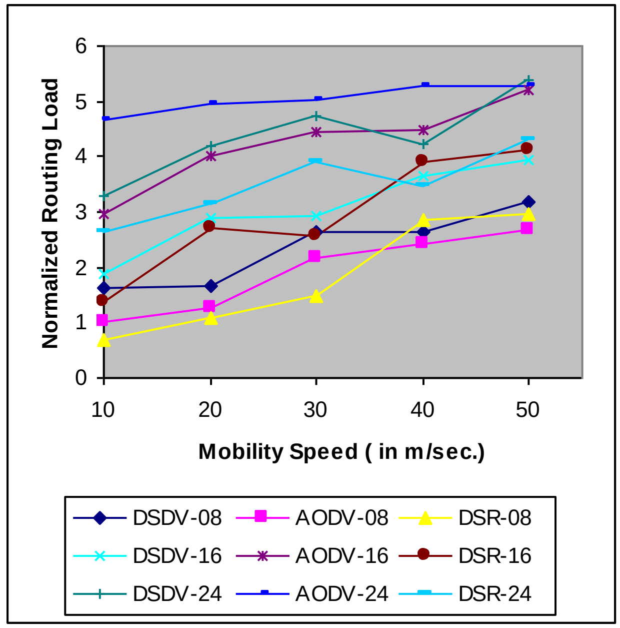

Fig. 5 NRL for CBR Traffic (Increasing mobility speed)

When number of sources is less (approx. 10 sources) AODV performs better than DSDV but as number of sources increases normalized routing load of AODV becomes more than normalized routing load of DSDV. The reason for this is that AODV is on demand routing protocol so as the number of sources increases the number of routing packets also increases.

Normalized routing load of DSR increases slowly with increasing number of sources (the number of connections in the network) due to its cashing mechanism at the source and intermediate nodes. It is more likely to find routes in its cache which results in lesser number of routes discovery requests then other protocols. The normalized routing load of these three protocols increases as the mobility speed increases.

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

Normalized routing load of DSR increases slowly with increasing number of sources (the number of connections in the network) due to its cashing mechanism at the source and intermediate nodes.

In TCP traffic pattern, normalized routing load of all these protocol is very low as compared to normalized routing load of these protocols in CBR traffic pattern for the same value of simulation parameters.

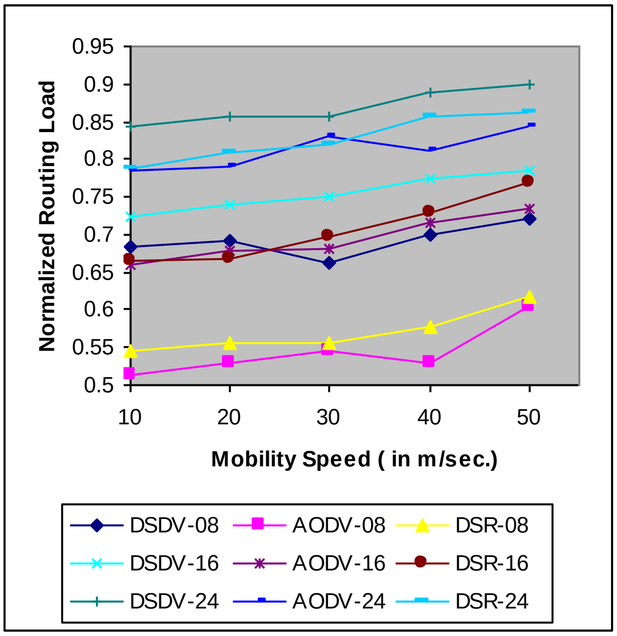

Fig. 6 NRL for TCP Traffic (Increasing mobility speed)

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. Each protocol's curve fluctuates around some similar values, and average jitter of all these protocol is slightly increases as mobility speed increases.

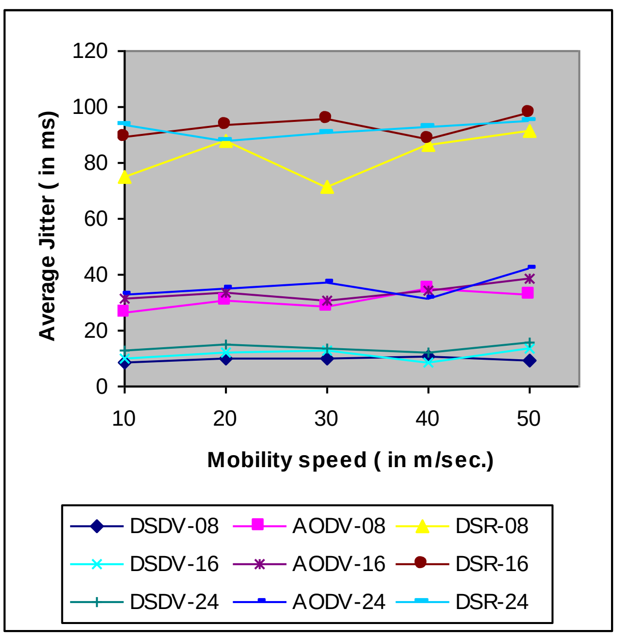

Fig. 7 Average Jitter for CBR Traffic (Increasing mobility speed)

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

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.

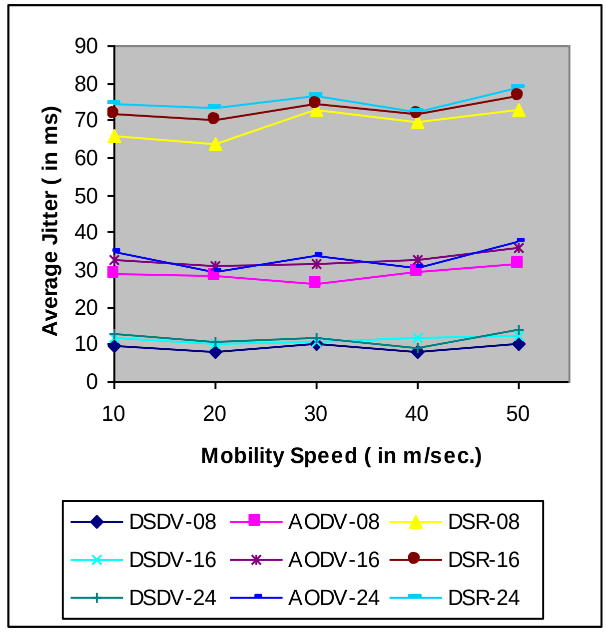

Fig. 8 Average Jitter for TCP Traffic (Increasing mobility speed)

5. CONCLUSIONS & FUTURE WORK

This study work was carried out 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 using NS-2 simulator. These routing protocols were compared in terms of packet delivery ratio, average end-to-end delay, normalized routing load, and average jitter when number of sources and mobility speed of nodes varied. From the simulation results, it is found that overall performance of reactive protocols is better than proactive protocols. In case of CBR traffic, for application oriented performance metrics such as packet delivery ratio and average end-to-end delay AODV outperforms DSR. At large number of sources and high mobility speed, DSR has the lowest packet delivery ratio amongst these three protocols.

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 mobility is high.

For all these protocols, performance metrics- packet delivery ratio, average end-to-end delay, normalized routing load, and average jitter are degrade as number of sources and mobility speed of nodes increases.

In case of 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 mobility speed of nodes 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.

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