Performance Analysis of MANET Routing Protocols in Different Mobility Models

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***Abstract*-Ad Hoc Networks are multi - hop wireless networks with dynamically changing network connectivity owing to mobility. The protocol suite includes several routing protocols designed for ad-hoc routing. The most widely used ad hoc routing protocols are AODV DSDV, DSR and TORA. In this paper, the three random based mobility models such as Random waypoint, Random walk and Random Directions are implemented. The two different parameter constraints like packet-delivery fraction and End-to-end packet delivery delay are compared with respect to mobility speed, Traffic and Network size. The simulation results shows that the AODV protocols in Random Waypoint mobility model performs better than DSDV, TORA and DSR in Random walk and random Direction mobility model. .**

***Keywords*- Mobile Ad Hoc Networks, Mobility Models, AODV, DSDV, TORA, DSR**

I. INTRODUCTION

A mobile ad hoc network (MANET) is an autonomous system of mobile hosts connected by wireless links. MANETs are self-organizing, self-forming, self-maintained and self-healing networks that do not require a fixed infrastructure. Two nodes communicate directly if they are in the transmission range of each other. Otherwise, they reach via a multi-hop route. Each MANET node must therefore be able to function as a router to forward data packets on behalf of other nodes . Because of their unique benefits and versatilities, MANETs have a wide range of applications such as collaborative, distributed mobile computing (e.g., sensors, conferences), disaster relief (e.g., flood, earthquake), war front activities and communication between automobiles on highways. Most of these applications demand multicast or group communication.

The main aim of this paper is :

- To acquire the detailed understanding of ad hoc routing protocols
- To implement the Mobility models
- To analyze the performance differentials of routing protocols under mobility.

The organization of the paper is as follows.-In Section 2 the major mobile Ad hoc routing protocols used in this evaluation study are discussed. Section 3 discusses the Random models used in this analysis. The simulation results, followed by their interpretations are presented in section 4. The results obtained in this simulation are discussed in section 5. Based on the analysis, Section 6 presents the conclusions.

II. MOBILE AD-HOC NETWORKING PROTOCOLS

The main problem with ad-hoc network is that how to send a message from one node to another without any direct link. The nodes in the network are moving around unpredictably, and it is very challenging to find which nodes are directly linked together. In order to facilitate communication within the network, a routing protocol is used to discover routes between nodes. As shown in Figure 2 below, these routing protocols may generally be categorized as: (a) table-driven and (b) source-initiated on-demand driven. Solid lines in this figure represent direct descendants while dotted lines depict logical descendants. Despite being designed for the same type of underlying network, the characteristics of each of these protocols are quite distinct.

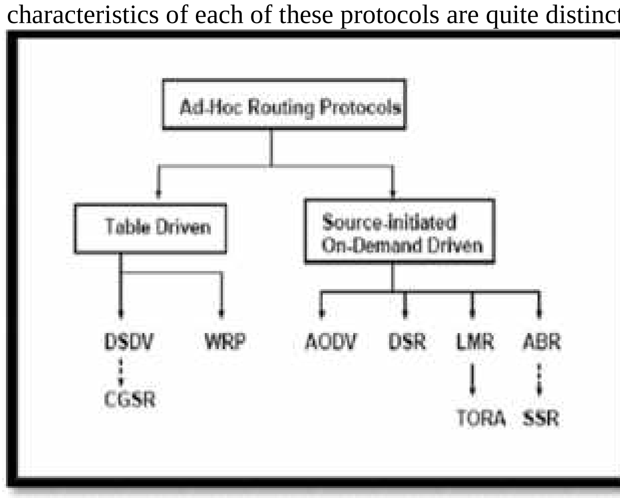


Fig 2. Categorization of Ad-hoc routing Protocol

A. Table-Driven Routing Protocols

The table-driven routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. These protocols require each node to maintain one or more tables to store routing information, and they respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent network view.

*1)Destination-Sequenced Distance-Vector Routing (DSDV):*DSDV is a table-driven algorithm based on the classical Bellman-Ford routing mechanism. Every mobile node in the network maintains a routing table in which all of the possible destinations within the network and the number of hops to each destination are recorded

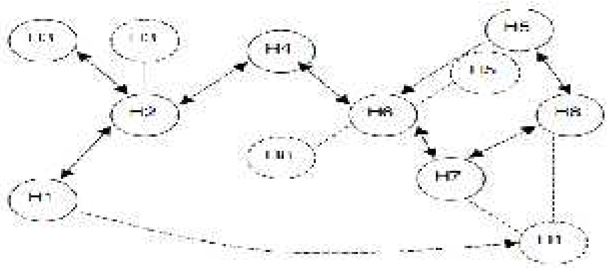


Table I . The routing table of node H6 at one instant

Dest	Next Hop	Metric	Seq.No.	Install
H1	H4	3	S406_H1	T001_H6
H2	H4	2	S128_H2	T001_H6
H3	H4	3	S564_H3	T001_H6
H4	H4	1	S710_H4	T002_H6
H5	H7	3	S392_H5	T001_H6
H6	H6	0	S076_H6	T001_H6
H7	H7	1	S128_H7	T002_H6
H8	H7	2	S050_H8	T002_H6

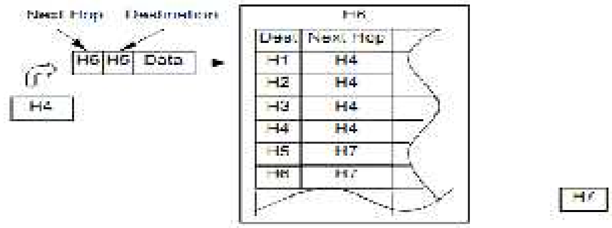
Figure 3 shows an example of an ad hoc network before and after the movement of the mobile nodes. Table I is the routing table of the node H6 at the moment before the movement of the nodes.

2) The Wireless Routing Protocol (WRP): WRP is a table-based protocol with the goal of maintaining routing information among all nodes in the network. Each node in the network is responsible for maintaining four tables: (a) distance table, (b) routing table, (c) link-cost table, and (d) message retransmission list (MRL) table.

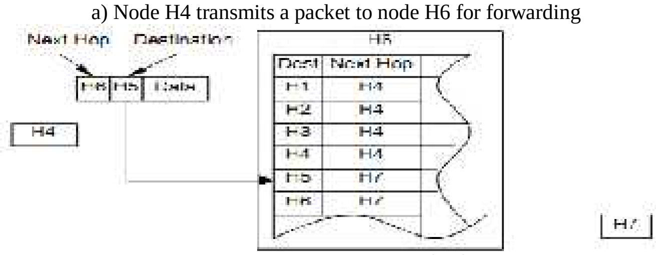
B. Source-Initiated On-Demand Routing

A different approach from table-driven routing is source-initiated on-demand routing. This type of routing creates 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. This process is completed once a route is found or all possible route permutations have been examined.

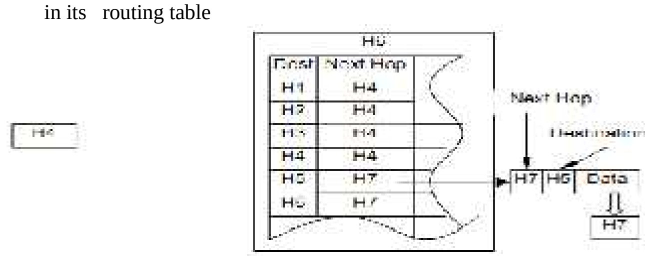
1) Ad-hoc On-Demand Distance Vector Routing (AODV): AODV routing protocol builds on the DSDV algorithm previously described.When a source node desires to send a message to some destination node and does not already have a valid route to that destination, it initiates a Path Discovery process to locate the other node. It broadcasts a route request (RREQ) packet to its neighbors, which then forward the request



a) Node H4 transmits a packet to node H6 for forwarding



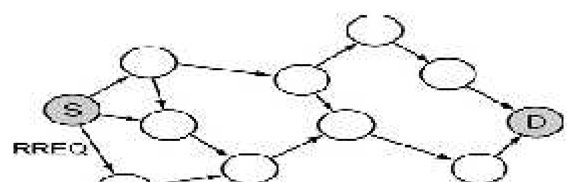
b) Node H6 looks up the destination and route for forwarding the packet in its routing table



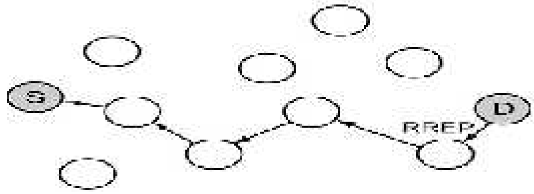
c) Node H6 forwards the packet to the next hop

Fig. 3 DSDV packet routing example

to their neighbors, and so on, until either the destination or an intermediate node with a “fresh enough" route to the destination is located(see Fig 4(a)). Once the RREQ reaches the destination or an intermediate node with a fresh enough route, the destination/intermediate node responds by unicasting a route reply (RREP) packet back to the neighbor from which it first received the RREQ(see fig.4(b)).



(a) Source node S initiates the path discovery process.



(b) A RREP packet is sent back to the source.

Fig. 4 AODV Path Discovery Process.

Route maintenance process is shown in fig. 5

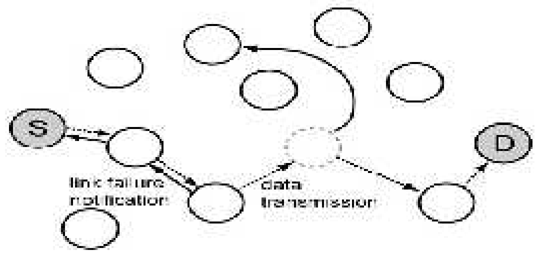
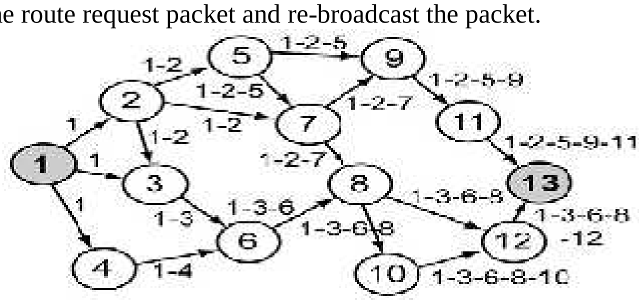


Fig 5 AODV Route Maintenance by using Link Failure Notification Message

2) Dynamic Source Routing (DSR): DSR protocol is an on-demand routing protocol that is based on the concept of source routing. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is aware. Entries in the route cache are continually updated as new routes are learned. The protocol consists of two major phases: route discovery and route maintenance.

During the route discovery process, the route record field is used to accumulate the sequence of hops already taken. First of all the sender initiates the route record as a list with a single element containing itself. When a host receives a route request packet, it is important to process the request in the order described below

1. If the pair < source node address, request_id > is found in the list of recent route requests, the packet is discarded.
2. If the host's address is already listed in the request's route record, the packet is also discarded.
3. If the destination address in the route request matches the host's address, the route record field contains the route by which the request reached this host from the source node.
4. Otherwise, add this host's address to the route record field of the route request packet and re-broadcast the packet.

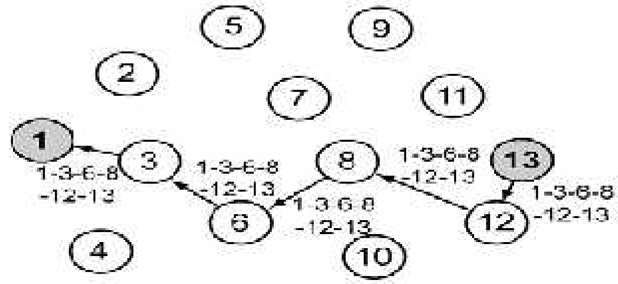


(a) Building of the route record.

Route maintenance can be accomplished by two different processes:

- Hop-by-hop acknowledgement at the data link layer
- End-to-end acknowledgements

Hop-by-hop acknowledgement at the data link layer allows an early detection and retransmission of lost or corrupt packets.
End-to-end acknowledgement may be used, if wireless transmission between two hosts does not work equally well in both directions.



(b) Propagation of the route reply.

Fig 6 DSR Route Discovery Process.

3) Temporally-Ordered Routing Algorithm (TORA): TORA is a highly adaptive, loop-free, distributed routing algorithm based on the concept of link reversal. The key design concept of TORA is the localization of control messages to a very small set of nodes near the occurrence of a topological change The protocol performs three basic functions: (a) route creation, (b) route maintenance, and (c) route erasure.

During the route creation and maintenance phases, nodes use a "height" metric to establish a directed acyclic graph (DAG) rooted at the destination. Thereafter, links are assigned a direction (upstream or downstream) based on the relative height metric of neighboring nodes. see Fig 7

In times of node mobility, the DAG route is broken and route maintenance is necessary to re-establish a DAG rooted at the same destination.

4) Associativity-Based Routing (ABR) : ABR protocol is free from loops, deadlock, and packet duplicates, and defines a new routing metric for ad-hoc mobile networks. This metric is known as the degree of association stability. The three phases of ABR are: (a) route discovery, (b) route re-construction (RRC), and (c) route deletion.
The route discovery phase uses broadcast query BQ messages and an await reply BQ_REPLY messages. Each BQ message has a uniquely identifier. A source node desiring a route to destination broadcasts the network with BQ messages.

An intermediate node that receives the query first checks if they have processed the packet: if yes query packet will be discarded, otherwise check if the node is the destination. If not intermediate nodes appends the following information before broadcasting the BQ message:

- its address
- the associativity ticks with its neighbors
- the route relaying load
- the link propogation delay
- the hop counts information

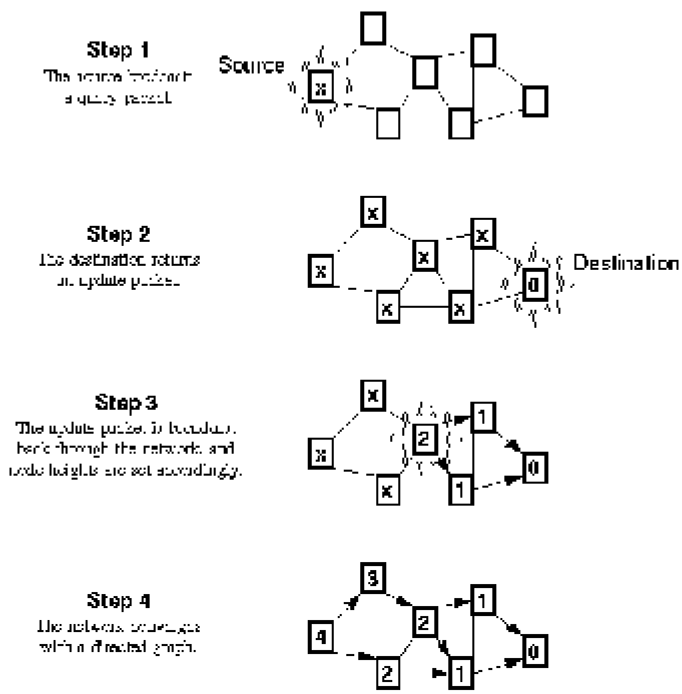


Fig 7 *Generation of an ordered graph in TORA.*

When one of the source, destination or intermediate nodes moves the route reconstruction operation start.
Route reconstruction phase includes:

- Partial Route Discovery
- Invalid Route Deletion
- Valid Route Updates
- New Route Discovery

Route deletion phase is used when a source no longer requires a route and it consists of a route delete RD broadcast from source node to all intermediate nodes.

5) Signal Stability Routing (SSR): Unlike the algorithms described so far, SSR selects routes based on the signal strength between nodes and on a node's location stability. This route selection criteria has the effect of choosing routes that have "stronger" connectivities. SSR can be divided into two cooperative protocols: the Dynamic Routing Protocol (DRP) and the Static Routing Protocol (SRP).

III. MOBILITY MODELS

The mobility model[8] plays a very important role in determining the protocol performance in mobile Ad Hoc Network. Hence, this work is done using the random mobility models like Random Waypoint, Random Walk and Random Direction. These models with various parameters reflect the realistic traveling pattern of the mobile nodes. The following are the three models with the traveling pattern of the mobile nodes during the simulation time.

A. Random Waypoint

The Random Way Point Mobility Model includes pauses between changes in direction and/or speed. A Mobile node (MN) begins by staying in one location for a certain period of time (i.e. pause). Once this time expires, the mobile node chooses a random destination in the simulation area and a speed that is uniformly distributed between [min-speed, max-speed]. The mobile node then travels toward the newly chosen destination at the selected speed. Upon arrival, the mobile node pauses for a specified period of time starting the process again. The movement trace of a mobile node using the Random Way-point model is shown in figure 8

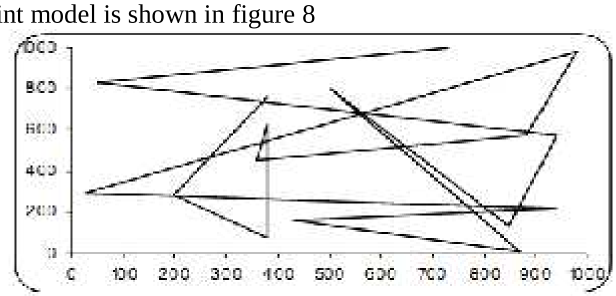


Fig 8. Node Movement in Random Way Point

B. Random Walk

In this mobility model, a mobile node moves from its current location to a new location by randomly choosing a direction and speed in which to travel. The new speed and direction are both chosen from pre-defined ranges, [min-speed, max-speed] and [0,2*pi] respectively. Each movement in the Random Walk Mobility Model occurs in either a constant time interval 't' or a constant traveled 'd' distance, at the end of which a new direction and speed are calculated. The movement trace of a mobile node using the Random Walk model is shown in figure 9

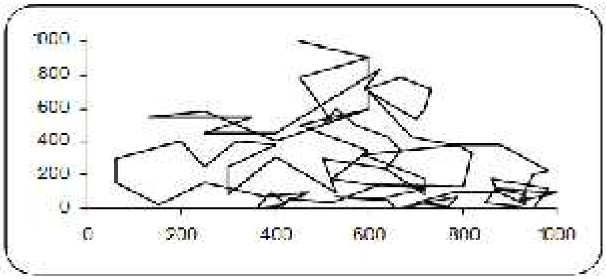


Fig. 9 Node Movement in Random Walk

C. Random Direction

A mobile node chooses a random direction in which to travel similar to the Random Walk Mobility Model. The node then travels to the border of the simulation area in that direction. Once the simulation boundary is reached, the node pauses for a specified time, chooses another angular direction (between 0 and 180 degrees) and continues the process. The movement trace of a mobile node using the Random Direction model is shown in figure 10

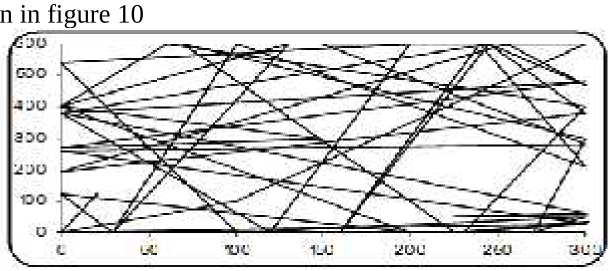


Fig. 10   Node Movement in Random Direction

IV. PERFORMNCE RESULTS

This section discusses the various predominance metrics used and the Performance differentials analyzed. The metrics used to measure the performance of routing protocols are :

Packet delivery ratio: The ratio of the number of packets originated by the application layer CBR sources to the number of packets successfully delivered to their CBR sink at the final destination.

Normalized routing overhead: It is the number of control packets transmitted per data packet received at the destination.

The protocols considered for analysis are AODV, DSDV, TORA and DSR.

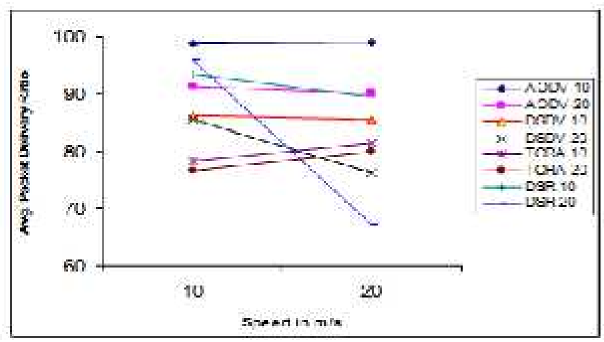
A. Speed vs Packet Delivery Fraction

The Performance of the routing protocols in terms of packet delivery ratio is examined with respect to the mobility of nodes. The simulation results are shown in the figure 11.

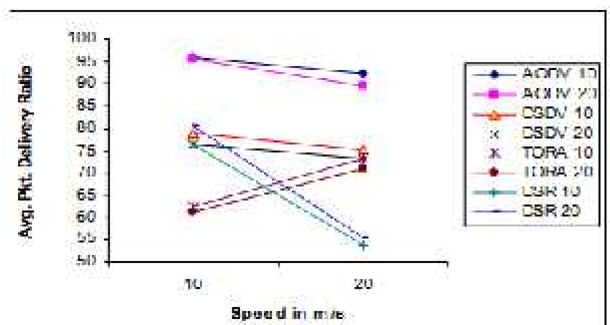
In Random Way point model, packet delivery ratios produced by all the protocols are very close when the speed is low. The slight difference in the ratio is produced for with 10 connections and 20 connections. When the speed is increased to 20 m/s. the packet delivery ratio s produced by the protocols differ sharply and this difference becomes more with 20 connections. In the case of Random walk and and Random Direction mobility models, the packet deli-very ratio differ heavily for lower mobility and higher mobility.

B. Traffic vs Packet Delivery Fraction

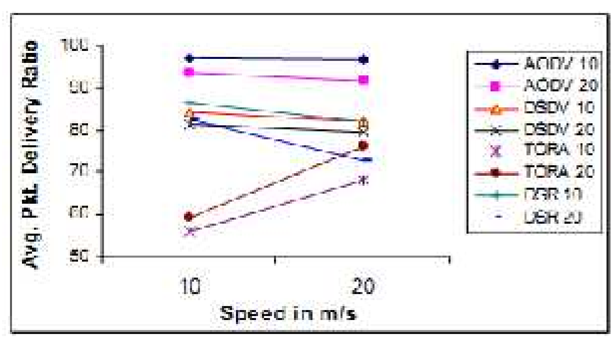
The performance of the routing protocols in terms of packet delivery ratio is examined with respect to traffic load. The simulation results are shown in the figure 12.



a) Random way Point



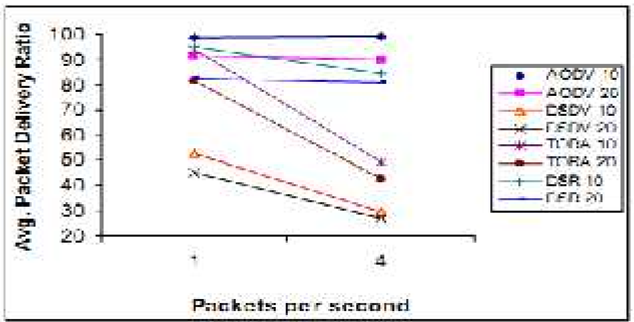
b) Random Walk



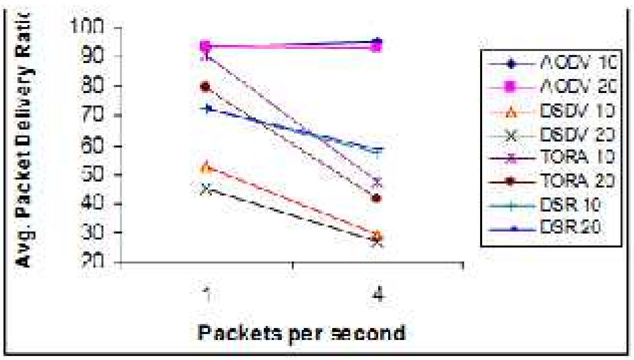
c) Random Direction

Fig. 11   Packet Delivery Fraction for varying speed

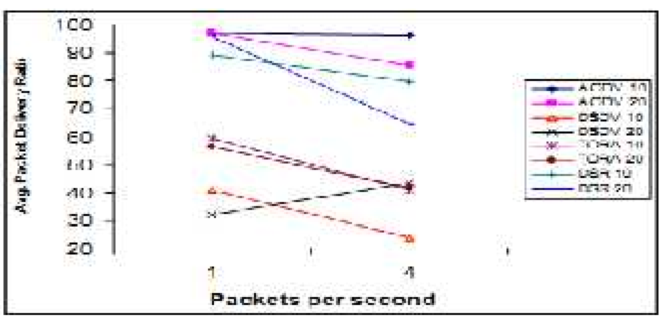
The packet delivery ratios obtained from the simulation sharp decrease when the number of packets is increased from 1 to 4 and number of connections is increased from 10 to 20. The differences in packet delivery ratios produced by the routing protocols are very less in Random Waypoint mobility model. Larger differences in packet delivery ratio are obtained in Random walk and random Direction mobility models.



a) Random way Point



b) Random Walk



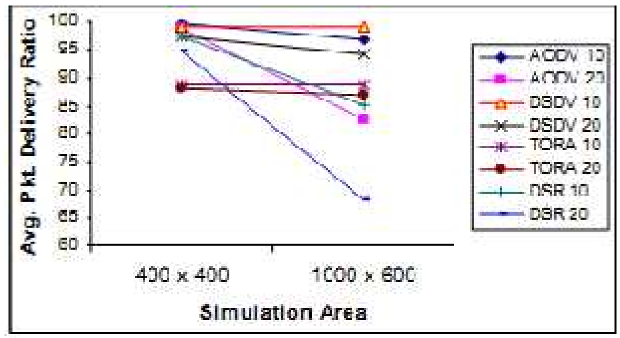
c) Random Direction

Fig. 12 Packet Delivery Fraction for varying number of sources

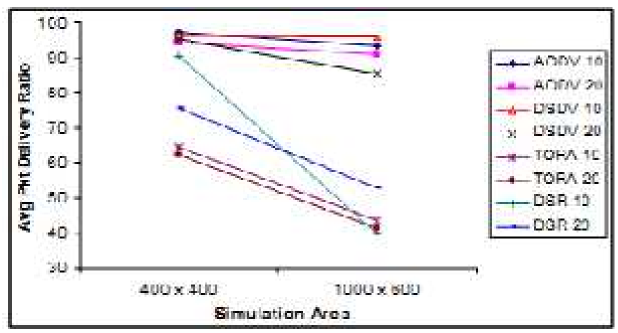
C. Node density Vs Packet Delivery Fraction

The performance of the Routing protocols in terms of packet delivery ratio is examined with respect to the area in which the nodes are likely to move. Packet delivery ratios are considered for 10 connections and 20 connections traffic density. The simulation results are shown in the figure 13.

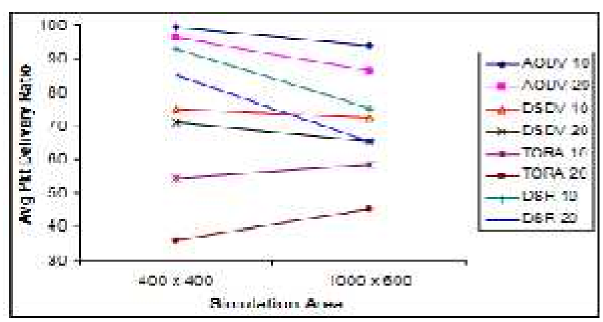
In this a higher packet delivery ratio for higher density of nodes and decreases when the when the node density becomes sparse. In Random waypoint mobility model AODV produces higher packet delivery ratio and DSDV, TORA, and DSR produces lower packet delivery ratio.



a) Random Way Point



b) Random Walk



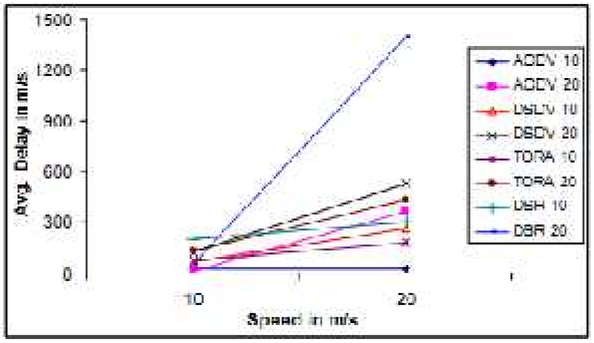
c) Random Direction

Fig. 13 Packet Delivery Fraction for Varying Network Size

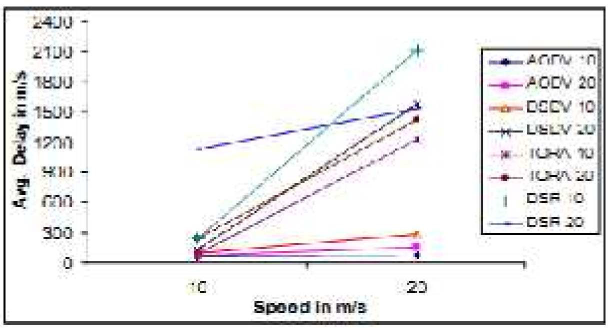
D. Speed vs End-to-End Delay

The performance of the routing protocols in terms of End-to-End Delay is examined with respect to mobility of the nodes. End-to-end delay are considered for 10 connections and 20 connections traffic density. The results are shown in the figure 14.

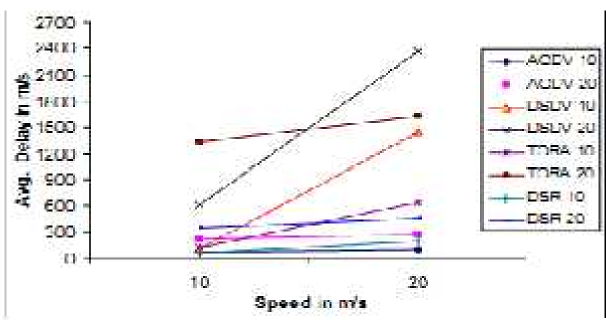
With Random waypoint and Random direction mobility models all the The protocols in random waypoint takes less time to deliver the packets compared to Random walk and Random Direction mobility model. The difference in time used by DSDV, TORA and DSR is very high in Random Walk and Random Direction, but its not so high in Random waypoint.



a) Random Way Point



b) Random Walk



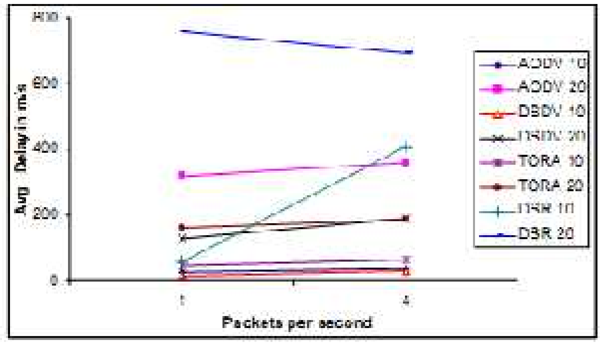
c) Random Direction

Fig. 14 End-to-End Delay for varying speeds

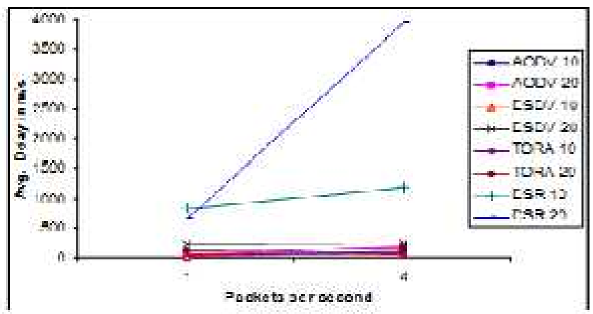
E. Traffic vs End-to-End Delay

The performance of the routing protocols in terms of End-to-End Delay is examined with respect to traffic load. End-to-end delay are considered for 10 connections and 20 connections traffic density scenarios. The simulation results are shown in the figure 15.

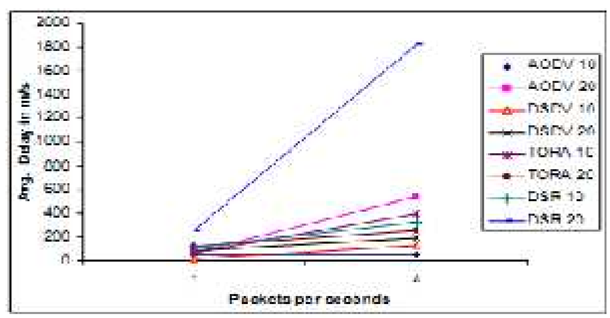
In all mobility models the routing protocols consume less time to deliver packets with 10 connections and 1 packets per second/connections protocols. More time is spend to deliver packets when the number of packets and connections are increased. AODV spends much lesser time than other protocols under random walk and Random direction mobility models



a) Random Way Point



b) Random Walk



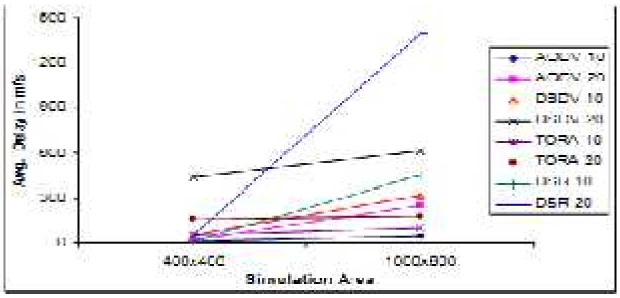
c) Random Direction

Fig. 15 End-to-end delay for Traffic load

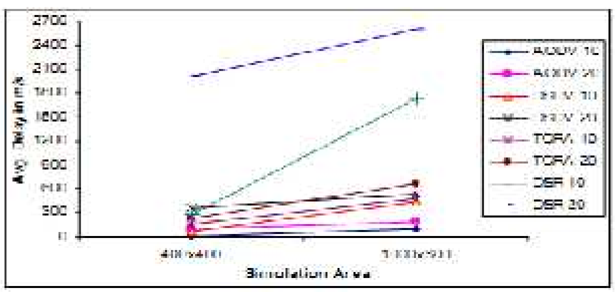
F. Node Density vs End-to-End Delay

The performance of the routing protocols in terms of end-to-end delay is examined with respect to the area with in which the nodes are likely to move. Two traffic density scenarios are considered- one with 10 connections and another with 20 connections. The results are shown graphically in figure 16.

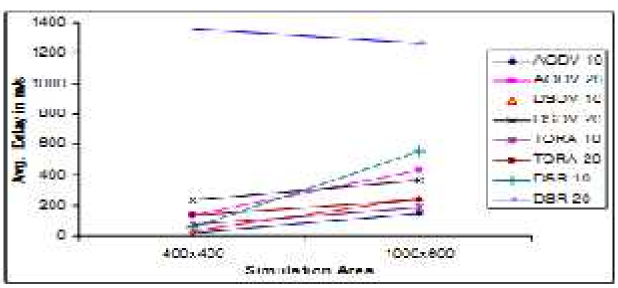
The end-to-end delay is very less with higher node density and increases heavily when the node becomes sparse. For the varying node density the end-to-end delay produced by the protocols in Random waypoint is very less and very high in Random walk and Random Direction Model.AODV in Random Way point model Performs better than other mobility models



a) Random Way Point



b) Random Walk



c) Random Direction

Fig. 16 End-to-end delay for node Density

V. DISCUSSION

In Random Waypoint model, most of the times the nodes choose destination closer to the centre of the simulation area and thus producing a dense wave near the centre and stays back there for the specified pause time, also having more neighbors to the nodes in the centre. This will give minimal hop distance between the source-destination pairs.

The Random Walk model creates a high mobility scenario with larger travel time the nodes will travel almost to all the areas. Since there is no pause time between change of speed and direction, the need for a protocol that updates the routing information quickly as uses the fresh information about the routing becomes mandatory.

The Random Direction Model is an unrealistic model because it is unlikely that people would spread them-selves evenly throughout an area. The nodes choose pause times only at the boundaries and no change of speed and direction before reaching the boundary. This will create a topography in which most of the times most of the nodes are in the boundary and the centre of the area becomes very sparse. Here theaverage number of hop distance becomes higher and gives lesser number of alternative paths

VI. CONCLUSION

In Random way point model the simulation results shows that when the network becomes sparse or the traffic load becomes high the performance produced by DSR and TORA decreases sharply. DSDV protocol's performance is closer to AODV under network size metric.TORA protocol's performance was not so good under this mobility model. Hence, AODV protocol can be chosen as the routing protocol in this type of mobility conditions.

In random walk model, AODV performs better than DSR, TORA and DSDV because the average hop distance between the source-destination becomes high in AODV, and this will increase packet overhead. So AODV protocols perform better under low and high mobility conditions.

The Random Direction Model produces better results than DSDV, TORA and DSR. When the network size is large, DSDV produces better results than TORA and DSR. This shows that AODV is the suitable choice under this mobility model.

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