Performance Evaluation of MANET Routing Protocols under Varying Node Mobility

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Abstract Mobile ad hoc network (MANET) is an autonomous system containing a cluster of mobile nodes which can dynamically change their network topology. It requires no pre-existing fixed network infrastructure or centralized administration. It operates in a standalone fashion. All the mobile nodes in the network are connected by wireless links. These nodes are free to move anywhere and organize themselves into a network. Each node behaves as a router and should therefore forward packets to other nodes in the network. For this purpose, a routing protocol is needed. Mobile ad-hoc network has certain characteristics such as dynamic topology that inserts new demands on the routing protocol which often limits resources such as storage capacity of CPU, battery power and bandwidth. Mobility models emulate the realistic conditions and dictate the movement of nodes. This paper aims to evaluate the performance and compare the three MANET routing protocols AODV, DSR and DSDV in different mobility conditions while varying pause time and node density. Three mobility models included are Random Waypoint, Random Walk and Random Direction. Lastly, we present simulation results that illustrate how the performance of a MANET protocols drastically change, as a result of changing the mobility taking Throughput, Average End-End Delay, Packet Delivery Ratio and Normalized Routing Load as differentials. The conclusion, which routing protocol is best in each of the varying mobility is also stated. Simulations are carried out using Ns2.

Key Words: MANET, AODV, DSDV, DSR, Mobility

I. INTRODUCTION

A wireless network is an emerging technology that allows the users to access the information electronically, irrespective of their geographic location. Wireless networks are broadly classified into two types namely Infrastructured network and Infrastructure less i.e. Adhoc network [3].

Infrastructured network is a network with fixed and wired gateways. A mobile host interacts with a bridge called base station in the network within its communication distance [1]. The mobile unit can move geographically while in communication with base station. When the mobile unit goes out of range of a specific base station, it then connects with a new base station and starts communicating through it. This is called handoff. In this approach the base stations are fixed.

A Mobile ad hoc network contains wireless nodes in which they form an arbitrary topology forwarding packets to each other allowing them to communicate with the nodes outside the direct range of wireless transmission. Ad hoc networks have no fixed network infrastructure such as base stations or access points and no centralized administration [2]. The Major challenge involved is each device has to maintain the information continuously, required to properly route the traffic.

This work aims to evaluate the performance of MANET routing protocols [4] AODV, DSR and DSDV and compare them in different mobility conditions. Finally proposing which routing protocol is best under each of varying mobility conditions. As per our results the differences in the protocol mechanism lead to significant performance variation.

This paper is organized as follows. Section II gives the description of MANET routing protocols. Section III discusses mobility models. Simulation environment and performance metrics parameters are described in Section IV. Results of our simulation are discussed in Section V. Finally, our conclusions from this study are listed.

II. MANET ROUTING PROTOCOLS

To compare and analyze mobile ad-hoc network routing protocols [4, 7], suitable classification methods are important. Based on the infrastructure of the network they are classified into flat, hierarchical and geographical assisted routing. Flat routing covers two types of routing protocols based on their routing algorithms i.e.

Proactive and Reactive protocols.

In order to assist communication within the network, a routing protocol is necessary. The main goal of such an ad-hoc network routing protocol is accurate and efficient route establishment between nodes enabling the messages to be delivered in a timely manner. The important parameters involved in route construction are a minimum of overhead and bandwidth consumption. An Ad-hoc routing protocol is a standard that dictates how nodes come to consent with one other to route packets between computing devices in a network [30]. In ad hoc networks, nodes do not have any prior knowledge of the network topology around them, they have to determine it. The nodes in the network discover the nodes that are nearby and the ways to reach them, hence announce them that it can reach those nodes. Each node knows about all other nodes with time.

AODV

The Ad-hoc On-Demand Distance Vector (AODV) routing protocol is an on demand routing protocol, but it is different to DSR as it is not a source based routing scheme. It rather maintains the information of every hop of a route and the next hop information by its own [30]. Its Operation is basically divided into two functions, one is route discovery and the other one is route maintenance. First step is that all the nodes send Hello message on its interface and receive Hello messages from its neighbours. This process repeats time to time in order to determine the neighbour connectivity. When a route to some destination is needed, it starts route discovery process by sending Route Request message . The source sends Route Request Message to all its neighbours. If a neighbour has no information on the destination, it will then send the message to all of its neighbours and process repeats. Once request reaches a node that has information about the destination which may be either the destination itself or some node that has a legitimate route to the destination, then that node sends Route Reply Message in response to the Route Request Message to the initiator [10]. The intermediate nodes, the nodes that forward Route Request Message save information about source and destination from Route Request Message. Address from which the Route Request Message came from is also saved. In this way, by the time Route Request Message reaches a node that has information to respond to it; a path will be saved in the intermediate nodes. This path that the Route Request Message took is identified as reverse path.

As each node forwards Route Request Message to all of its neighbours, more than one replica of the original Route Request Message may arrive at a node. To avoid this conflict, when a Route Request Message is created it is assigned a unique id by the source. Finally when a node receives Route Request Message, it will check the unique id and the address of the source that initiated the request and will discard the message had it been processed earlier. A node which has information about route to the destination sends Route Reply Message to the neighbour from which it received Route Request Message [10]. This neighbour also then does the same. The reverse path created by the Route Request Message is used here. The Route is ready when Route Reply Message reaches the initiator and the source can start sending the information packets. If any one of the links on the forward path breaks down, the intermediate node present just above the failed link sends new Route Reply Message to all the sources which are using the forward path in order to inform them. In turn, they will send to their neighbours until all nodes that use forward path are kept informed. The source nodes can then initiate new route request procedures if they still need to route packets to the destination.

DSR

The Dynamic Source Routing (DSR) [11] protocol is an on-demand routing protocol which is based on the concept of source routing. Similar to AODV, Operation of DSR is divided into two functions, route discovery and route maintenance. Route discovery operation is initiated when the routes to unknown nodes are required for data transmission. Route maintenance operation is used to monitor accuracy of the established routes and to initiate the route discovery process if a route fails. In DSR, when a node desires to send a packet to a destination node which it does not know about, then the source node will start a route discovery process. The route discovery request is sent to its neighbours. The neighbours can transmit a reply to the initiator if it possess route to destination or simply can send the route request message to their neighbours after adding their address to the request message. This is called source routing. Each of the nodes that receive the route request message does the following:

- If the node has already seen this request message, then it is discarded.
- If the node has not seen it, but the route request message already has address of this host, then also it is discarded.
- In case if this host is the target of the route discovery message, then it appends the address of this host and returns it to the initiator of the route request message. The route request packet contains the route from the initiator to this host, which is the destination.
- If this host is not the destination, then just append the host's address in the packet and forward it to all of hosts' neighbours.

The route reply message can be returned to the initiator in two ways. If the host that sends route reply has the route to the initiator, it can use that route to send the reply or else it uses the route available in the route request message to send the reply. When there is an error with an active route in the network route maintenance is performed. When a node detects that it cannot send packets to next hop, it will generate a Route Error message and transmits it to the initiator of data packets. The Route Error message contains the addresses of the node that sent the packet and of the next hop that is unreachable. When the Route Error message reaches the initiator, the source then removes all the routes that a have address of the node in error from its route cache.. It then again starts route discovery for a new route if needed [14].

DSDV

The Destination Sequence Distance Vector is a table driven or a proactive routing protocol. The DSDV is based on the classical Bellman-Ford routing mechanism [12]. In DSDV a routing table is maintained by each and every node containing the list of all known destination nodes present in the network besides the number of hops that are required to reach a particular node. Each entry in the routing table is distinguished with a sequence number that is assigned by the destination node. These sequence numbers help in identifying stale routes and thereby avoiding the formation of loops. In DSDV [13] routing table contains information about the address of destination node, the minimum number of hops to that destination node and the next hop in the direction of that destination node. In DSDV the routing tables have space to slot in the sequence numbers for every destination. These sequence numbers ensure that the nodes can distinguish between new and stale routes and plays an important part. Here each node is associated with a sequence number and this sequence number value is incremented or changed only by the node with which it is associated. Thus, these increasing sequence numbers emulate a logical clock.

In case if a node receives two routing updates from the same source, then the receiving node makes a decision based on the sequence number in order to incorporate corresponding update in its routing table. A higher sequence number usually indicates a more recent update sent by the source node. Therefore node updates its routing table with more authentic information and by this can avoid false routes or route loops. In DSDV the network topology information and route information is determined by exchanging the routing tables maintained by every node in the network. When a change is identified in the topology the nodes then exchange routing updates. The node on receiving an update packet checks the sequence number in the packet and the packet is discarded if it has older information than the receiving node has in its routing tables [7]. Else, information is updated in the receiving node's routing table. Then the update packet is forwarded to all other neighbouring nodes. Besides the node can also send any new information that resulted from the unification of the information provided by the update packet. The updates resulting from a change can be of two types that is either a full update or a partial update. A whole routing table is sent away in case of full update and only the changes since last full update are sent away in partial update.

III. MOBILITY MODELS

Mobility models [15] define the Nodal movement in Network. In order to simulate a protocol its imperative to use a mobility model that are crucial for the performance evaluation. The nodal mobility affects the number of connected paths between the nodes, which affects the overall performance of the routing algorithm. Change in direction and speed should occur in reasonable time slots. For example, we do not want mobile nodes to travel along straight lines at uniform speeds throughout the course of simulation because real mobile nodes would not travel in such a manner. A survey of entity mobility models for ad hoc networks has been done. They are:

- Random Walk Mobility Model: A simple mobility model that is based on random directions and speeds.
- Random Waypoint Mobility Model: A model similar to Random Walk that includes pause times in between the change of destination and speed that node sets.
- Random Direction Mobility Model: In this model, mobile nodes move to the edges of the simulation area and then pauses for given pause time before changing speed and direction.

Random Walk Mobility

The Random Walk Mobility Model [8] was first explained by Einstein in 1926. This model emulates the many entities in nature which have unpredictable movement. It is also referred to as the Brownian motion. This model is based on random directions and speeds. By randomly choosing a direction between [0;2pi], and speed between [speedmin; speedmax]the mobile node moves from its current position. After a given time or a given distance walked recalculation of speed and direction occurs. This model is memory less. Its future directions and speeds are independent of the past speeds and directions. This model usually causes movements such as sharp turns or sudden stops which are unrealistic. If the specified distance or time is short, the nodes are only travelling on a very restricted area on the simulation area. If the specified time or specified distance of a mobile node in the Random Walk Mobility Model is short, then the movement pattern is restricted to a small portion of the simulation area.

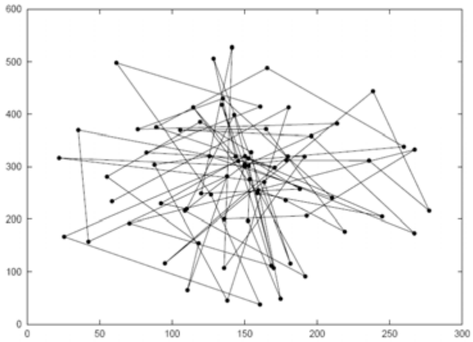

Fig. 1. Travelling pattern in RW mobility

Random Waypoint

The Random Waypoint model [20] is the most widely used mobility model that emulates the mobile users in real time. The pause times are included in this model between changes in direction and speed. In this model a mobile node randomly chooses a destination, velocity uniformly distributed between [V_min, V_max] where V_min is the minimum allowable velocity and V_max is the maximum allowable speed for every mobile node and moves towards that direction. After reaching the destination, the node stops for a specified pause time before selecting a new way point and speed. After this, it again chooses a random destination and whole process is repeated until the simulation ends. We note that the movement of the mobile node in Random Waypoint Mobility is similar to the Random Walk Mobility if the pause time is set to zero and [minspeed, maxspeed] = [speedmin, speedmax].

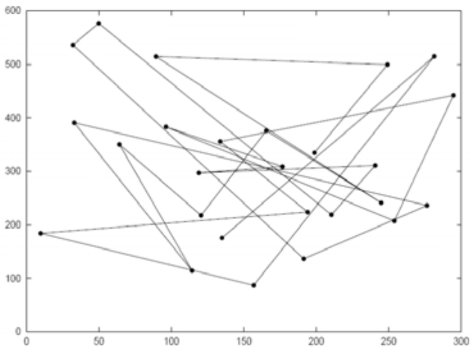

Fig. 2. Travelling Pattern in RWP mobility

Random Direction Mobility

The Random Direction Mobility Model [15] was created in order to overcome the flaw of density waves which discovered in the Random Waypoint Mobility Model. A density wave is the grouping of mobile nodes in one area of the Simulation area. In the Random Waypoint Mobility Model, this clustering occurs near the centre of the simulation area. In the Random Waypoint Mobility Model, the probability of a mobile node passing through centre of simulation area is very high. Since it chooses its destination at centre or it travels through centre to go selected destination.

In order to alleviate this type of behaviour Random Direction Mobility Model was developed [20]. In this model, mobile nodes choose a random direction in which travel to border of the simulation area in that direction. On reaching the mobile nodes pauses for a specified pause time, then chooses another angular direction (between 0 and 180 degrees) and continues the process. As they travel to border the average Hop count is higher in Random direction than in other models.

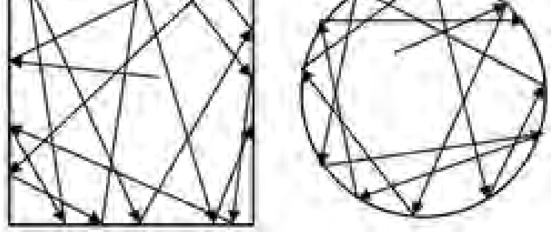

Fig. 3. Travelling Pattern in RD mobility

IV. SIMULATION MODEL

The simulations were performed using NS2, particularly popular in the ad-hoc networking community.The following figure depicts the methodology involved.

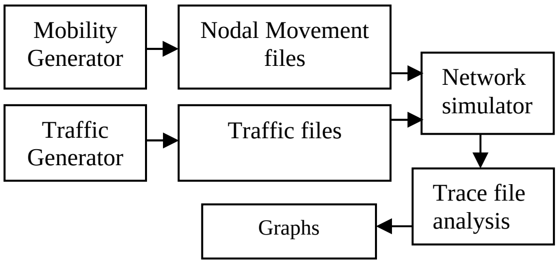

Fig. 4. Flow Chart

Scenario for NS2 topology: Table-1

Mobility Models	Random Waypoint, Random Walk, Random Direction
Number of Nodes	25,50,100
Size of X,Y axis	220 x 220
Routing protocols	AODV,DSR,DSDV
Packet Size	512 bytes
Packet rate	20 packets/sec
Traffic type	Cbr
Nodal Speed	15,25
Pause time	0 to 180
Simulation time	200

Generation of traffic models

The traffic patterns are generated by traffic scenario generation script (cbrgen) available in Ns2 [18, 19]. Constant bit rate (CBR) traffic sources are used. Only 512-byte data packets are used. The packet rate used is 20 packets/sec. The number nodes used are 25, 50, 100. The maximum connections between the nodes are varied as 10, 15 and 20. Random Seed is chosen as 1.

$ ns cbrgen.tcl [-type cbr|tcp] [-nn nodes] [-seed seed] [-mc connections][-rate rate]

Generation of Mobility models

Bonn motion tool [24] is used to generate mobility models. Three mobility models Random Waypoint, Radom Walk, Random Direction are created in a rectangular field. The pause time, which affects mobility of nodes is varied. Simulations are run for 200 simulated seconds. Pause time is varied from 0 to 180. Speed of mobile nodes is varied from 15 to 25. The field dimensions used is: 220 m x 220 m field. The number of nodes taken is 25, 50 and 100 nodes.

Metrics for Performance Evaluation

The following parameters are used for performance evaluation of the routing protocols [17].

1. Packet Delivery Fraction (PDF): This is the ratio of total number of packets successfully received by the destination nodes to the number of packets sent by the source nodes throughout the simulation.

2. Average End to End delay [ms]: This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times.

3. Throughput [kbps]: The amount of data transferred over a period a period of time expresses in kbps.

4. Normalized routing load: The number of routing packets transmitted per data packet delivered at the destination.

V. PERFORMANCE COMPARISION OF PROTOCOLS AND SIMULATION RESULTS

This section presents a comparative analysis of the performance of AODV,DSR,DSDV and evaluating the routing protocols in the diversity of network mobility models, varying node density.

The simulations were conducted in NS2 using three different node mobility models to discuss the behaviour of the routing protocols AODV, DSR, DSDV.AWK Programming is used for the analysis of traces generated during simulation. NAM gives us the visual interpretation.

Pause time vs. Performance Parameters

To analyze the effect of mobility in, pause time is varied from 0 seconds (high mobility) to 180 seconds (low mobility). The number of nodes is taken as 25 and the maximum number of connection as 10. Speed of mobile nodes is taken as 20. Graphs shown in Figures 5 to 16 show the effect of Mobility for DSDV, DSR and AODV protocols with respect to various performance metric parameters.

In Random Waypoint

Throughput of DSDV is very poor at lower pause times i.e. high mobility, hence the performance of DSDV protocol decreases as mobility increases compared to on demand protocols DSR and AODV. From the figure we can conclude that AODV performs better at high mobility and DSR performs better at low mobility.

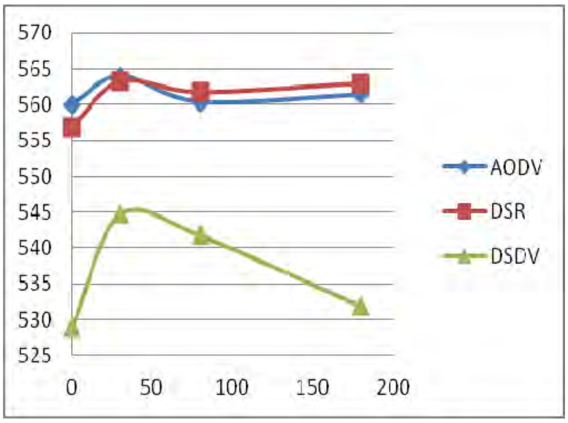

Fig. 5. Pause time vs. Throughput

End-to-End delay in DSDV is more compared to AODV and DSR as DSDV follows the table driven approach while AODV and DSR are on demand protocols. DSDV protocol takes more time to deliver the packets since its route construction may no occur quickly. Generally lower the mobility more is the delay as more packets are to be delivered than at higher mobility.

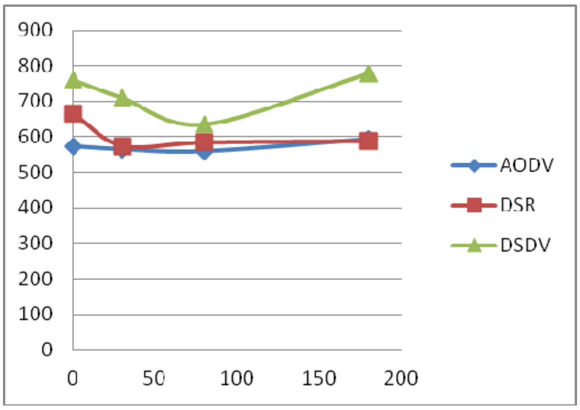

Fig. 6. Pause time vs. Average End-End Delay

DSDV uses the table-driven approach which is not 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 DSDV results in to more routing overhead irrespective of mobility than on demand Routing protocols AODV and DSR. Among these two on demand protocols DSR has less Routing load.

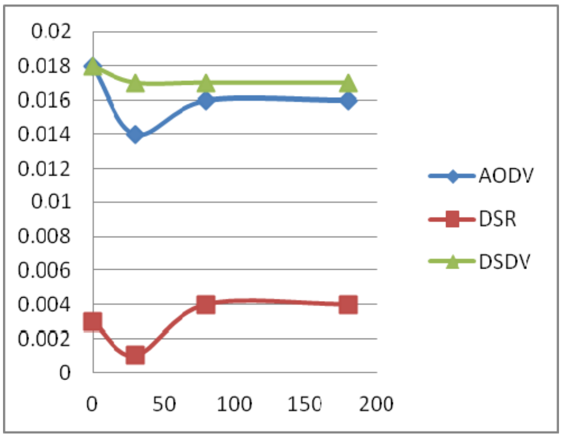

Fig. 7. Pause time vs NRL

Packet delivery ratio of DSDV is very less as compared to on demand protocols DSR and AODV at lower pause time (high mobility). AODV and DSR perform best among all at high mobility. The reason for having better packet delivery ratio of DSR and AODV is that both allow packets to stay in the buffer for route discovery and once the route is discovered, data packets are sent on that route to be delivered at the destination.

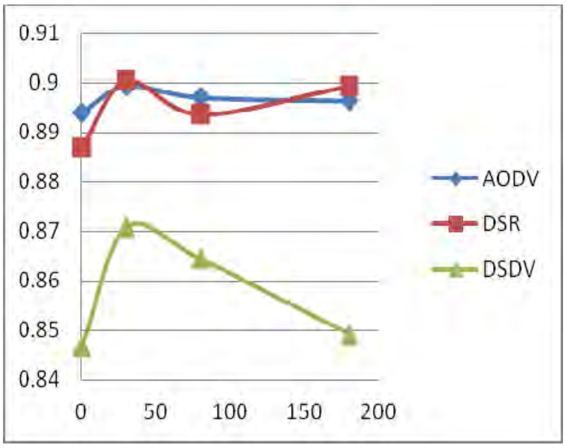

Fig. 8. Pause time vs PDR

In Random Walk

In the Random Walk mobility the Pause time does not have any effect on the Performance parameters because in this model it is the distance d or time t chosen that defines the mobility. So the values remain constant in this mobility model.

Throughput in AODV and DSR is much higher than DSDV since they are on demand routing protocols having better bandwidth utilization.

Delay is more in DSDV as it takes more time for Route construction during transmission compared to AODV and DSR.

NRL is high in DSDV as more routing updates are done in table driven protocol.PDR is almost the same for the reactive routing protocols and is much higher than proactive protocol.

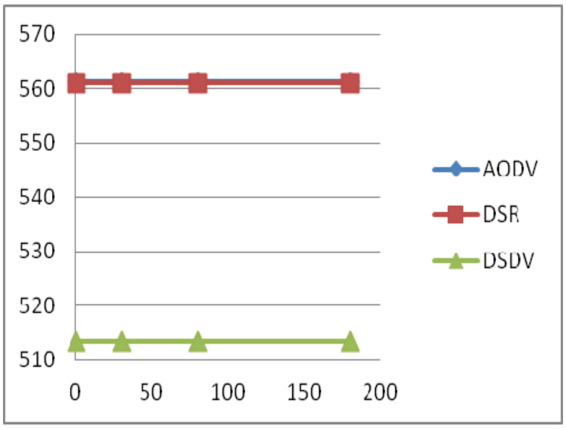

Fig. 9. Pause time vs. Throughput

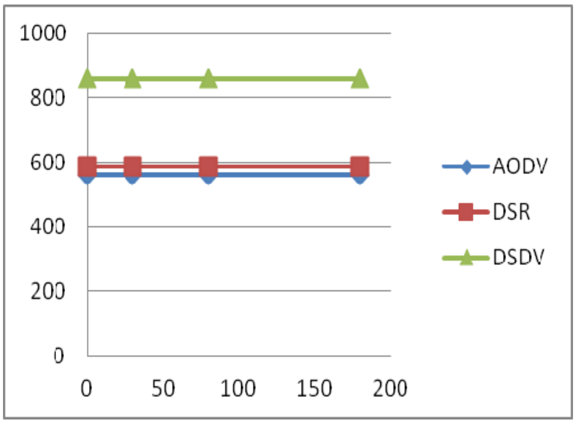

Fig. 10. Pause time vs Average End-End Delay

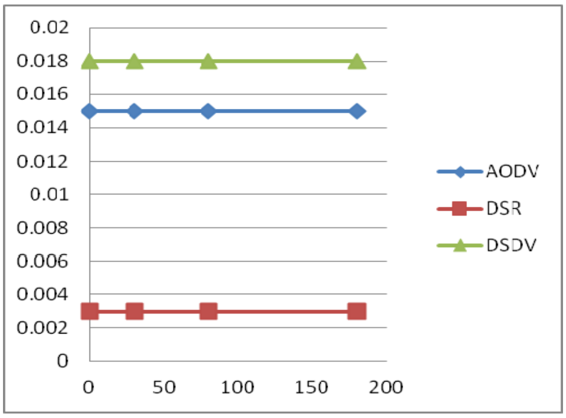

Fig. 11. Pause time vs NRL

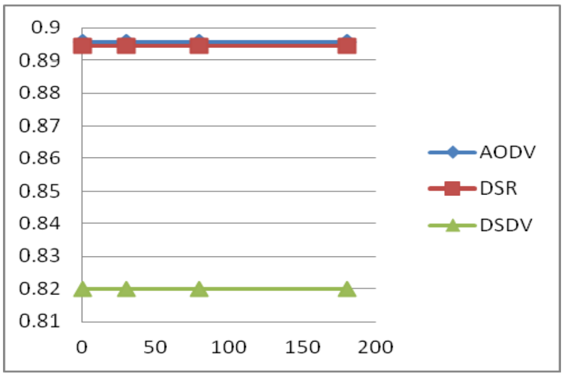

Fig. 12. Pause time vs PDR

In Random Direction

In this model at higher mobility i. e low pause time AODV works better than DSR and at lower mobility i.e higher pause time DSR works better than AODV based on their throughput.

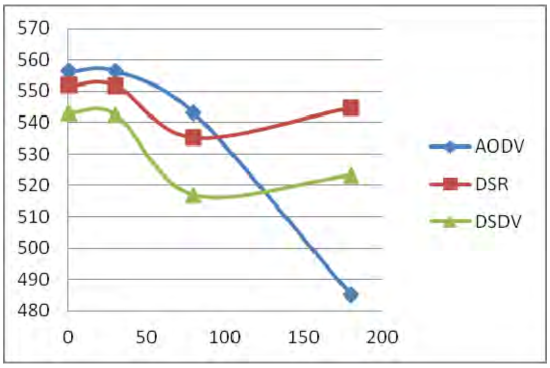

Fig. 13. Pause time vs. Throughput

Average End2End Delay at higher mobility is almost the same in all three protocols and increases with pause time as more packets are to be delivered than at less pause time.

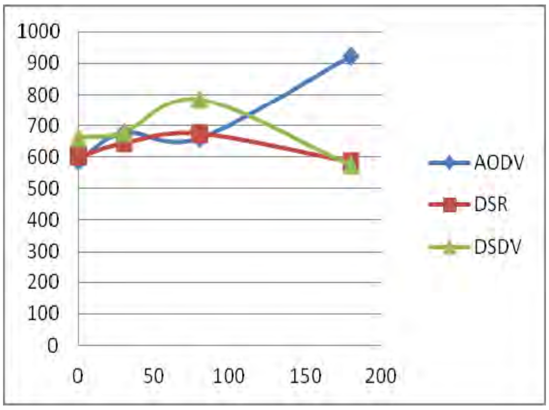

Fig. 14. Pause time vs. Average End-End Delay

Normalized Routing Load in AODV is higher than table driven DSDV, DSR unlike in Random Waypoint. As in this model nodes are forced to border of the simulation area so may be more routing packets are needed.

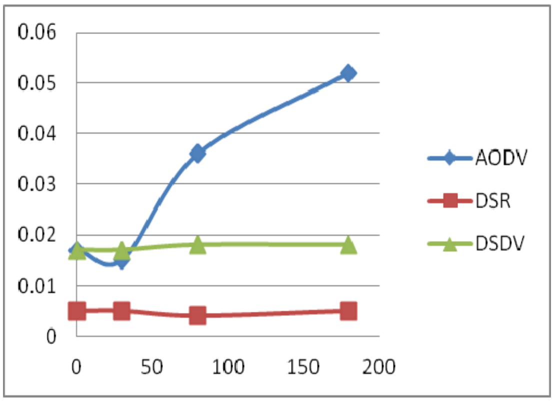

Fig. 15. Pause time vs NRL

Packet delivery Ratio in this model decreases with pause time as less number of packets are generated at higher pause time.

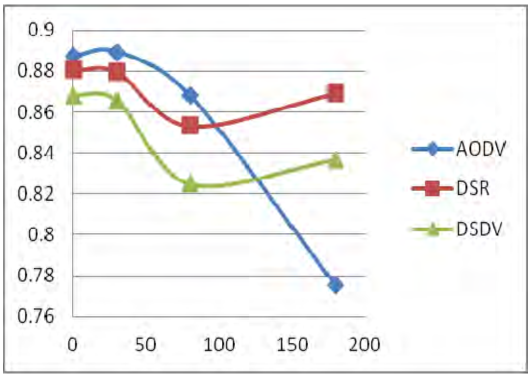

Fig. 16. Pause time vs PDR

Node density vs. Performance parameters:

As the number of nodes increases more nodes are involved in the transmission. So Throughput, PDR and more packets are generated. Delay also increases as it takes more time to transmit the generated packets. Normalized routing load also increases accordingly as more routing packets are needed to initiate more route discovery process for data transimission.

In this the nodes are taken as 25, 50 and 100. Pause time is kept constant at 0 sec. Speed is 20 mts/sec.

In RandomWaypoint:

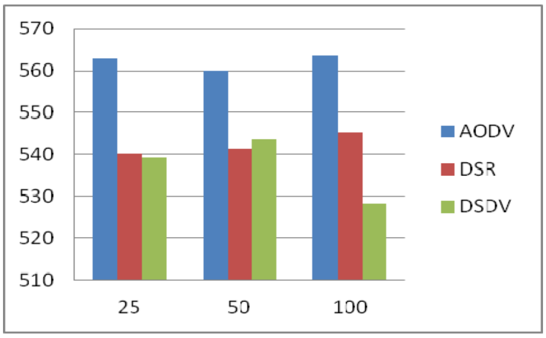

Fig. 17. Nodes vs Throughput

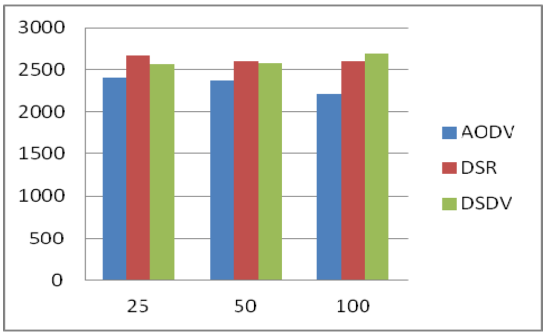

Fig. 18. Nodes vs Average End-End Delay

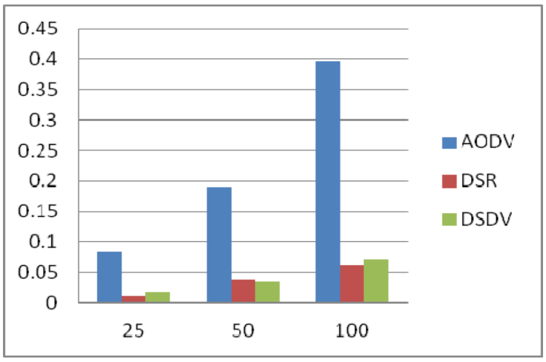

Fig. 19. Nodes vs NRL

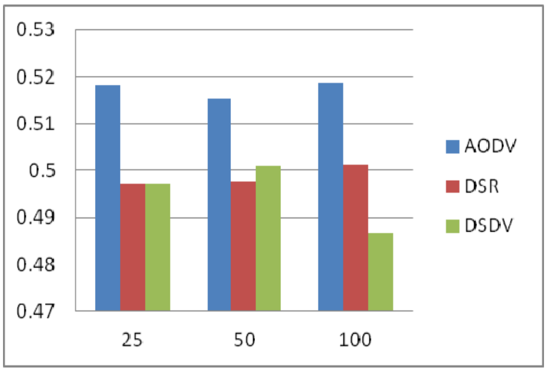

Fig. 20. Nodes vs PDR

In Random Walk:

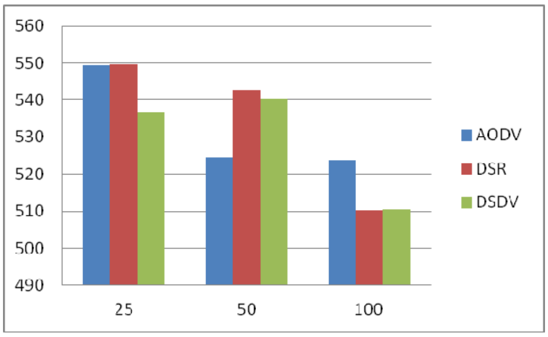

Fig. 21. Nodes vs Throughput

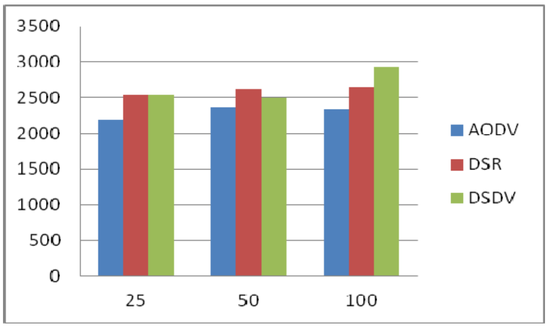

Fig. 22. Nodes vs Average End-End Delay

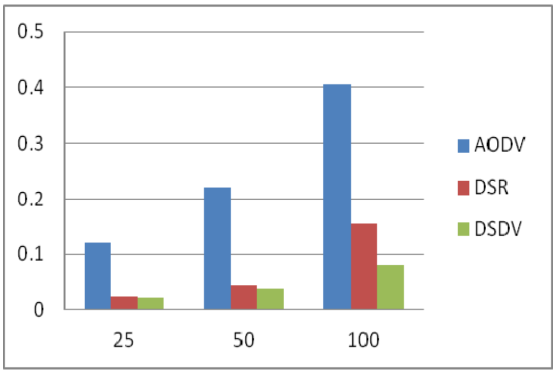

Fig. 23. Nodes vs NRL

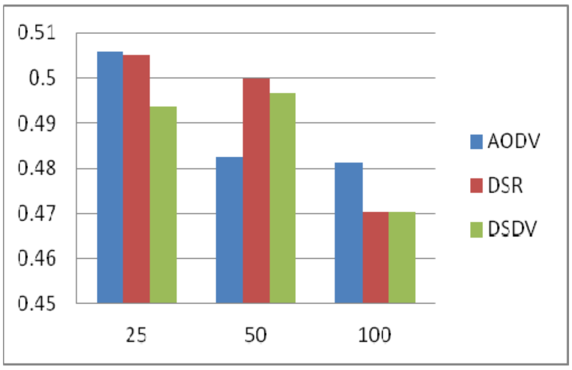

Fig. 24. Nodes vs PDR

In Radom Direction:

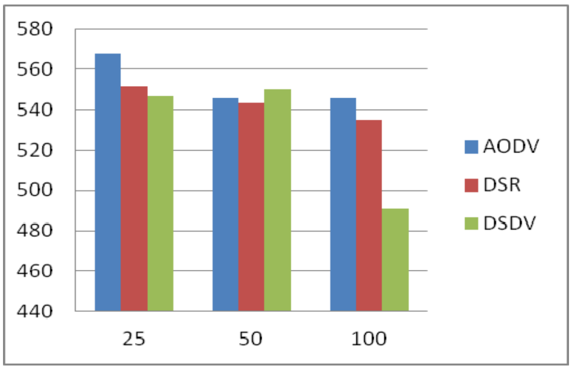

Fig. 25. Nodes vs Throughput

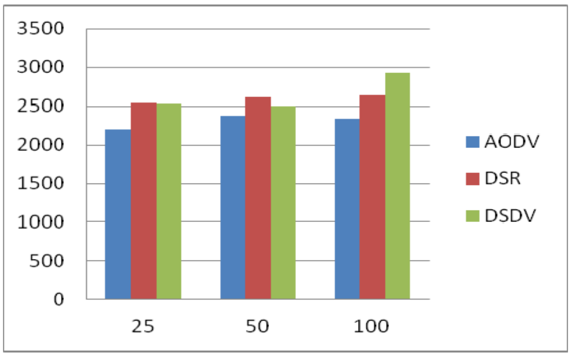

Fig. 26. Nodes vs Average End-End Delay

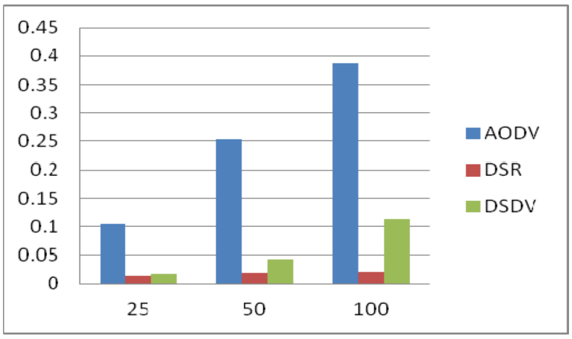

Fig. 27. Nodes vs NRL

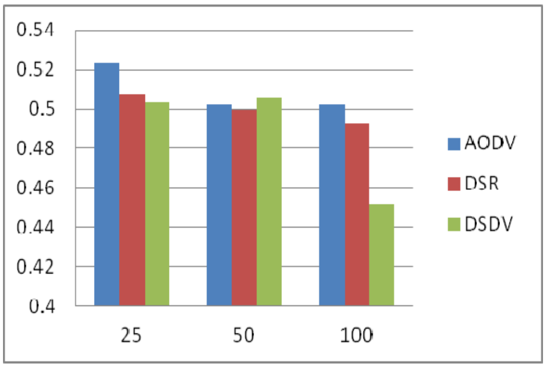

Fig. 28. Nodes vs PDR

CONCLUSION:

The area of MANET has been receiving increasing attention among researchers in recent years, as the available wireless networking and mobile computing hardware bases are now capable of supporting the promise of this technology. Over the past few years, a variety of new routing protocols targeted specifically at the ad-hoc networking environment have been proposed, but little performance information on each protocol and detailed performance comparison between the protocols has previously been available.

The simulation results have demonstrated some important characteristic differences among the various routing protocols performance of different working mechanism. The presence of high mobility implies frequent link failures and each routing protocol reacts differently during link failures.

The general observations from our simulation include:

1. The performance of an ad hoc network protocol can vary significantly with different mobility models and nodal density. Figures 5–28 illustrate the performance of one ad hoc network routing protocol with different mobility models varying node density. As shown, the performance of the protocol is greatly affected by the mobility model.

2. From the figures 5,9,13 At higher rates of mobility (lower pause times), DSDV performs poorly dropping more number of packets as it maintains one route per destination and there are no alternate routes.

3. The reason for having better packet delivery ratio of DSR and AODV is that both allow packets to stay in buffer for route discovery and once the route is discovered, data packets are sent on that route to be delivered at the destination.

4. In the Random Waypoint mobility AODV works best at higher mobility while DSR works best at lower mobility. In Reference to figures 5 to 8.

5. In the Random Walk mobility DSR protocol performs best having higher PDR, Throughput and also having less Delay, NRL compared to AODV, DSDV. In Reference to figures 9-12.

6. In the Random Direction mobility DSR works best at higher mobility and AODV at lower mobility. In Reference to figures 13-16.

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