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Performance Analysis of Routing Protocols based on Simulation Models in MANET's

Salma Fauzia
ECE Dept
M.J.C.E.T
Hyderabad, India

Nazma Sultana
ECE Dept
M.J.C.E.T
Hyderabad, India

Abstract—**Mobile Ad Hoc Network (MANETs) is an autonomous system of mobile nodes which communicate using wireless channels and as the transmission and reception range of the mobile nodes is limited, the transmission of all types of data takes place through multiple hops. It is a self organizing network without any fixed infrastructure. Because of the absence of centralized infrastructure and highly dynamic nature, the network experiences rapid and unpredictable topological changes in the network. Therefore the need of an efficient routing protocol raises which not only facilitate communication between routers (nodes) but can also be used for route discovery and maintenance. There are several routing protocols developed for MANET's, popular among them are AODV (reactive), DSR (reactive) and DSDV (proactive). This paper gives performance analysis of Ad hoc On Demand (AODV), Dynamic Source Routing (DSR) protocol which develop routes on demand and Destination Sequence Distance Vector (DSDV) protocol in which each node maintain a routing table containing next hop to every other node in the network using 5 simulation models and shows the effect of various network parameters on these protocols. All the simulation results are obtained using Network Simulator2. Our simulation result shows that AODV is the best protocol in terms of packet delivery ratio (PDF).**

Keywords—*MANET,AODV,DSR,DSDV,PDF.*

I. INTRODUCTION

Nowadays, with the rapid increase of lightweight devices such as laptops, wireless mobile phones and 802.11 based Wi-Fi networking; the potential and importance of mobile ad hoc networking have become apparent [9]. Mobile Ad Hoc Network (MANETs) is a network of mobile nodes which communicate with each other using wireless channels and as the transmission and reception range of the mobile nodes is limited, the transmission of all types of data takes place through multiple hops. In short, it is a self organizing network with no centralized infrastructure, unlike traditional networks, MANET's does not have an access point to for the nodes to connect and communicate. In this type of network each and every node can play the perfect role of a host and a router simultaneously and can freely move in and out of a network. In such type of instantly created network environment, as the transmission range of a mobile node is limited, it may to necessary for a host to list out the aid of other intermediate nodes in forwarding the packets to a destination not within its range. Therefore, designing an efficient and reliable routing protocol is a very challenging job as there are limited resources such as the battery life of a mobile phone, the processing power of a CPU, the available wireless RF channels etc. each mobile node randomly select a wireless channel and can only communicate with nodes located in its transmission range R. while for a destination outside the transmission range R, all the nodes in the network cooperate in the task of forwarding the packets to the destination[1]. The Figure 1.1 shows a wireless multi-hop ad-hoc network without the need of a base infrastructure.

The characteristics of a Mobile Ad-Hoc Network are:

1. Autonomous and Infra-structure less.
2. Multiple-hop based routing.
3. Continuously changing topologies.
4. Scalability issues- supporting large users.
5. Processing power of mobile node.

Fig.1: A multi-hop network MANET scenario.

This section gives an over view on MANET's. In the subsequent section, we would be going through the details of routing protocols. The third section deals with the basic architecture of network simulator NS2. Finally in the last section, we discuss the simulation models and their effect on the performance of routing protocols.

II. ROUTING PROTOCOLS

Routing protocols for mobile ad-hoc networks can be broadly classified into 2 categories:

1. Proactive routing protocols:

Proactive routing protocols are also known as table driven routing protocols. As the name specifies the every node maintains a consistent view of the network all the time. That is, every node maintains a routing table containing the routing information about every other node participating in the network. The advantage of this type of routing protocol is that because of the maintenance of routing information at every node, immediate routing decisions are made for forwarding of the packets in the network.

A. Destination Sequence Distance Vector: (DSDV)

Destination Sequence Distance Vector is a type of proactive routing protocol which is based on bellman-ford shortest path algorithm. This algorithm is an improvement of distance vector. Like Distance Vector, this algorithm also uses routing table but each routing entry is tagged by a destination generated sequence number. Because of the unpredictable and rapid variations in the topology, periodically routing table updates are transmitted to maintain a consistency among the routing tables at every node in the network [2].

The routing table update is disseminated either by using broadcast or multicast technique. As the changes are detected in the topology of the network, the node transmits a route table update packet with metric (hop) of one to every one-hop neighbor. After receiving the update packets the neighbors first increment their metric to one and then retransmit to their one-hop neighbors. This process continues until each and every node in the network receives a copy of the update packet with a corresponding metric. But, each node before updating its routing table and retransmitting the update packet [4], keeps the update data for a while until it gets the best route for the particular destination node in the network. If a node receives more number of updates for the same destination within the waiting time, the route with the most recent sequence number is preferred.

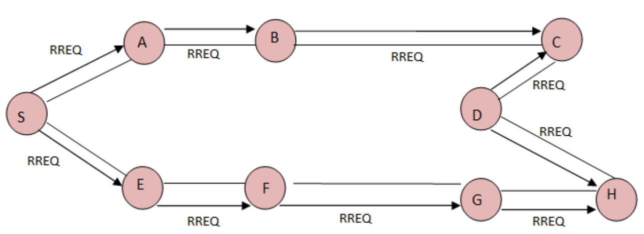

Fig.2: An example of DSDV

Figure2 illustrates the example of DSDV routing protocol

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Destination	Next	Metric	Seq.no	Install time	Stable data
A	A	0	A-500	001000	Ptr_A
B	B	1	B-300	001200	Ptr_B
C	B	2	C-550	001200	Ptr_C
D	B	3	D-312	001200	Ptr_D
E	E	1	E-160	001000	Ptr_E
F	E	2	F-200	001200	Ptr_F
G	E	3	G-280	001200	Ptr_G
H	E	4	H-300	001200	Ptr_H

Fig.3: Table entries in DSDV protocol.

Figure 3 shows the route table entries in DSDV routing protocol. It contains parameters like Sequence number, Stale data, Install time which are defined as follows:

- Sequence number: It is destination generated sequence number, used to prevent to prevent routing loops.
- Install time: It is the time when route entry was made for a specific destination node in the network.
- Stale data: It is basically a pointer to a table which holds the information of how stable a node is.

2. Reactive routing protocols:

Reactive routing protocols are also known as on-demand routing protocols. As the name indicates this type of routing protocol finds a route from source to destination node when needed or on demand by the source node.

- Route establishment phase: The route is found by flooding the network with control packets. (RREQ packets).
- Route maintenance: if any intermediate node detects a link failure in the route between source and destination then it generates a RERR message.

A. *Dyanamic Source Routing: (DSR)*

Dynamic Source Routing is an on-demand routing protocol which uses source routing. In this protocol, only source node provides the path to the destination, where as the intermediate nodes does not provide any information about the destination node. DSR working can be divided into 2 phases; phase1- Route establishment, phase2- Route maintenance. Whenever a node finds a new route to destination node, it saves/stores the route in its cache [1]. If a source node has many paths to the same destination then the source node is entirely responsible for the selection of one path to that destination.

1. Route establishment phase: When a node wants to transmit some data to destination D, then the source adds route information in terms of sequence of hops between the source and the destination to the packet header. Before transmission, source looks into its route cache. If it finds the route to the destination in the cache then it has the path to the destination and does not require a route establishment phase. Or else it starts the route discovery phase. In this phase, the source node first flood the network with the Route Request (RREQ) packet with the source (originator) and destination (receiver) address of the packet and the ID attached with it [12]. Any intermediate node on reception of route request packets checks for the ID attached with it and also checks for its address in the route record. If it found its address in the route record it simply discards the packet, else add its own address in the route record. And finally when the Destination node receives the route request (RREQ) it simple generates a route reply (RREP) to the source node. When the destination receives RREQ from different paths, it replies to all the received RREQ from different paths [9]. Thus a source node receives multiple paths to the destination for a single route discovery query. The following figure shows route request scenario in DSR routing protocol.

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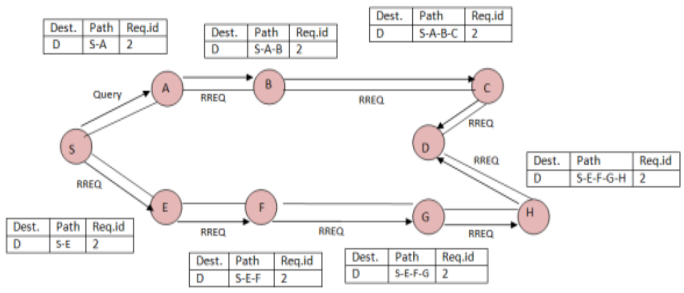

Fig. 4: Route Request phase in DSR

1. *Route Maintenance Process:* As the wireless networks are rapidly varying because of the mobility of the nodes and due to interference, the expiry time of the link between 2 nodes is too short and may not exists longer. The probability of a link present now between 2 nodes to be efficiently working in the future is low. As a solution to this, Route Maintenance procedure was developed. Whenever an intermediate node detects a broken or damaged link along the path from source to destination, it generates a Rote Error message (RERR) to the source node [4]. Source node upon reception of the RERR control packet purge the link from its route Cache and search for another path to the specified destination node in the Cache. If no other path to the specified Destination is present in its route Cache then it restarts the route establishment phase for the specified destination node. Figure6 shows the route maintenance phase in DSR routing protocol.

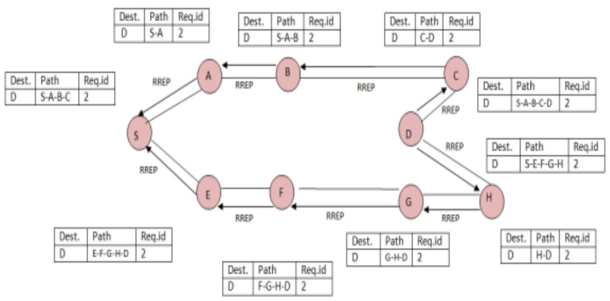

Fig. 5: Route Reply phase in DSR

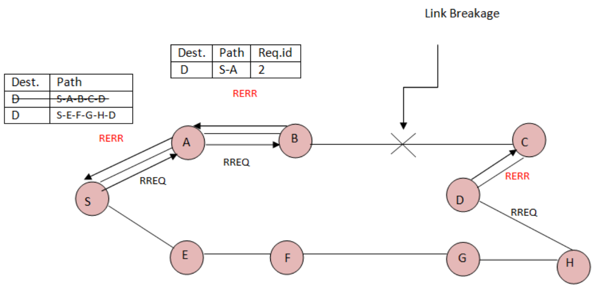

Fig. 6: Route Maintenance phase in DSR

B. Ad-hoc On Distance Vector: (AODV):

AODV is a reactive protocol and is a variation of DSDV routing protocol. Unlike DSDV, in AODV every node need not maintain a routing table containing the shortest path to every other node, rather the route is discovered a when needed and maintained as long as required. The difference in the AODV and the DSR routing protocol is in the routing strategy. In DSR, the source node is only responsible for the path to the destination node and this source routing metrics (hops) is placed in the header of the data packet. Where as in AODV, the source and the intermediate nodes keeps a record of the next hop corresponding to the data packet transmission [6].

Source Address	Request ID	Source sequence no.	Destination Address	Destination sequence no.	Hop count

Fig. 7: Format of RREQ packet

Route Discovery: When a node needs to transmit to a node which is not in its transmission range and has got no route which leads to that node then the source node flood the network with the RREQ packets (control packets). The route request packet format is the above figure7.

Each route request packet (RREQ) is uniquely identified by the pair (source address and request id) and every time a new request is made by the source node the request id is incremented [7]. And when a node receives a route request packet it checks the source address and the request id stored in the packet. And if the node has already received the RREQ packet with the same source address and request id then it knows that the currently received packet is a duplicate packet and simple discards it.

Each route request packet (RREQ) is uniquely identified by the pair (source address and request id) and every time a new request is made by the source node the request id is incremented [7]. And when a node receives a route request packet it checks the source address and the request id stored in the packet. And if the node has already received the RREQ packet with the same source address and request id then it knows that the currently received packet is a duplicate packet and simple discards it. Else, the receiving node either forwards the packet or replies with a Route reply packet (RREP): the node simply rebroadcast a packet with the hop count incremented if the node has no route to the destination or has a no updated route entry. And the reply packet is generated and back to the source node only when the node has a route with sequence number greater than or equal to the sequence number in the received RREQ packet [6].

The Time to Live (TTL) parameter in the RREQ packet specifies the number of times the packet can be re-broadcasted. During the first transmission of the RREQ packet by the source node the TTL parameter is given a value which is incremented at each re-transmission [7].

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The format of the route reply packet (RREP) is shown in the figure8. Every node forwarding a RREQ message caches a route back to the source node which can be used to unicast the RREP packet back to the source node [10].

Source Address	Destination Address	Destination sequence no.	Hop count	Life Time

Fig.8. Format of RREP

Fig. 9 represent route establishment of AODV.

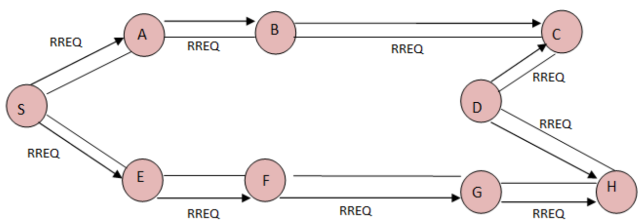


Fig.9: Route establishment in AODV

III. NETWORK SIMULATOR

Network Simulator basically is software that is used to analyze the behavior of computer networks. It provides a means for the user to design a network, model the network by varying various parameters such as traffic flow, node density etc. There are various types of network simulators such as OPNET, NetSim, GloMoSim, NS2 etc. Network simulator version-2 is also known as NS2. It is a discrete event-driven network simulator, which will store all the activities of the network as events and these events are scheduled to occur at a specified time. In the list of events, some events may trigger the future events. NS2 can be used for wireless and the wired networks.

NS2 uses 2 languages namely C++ and Otcl (an object oriented extension of tcl) [8]. In the front end design, the user creates new simulator objects and assemble them using Otcl interpreter which has a one to one correspondence with the C++ compiler class. Figure 9 shows the architecture of the NS2 simulator. Otcl interpreter is also used to schedule the events using the command "at" in the script. TclCL is a mapping class between C++ (compiler hierarchy class) to Otcl (interpreter hierarchy class).

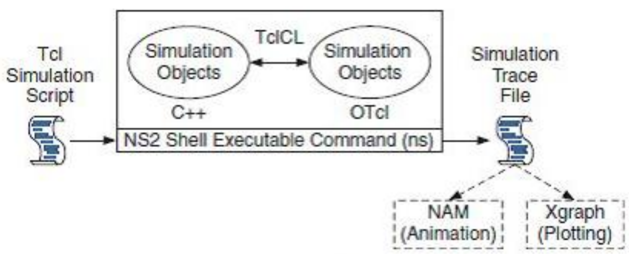
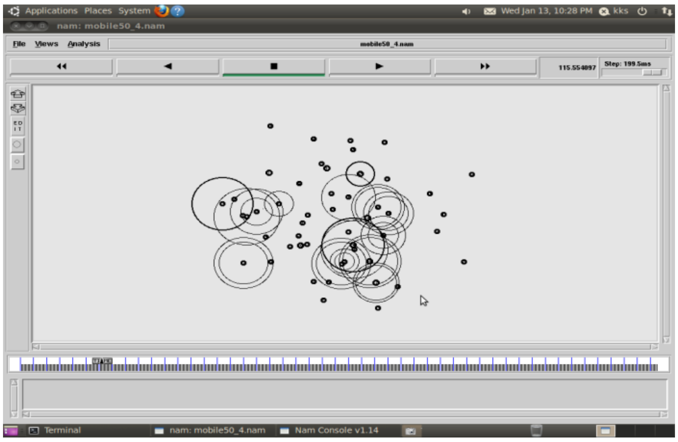


Fig10: Basic architecture of NS2

As shown in the figure10, the output of simulator would be a trace file and a network animator (NAM). The screen of the NAM is shown in the Figure 11.



The format of the trace file generated as output of the tcl script as shown below.

```
s -t 2.556838879 -Hs 1 -Hd -2 -Ni 1 -Nx 1981.93 -Ny 1093.66 -Nz 0.00 -Ne -1.000000
-Nl AGT -Nw --- -Ma 0 -Md 0 -Ms 0 -Mt 0 -Is 1.0 -Id 2.0 -It cbr -Il 512 -If 0 -Ii
0 -Iv 32 -Pn cbr -Pi 0 -Pf 0 -Po 16777215
r -t 2.556838879 -Hs 1 -Hd -2 -Ni 1 -Nx 1981.93 -Ny 1093.66 -Nz 0.00 -Ne -1.000000
-Nl RTR -Nw --- -Ma 0 -Md 0 -Ms 0 -Mt 0 -Is 1.0 -Id 2.0 -It cbr -Il 512 -If 0 -Ii
0 -Iv 32 -Pn cbr -Pi 0 -Pf 0 -Po 16777215
```

A. *Simulation flow:* We have generated 25 sceneraios for simulation purpose. The default paramters for every simulation is shown in the following table.

Simulator	NS2
Protocols	AODV;DSR;DSDV
Time of simulation	900 seconds
Simulation area	2000x2000
Mobility model	Random waypoint
Speed of mobile nodes	10
Type of traffic	Constant Bit Rate (CBR)
Pause time of nodes	0
Number of nodes	50
Packet rate	16K
Channel	Wireless Channel
Propagation Model	Two Ray Ground
Mac type	802.11
Link Layer type	LL
Antenna	Omni antenna

The traffic files are generated with the help of cbrgen.tcl using the ns command in the terminal. The scenario files are created using setdest command in the terminal. All the generated traffic and scenario files are then imported in to the Tcl script. The size of send buffer is 64, which is used to store the data packets to be routed. The maximum size of the IFQ buffer is 30 packets, which stores the data packets at the interface before the MAC layer transmits them in to the network. The simulation flow is shown in the figure 12.

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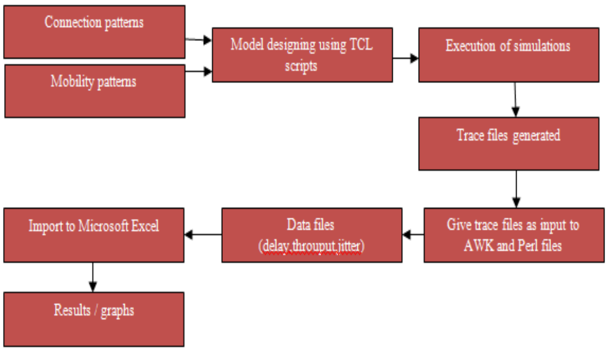

Fig 12: Simulation flow

B. Simulaton models:

We have generated 25 scenarios and divided these in to 5 parts based on 5 parameter variations. The 5 models are:

1. Node pause time based model: In this model, we varied the nodes' pause time while the other parameters are kept constant such as CBR connections, speed of the node, number of nodes, packet rate. The nodes pause time is varied from 0 to 400 in steps of 100 seconds. Each time the pause time is varied, the nod e stops at the specified pause time and changes the direction of movement.

2. Nodes speed based model: In this model, we varied the nodes speed while the other parameters are kept constant such as CBR connections, pause time of the node, number of nodes, packet rate. The nodes speed is varied from 10 to 50 in steps of 10. This model is used to measure the ability of routing protocol to deliver data packets in highly mobile network.

3. Network density based model: In this model, we varied the network while the other parameters are kept constant such as CBR connections, speed of the node, pause time of the nodes, packet rate. The number of nodes in the network is varied from 10 to 50 in steps of 10. This model is used to measure the efficiency of the routing protocols in larger networks.

4. Packet rate based model: In this model, we varied the rate at which the packets are send per second while the other parameters are kept constant such as CBR connections, speed of the node, number of nodes, pause time of the nodes. This model studies the effect of traffic flow in the network.

6. Flow based model: In this model, we varied the number of CBR connections i.e., source to destination pairs are varied while the other parameters are kept constant such as pause time of the node, speed of the node, number of nodes, packet rate. The number of CBR connections is varied i.e. Source to destination pair is varied from 5 to 25 in steps of 5. Each time the CBR connection is varied the number of connections between the source and destination pair is varied.

IV. ANALYSIS OF SIMULATION RESULTS

To analyze the performance of the routing protocols in MANET's, we performed a set of experiments. The Quantitative metrics used for performance analysis of routing protocols are Average throughput and Packet delivery fraction (P.D.F).

1. Packet delivery fraction (P.D.F): P.D.F is the ratio of total number of data packets delivered successfully to the total number of packets generated by the CBR source agent. This metric shows the efficiency of the routing protocols in successful delivery of packets.

PDF= (∑total pkts rcvd/∑ total pkts sent) * 100 Eq.1

2. Average throughput: It is the ratio of total number of packets received to the difference in the received and sent time.

This metrics measures the efficient usage of the channel for packet transmission.

Avg_Tput=(∑rcvd pkts)/(rcvd time- sent time) Eq.2

We tested these metrics under rapidly changing topologies and varying parameters such as pause time of mobile node, speed of the node, number of CBR connections, number of mobile nodes and packet transmission rate.

4.1 Node pause time based model:

In this model performance of the routing protocols under increasing pause time of the nodes is studied. As the pause time of the mobile node is increased, portability of the nodes decreases. Each time the pause time is varied; the node stops at the specified pause time and changes the direction of movement. In this type of model, the pause time of the mobile node is varied from 0s to 400s in the increasing steps of 100s while the other parameters are kept constant such as CBR connections=10, speed of the mobile node=10m/second, number of nodes=50, rate at which the packets are sent =16Kbps.

The Figure 13(b) demonstrates the performance of routing protocols in MANET's, when the pause time of the mobile node is changed from 0s to 400s. It shows the effect of pause time of mobile node on average throughput of the network. As shown, the AODV shows better performance than DSR and DSDV. AODV achieves highest average throughput value of 157.5 Kbps at pause time of the mobile node equal to 300s.

The Figure 13(a) shows the experimental results obtained.
The values shown in the table clearly shows that the AODV protocol gives best performance when compared to DSR and DSDV routing protocols.

Pause time	AODV	DSDV	DSR
0	104.51	52.2	88.59
100	110.956	76.69	97.314

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200	138.938	63.71	120.719
300	157.5	51.03	137.49
400	96.65	76.19	88.701

Fig.13 (a): Experimental results obtained using P.D.F calculations

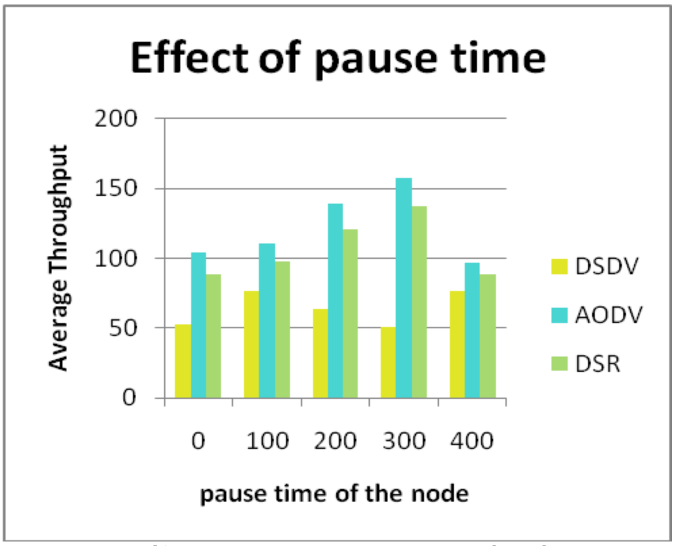

Fig.13 (b): Varying pause time versus average throughput

The second metrics used is P.D.F. The figure 14(a) and 14(b) shows the effect of pause time on P.D.F of routing protocols.

The highest P.D.F % recorded by AODV is 25.96% while the second best performance is given by DSR. As the pause time increases, DSR shows almost same performance as AODV.

Pause time	AODV	DSR	DSDV
0	19.43	12.12	9.23
100	25.96	22.39	19.74
200	17.1	16.09	11.23
300	11.7	11.62	8.29
400	13.9	13.44	12.35

Fig.14 (a): Experimental results obtained using P.D.F calculations

4.2. Nodes speed based model:

Speed of the mobile node is an important parameter and plays a vital role in the MANET's. In this model, we varied the speed of the node from 10m/sec to 50m/sec with pause time being zero while the other parameters are kept constant such as CBR connections=10, number of nodes=50, rate at which the packets are sent =16Kbps.

The Figure15 (a) and 15 (b) shows the effect of nodes velocity on average throughput of the network. AODV outperformed and gave a highest average of 150.243Kbps throughput in the network. As shown in the figure 15(a), AODV gives an average throughput of 132.712 Kbps at speed=50m/sec while DSR gives average throughput of 85.103Kbps and DSDV gives about 78.27Kbps at the same velocity. Thus, AODV gives best performance and can be used in highly mobile networks.

The Figure16 (a) and 16 (b) shows the effect of nodes velocity on P.D.F of the network. AODV outperformed and gave a highest P.D.F% of 35.89% when speed =50m/sec. as shown in the figure 16(a), AODV gives a high P.D.F as the speed of the mobile nodes increases. The second best performance is given by DSDV. The figure16 (b) show the graphical representation of comparison.

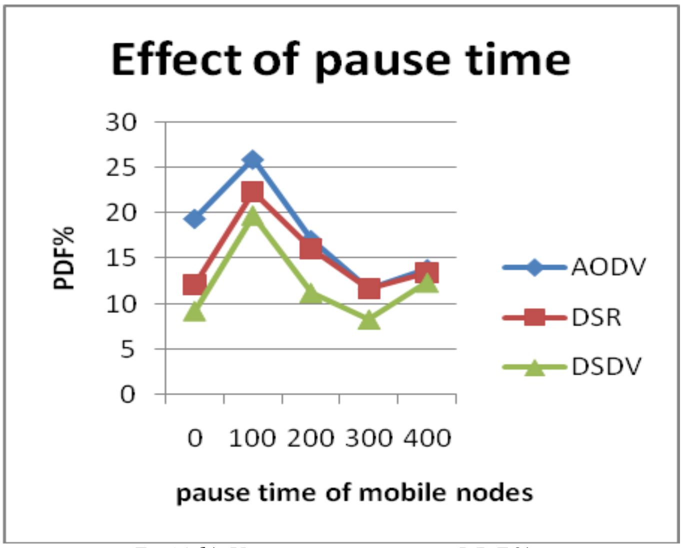

Fig.14 (b): Varying pause time versus P.D.F %

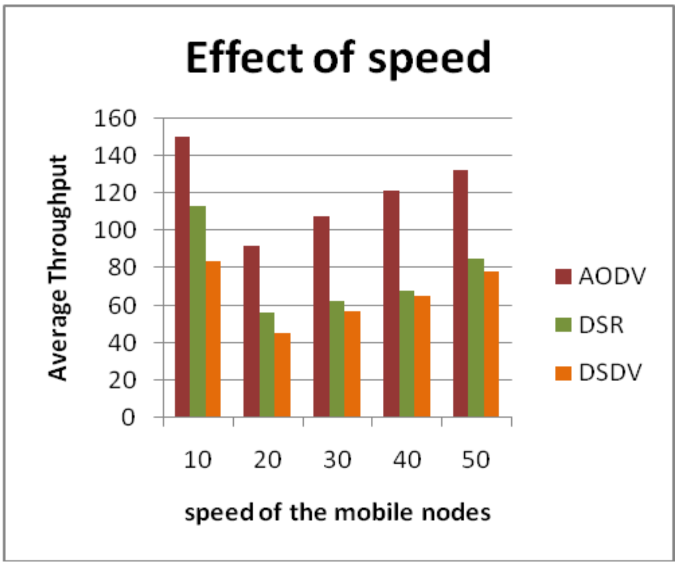

Fig.15 (a): Varying speed of mobile node versus average throughput.

Speed	AODV	DSR	DSDV
10	150.243	113.448	83.507
20	92.08	56.545	45.29
30	107.817	62.381	57.12
40	121.517	68.28	65.45
50	132.712	85.103	78.27

Fig.15 (b): Experimental results obtained using Average Throughput

4.3 Network density based model:

In this model, we vary the density of the network i.e., the number of nodes in the network are varied and study the effect of node density on average throughput of the network. The other parameters are kept constant such as CBR connections=10, pause time of the mobile node is zero, rate at which the packets are sent =16Kbps.

Speed	DSDV	AODV	DSR
10	20.15	23.69	18.15
20	17.48	16.14	14.94
30	15.57	20.22	11.62
40	17.23	21.96	12.63
50	24.12	35.89	30.31

Fig.16 (a): Experimental results obtained using P.D.F.

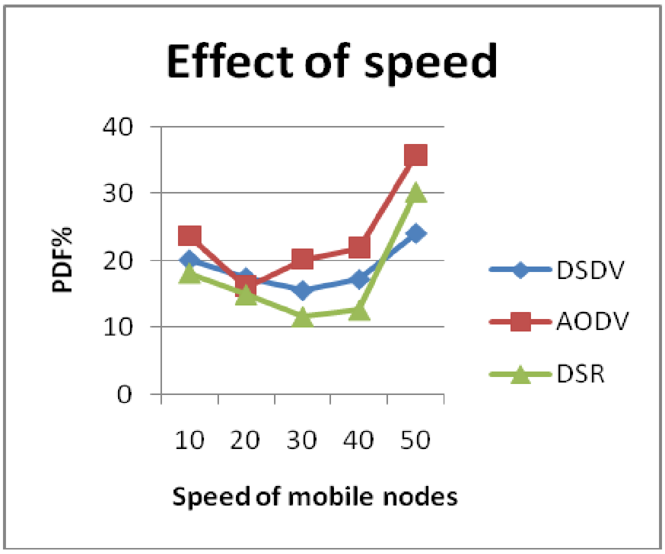

Fig.16 (b): Varying speed of mobile node versus speed of the mobile nodes.

The Figure 17(a) and 17(b) shows the effect of node density on average Throughput of the network. As shown in the figure 17 (a), as the number of nodes increases the average amount of throughput given by AODV is more than average throughput of DSR and DSDV. When the node density is at its max the throughput of AODV is 123.517Kbps while DSR and DSDV are 82.2591 Kbps and 75.491Kbps respectively.

Nodes	AODV	DSR	DSDV
10	82.0497	76.613	42.404
20	48.7781	49.0892	34.701
30	109.338	99.467	65.946
40	189.2289	171.556	120.256
50	123.517	82.2591	75.491

Fig.17 (a): Experimental results obtained using Average Throughput.

The figure 18(a) and 18(b) shows the effect of node density on P.D.F % of the routing protocols in MANET's. As shown in the figure 18 (a), as the number of nodes in the network increases the P.D.F increases. AODV gives the best P.D.F% of 49.4% at node density of 50.While DSR and DSDV give a P.D.F% of 44.16% and 35.67% respectively. The figure 18 (b) shows the graphical comparison of routing protocols.

Nodes	AODV	DSR	DSDV
10	37.14	29.86	20.12
20	22.7	22.58	16.56
30	32.12	27.43	23.45
40	39.23	35.72	31.9
50	49.4	44.16	35.67

Fig.17 (b): Experimental results obtained using P.D.F.

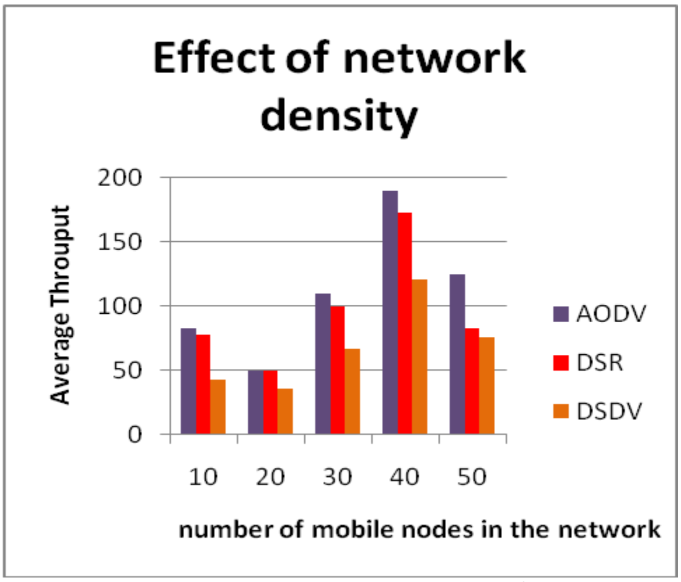

Fig.17 (b): Varying network density versus packet delivery fraction (P.D.F).

Nodes	AODV	DSR	DSDV
10	37.14	29.86	20.12
20	22.7	22.58	16.56
30	32.12	27.43	23.45
40	39.23	35.72	31.9
50	49.4	44.16	35.67

Fig.18 (a): Experimental results obtained using P.D.F.

4.4 Rate model:

In this model, the rate at which the packet is sent is varied and studied the effect of packet rate on average throughput of the network. The other parameters are kept constant such as CBR connections=10, pause time of the mobile node is zero, number of nodes =50, speed of the mobile nodes=50.

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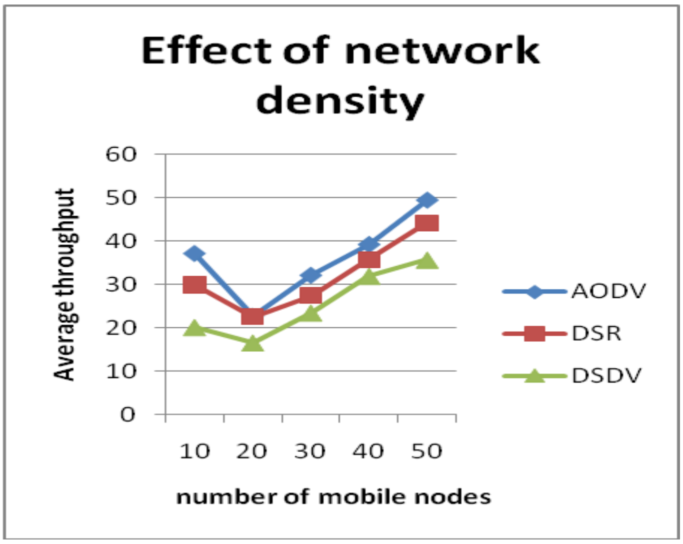

Fig.18 (b): Varying the number of mobile node versus Average throughput.

The Figure 19 (a) and 19 (b) shows the effect of packet rate on average Throughput of the network. As shown in the figure 19 (a), as the packet rate increases the average amount of throughput given by AODV is more than average throughput of DSR and DSDV. As the rate increases, the throughput of the network increases. The highest throughput recorded by AODV is 98.29Kbps, while DSR and DSDV give 83.52Kbps and 90.32Kbps respectively. The figure 19 (b) shows the graphical representation of the effect of packet rate on average throughput of the network.

Rate	AODV	DSR	DSDV
4	41.032	41.4026	25.2
8	74.2988	68.8607	55.231
12	96.1174	80.5245	73.216
16	86.3111	68.8754	61.3964
20	98.296	83.52	90.32

Fig.19 (a): Experimental results obtained using Average Throughput

The Figure 20 (a) and 20 (b) shows the effect of packet rate on P.D.F of the network. As shown in the figure 20 (a), as the packet rate increases the average amount of throughput given by AODV is more than average throughput of DSR and DSDV. As the packet rate increase, the P.D.F decreases. The highest P.D.F recorded by AODV is 25.43%, while DSR and DSDV give 26.52% and 18.13% respectively. The figure 20 (b) shows the graphical representation of the effect of packet rate on P.D.F of the network.

4.5 Connection model:

In this model, we vary the number of connections between the source and destination and study its effect on average throughput of the network. While the other parameters are kept constant such as, pause time of the mobile node is zero, rate at which the packets are sent =16Kbps,speed=10m/sec, number of mobile nodes=50.

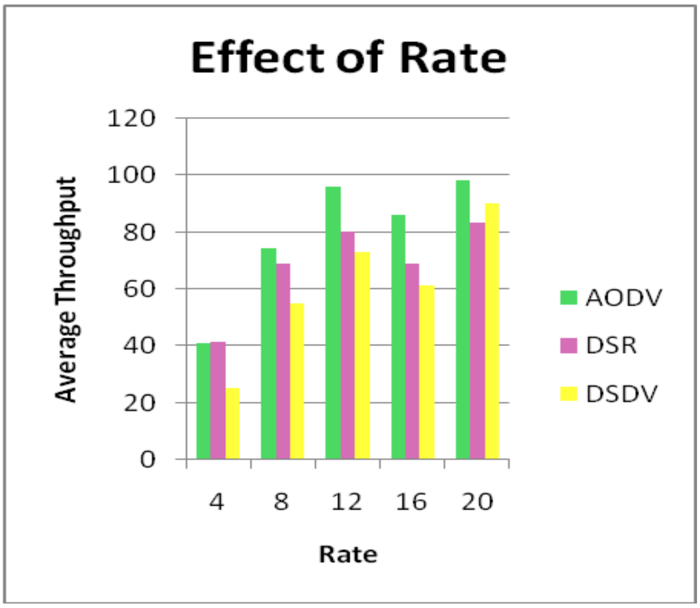

Fig.19 (b): Varying the number of connections between source –destination versus Average throughput

Rate	AODV	DSR	DSDV
4	25.43	26.52	18.13
8	22.9	21.93	14.57
12	20.48	17.72	9.34
16	14.8	12.97	10.91
20	14.3	12.57	7.25

Fig.20 (a): Experimental results obtained using P.D.F.

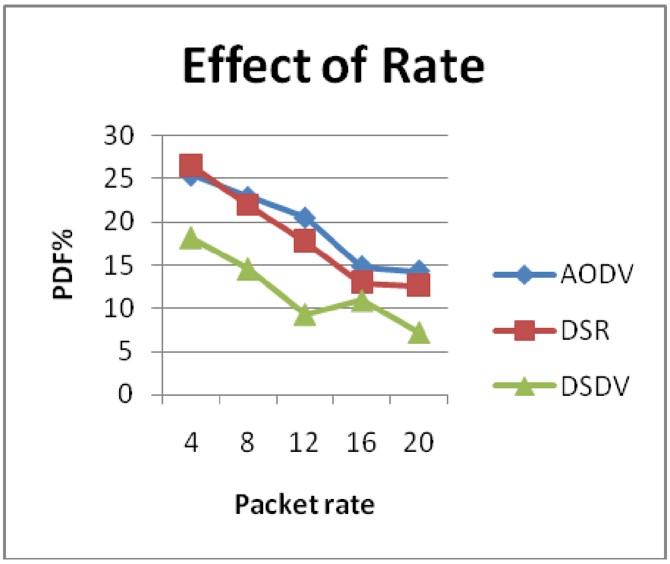

Fig.20 (b): Varying packet rate versus Average throughput.

The Figure 21 (a) and 21 (b) shows the effect of number of connections between source-destination pair on average Throughput of the network. As shown in the figure 21 (a), as the number of connections increases the average amount of throughput given by AODV is more than average throughput of DSR and DSDV. As the number of connections increases, the throughput of the network increases. The highest throughput recorded by AODV is 205.401Kbps, while DSR and DSDV give 157.628Kbps and 118.345Kbps respectively. The figure 21 (b) shows the graphical representation of the effect of node connections on average throughput of the network.

connections	DSDV	AODV	DSR
5	25.2	37.3061	39.5235
10	53.3086	81.3111	68.8754
15	73.5692	108.849	98.4525
20	98.234	161.011	133.216
25	118.345	205.401	157.628

Fig.21 (a): Experimental results obtained using Average Throughput

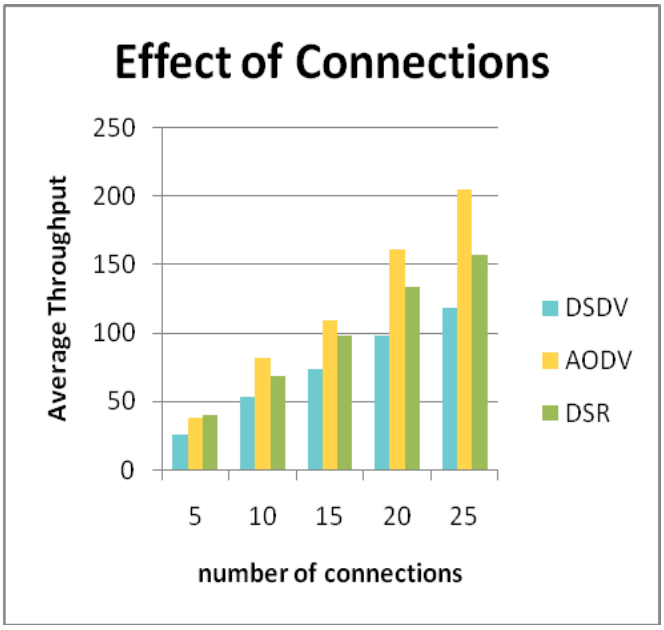

Fig.21 (b): Varying node connections versus Average throughput.

The Figure 22 (a) and 22 (b) shows the effect of number of connections on P.D.F of the network. As shown in the figure 20 (a), as the number of node connections increases the P.D.F % given by AODV is more than DSR and DSDV. As the packet rate increase, the P.D.F increases. The highest P.D.F recorded by AODV is 15.29%, while DSR and DSDV give 14.2% and 10.45% respectively. The figure 22 (b) shows the graphical representation of the effect of node-connections on P.D.F of the network.

connection	AODV	DSR	DSDV
5	13.6	14.2	10.45
10	14.8	12.9	8.29
15	13.47	11.87	7.21
20	14.6	12.506	9.87
25	15.29	11.87	6.62

Fig.22 (a): Experimental results obtained using Average Throughput.

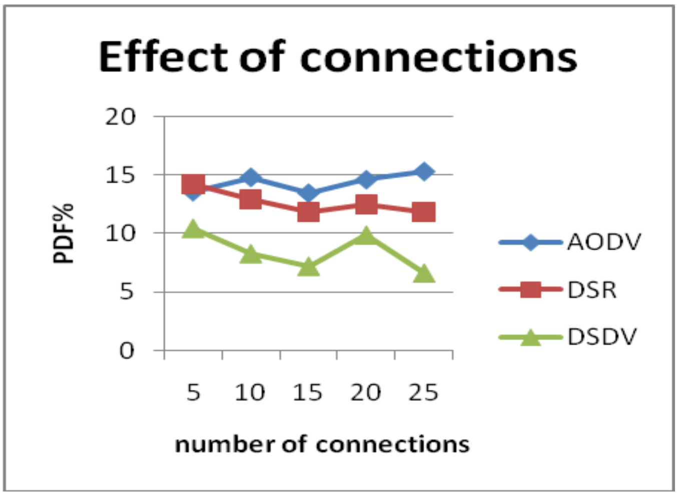

Fig.22 (b): Varying node connections versus P.D.F%.

V. CONCLUSION

In this paper, the performance of three routing protocols AODV, DSR and DSDV is analyzed using Network simulator version-2. The analysis is based on five simulation models. Two quantitative metrics used for performance analysis are Packet Delivery Fraction (P.D.F) and Average Throughput. In all the simulation models used, AODV outperformed in terms of both packet delivery and average throughput. As AODV uses on-demand routing technique, it selects the best fresh, active route for the data packet delivery. Thus AODV can be used for larger and highly mobile networks. While DSR gives the second best performance and can be used in moderately changing topologies. DSDV suffers from poor data delivery.

Thus, AODV is the best routing protocol in MANET's of all the three.

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