Performance Analysis of Routing Protocols for Mobile Ad-hoc Networks

Anil Choudhary
Department of Electrical and Electronics Engineering
Rajiv Gandhi Govt. Polytechnic, Itanagar, Arunachal Pradesh, India

Dr. O. P. Roy
Department of Electrical Engineering
North Eastern Regional Institute of Science & Technology(NERIST), Itanagar,, Arunachal Pradesh, India

Dr. T. Tuithung
Department of Electrical Engineering
North Eastern Regional Institute of Science & Technology(NERIST), Itanagar,, Arunachal Pradesh, India

Abstract- In this paper, an effort was made to analyze the performance of Routing Protocols for Mobile Ad-hoc Networks. Wireless networks can be classified in two types: infrastructured wireless networks and infrastructureless (ad hoc) wireless networks. Ad hoc networks are characterized by the need for efficient routing protocols. According to previous research, the Destination-Sequenced Distance-Vector (DSDV) routing protocol and the Ad-hoc On-Demand Distance Vector (AODV) routing protocol are two good representatives for each routing protocol category i.e. Table-Driven category and On Demand category respectively. The Simulation results have been compared to get their performance with respect to the mobility, offered load, number of nodes and pause time of nodes movement. It was tried to find which routing protocol is appropriate for certain network conditions. When the nodes move continually then AODV seems to be better than DSDV. When nodes stay unmoving for a long time then DSDV is preferable.

Key-words: Ad Hoc, Mobile Networks, Performance Evaluation, Routing Protocol, Destination-Sequenced Distance-Vector (DSDV), Ad-hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA).

I. INTRODUCTION

Wireless communication[1] between mobile users is becoming more popular than ever before. There are two distinct approaches for enabling wireless communication between two hosts. The first approach is to let the existing cellular network infrastructure carry data as well as voice. The major problems include the problem of handoff, which tries to handle the situation when a connection should be smoothly handed over from one base station to another base station without noticeable delay or packet loss. Another problem is that networks based on the cellular infrastructure are limited to places where there exists such a cellular network infrastructure.

The second approach is to form an ad-hoc network among all users wanting to communicate with each other. This means that all users participating in the ad-hoc network must be willing to forward data packets to make sure that the packets are delivered from source to destination successfully. This form of networking is limited in range by the individual node transmission range and is typically smaller compared to the range of cellular systems. This does not mean that the cellular approach is better than the ad-hoc approach. Ad-hoc networks have several advantages compared to traditional cellular systems. These advantages include on demand setup, Fault tolerance, and unconstrained connectivity.

Ad-hoc networks do not rely on any pre-established infrastructure and can therefore be deployed in places with no infrastructure. This is useful in disaster recovery situations and places with non-existing or damaged communication infrastructure where rapid deployment of a communication network is needed. Because nodes are forwarding packets for each other, some sort of routing protocol is necessary to make the routing decisions. Currently, there does not exist any standard for a routing protocol for ad-hoc networks, instead this is in progress. Many problems

remain to be solved before any standard can be achieved.
The DSDV algorithm is selected as the representative of the Table-Driven protocols because it maintains a loop-free, fewest-hop path to every destination in the network. DSDV prevents loops because of the sequence number, which gives the ability to the network to distinguish stale routes from new ones. Hence, this protocol achieves low routing overhead and low packet delay. Routing information is exchanged when significant new information is available, for instance, when the neighborhood of a node changes. The AODV algorithm is considered as the representative of the On-Demand protocols, because on the contrary to other On-Demand protocols, it supports unicast and multicast packet transmissions. None of the other On-Demand algorithms incorporate multicast communication. It also appears to achieve the lowest Routing Overhead from all other protocols in its category in accordance with other papers.
This paper emphasizes at some of these problems and tries to evaluate performance of DSDV[2], AODV[3], DSR[4] and TORA[5].

II. SIMULATION ENVIRONMENT

The Network Simulator (NS2)[6,7] is written in C++ and a script language called OTcl. NS uses an OTcl interpreter towards the user. This means that the user writes an OTcl script that defines the network (number of nodes, links), the traffic in the network (sources, destinations, and type of traffic) and the protocol to be use. This script is then used by NS2 during the simulation. The result of the simulation is an output trace file that can be used for data processing (calculate delay, throughput, etc) and to visualize the simulation with a program called Network Animator.

SIMULATION RESULT

The protocols that have simulated are DSDV, AODV, DSR, and TORA. The simulations were carried on an Intel Core-2 Duo processor at 400 MHz, 2 GB of RAM with Fedora 8.0 OS and AWK[8] script.

Scenario MANET

A MANET scenario was set up in order to gain some experience and to verify the structure of the experiment. The simulation settings were as follows:

• 60 wireless nodes
• Simulation area is taken of 1000m × 800m. A rectangle area is chosen to have longer distances between the nodes than in a quadratic area, i.e. packets are sent over more number of hops.

• IEEE 802.11 MAC
• Two rays ground propagation model
• Node mobility defined by random waypoint movement model.
• Constant bit rate traffic
• User Datagram Protocol (UDP)

Movement Model[9]

The movement of the nodes is defined by the random waypoint model. The movement scenario files are generated by the setdest program included in the NS2 distribution. The scenario files are characterized by the pause time. The simulation runs for 300 seconds of simulated time with movement patterns for pause time of 1 second. 10 different movement patterns for each of the ten selected speed are generated. Each protocol is tested with the same patterns. The setdest program offers only the possibility to specify a Vmax. Vmin is set to zero.

Communication Patterns9

The traffic sources are constant bit rate (CBR) sources. The sending rate is fixed to 5 packets per second. The different communication patterns with 20 number of sources were generated. All communications are peer-to-peer in these patterns. For the pure MANET simulation all these scenario files were tested with each of the four routing protocols (AODV, DSDV, DSR and TORA). The Parameters used during various simulations[1] are shown in Table 1.

Parameters	Value
Simulator	NS-2
No. of Nodes	10/20/30/40/50 (Network Size Simulation)
Packet Size	512 bytes
Simulation Time	300 Seconds
Traffic Type	Constant Bit Rate (CBR)
Environment Size	1000 X 800 m
Packet Rate	5/10/15/20/25/30 packets/ sec. **(Offered load Simulation)**
Max. Connection	20
Seed	0.1
Pause Time	1/50/100/200/300 sec. (Variable Pause Time Simulation)
Max. Speed	1, 3, 6, 9, 12, 15, 18, 21, 24, 27 m/s. **(Mobility Simulation))**

Table 1: Simulation parameters and their values

Mobility Simulations: The speed is varied to see how it affects the different metrics that are to be measured.
Offered Load Simulations: The load is varied i.e. rate (packets per sec.) that offer the network to see how the protocols behave when for instance the load is high.
Network Size Simulations: The number of nodes is varied in the network.

A. Mobility Simulations

The movements are generated at the speed of 1, 3, 6, 9, 12, 15, 18, 21, 24 and 27 m/s. The mobility can be increased by varying the speed in the scenario generation. For the randomized simulations, the speed has varied in between 1 and 27 m/s. The traffic pattern consists of CBR sources that started at different times. It is required to evaluate the general view of how each of the routing protocol behaves. The communication pattern was randomly created. The parameters that were specified when randomizing the communication pattern were the number of wanted sources, the packet size, the rate at which they were sending and the simulation time. In these simulations, it is emphasized to investigate how the mobility affects the protocols. CBR sources are sending large packets (512 bytes) with a rate of 5 packets per sec.

Packet Delivery Fraction (PDF)

As shown in the figure 1 the fraction of received packets for the DSDV is very large for high mobility. When comparing these results, it is clear that a reactive approach is not suitable when the mobility increases. The fraction received packets drastically goes down to 60-40 % for AODV and DSR. The fraction of received packets is not 100 % at the mobility 0 for all protocols.

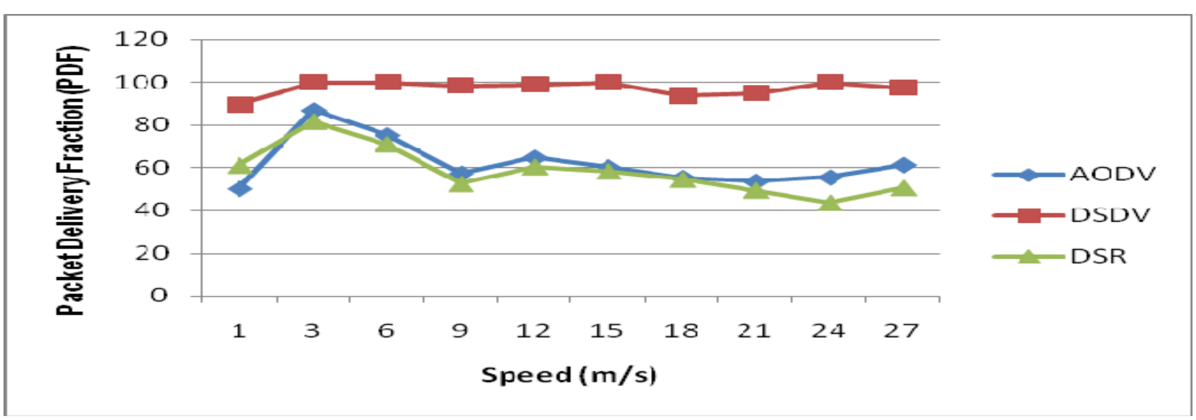


Figure 1: Packet Delivery Fraction Vs Mobility.
End-to-End Delay

As shown in figure 2, it is clear that DSR protocol is having the lowest delay. AODV have a slightly higher delay than the DSDV. AODV has comparatively more delay than DSR and DSDV, this is due to the source routing concept of DSR. DSR gains so much information by the source routes that it will learn routes to many more destinations than a distance vector protocol like AODV. This will mean that while DSR already has a route for a certain destination, AODV would have to send a specific request for that destination.

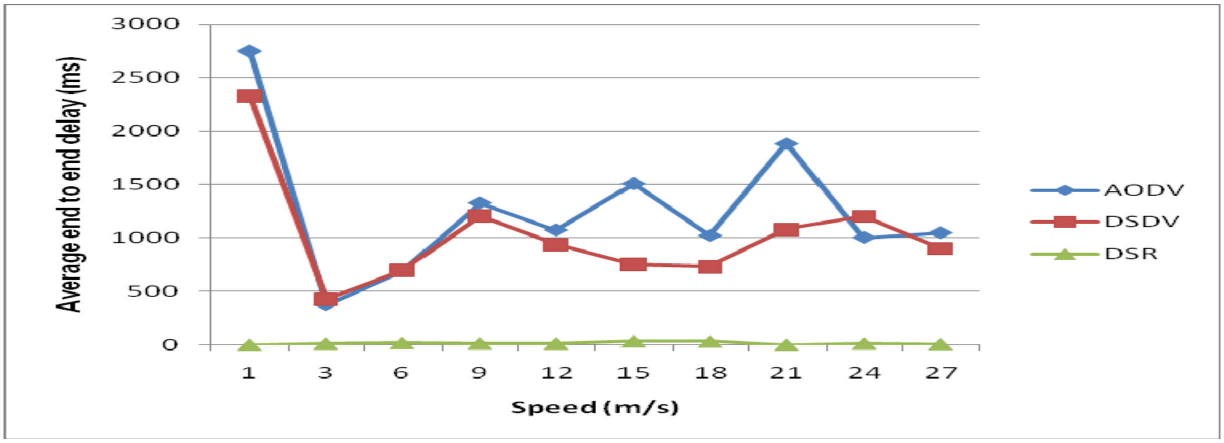


Figure 2: End to End Delay Vs Mobility Response.

Meanwhile, the packets have to stay in a buffer until a valid route is found. This will take some time and will therefore, increase the average delay as mobility increases.

End-to-End Throughput

Figure 3 shows the throughput curves for the different protocols with a packet size of 512 bytes. It is clear that throughput curves for all protocols are almost similar to the fraction received packet curves because of large packet drops will lower the throughput. The DSDV and the AODV have almost identical throughput. These throughputs are almost constant. The throughput curves of AODV and DSDV gradually decrease when their mobility increase. Moreover, the performance of DSR is very poor with this scenario.

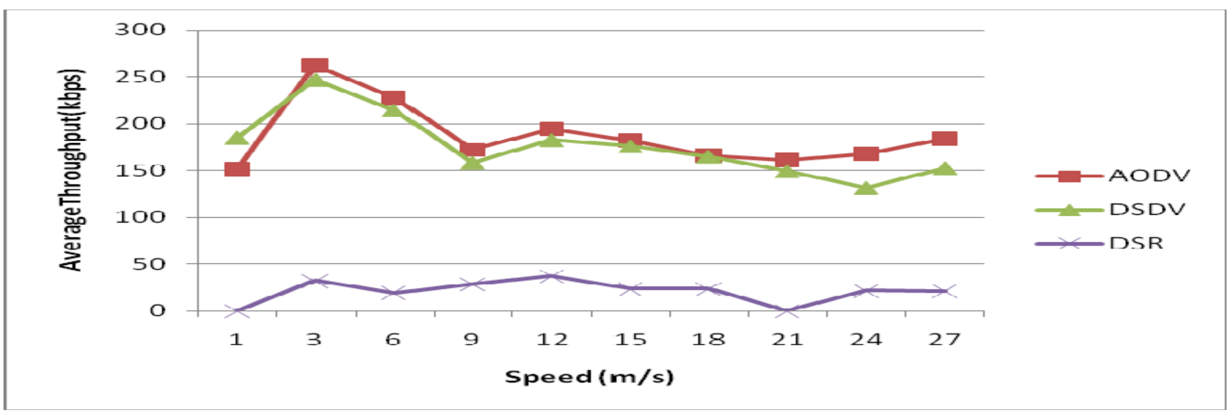


Figure 3: Throughput Vs Mobility Response.

Average Jitter

The average jitter is almost zero for DSR and having no variation with increase in speed. In case of AODV and

DSDV, the jitter decreases drastically at the beginning and later on increases slowly with increase in speed.

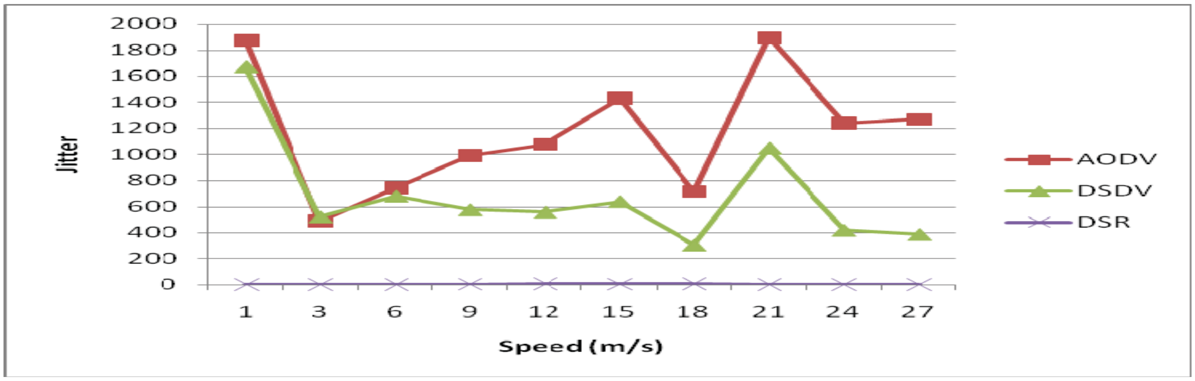


Figure 4: Mobility Simulations – Average Jitter.

Finally, the fraction of packets received for DSR and AODV protocols is almost constant as mobility increases. This result indicates that the value of PDF is in between 50% and 70%, and these protocols are working moderately even when mobility increases. Protocol (DSDV) is highly dependent on periodic broadcast, shows rather good results i.e. almost 100 % of the packets received as mobility increases.

In case of DSR, it is interesting to see how much overhead this will have. The byte overhead is larger than the AODV, which uses both hello messages and link layer support for link breakage detection. The number of control messages is much smaller for DSR than any other protocol. This means that an approach that uses a source routing based approach to find routes combined with a destination vector approach for sending data packets could be desirable.

B. Offered Load Simulations

The offered load simulations are done by varying the load to the network. There are mainly three parameters to adjust in the offered load simulations: Packet size, Number of CBR flows, Rate at which flows are sending.

It is already described in the mobility simulations by using a packet size of 512 bytes, a rate of 5 packets per sec and 20 CBR flows. This is a kind of fairly moderate load. For the offered load simulations, this required to investigate how the protocols behave when the load are increasing. The load will be increased by increasing the packet size or the number of CBR flows, but the parameter that best describes the load is the rate at which they are sending. We have used four different offered load cases: 5, 10, 15, 20, 25 and 30 packets per second.

The packet size and CBR flows are taken constant as 512 bytes and 20 respectively. The same randomized scenario files as in the mobility simulations are used. Similarly, the same communication file is also used with the exception that rate for the CBR only changed.

Packet Delivery Fraction (PDF)

It is clear from the figure 5, at 5 packets per sec, both AODV and DSDV are constant (above 70%); the fraction of received packets is decreasing when mobility increases in case of all three protocols (100% in case of DSR). At 10 packets per sec, it can be seen that the fraction received packets is decreasing much faster. At 15, 20 and 25 packets per sec, both AODV and DSDV are dropping a large fraction of the packets.

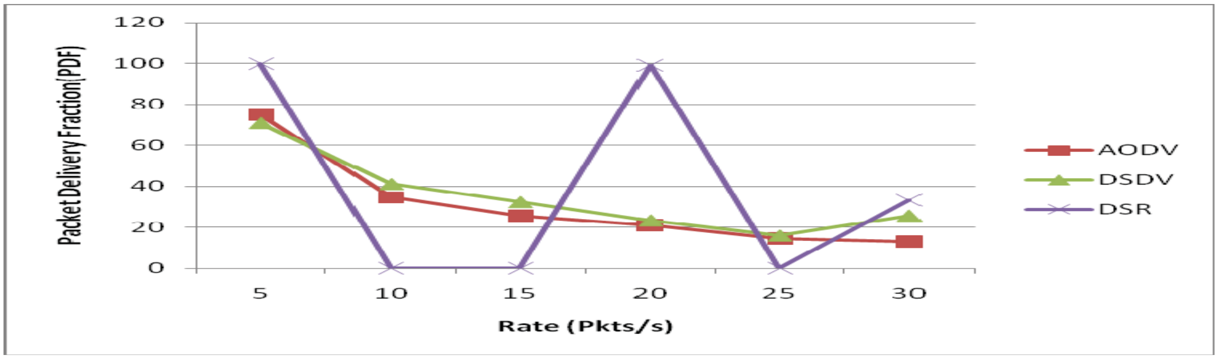


Figure 5: Packet Delivery Fraction Vs Packet Rate Response.

At the highest speed and a rate of 30 packets per sec, only 15 - 20 % of the sent packets are received. The reason behind this is the more collisions in the air and congestion in buffers. The response for AODV and DSDV are fairly similar at a various packet rates. At data rates of 5, 20 and 30 packets per sec, DSR shows a better result than AODV and DSDV. But, at data rates of 10, 15, and 25 packets per sec, the DSR results are unpredictable and misleading. DSR will have a much larger byte overhead than AODV at higher data rates. The reason for this is the source route in each data packet.

This also increases the load on the network and causes more packets to be dropped. Thus, AODV will get more packets through the network. The increase in dropped packets is not as large for DSDV as for AODV and DSR. At the highest data rate of 30 packets per sec, DSDV is almost as good as DSR. DSDV performs moderately for all data rates and seems to be more reliable protocol in case of increase in load/overhead.

Average End-to-End Delay

The delay is also affected by high rate of CBR packets as shown in the figure 6. The buffer becomes full, much quicker, so the packets have to stay in the buffers a much longer period of time before they are sent.

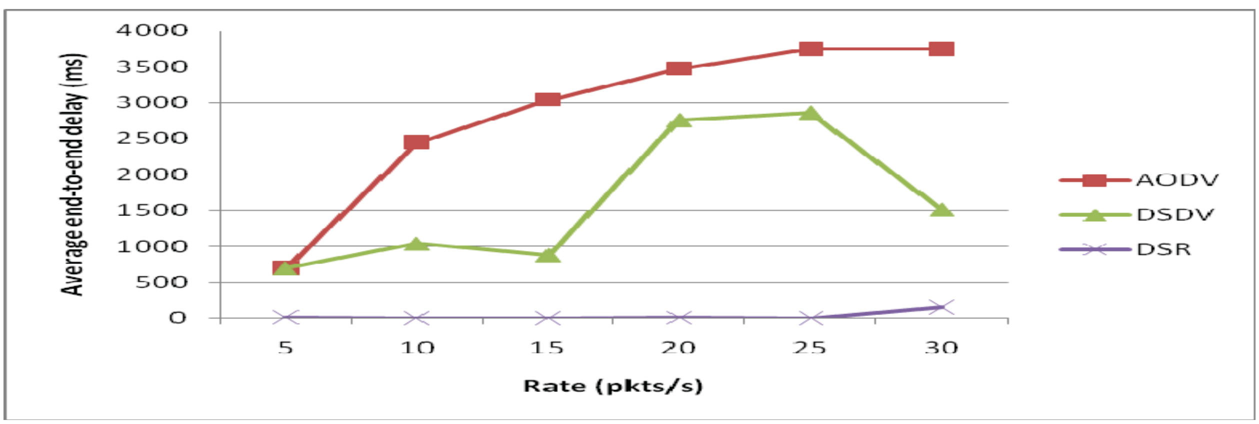


Figure 6: Average delay Vs Packet Rate Response.

This is clear that at the highest rate 25 packets per sec, DSR has a lower delay compared to AODV and DSR. It has the lowest delay in all of them and some times it gives unpredictable results. In case of AODV, the delay is higher and is increasing gradually with increase in the rate. In case of DSDV, at the rate of 5, 10 and 15 packets per sec, the average delay is very less and almost constant. But it increases drastically in between the rate of 20 and 25 packets per sec and at highest rate of 30 packets per sec again it drops greatly. The increase in delay for DSDV also includes the increased time that the packets must stay in the buffer.

In case of DSDV, the average delay at highest data rate i.e. 30 packets per sec, is lower than that of at the rate of 20 and 25 packets per sec. At the rate of 20 and 25 packets per sec, when mobility is high than the topology changes frequently, which results in 40 - 60 % of the packets gets through the network. These topology changes means that the protocol needs more time to converge before the packets can be sent. The buffers will therefore be congested almost all the time so the packets that actually get through and have approximately the same delay.

Average End-to-End Throughput

At low CBR rates the throughput of DSDV and AODV is unaffected and stays almost constant as shown in the figure 7. At higher CBR rates (20 packets per sec), the throughput increases and again it drops to the previous values.

The result for DSDV is slightly better than for AODV. It must however, be noted that the offered load definition used, only includes the rate at which the packets to be sent with, no control packets are included in this definition. The same applies for the throughput, only the data packets are included in the calculations of throughput.

DSR drops a large fraction of the packets at a rate of 5, 10 and 15 packets per sec. The throughput for DSR is very low in comparisons to AODV and DSDV.

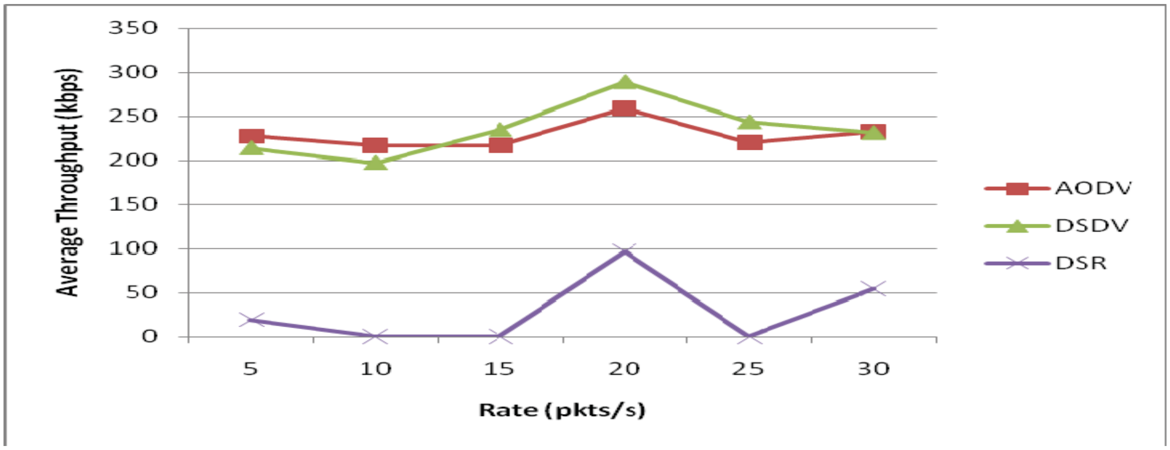


Figure 7: Average throughput Vs Packet Rate Response.

Average Jitter

The average jitter is almost zero when DSR is used as routing protocol as shown in figure 8. In case of AODV, jitter increases drastically at the rate of 10 packets per sec and afterward decreases gradually with increase in rate. Jitter is higher for AODV than other protocols. In case of DSDV, jitter is much less at the lower rate and it increases drastically at the rate of 20 and maintained up to rate 25 packets per sec. After the rate of 25 packets per sec it again decreases drastically.

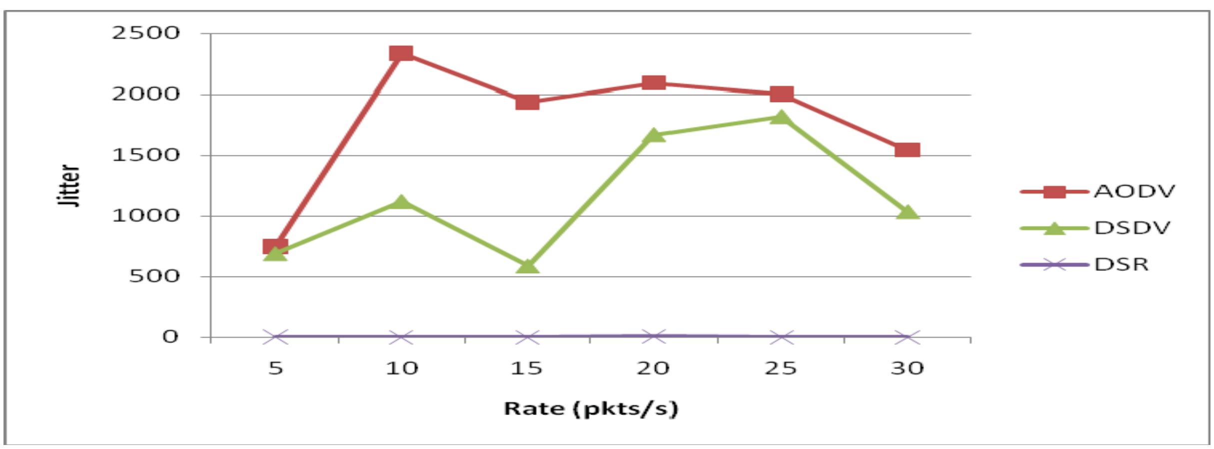


Figure 8: Average Jitter Vs Packet Rate Response.

It is seen that the DSDV performs moderately for all data rates and seems to be more reliable protocol in case of increase in load. The DSR has a much lower delay compared to AODV and DSDV. The DSR has the lowest delay among them, but some times it gives unpredictable results. A higher sending rate causes the protocol to detect broken links faster and thus, reacting faster. This leads to a slight increase in control packets and also affects the byte overhead.

The throughput for DSR is very low in comparisons to AODV and DSDV. In case of DSDV, jitter is very low at lower data rate and it increases for the rate of 20 and 25 packet per sec and after it again decreases.

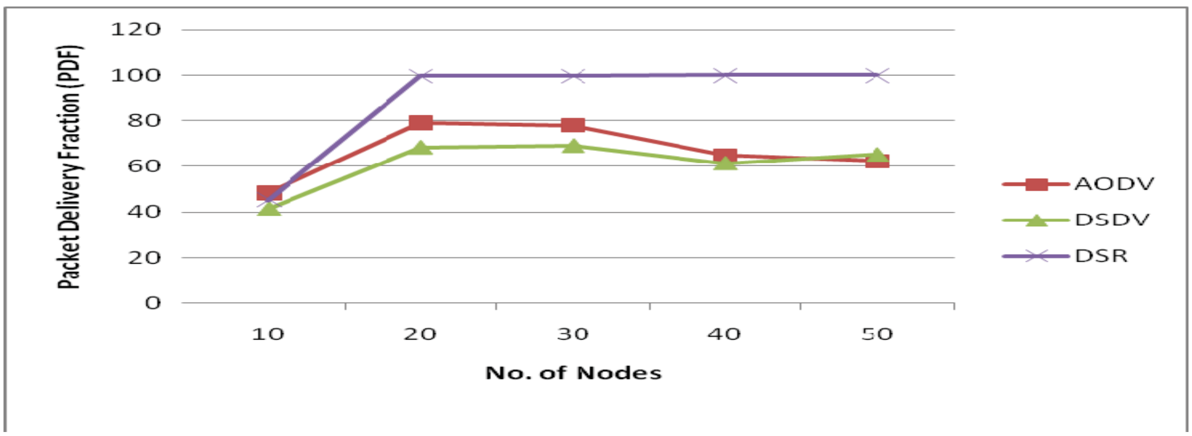
The overall performance of DSDV is more satisfactory with increase in data rates.

C. Network Size Simulations

The simulation parameters that have been considered are already shown in Table 1. The simulation is carried on some of the protocols with varying the number of nodes that participated in the network. The number of nodes is taken in between 10 and 50.

Packet Delivery Fraction (PDF)

It is shown in the figure 9 that with increase in number of nodes the PDF curves for AODV and DSDV shows 60 to



80% and nature of both the curves are almost identical.

Figure 9: Packet Delivery Fraction Vs Number of Nodes Response.

The PDF curve for DSR is perfect straight line for the nodes more than 20 and is 100% i.e. DSR is unaffected by change in number of nodes. All the three protocols have very less impact of increase in number of nodes.

Average End-to-End Delay

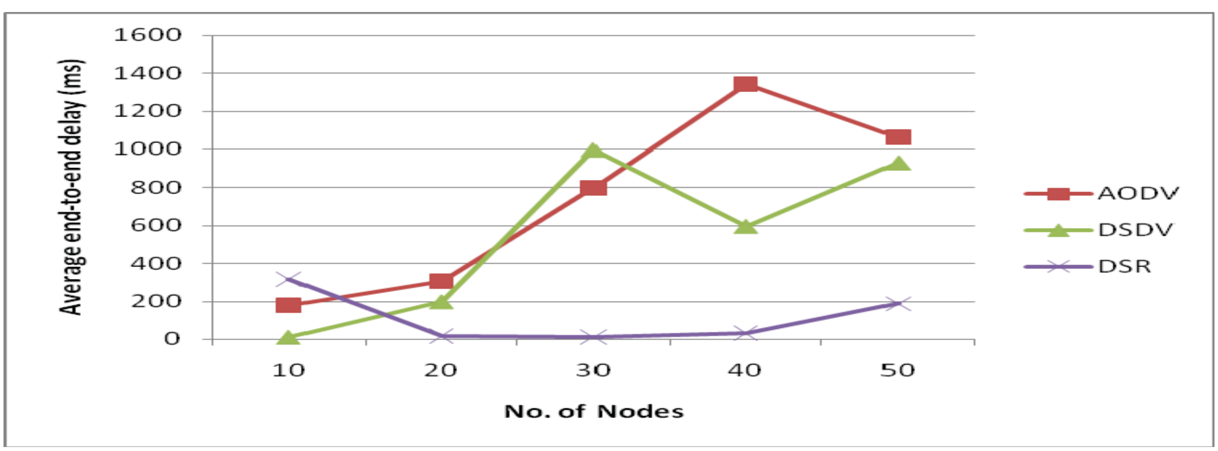


Figure 10: Average Delay Vs Number of Nodes Response.

Average delay increses with increse in number of nodes in case of AODV and DSDV. For DSR, the average delay is more in the beginning when number of nodes are 10. For higher values of number of nodes except 50, it is allmost zero. Hence, DSR is unaffected due to increse in number of nodes as is shown in the figure 10.

Average Throughput

For AODV and DSDV, Average throughput increases with increase in number of nodes up to 30 and almost constant in between 30 and 40, further, it decreases in between 40 and 50 number of nodes. Average throughput is low in case of DSR and is almost unaffected due to change in number of nodes.

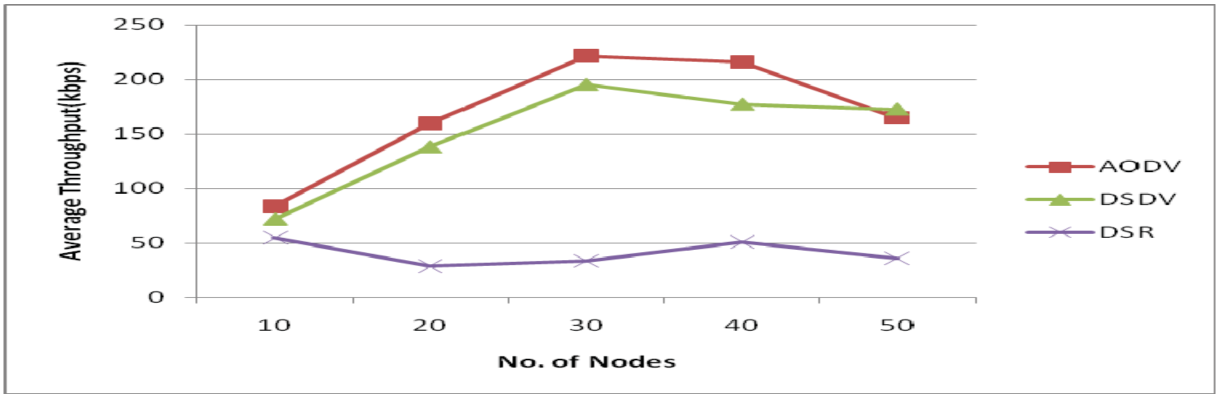


Figure 11: Average Throughput Vs Number of Nodes Response.

Average Jitter

Average jitter is zero for DSR and is completely unaffected of change in number of nodes. In case of AODV and DSR, jitter is higher and increases with increase in number of node till 30 for DSDV and 40 for AODV. After 40 number of nodes for AODV and 30 for DSDV, the response further decreases.

It is concluded that DSR is not affected much due to increase in number of nodes. Decreased in connectivity implies that it did not get as many packets through the network as in the mobility simulation. The worst results for each protocol happened when the mobility was 0. The nodes are not moving and cannot therefore affect the connectivity. However, in a scenario with moving nodes the connectivity will vary during the whole simulation. So even if a node is unreachable from the beginning, there is still a chance that it will be reachable after some time.

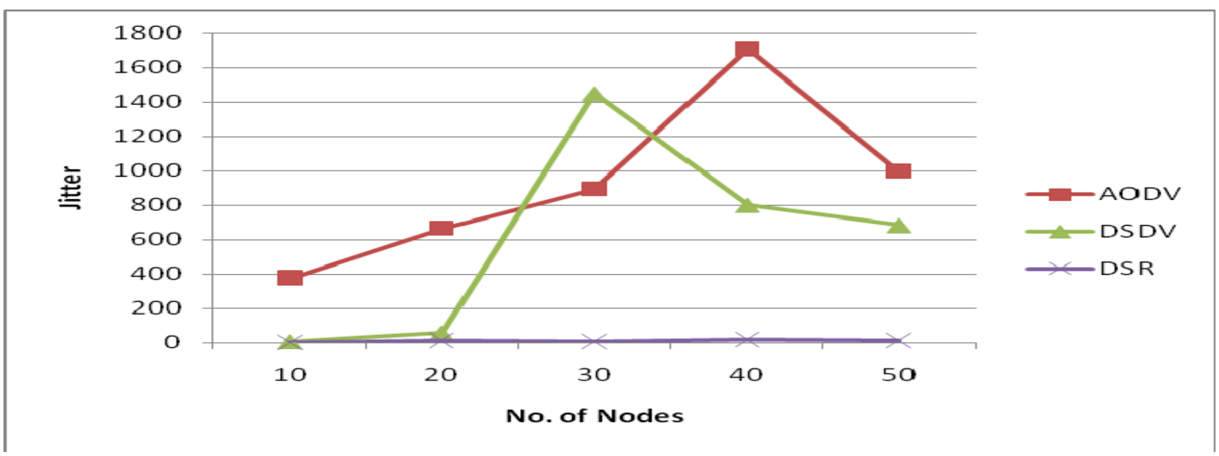


Figure 12: Average Jitter Vs Number of Nodes Response.

III.CONCLUSION

The overall performance of DSDV is found satisfactory with increase in data rate. It must however be noted that the dependency between the scenarios and results are much larger in the network size simulation.

However, DSR is based on source routing in which the byte overhead in each packet affects the total byte overhead in the network quite drastically when the offered load to the network and the size of the network increased. In these situations, a hop-by-hop based routing protocol like AODV is more preferable. Advantage with the source routing approach is that in its route discovery operation it learns more routes. However, source routing is not desirable in ordinary forwarding of data packets because of the large byte overhead. A combination of AODV and DSR is therefore, be a solution with even better performance than individual AODV and DSR.

AODV algorithm is a more efficient routing protocol than DSDV when the pause time of node movement is small. When the nodes stay unmoving for a long time, DSDV is preferable.

It is further clear from the simulations that conventional types of protocols like DSDV have a drastic decrease in performance when mobility increases and are therefore, not suitable for mobile ad-hoc networks. It is therefore desired for special ad-hoc routing protocol when the mobility increases.

Finally, it was emphasized to identify possible applications and challenges facing the ad-hoc mobile wireless network. It is also found that not any particular algorithm is the best suitable for all scenarios. Each protocol has definite advantages and disadvantages, and is well suited for certain situation. The performance of routing protocols is dependent on type of simulator used, as there are no standards available for ad-hoc networks. The field of ad hoc mobile networks is rapidly growing and changing. There are still many challenges that need to be met; it is likely that such networks will see widespread use within the next few years.

REFERENCES

[1] Routing Protocols in wireless Ad-hoc networks- A simulation study, Tony Larsson and Nicklas Hedman, Lulea university of Technology, Stockholm, 1998.

[2] C. Perkins and P. Bhagwat, "Highly dynamic destination sequenced distance vector routing (DSDV) for mobile computers" in ACM SIGCOMM'94 conference on communication Architecture , protocols and applications , London, U.K., Aug'1994.

[3] C.E. Perkins and E. Royers, " Ad-hoc on demand distance vector routing" in WMCSA: 2nd IEEE workshop on mobile computing systems and appliances, New Orleans, USA, Feb'1999.

[4] D. B. Johnson, D.A. Maltz and J Broch, "DSR: The dynamic source routing protocol for multihop wireless ad-hoc networks" in Ad-hoc networking Addison-Wesley, 2001.

[5] Vincent D. Park and M. Scott Corson, "Temporally-ordered routing algorithm (TORA) , August 1998.

[6] S. McCanne and S. Floyd (2003, December) network simulator 2 (ns2) [online].: http://www,isi.edu/nsnam/ns

[7] K. Fall, K. Varadhan and VINT project (2003, December) the ns manual [online]: http://www,isi.edu/nsnam/ns/ns-documen tation.htm

[8] The AWK Manual, Edition 1.0, Diane Barlow Close, Arnold D. Robbins, Paul H. Rubin, Richard Stallman, Piet van Oostrum, December 1995.

[9] Ad-hoc and Hybrid networks, performance comparison of MANET Routing protocols in Ad-hoc and Hybrid Networks, Thomas Staub, IAM, University of Berne, Switzerland, Feb'2004.