A Simulation Study and Comparison of On-Demand Ad-hoc Routing Protocols using QualNet 5.2

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ABSTRACT
A mobile ad-hoc network is a wireless network of mobile devices in which the devices can locate them randomly and thus the network cannot have any fixed or centralized infrastructure. The paper aims to evaluate the performance of two main on-demand ad-hoc routing protocols- AODV and DSR using QUALNET 5.2 network simulator. Here, these protocols are analysed under two network simulation scenarios- varying number of nodes and mobility. Various performance metrics- average end-to-end delay, throughput, packet loss percentage, Packet delivery ratio and average jitter are examined to compare the network performance of these protocols. The simulation results show that DSR outperforms AODV with respect to increasing number of nodes while AODV performs better than DSR with respect to increasing pause time.

Keywords
MANET, AODV, DSR, Packet delivery ratio, throughput, average end-to-end delay, packet loss percentage and jitter.

1. INTRODUCTION
A mobile ad-hoc network is a dynamic network of mobile devices that do not have any fixed infrastructure. In case, any of the communicating devices move out of transmission range, the existing network configures itself automatically. However, routing in MANET is difficult as the conventional routing protocols cannot handle broken links caused due to the movement of the participating node. These conventional protocols converge slowly to topological changes and may lead to excessive periodic exchanges when employed in MANET [2]. Thus, routing in MANET has emerged as an important research area.

A routing protocol is a network layer protocol that is used to determine appropriate routes before the data transmission from source to destination. The ad-hoc routing protocols are broadly classified in three categories- table driven routing protocols, hybrid routing protocol and Source-initiated on-demand routing protocols [1].

Table-driven routing protocols also known as proactive protocols are used to maintain consistent routing information in mobile ad-hoc network. Here, routing information is periodically broadcasted from each node to every other node even though there is no change in network topology. The source-initiated on-demand driven routing protocols also known as reactive protocols create routes only when initiated by the source node. Here, routing is done in two steps-route discovery process and route maintenance process. When a source requires a route to a destination, it initiates the process for route discovery. Once the route is determined, it is maintained by some route maintenance procedures until the route is no longer desired by the source [2]. The hybrid routing protocols combines the advantage of both proactive and reactive ad-hoc routing protocols. Here, routing is initially established using proactive routing and then reactive routing is used in the network.

In this paper section 2 introduces related work, section 3 gives an introduction of on-demand ad-hoc routing protocols- AODV and DSR, section 4 discusses simulation setup, and section 5 discusses the simulation results. Finally, section 6 concludes the paper followed by future work.

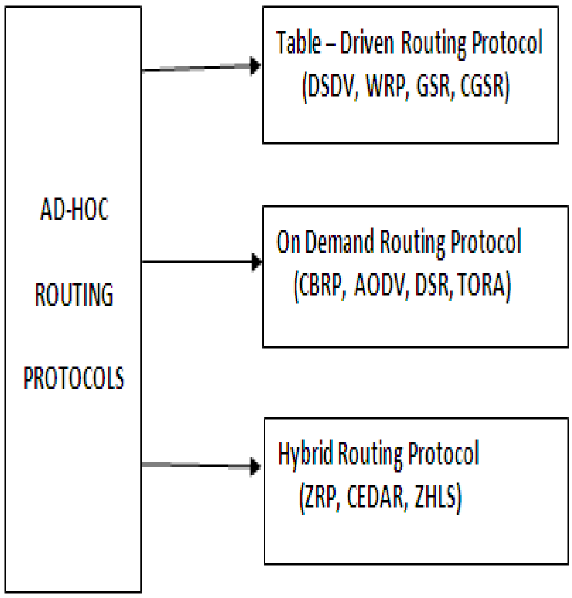

Fig. 1: Classification of ad-hoc routing protocol

2. RELATED WORK
Elizabeth M. Roger and C K Toh [2] discussed various ad-hoc routing protocols – table driven routing protocol (DSDV, WRP and CGSR) and source initiated on-demand driven routing protocol (AODV, DSR, LMR, ABR, TORA and SSR). The authors [2] have also compared these protocols on the basis of various network performance metrics. Md. Shohidul Islam et.al [3] compared DSDV, AODV and DSR ad-hoc routing protocols under two network scenarios- increasing number of nodes (upto 20 nodes) and simulation time (up to 70 seconds) using NS2 simulator. Priyanka Jangir and Saurabh Mishra [4] discussed the general comparison of AODV, DSDV and DSR protocols using QualNet 5.0 simulator with respect to increasing number of nodes (up to 50 nodes). Mukesh Kumar garg et.al [5] evaluated the performance of reactive (AODV and DSR) and hybrid (ZRP) routing protocols on the basis of various performance metrics-

number of routes selected, number of hop count, number of RREQ packets forwarded, number of RREP packets received and number of update packets received with respect to increasing number of nodes in QualNet 5.0. Subramanya Bhat.M et.al [6] discussed the performance of proactive (OLSR), reactive (AODV, DSR, LAR) and hybrid (ZRP) routing protocols for stationary and mobile nodes with respect to node density using Qualnet 5.0.2 simulator. Shaily Mittal and Prabhjot Kaur [7] discussed the performance comparison of three different ad-hoc routing protocols - DSR, AODV and ZRP on the basis of average end-to-end delay, TTL based average hop count and packet delivery ratio as a function of pause time in QualNet 5.0. Ambica Raina et.al [8] discussed and compared AODV and DSR using QualNet 5.0 simulator on the basis of some network metrics- throughput, jitter and data received at the server with respect to increasing number of nodes**.**

In the present research, we are using QualNet 5.2 network simulator to analyse the performance of AODV and DSR protocols in MANET on the basis of different performance metrics under two different network scenarios- number of nodes and decreasing mobility.

3. OVERVIEW OF ON DEMAND AD-HOC ROUTING PROTOCOLS (AODV and DSR)

3.1 Ad-hoc on demand distance vector routing protocol (AODV)

Ad-hoc On-demand distance vector routing protocol (AODV) is basically built on DSDV protocol but, is an improvement to DSDV as it minimizes the number of broadcasts in network. Here, the nodes exchange routing information only if the source desires a route to transmit data packets. AODV is classified as pure on-demand route acquisition system [9], as nodes that are not on a selected path do not participate in routing table exchanges. AODV works on two main processes- route discovery and route maintenance. The route discovery process is initiated whenever a source node wants to transmit data to destination and it has no valid routing information. The source node then floods the network with route request packet, which comprises source sequence number, source ip address, the broadcast id, destination ip address, destination sequence number and hop count [10]. Here, each node maintains two separate counters [10] node sequence number and the broadcast id. The intermediate node records the address of the previous node and can reply to the source node only if it has a route to the destination with equal or greater sequence number than the destination sequence number present in route request packet. Thereby, the reverse path is set up with the propagation of these route reply packets. Similarly, forward path is determined with the help of recorded address of neighbouring nodes and thus, the route from source to destination is discovered. Moreover, route maintenance process is implemented to handle broken links in the discovered route. If the source or intermediate or destination node moves out of transmission range, then the source reinitiates route discovery process. In such cases, route error packet is propagated in the network along with a route reply packet to upstream neighbours. Once route error packet reaches source, it reinitiates route discovery process. Local connectivity is maintained with the use of HELLO messages or acknowledgements. This routing protocol has its own merits and demerits. AODV is suitable in large or dynamic network and hence, preferable in VANET [11]. It incurs less routing overhead than DSR as it records only the address of its neighbour node. It also supports multicasting [12] and in contrast, it incurs a considerable delay, due to route discovery process and repairing of broken links.

3.2 Dynamic source routing protocol (DSR)

The Dynamic Source Routing protocol (DSR) is an efficient on-demand source routing protocol [2] which denotes that the source has knowledge of entire hop sequence to the destination before transmitting any data. Here, each mobile node maintains a route cache where it records all possible learned routes from itself to all other destinations. When a source wants to transmit data to destination, it first looks into its route cache. If it finds a valid route, it uses that route; else it initiates route discovery process by broadcasting the route request packet, which comprises- source ip-address, destination ip-address, request identification number [10]. The request identification number is unique id generated by the source node for each new request. The route record packet is also attached to route request packet to get the hop sequence to destination. When an intermediate node receives route request packet, it searches its route cache for the route to destination. If no route is found, it appends its own address to the route record packet, and then forwards route request packet in network, until it reaches destination, else, it appends the route found in route cache to the route record packet, and then forwards route reply containing entire hop sequence from source to destination along the discovered hop sequence in reverse direction. Similarly, the destination node can also initiate the route reply. Once route is known to source, the network is maintained against link-failure. Here, when an intermediate node discovers broken link, it forwards route error message to upstream neighbour and so on, along the reverse hop sequence present in route record. Once, route error message reaches source, it restarts the entire process. DSR protocol has some merits and demerits. Here, each node learns the entire route from the source to itself and thus less routing load, if routes are available in route cache. In contrast, It is suitable only in less dynamic network and hence, not suitable in VANET [11]. It maintains route record in route request packet, which creates an overhead in large or dynamic network. Also, it does not support multicasting [12].

4. SIMULATION METHODOLOGY

Here, QUALNET 5.2 network simulator is used to analyse the performance of AODV and DSR ad-hoc routing protocols. It can support simulation of protocols involving up to 1000 number of nodes [13] [14]. The key features of QualNet are high speed, Scalability, model fidelity, Portability and Extensibility [13]. The general procedure to get the scenario based simulation results comprises three main steps- Create scenario, Execute scenario and collect statistics, and analyze the simulation results. QualNet Graphical User Interface (GUI) consists of four major modes - Architect, Analyser, Packet Tracer, and File Editor [13]. The architect is a network design and visualization tool which comprises design and visualize mode. With design mode, user can set up terrain, network connections, subnets, mobility patterns of devices, and other functional parameters of network nodes to create a network model. While in visualize mode, user can perform analysis of a designed network scenario. Analyser is a statistical graphing tool that displays the metrics collected during the simulation of a network scenario in a graphical format. Packet Tracer provides a visual representation of packet trace files generated during the simulation of a network scenario. File Editor is a text editing tool that displays the contents of the selected file in text format and allows the user to edit files [13]. There is various input and output files associated with a particular network scenario- scenario configuration file, node placement file, application configuration file and statistics file. Scenario configuration file is the primary input file for QualNet and specifies the network scenario and parameters for simulation. Node placement file specifies the initial position of nodes in the scenario. Application configuration file specifies the applications running on the nodes in the scenario. Statistics file contains the statistics collected during the simulation run [13].

The performance analysis of AODV and DSR protocols in terms of packet delivery ratio, average end-to-end delay, throughput, packet loss percentage and jitter is done on the basis of simulation results in QualNet 5.2. Table 1 lists the simulation parameters that are set up in the given network scenarios.

Table 1. Simulation Parameters

Network simulation model Parameters	Value of parameters
Network type	Wireless
Radio propagation model	Two ray ground propagation
Antenna	Omni directional
Mobility pattern	Random
MAC	MAC 802.11
Number of sources	2
Number of queues	3
Queue length	50
Number of nodes	50, 100, 150, 200
Pause Time	0, 25, 50, 125, 150
Traffic Type (Application/Agent)	CBR/UDP
Simulation area	1500x1500
Data rate	10 Mbps
Packet size	512 Bytes

Fig. 2 shows design mode of canvass in architect mode with 200 nodes. Here default devices are selected from toolkit and the link shows the CBR applications for two sources with identifiers 36 and 39 respectively. The data regarding application can be collected from the application configuration file.

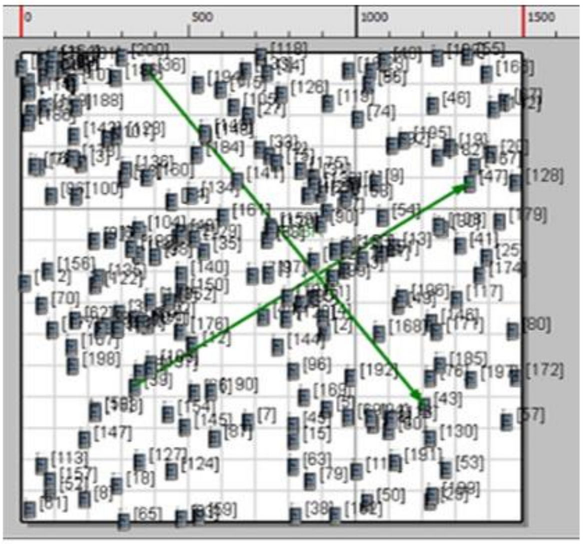

Fig. 2: Snapshot of network scenario in Design Mode (Architect) of canvass with 200 nodes and two sources

The scenarios are analysed in the analyser mode and the value of various metrics – throughput, average end-to-end delay, number of packets received, number of packets sent, jitter, time when last packet is received and time when first packet is received can be directly viewed in statistics mode.

5. RESULTS AND DISCUSSION

On the basis of simulation results, the performance of AODV and DSR ad-hoc routing protocols is compared. The simulation is done using two network scenarios- increasing number of nodes and increasing pause time or decreasing mobility.

5.1 Simulation results with increasing number of nodes

Here, the number of nodes varies as- 50, 100, 150 and 200 nodes in network, simulation time is 1001 seconds and number of sent packets is 1000.

Figure 3 represents a comparison of AODV and DSR on the basis of packet delivery ratio. Packet delivery ratio is computed as the ratio of total number of packets received by CBR server at destination to the total number of packets sent by CBR client at the source [14].

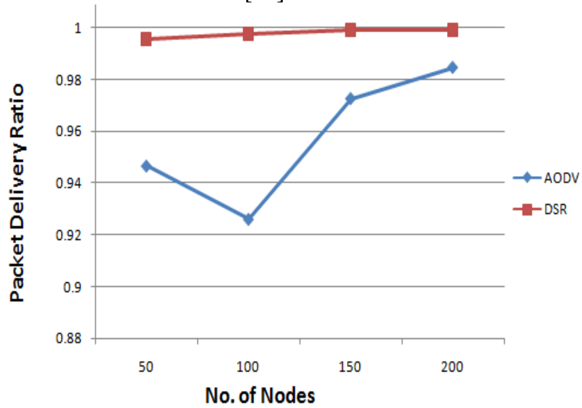

Fig. 3: Packet delivery ratio with varying number of nodes

The above figure shows that DSR performs slightly better than AODV as it has route cache where it maintains routes to all possible destinations. Besides, AODV shows considerable fall in performance at 100 nodes, as the number of intermediate nodes are increased and this lowers delivery of packets at destination but overall, it improves performance with increasing number of nodes.

Figure 4 shows the behavior of AODV and DSR protocols in terms of average end-to-end delay. The average end-to-end delay at server is calculated as ratio of total of packet delays for all packets to the total packets received where; packet delay is the difference between time when packet is received at server and the time when the packet is transmitted at client [14].

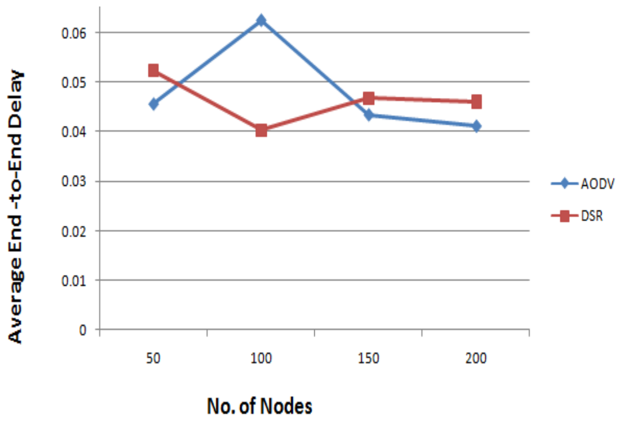

Fig. 4: Average end-to-end delay with varying number of nodes

It is observed that in DSR, if routes are found in route cache, then the value of total packets received at destination can be greater than AODV protocol, but DSR faces larger queuing and transmission delay [15] in dense network and hence, later it decreases the performance. Unlike DSR, AODV does not incur routing overhead caused due to maintenance of route record.

Figure 5 shows the behavior of AODV and DSR protocols in terms of throughput. Throughput is defined as number of bits received at destination per unit time. Throughput at the CBR server is computed as [14]:

Throughput (bits/sec) = (Total Number of bytes received at destination *8) / (time when last packet received - time when first packet received)

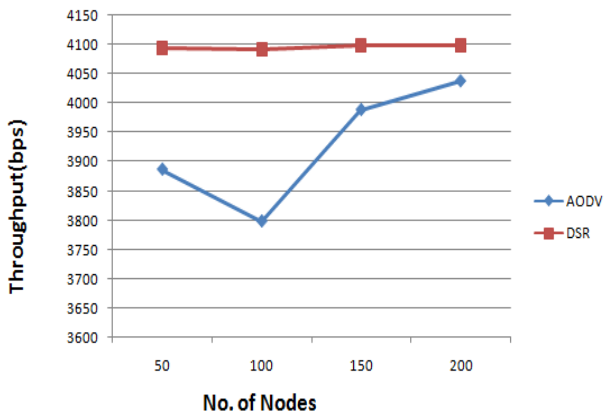

Fig. 5: Throughput with varying number of nodes

The above figure shows that DSR outperforms AODV in terms of throughput as it has incurred lower value of total time to transmit packets which is defined as difference of time when last packet received and time when first packet received.

Figure 6 shows the packet loss percentage of AODV and DSR protocols. Packet loss percentage is the percentage of packets lost when transmitted from source to destination and is inversely related to packet delivery ratio.

It can be expressed as:

Packet loss percentage = (1 - Packet Delivery Ratio) * 100

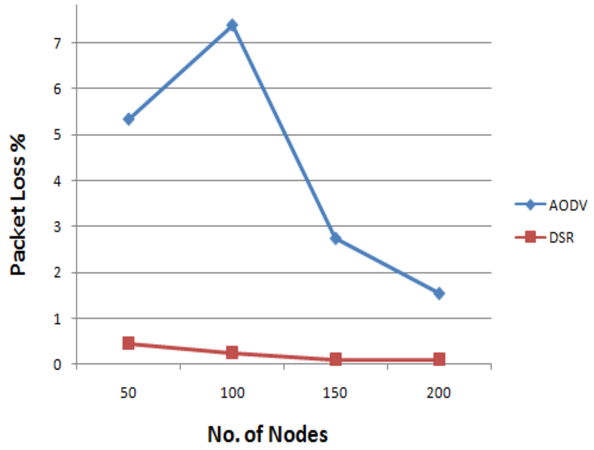

Fig. 6: Packet loss percentage with varying number of nodes

The above figure shows that DSR outperforms while AODV improves the performance for larger number of nodes.

Figure 7 shows the behavior of AODV and DSR protocols in terms of average jitter. Jitter of a packet is defined as the difference between transmission delay [15] of the current packet and transmission delay of the previous packet; hence, jitter can be calculated if at least two packets have been received at destination. Average jitter [14] is computed as:

Average jitter = (total packet jitter for all received packets) / (number of packets received - 1)

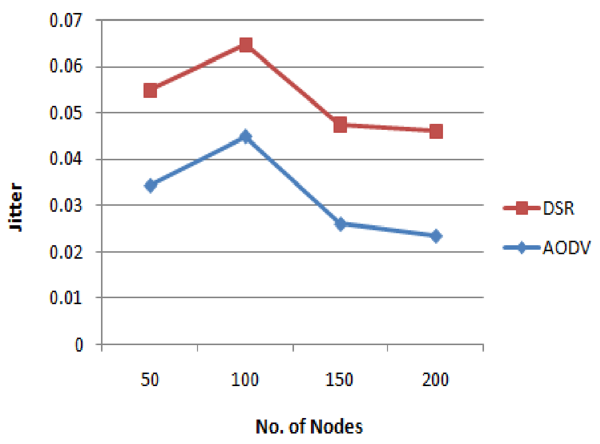

Fig. 7: Average jitter with varying number of nodes

Here, AODV outperforms DSR in terms of average jitter.

5.2 Simulation results with increasing number of nodes

Mobility of network is inversely related to pause time. Here, number of nodes is fixed at 100 and pause time varies as- 0, 25, 50, 100 and 150. The simulation time is 151 seconds. The '0' pause time stands for the highly mobile network while '150' stands for no mobility at all. The number of sent packets is 150 and these packets are transmitted from source after every 1 simulation second. Figure 8 shows the comparison of AODV and DSR protocols on the basis of packet delivery ratio.

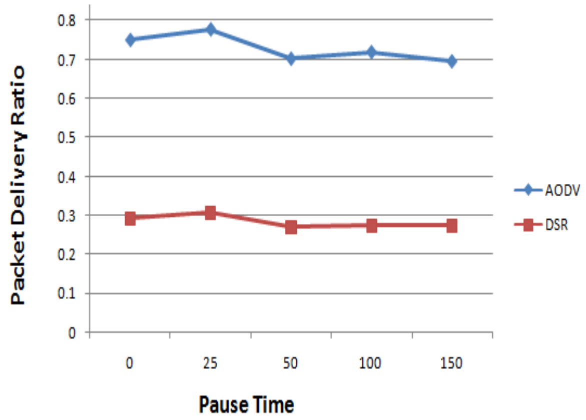

Fig. 8: Packet delivery ratio with varying pause time

Here, AODV outperforms DSR in terms of packet delivery ratio as the increased mobility in the network leads to routing overhead. During updating of route record in Route request packet in DSR increases with the increase of broken links and hence, route cache is no more helpful. Figure 9 shows the comparison of AODV and DSR protocols on the basis of average end-to-end delay.

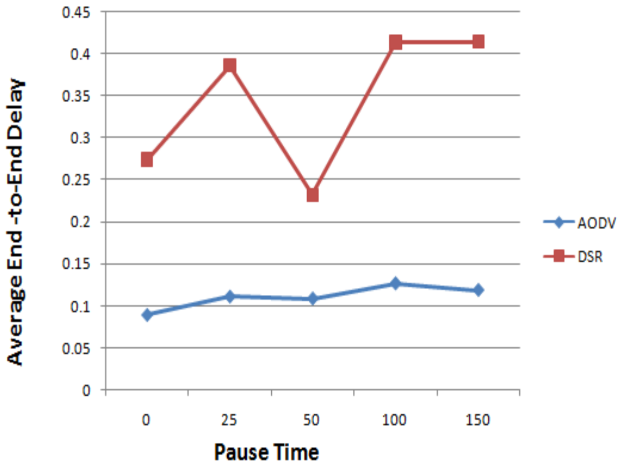

Fig. 9: Average end-to-end delay with varying pause time

The above figure shows that AODV outperforms DSR. Here, DSR consumes more time to handle broken links and thus, it incurs higher transmission delay. Figure 10 represents that performance of AODV is better than DSR protocol in terms of throughput.

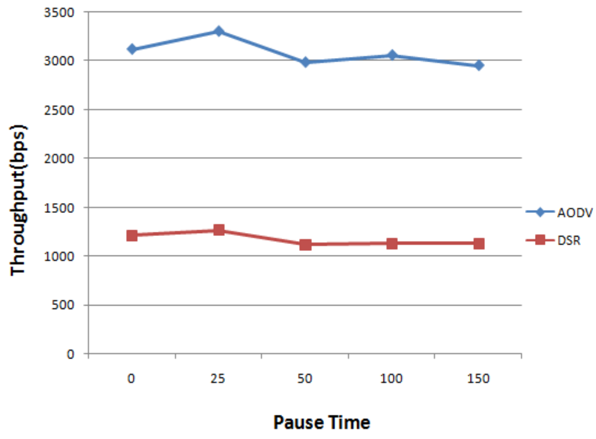

Fig. 10: Throughput with varying pause time

DSR incurs longer transmission time due to link failure. Also, network settling time degrades the performance of DSR. Figure 11 represents that the lesser number of packets are lost in AODV than DSR.

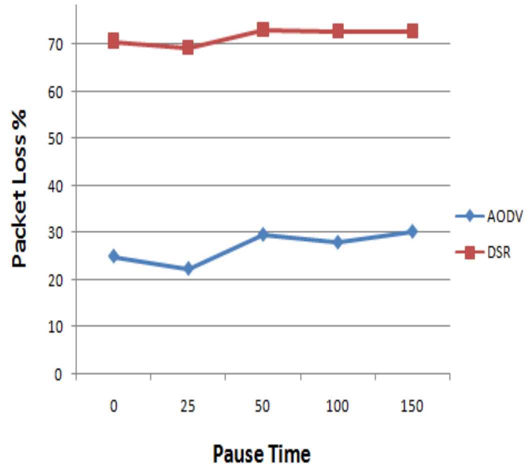

Fig. 11: Packet loss percentage with varying pause time

Figure 12 compares AODV and DSR in terms of average jitter where DSR outperforms AODV.

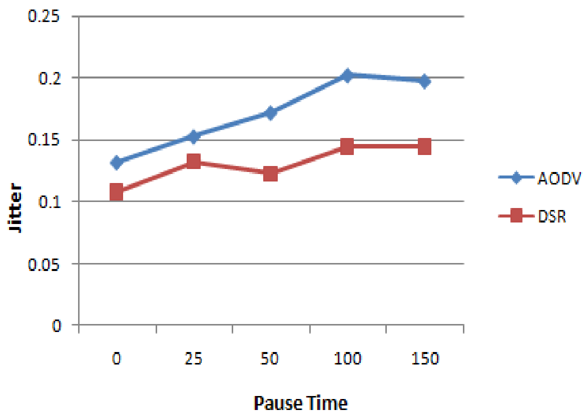

Fig. 12: Average jitter with varying pause time

6. CONCLUSION AND FUTURE SCOPE

The simulation results with increasing number of nodes conclude that DSR outperforms AODV in terms of packet delivery ratio, throughput and packet loss percentage while AODV performs slightly better than DSR in terms of average end-to-end delay and average jitter. But, the simulation results in terms of pause time summarize that AODV shows better performance than DSR protocol except in terms of average jitter. Hence, the paper concludes that DSR can be used in larger or less mobile network while, AODV is preferred in high dynamics and also when lower delay is the major concern (as in transmission of multimedia data). In future, more performance parameters can be considered. Next step is to create network scenarios considering various network factors- weather conditions like cloudy or dry weather, variation due to terrain obstacles and then analyze the performance of routing protocols under these circumstances.

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