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A Comparative Study On Vehicular Ad-Hoc Networks Topology Based Routing Protocols

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ABSTRACT
Vehicular Ad Hoc Network (VANET) is a new intelligent technology that includes communication between vehicles that are moving at high speed. It is used to establish a safer environment on the roads, reduce fuel consumption and pollution, or help the driver to discover services (shops, gas stations, etc.) on that street. All of this is intended for the safety and comfortability of the passengers while using their vehicles. Its target to obtain a spread continuous connectivity for vehicles, which can be achieved by either efficient vehicle-to-vehicle (V2V) or vehicle-to-roadside unit (V2RSU) communication. This paper aims to compare the average throughput, packet delivery ratio and packet loss ratio for AODV, AOMDV, DSDV, and DSR topology-based protocols. The results indicate that the best protocol for all metrics is AODV. For medium and high density, DSR is the worst.

KEYWORDS: Wireless Communications - VANET –Routing issues, AODV, AOMDV, DSDV, and DSR.

1. INTRODUCTION

During the last few years, communication between moving vehicles along roads has been introduced as a new field within the computer and network science. VANET is a self-organizing network. VANET is a branch of wireless communication networks that are responsible for the communication and data transmission between moving vehicles in a certain area this kind of communication is called Vehicular Ad-Hoc Network (VANET). It is a similar branch to the Mobile Ad-Hoc Networks (MANET), every vehicle is equipped with an electronic equipment, a wireless network card that provides Vehicles the ability to send and receive data among moving vehicles within roads (V2V), and between these vehicles and roadside units (V2RSU) [1] As shown in figure (1).

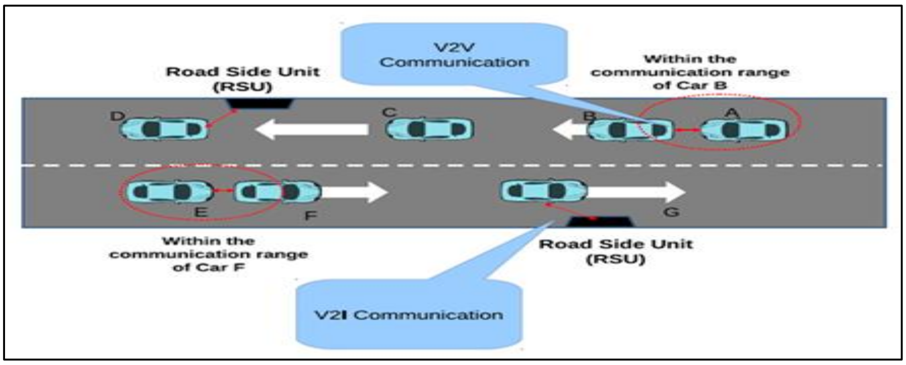

Figure 1 Creating an Ad-hoc Network using Vehicles (VANETs) [1]

Every node within VANET serves as both, the sender and receiver inside the network [2], nodes usually communicate by using other intermediate nodes that stand within their transmission range. It has no fixed network infrastructure. The most important target of VANET is to increase the safety on different roads and comfortability for the passengers.

This paper is organized into seven sections. The previous section covers the introduction of the VANET network; the following two sections provide a brief study on different types of topology-based routing protocols compared in this paper. Section 4 describes the related work. Section 5 provides a simulation setup. Section 6 provides the terminology used to compare the performance of different routing protocols with the results and the analysis. The final section concludes the paper.

2. VANETS AD-HOC ROUTING PROTOCOLS

Routing Protocol is a standard, which specifies how different nodes communicate with each other, dealing and analyzing information, which provides them with the capability to choose and select routes between any two nodes on a network. Routing algorithms determine the specific choice of route. Every node has a preknowledge of nodes that are already attached to it directly. There are two main categories for routing protocols [3] for VANET, topology-based and position-based. This paper focuses on the topology-based routing protocols.

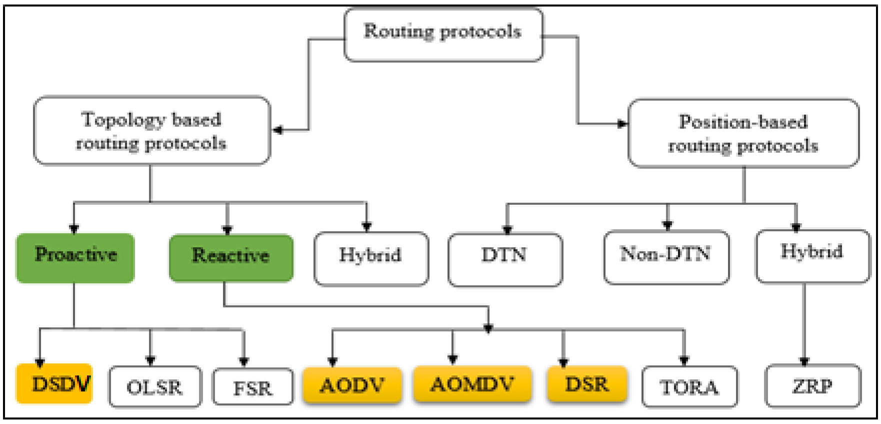

Figure 2 VANET Routing Protocols [3]

3. TOPOLOGY-BASED ROUTING PROTOCOLS

Topology-based routing protocols have to create and maintain a global route from the source node to destination node [4]; this is significant in terms of Packet Delivery Ratio, Throughput, and End-to-End delay [5]. Topology Based Routing schemes generally require additional node topology information during the routing decision process. Topology Based Routing Protocols are divided into Proactive and Reactive [6] or hybrid.

A. PROACTIVE ROUTING PROTOCOLS

Within Proactive routing protocols [6] outing data area maintained and updated between all nodes at all times, updating Routes is performed periodically regardless of network load, bandwidth constraints, or network size. Each node inside the network has [7] its routing table to be used for broadcasting of the data packets and on the other side, The nodes want to create a connection to other nodes inside the network. These records inside each node contain information related to all the presented destinations, how many hops required to arrive at each destination within the routing table. The routing entry is marked with a sequence number that is created by the destination node. To maintain the stability, broadcasting and modifying routing tables by each station occurs from time to time. Which stations are accessible and can be reached, using how many hops, this is all the result of broadcasting of packets between nodes. Each node makes broadcasting for its data will contain its new sequence number and for each new route, the node contains the next information:

- How many hops are needed to reach a specific destination node?
- Creating of new sequence number tagged by the destination.
- At last, the destination address.

The proactive protocols are suitable for a low number of nodes within networks; each node needs a continuous update for node entries within their routing table. Besides, it is noticed that such protocols within this category maintain the different number of tables for continuous [6] understanding of network topology. This of course results in more Routing overhead problems, and a significant amount of memory overhead within each node as the size of the network increases. Which led to a consumption of more bandwidth inside the routing table, as well as power because each node is required to stay active at all times

Destination Sequenced Distance Vector (DSDV**)**

DSDV is a table-driven routing scheme [8] used for ad-hoc mobile networks. It is based on the classical Bellman-Ford routing algorithm that is used to select the shortest path from in-neighbors and to out-neighbors. Each packet has a sequence number that is increasing to prevent loops, counter the count-to-infinity problem and faster convergence.

It exchanges these tables periodically to its neighbor nodes. Two methods for updating routing tables will be used. Firstly, the “full dump” strategy in which the complete routing table is sent in an update message. The second is the “incremental update” strategy, which contains only the data of the entries with the minor changes that have been changed since the last full dump exchange. When the nodes detect a link breakage [9] it sets all routes through a broken link to infinity. It then informs neighbors about alternate shortest path to a destination. This mechanism makes DSDV has a very fast route set-up process. In counter, such mechanism within highly dynamic networks such as VANET leads to a huge volume of control traffic, which results in consuming a large amount of network bandwidth.

B. REACTIVE ROUTING PROTOCOLS

Within Reactive routing [10] f a node wishes to send a data packet to another node, using this protocol it searches for the routes in an on-demand manner and creates the connection in order to transmit and receive the packets. For on-demand routing protocol there are two components: Route Discovery: If the route towards the destination is not included by the source in its current routing table, it issues a route discovery broadcast packets within the network. When a route between both the source and destination has been established, the selected route can exchange the data.

Route Maintenance: As the dynamic nature of VANETs, networks may lead to the continuous failure of the links within the established route. It is desired that a route maintenance mechanism must be placed to deal with route breaks. Confirming of correctly received packed is done by downstream node (backward Route) by the use of one of three types of acknowledgments: link-level, passive (listening to the forwarding by next-hop node), and network-layer. Below are representatives of two well-Known reactive routing protocols with their characteristics in VANETs:

(1)Ad-hoc on-demand distance vector (AODV**)**

A reactive routing protocol, which means that routes are created when needed [11]. When a node does not have a valid route to the destination, The Route Request (RREQ) message is sent to all of its neighboring nodes, by using sequence numbers to discard multiple copies of the same route request. If an intermediate node received it, and it already knew a route to the required destination, it will reply by (RREP) packet to the sender node. Otherwise, it will forward the packet until it reaches the destination. The broadcast address of all previous nodes will be stored, as it is needed to forward the packet to the source. If a reply is not received before time expiration, the entry will be deleted. Route maintenance will be needed when a route fails. The closest node to the break creates RERR (Route Error). RERR will contain a list of all nodes that were affected by the link failure.

(2)Ad-hoc on-demand multipath distance vector (AOMDV**)**

AOMDV is an extension to the AODV routing protocol, [12] where multiple routes are founded between the source and destination during the route discovery process. Such a technique helps in load spreading, minimizes congestion possibility and provides better relatability. AOMDV keeps routing table for each node in the network. The route construction process is done by flooding a RREQ packet in the network [13]any intermediate node receives this packet will set a reverse path to the node that sends it to this packet. If it has no information about the requested route, it will rebroadcast it again. Any later copy of the same RREQ packet will be neglected. The result is multiple paths to destination with a different hop count. The route with maximum hop count will be shared. To maintain a loop-free path, AOMDV ensures that the loop will be avoided by forcing intermediate nodes not to respond for RREQ packets coming from a path that does not include an intermediate node itself. AOMDV maintains multiple link disjoint paths. After flooding the network with RREQ packets, multiple copies are received. Each arriving via different neighbor defining node disjoint paths, no node common in received paths except source and destination [14].

(3)Dynamic source routing (DSR)

It is a source routing protocol. It does not use (Hello) packets aiming to reduce the amount of bandwidth consumed by Control packets [8]. During route construction [15] & [16] every node stores every route started from itself to another node. If a node wants to send a message, a checkout for the route cache is performed for checking the availability of an unexpired route to the wanted destination. If it is already found, the transfer procedure is started. Otherwise, a new route discovery process is established by flooding route request packets in the network The route request packet contains the source node address, the destination node id and a new sequence number which is used to prevent loop information. Every node receives that packet checks its sequence number and rebroadcast it to its neighbors after adding its address information to the packet if it is not already the destination node. If a link breakage is detected, an error message is generated and sent by the node to the source. The source then removes all broken links, and if it is needed another route request is initiated.

With the use of DSR [17] the network is completely self-configured and self-organized, with no need for either administration nor already build infrastructure, sender nodes already knew the complete hop-by-hop route to the destination node, as the routes are stored in the route cache.

4. RELATED WORK

On paper [18], it uses the NS-2 simulator to compare (AODV, AOMDV, DSR, and DSDV) protocols. Its metrics are Throughput, End-to-End Delay and the Packet Delivery Ratio with two mobility models the Random waypoint model, with velocity and acceleration changes over time and the Freeway mobility model in urban areas. Where they move in an organized manner using vertical and horizontal directions. The AODV has the best performance in terms of throughput, but it consumes more power. In the case of Packet Delivery Ratio, within small density, AODV and DSR have the same diagram, but by increasing the number of nodes, AODV performs better than DSR. In both scenarios, DSDV has the lowest throughput; also, it performs badly in the Packet Delivery Ratio in case of increasing nodes. DSR has the highest average End-to-End Delay in both scenarios. AOMDV has low End-to-End Delay with middle pattern in all metrics.

At [19], it focuses on the possibility of applying MANET routing protocols Within VANET networks. Especially when the number of vehicles increases. Also by increasing nodes speed, when it moves inside the environment. AODV, AOMDV, DSR, DSDV. Where compared in terms of Packet Delivery Ratio, End-to-End Delay, true Normalized Routing Load and Packet loss ratio. It uses two scenarios: first, is a high-speed scenario (Kilometer/hour), second is a high-density scenario (vehicles / meter^2). The experiment was done using from 100 to 300 vehicles. To evaluate dentist varying performance. In addition, the speed varies from 60 to 100 kilometer per hour when evaluating speed-varying performance. At speed variation. At all scenarios, the transmission range for the vehicles was 85 meters. That Packet generation rate was five packets. That Packet size was 100 bytes. In addition, the Simulation area is 10 by 1000 meters. The Simulation Lasts for 200 seconds. In the case of evaluating the performance of the Packet Delivery Ratio (PDR), Both AODV & AOMDV has similar results. DSR decreases by increasing the speed, and it becomes more unstable. On the other hand. PDR of the DSDV routing protocol Decrease at high speed very much. The DSR has the lowest PDR, as the velocity increases. In terms of End-to-End delay, DSDV In both scenarios has the lowest delay. Both AODV & AOMDV have the highest delay and in between DSDV and (AODV & AOMDV) Lies DSDV. In terms of Normalized Routing Load, DSR has the best. Followed by DSDV In the velocity diagram, and AODV in the density diagram. AOMDV has the highest in NRL in speed diagram, DSDV Has the highest in density diagram. DSDV is not recommended for delay-sensitive networks.

In [14], a probabilistic relay technique was tested with both, AODV & AOMDV. The two protocols were examined to evaluate their performance by measuring metrics (Packet Delivery Ratio – Routing Overload - Average Delivery Delay). This proposed technique could allow adjacent vehicles to the sender and receiver to retransmit undelivered packets, in order to improve Packet Delivery Ratio performance under high speed. For this experiment, several assumptions were taken into consideration. Two hundred data packets were sent from one hundred vehicles in area of 1000*1000 m2. The radio range was 250 m, and the simulation lasts for 500s. Vehicles speed varies from (10 - 30) m/s. the results were collected from five random pairs of sources and receivers. The main idea of the probabilistic relay technique is that instead of retransmission of undelivered packets by the same source, we can use another adjacent source to retransmit the packet. As sending and retransmitting, the same undelivered packet from several adjacent may result in the possibility of collusion probability. Each adjacent vehicle calculates its relaying probability locally. At low speed, No effect for the AODV routing protocol, as its multipath mechanism deals well with connectivity problems. For the AOMDV routing protocol, good support is noticed in order to recover unsuccessful packet transmission through its uni-path. At high speed with highly dynamic topology, both AODV & AOMDV outperform their original performance in terms of PDR and succeed to resolve connectivity problems at high speed while keeping almost the same amount of routing overhead.

The aim of [20] is to quantify the impacts and effects of changing the sending rate of source node with multiple pause times using a node movement model and a CBR source traffic model, by simulating three different routing protocols AODV, DSR, and DSDV on NS2 platform. The protocols were analyzed using three performance metrics named Packet Delivery Ratio, average End-to-End delay and normalized routing overhead. To evaluate the performance of a specific factor, the simulation was done five times resulting in five different scenario patterns. The average of these five outputs is used to calculate the required performance. For each factor, seven sample points used to compare the three different ad hoc protocols. The experiment was done in a 1000 * 300 square using 50 mobile nodes with a constant maximum speed of 20 m/s. Pause times used for the mobility for all nodes varies from zero to 900s. Each source has a sending packets rate, which varies from 2 PPS to 4 PPS. Total Simulation time is 900s.

5. SIMULATION SETUP

There are many simulation software, such as OPNET, OMNET++, NS2, NS3, Matlab …etc. In this paper, the simulation is based on NS2 (Network Simulator Version 2). Because it is an open-source, event-driven simulator designed specifically for research in computer communication networks; the paper authors are familiar with it.

This paper uses NS2 Scenarios Generator version 2.1 (NSG 2.1) which is a TCL script generator tool used to generate TCL Scripts automatically. This tool is used to generate the stimulation protocol, with simulation time, type of network and number of nodes. After the TCL code file is generated. Then run this file on NS2 to get the output file (.tr). Using NS2 scripts on the output file, to get the results for average throughput and Packet Delivery Ratio. Finally, then uses the Network Animator (NAM) to visualize and play the movement of the vehicles. This paper uses the following Simulation Parameters:

Table 1 Simulation Setup

Sim. Parameter	Values
Simulator	NS 2.35
Antenna Model	Antenna/ OmniAntenna
Radio-propagation model	Propagation/ TwoRayGround
Channel type	Channel/ WirelessChannel
Interface queue type	Queue/DropTail/PriQueue
MAC type	Mac/802_11
Routing protocol	AODV, AOMDV, DSDV, and DSR.
Number of Vehicles	50,100,150,200,250,300,350,400 and 450
Vehicles Speed	Min 10 m/s, Max 40 m/s
Simulation time	100 s
Simulation area	2 km^2

6. RESULTS AND ANALYSIS

Different performance metrics are available for checking the performance of routing protocols. The used operating system is UBUNTU release 16.04 on Virtual machine with six Intel Xeon processors and 48 GB Ram. This study chooses Average Throughput, Packet Delivery Ratio and Packet loss Ratio with a different number of vehicles (50,100,150,200,250,300,350, 400 and 450 vehicles) in order to check the performance of topology routing protocols in highly dynamic VANET environment within area of 2km2 within 100 seconds. The selected metrics for routing protocols evaluation are as follows:

Average Throughput: the rate of successful message delivery over a communication channel. It is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second (p/s or PPS) or data packets per time slot.

Packet Delivery Ratio: The ratio between packets originated by the source and the number of packets received at the final destination.

$$\text{Packet Delivery}=\frac{\sum Total\ Data\ Packets\ Recived}{\sum Total\ Data\ Packets\ Sent}$$

- **Packet Loss Ratio:** The packet loss ratio represents the ratio of the number of lost packets to the total number of originated packets.

$$\text{Packet Loss}=\frac{\sum Total\ Data\ Packets\ Sent - Total\ Data\ Packets\ Recived}{\sum Total\ Data\ Packets\ Sent}$$

The first scenario uses (50 to 250) nodes and evaluates the above-mentioned four protocols (DSDV, AODV, AOMDV, and DSR). The second scenario uses 50 to 450 nodes and evaluates the above-mentioned three protocols (AODV, AOMDV, and DSR). These two scenarios because of the execution of the experiment use NS2 is hung up in simulating DSDV protocol when the number of nodes becomes more than 250 nodes, so that the experiment is executed without it.

Figure (3) and figure (4) show Average throughput concerning the number of vehicles for the experimental results of the first scenario and second scenario respectively. It notices that AODV has the best throughput for all the nodes.

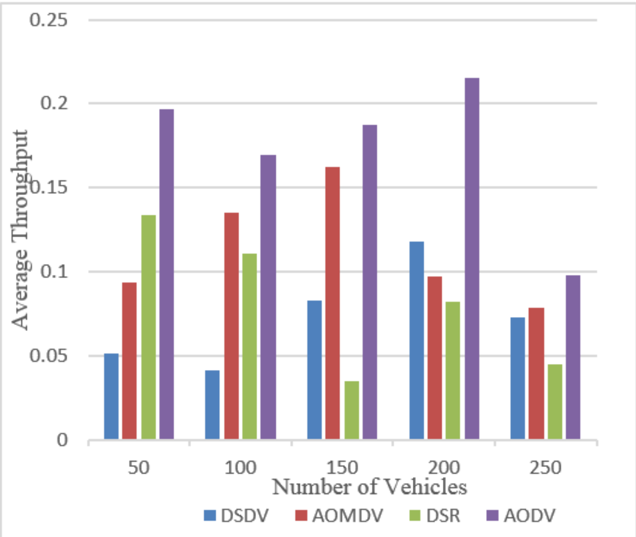

Figure 3 Average throughput ratio VS. Number of vehicles for (AOMDV, DSDV, DSR and AODV)

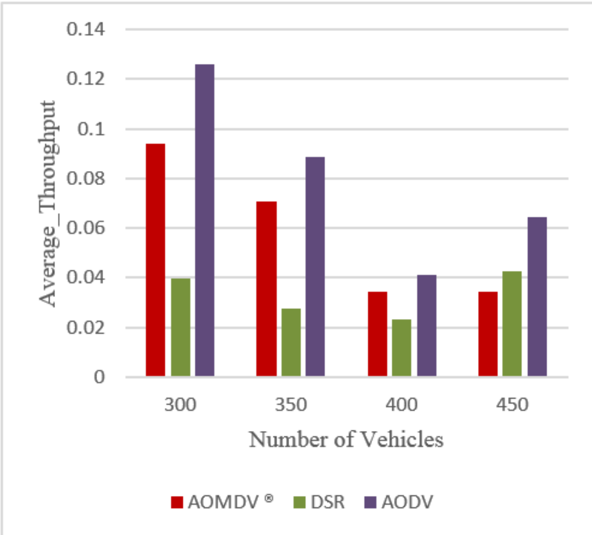

Figure 4 Average throughput ratio VS. Number of vehicles for (AOMDV, DSR and AODV)

For 100 nodes, AOMDV is better than DSR by 18%, and for 150 nodes, it also better than DSR by 78%. For 100 nodes, AOMDV is better than DSDV by 69% and for 150 nodes, it also better than DSDV by 48%. For 200 nodes, DSDV outperforms AOMDV by 17%. At 400 nodes, AOMDV exceeds DSR slightly by 32%. DSR has the lowest Throughput, except At 450 node, DSR is better than AOMDV by 18%.

Figure (5) and figure (6) show the Packet Delivery Ratio concerning the number of vehicles for the experimental results of the first scenario and second scenario respectively. It notices that AODV has the best PDR for all the nodes.

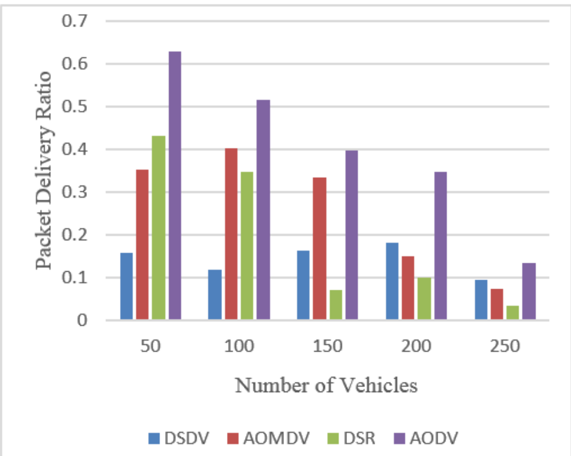

Figure 5 Packet delivery ratio VS. Number of vehicles for (DSDV, AOMDV, DSR and AODV)

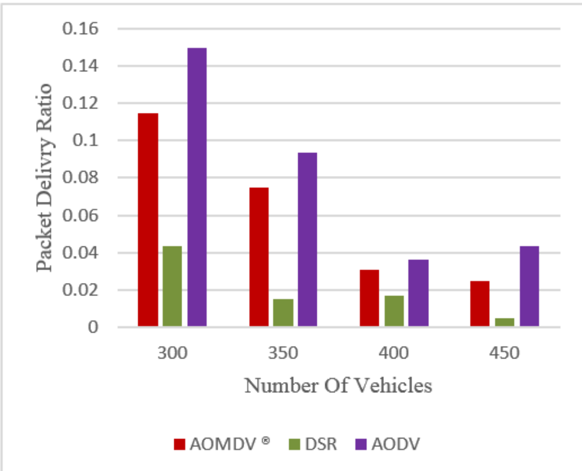

Figure 6 Packet delivery ratio VS. Number of vehicles for (AOMDV, DSR and AODV)

For 50 nodes, AOMDV is better than DSDV by 50%. For 100 nodes, AOMDV is better than DSDV by 70%. For 150 nodes, AOMDV is better than DSDV by 50%. For 200 nodes, DSDV is better than AOMDV by 17%. For 250 nodes, AOMDV is better than DSDV by 16%. From 150 nodes to 450 nodes, DSR has the lowest PDR. Except At 400 node, DSR outperforms AOMDV PDR by nearly 45%.

Figure (7) and figure (8) show Packet loss concerning the number of vehicles for the experimental results of the first scenario and second scenario respectively. It notices that AODV has the lowest Packet loss for all the nodes.

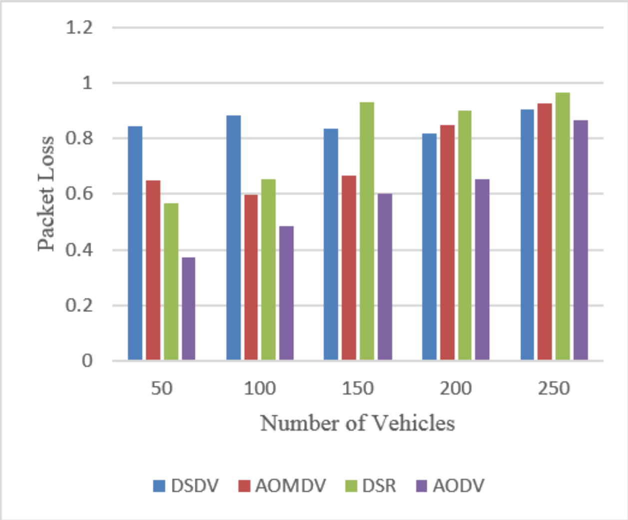

Figure 7 Packet Loss VS. Number of vehicles for (DSDV, AOMDV, DSR and AODV)

Figure 8 Packet Loss VS. Number of vehicles for (AOMDV, DSR and AODV)

For 50 nodes, AOMDV has more Packet loss than DSR by 23%. For 100 nodes, DSR has more Packet loss than AOMDV by 8%. For 150 nodes, DSR has more Packet loss than AOMDV by 28%. For 200 nodes, DSR has more Packet loss than AOMDV by 5%; DSDV has less Packet loss than AOMDV by 3%. DSDV has less Packet loss than AOMDV by 2%. For 250 nodes, DSDV has less Packet loss than AOMDV by 2%.

7. CONCLUSION

In this paper, the main goal is the analysis of topology-based routing protocol using the NS2 simulator to simulate DSDV, AOMDV, DSR, and AODV routing protocols. The evaluated metrics are Average Throughput, Packet Delivery Ratio, and packet loss ratio. The best protocol for all metrics is AODV. For medium (from 100 nodes to 150 nodes), and high density (from 150 node t0 450 nodes), DSR is the worst. For Average throughput, AOMDV Follows AODV; at low density (50 nodes), DSR has better Average Throughput. At high density, AOMDV Follows AODV for PDR. At low density (50 nodes), DSR has better PDR. At medium Density, DSDV has better PDR. At high density, AOMDV Follows AODV for Packet Loss. At low density (50 nodes), DSR is better. At medium density, DSDV is better. The overall performance of the experiment began to decay gradually after 200 nodes. For the future work, we will try to evaluate both Delay and Normalized Routing Load for the above-mentioned protocols. Moreover, find a way to simulate more nodes in DSDV protocol.

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