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Performance Analysis of AODV, AOMDV, DSR, DSDV Routing Protocols in Vehicular Ad Hoc Network

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Abstract

Vehicular Ad Hoc Network (VANET) is appeared to be a new technology to integrate the susceptibility of vastly employed wireless networks to vehicles. The idea is to attain the ubiquitous connectivity for vehicles either through efficient vehicle-to-vehicle or vehicle-to-infrastructure communication that enables the Intelligent Transportation Systems (ITS). In order to design a suitable and efficient routing protocol in VANET, a comprehensive study on popular existing VANET routing protocols must be considered as a tangible need. In this paper, AODV, AOMDV, DSR, DSDV are exploited to be compared in terms of routing performance based on vehicle velocity and vehicle density.

Keywords: VANET, AODV, AOMDV, DSR, DSDV, Routing performance.

Introduction

Vehicular Ad hoc Networks are derived from Mobile Ad hoc Networks (MANET)[1]. Therefore, it is safe to accept that some of MANET characteristics are deployed on VANET structure. For instance, both network protocols are considered as multi-hop mobile networks which are having the dynamic topology. Additionally, there is no centralized entity to manage the packet routing across the network but the vehicles themselves route data packets from source to destination. Being infrastructure independent is counted as another specification of MANET and pure VANET. However some mobility patterns in VANET protocol make it distinguished from MANET, where the nodes are restricted to travel in specific boundaries and paths such as roads or highways and therefore not in random directions. Being limited in storage capacity and low processing power also is considered as MANET specifications while VANET is not suffering from those limitations due to deployment of vehicles which is fully guaranteed in providing sufficient storage capacity and high processing power. Additionally vehicles are known as long range communication entities with enough battery power. Moving in high velocity and unpredictable vehicle density are other disparities between VANET and MANET that cause the lifetime communication link shorter between vehicles or mobile nodes[2,3].

VANET is one of the latest technologies that have been used in wireless communication particularly in vehicular communication in urban areas. Road accidents seem to be inevitable with the fast growth of number of vehicles being deployed in urbanized societies. VANET protocol provides the opportunity to eliminate the accidents occurrence by providing some information about traffic congestion, lane changing and road condition. Communication between vehicles are either “unicast” by which communication is provided for vehicles that are one hop away or “multicast” by which delivering data packets to specific destination is possible through multi-hop communication. Multicasting which is more likely than the other propagation method must be done precisely due to the need of delivering packets to destinations within specific time. VANET also known as Inter-Vehicle Communication (IVC) has severely drawn a significant interests on not only research communities but also industries. Association of Electronic Technology for Automobile Traffic and Driving[4] implemented in Japan, California PATH[5], Chauffeur of EU[6] and European Project CarTALK[7] have demonstrate the mechanisms and approaches to couple two or more vehicles in order to communicate with each other in the form of a train in addition to investigate the shortcomings related to safe and comfortable driving. A new task group called IEEE 802.11p [8] is formed by IEEE in order to provide wireless communication in vehicular environment. Due to high velocity, dynamic topology and unreliable channel conditions, many challenging issues are proposed in VANET for further in depth investigations such as data packet delivery delay, dissemination mechanisms, data sharing and security issues. In this article, routing protocol which is considered as a very vital issue in VANET is investigated. Here we are considering AODV, AOMDV, DSR and DSDV routing protocol based on two parameters: vehicle velocity and the vehicle density. In the first scenario, the performance of the aforementioned routing protocols is investigated as the velocity increases. The second scenario demonstrates the performance of routing protocols based on various vehicle densities.

Related works

Ad Hoc on Demand Distance Vector (AODV): AODV is the on-demand (reactive) topology-based routing protocol [9] in which backward learning procedure is utilized in order to record the previous hop (previous sender) in the routing table. In the backward learning procedure, upon receipt of a broadcast query (RREQ)[10] which contains source and destination address, sequence numbers of source and destination address[11], request ID and message lifespan, the address of the node sending the query will be recorded in the routing table. Recording the specifications of previous sender node into the table enables the destination to send the reply packet (RREP) to the source through the path obtained from backward learning. A full duplex path is established by flooding query and sending of reply packets. As long as the source uses the path, it will be maintained. Source may trigger to establish another query-response procedure in order to find a new path upon receiving a link failure report (RERR) message which is forwarded recursively to the source[12]. Being on-demand to establish a new route from source to destination enables AODV protocol to be utilized in both unicast and multicast routing[13]. Figure 1 illustrates the propagation of RREQ packet and path of RREP reply packet to the source.

Multiple RREP messages may be delivered to the source via different routes but updating the routing entries will occur under one condition which is if the RREP has the greater sequence number. A message with higher sequence number represents the more accurate and fresh information. Several enhanced approaches were proposed to eliminate the large overhead and high latency (End-to-End Delay) which result in encountering high amount of packet loss occur in AODV routing protocol.

Literature[14] offers to utilize some specific parameters such as velocity and movement direction that could be obtained by GPS device in addition to deployment of sets of on-board sensors in order to make the routing stabled. Selecting nodes with more stable link in route discovery procedure at the first step and selecting the most stable route in route selection procedure at the second step, could be considered as the two major steps in AODV enhancement project. AODV with Broadcasting Data packet (AODV-BD) [15] is proposed to reduce the end-to-end delay by establishing the route to the destination by having data packets broadcasted to destination. This approach sets up the routing along with sending data packets which decreases the delay. However, broadcasting data to the destination violates the integrity of data packet forwarding along with huge amount of bandwidth occupancy.

Improved AODV (IMAODV)[16] is proposed to eliminate the delay and routing overhead by improving the route discovery process in AODV routing protocol. In IMAODV approach, the AODV route discovery process and Dynamic Source Routing (DSR) process are merged accompanied with appending node`s address on RREQ to achieve less handover latency.

Literature[17] proposed a scheme in which each node is offered to maintain an alternative route to the specified destination. Therefore, upon primary route failure, the sender is able to use the alternative route, by which the end-to-end delay, routing overhead and route discovery frequency will be improved.

A combination of DSR and AOMDV routing protocols is proposed in Sutariya D. and Pradhan S.[18] results in proposing another scheme called Improved AODV (IAODV) in which source routing is limited up to two hops along with backing up route between source and destination.

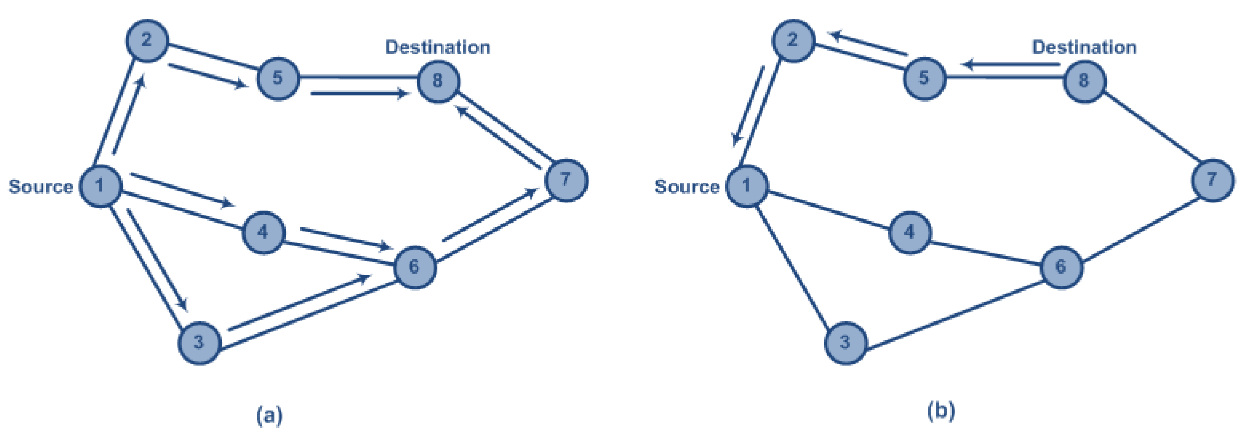

Figure-1
(a) Propagation of the RREQ, (b) RREP Path to the Source

Ad Hoc on-demand Multipath Distance Vector (AOMDV): AOMDV is designed to calculate multiple paths during the route discovery in highly dynamic ad hoc networks where the link breakage occurs frequently due to high velocity of vehicles. In AODV routing protocol, a route discovery procedure is needed after each link failure. Performing such procedure results in high overhead and latency. Thus, this defect is overcome by having multiple paths available. In AOMDV, performing the route discovery procedure will be done after all paths to either source or destination fail. In AOMDV routing protocol, it is endeavored to utilize the routing information already available in the underlying AODV protocol. However, little additional modification is required in order to calculate the multiple paths. The AOMDV protocol includes two main sup-procedures:

Calculating multiple loop-free paths at each node: In AODV routing protocol, route discovery procedure defines an alternate path to either source or destination potentially. Each copy of the RREQ packet received by a node, introduce an alternate path back to the source. However, utilizing all such copies to establish routes will result in routing loops. Therefore, in order to overcome such defect, a similar invariant is maintained as it is defined in single path case. However, the major disparity is the multiple next-hop routes obtained by multiple route advertisement are accepted and maintained as long as the invariant is complied. A possible drawback is that various routes to the same destination may have different hop-counts. Therefore, route identification is required to determine which of these hop-counts is advertised to others due to impossibility of advertising different hop-count to different neighbors with the same destination sequence number.

AOMDV invariant is built based on new definition of advertised hop-count. According to the node i and the destination d, the advertised hop-count is defined as the maximum hop-count of the multiple paths for d available at i. by utilization of the maximum hop-count, the advertised hop-count may not be changed for the same sequence number. Alternate routes with lower hop-counts could only be accepted by applying this protocol which is necessary to guarantee loop-free paths. Table 1 depicts the structure of routing table entries for AODV and AOMDV.

Table-1
AODV Routing Table

AODV	**AOMDV**
Destination	Destination
Sequence number	Sequence number
Hop-count	Advertised-hop-count
Next hop	Route-list {(nexthop$_1$, hop-count$_1$), (nexthop$_2$, hop-count$_2$),..}
Expiration-timeout	Expiration-timeout

In AOMDV, advertised hop-count and route-list replace the hop-count and next-hop in AODV respectively, in addition to introducing the multiple next hops with respective hop-counts. Basically, advertised hop-count is updated by node i for destination d whenever a route advertisement is sent by node i for d.

Finding the link-disjoint paths by deployment of distributed protocols: Loop-free mechanism enables the node to establish multiple paths to a destination which conveys us to the next stage that is the disjointness process. Two types of disjointness may be applied i. node-disjoint and ii. link- disjoint. The node - disjoint process does not have any node and link-disjoint does not have any link in common. A simple modification makes AOMDV routing protocol to be able to apply either node-disjoint or link disjoint process which is adding a flag and controlling it [19].

Literature[20] proposed preemptive multiple paths AODV (PM-AODV) routing protocol, in which all the AOMDV routing discovery procedure is utilized. The major disparity, however, is the identification of a flag called Warning flag indicated as w in RERR message in addition to introduction of a new message header called Route Warning (RWRN) message. In other words, RWRN message is the RERR message with the flag w. Flag w represents that the route to the destination node indicated in RWRN message is about to be broken any time. Routing table is also modified to cover the link state changing represented by flag w. In PM-AODV routing protocol, the signal strength of RREQ and RREP message will be compared with the pre-defined threshold and the suitable decision will be made upon the comparison result to either continue to broadcast the message of sending the RWRN message to utilize the other path before link breakage. PM-AODV routing table is depicted in table 2.

Table-2
PM-AODV Routing Table

PM-AODV
Destination
Sequence number
Advertised-hop-count
Route-list {(nexthop$_1$, hop-count$_1$, w), (nexthop$_2$, hopcount$_2$, w),..}
Expiration-timeout

AOMDV with Accessibility predication and Link breakage prediction (AOMDV-APLP) [21] is proposed to enable AOMDV protocol to predict the relative state of the node using the ordinary and routine routing information to be utilized for reducing control overhead in future. Additionally, link breakage algorithm is applied to enable nodes to switch to the other available routes based on signal strength. Therefore, two major modifications are done to make the AOMDV-APLP implemented; modification at protocol layer and MAC layer to support accessibility prediction and link breakage prediction respectively. Table 3 illustrates the AOMDV-APLP routing table.

Table-3
AOMDV-APLP Routing Table

AOMDV-APLP
Destination
Sequence number
Advertised-hop-count
Expiration-timeout
Route-list {(nexthop$_1$, hop-count$_1$), (nexthop$_2$, hopcount$_2$),..}
Accessibility

Dynamic Source Routing (DSR): DSR[22] is a reactive routing protocol in which the primary aspect is to store the whole path from source to destination in the routing table instead of having the next hop stored (AODV routing protocol). Therefore, the packet header must include all nodes through which the packet must travel to be delivered to the destination. Similar to AODV, the RREQ and RREP are used to perform the route discovery and delivering the reply message back to the source. In this protocol, the RREQ message rebroadcast method is used if the node receiving the RREQ message does not have the destination information in its routing table. However, in DSR routing protocol, cache route mechanism is used in case of link breakage. For instance, suppose the source node S has route <S, A, B, C, D> to destination node D, and the link <C, D> encountered a failure due to node`s movement. In such scenario, the source node S looks up in its cache route for another route to destination node D. It is noted that other routes to destination node were maintained in cache route due to overhearing the RREQ message by intermediate nodes via various routes. The cache route mechanism results in boosting up the data transmission. Upon receiving the RERR message by the source node, the new route discovery procedure will be initiated. The RERR message will be originated and sent to the source by the very first node which is closer to the source than others. Thereafter, the source applying piggyback strategy based on the RERR message received and the new RREQ message will be broadcasted to all the nodes used to deploy the failed link. Figure 2 illustrates the transmission of pair of <RREQ, RREP> while performing the route discovery procedure until receiving the reply message.

Dashed lines represent the route stored in cache route memory for further utilization when the link breakage happens. Figuratively, the size of the packets in the DSR routing protocol increases due to adding any arrived node specifications into packet header. This can be considered as a possible drawback when the number of nodes increases. Another issue that must be taken into account is being unaware of neighbor list or their link status. Since no periodic updating packet exchanged between nodes, applying cache route mechanism may cause failure due to deployment of invalid or expired links.

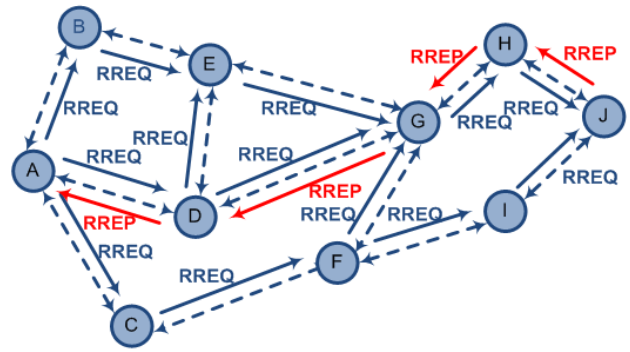

Figure-2
Route Discovery Procedure in DSR Routing Pprotocol

Destination Sequenced Distance Vector (DSDV): The aforementioned discussed routing protocols are all reactive protocols in which the routes are established on demands. DSDV [23] is a proactive routing protocol which maintains the route to the destination before it is required to be established. Therefore, each node maintains a routing table including next hop, cost metric towards the destination node and the sequence number generated by the destination node. Nodes exchange their routing tables periodically or when it is required to be exchanged. Thus each node is able to utilize the updated list of nodes to communicate with. Due to being aware of the neighbor`s routing table, the shortest path towards the destination could be determined. However, the DSDV mechanism incurs large volume of control traffic in highly dynamic networks such as VANET which results in experiencing a considerable amount of bandwidth consumed. In order to overcome the mentioned shortcoming, two update strategy in proposed; i. full dump strategy which is infrequently broadcasting the whole routing table, and ii. incremental dump which is exchanging the minor changes since the last full dump exchange. Figure 3 and table 4 illustrate the DSDV scenario and the possible routing table to be forwarded towards the neighbors.

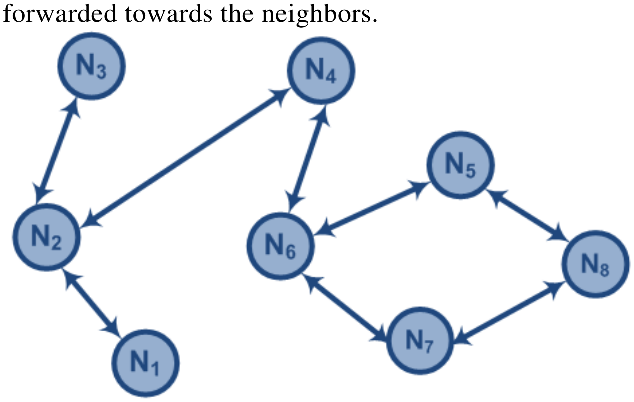

Figure-3
DSDV Structure Scenario

Table-4
Possible Forwarded Routing Table

Destination	Next Hop	Metric	Sequence number
N_1	N_4	3	S400N1
N_2	N_4	2	S300N2
N_3	N_4	3	S450N3
N_4	N_4	1	S200N4
N_5	N_5	1	S210N5
N_6	N_6	0	S800N6
N_7	N_7	1	S220N7
N_8	N_5, N_7	2	S350N8

Considering node N_6 in figure 3, table 4 depicts the possible structure of forwarding table which is maintained at N_6. The sequence number S---N_i represent the sequence number generated at node N_i.

Simulation results and data analysis: In this paper, various parameters such as Packet Delivery Ratio, Average End-to-End Delay, Normalized Routing Load Number of Dropped Packets and Packet Loss are investigated based on a variety of vehicle density and vehicle velocity. This section reveals the simulated results according to aforementioned VANET routing protocol. The NS-2 simulation framework is used for simulation purposes. Table 5 illustrates the characteristics of the environment in which the simulation is experimented.

Simulated network environment snapshot is illustrated in figure 4 which represents the variety of vehicle density from 100 vehicles per m^2 to 300 vehicles per m^2.

Packet Delivery Ratio: In order to calculate the Packet Delivery Ratio (PDR) in velocity and density scenarios, the number of packets received by the destination will be divided by the number of packets originated. The attained value specifies the packet loss rate which confines the maximum throughput of the network. The better PDR implies the more accurate and suitable routing protocol. Considering vehicle speed diagram, AODV and AOMDV have shown the similar result while the DSR protocol slightly decreased at the speed of 70. The DSDV routing protocol represents a significant downward trend of nearly 11% while the velocity of vehicles varies from 60 km/h to 100 km/h. PDR fluctuation in terms of vehicle density represents a level of dependency of routing protocols in variation of vehicle density. AODV and AOMDV have shown approximately the same results as the velocity variation described before. However the DSR diagram indicates more PDR instability. Furthermore, the DSDV routing protocol represents the lowest PDR values as the vehicle velocity increases due to frequent changing of the vehicle positions and having the routing table updated based on specific interval which make the vehicles to route based on obsolete information in their routing tables. PDR of aforementioned routing protocols based on a variety of vehicle velocity and vehicle density (figure 5).

Table-5
Simulation Parameters

Parameter Type	Value
Network Simulator	ns-2.34
Routing Protocol	DSDV, AODV, AOMDV, DSR
Simulation Time	200 s
Simulation Area	10 * 1000 m
Number of Nodes	100,150,200,250,300
Traffic Source/Destination	Deterministic
DATA TYPE	CBR
Packets Generation Rate	5 packets
CBR interval	0.25 s
Packet Size	100 bytes
MAC Protocol	IEEE802.11p WAVE
MAC Rate	1 Mbps
RTS/CTS	None
Transmission Range	85 meters
Radio Propagation Models	Two-ray Ground
Hello *DYMO* Interval	1 s
Length of highway	10000 m
Number of lanes	3
Speed of vehicles	60-100 km/h
Sensing range	85 meters

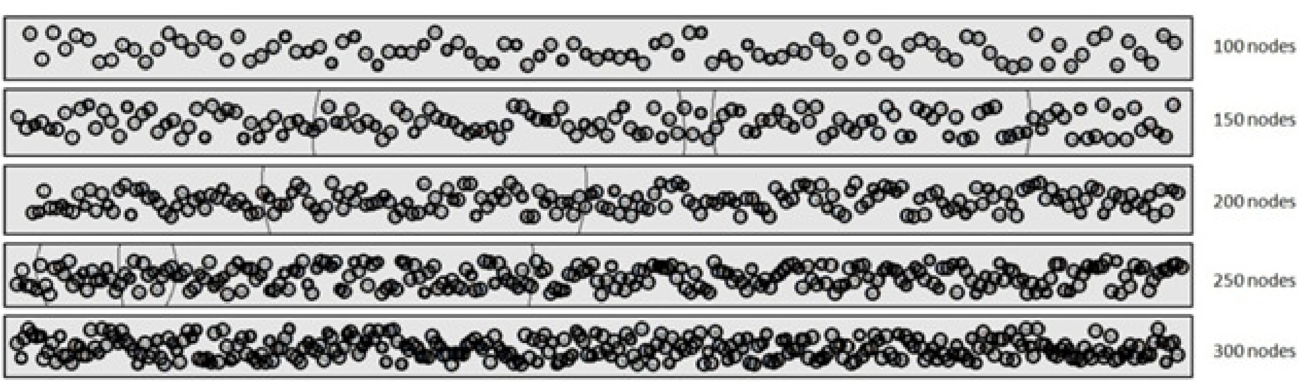

Figure-4
The Simulated Variety of Density

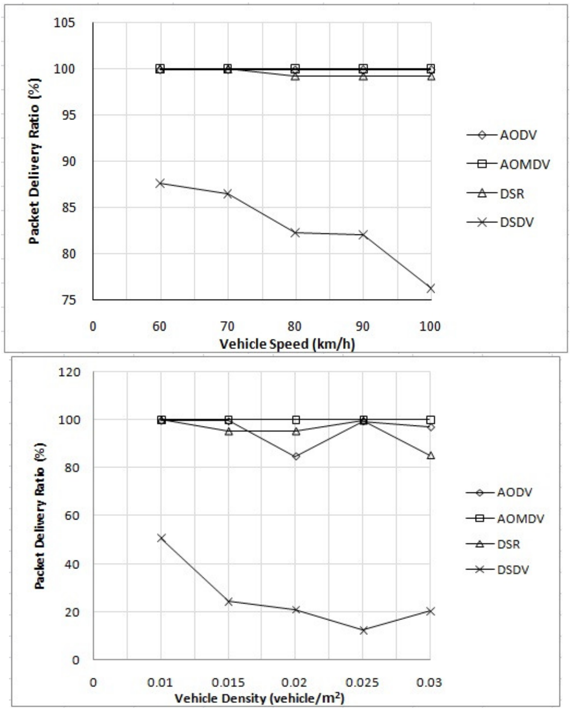

Figure-5
Packet Loss Ratio Fluctuations Based on Vehicle Velocity and Vehicle Density

Average End-to-End Delay: The time taken by the data packets to be delivered from source to destination is known as Average End-to-End Delay. Therefore, the time at which the first data packet is received by destination deducted from the time at which the first packet transmitted by the source. The Average End-to-End delay value implies the time consumed for all possible delays caused by buffering procedure whilst performing route discovery procedure, interface queuing, the retransmission procedure performed at MAC and propagation times. Figure 6 illustrates the Average End-to-End delay diagram associated with mentioned routing protocols. Although the DSDV routing protocol represents the worst PDR in both velocity and density diagrams, it routes data packets to a destination with the lowest Average End-to-End delay in both density and velocity diagrams due to intrinsic of proactive routing protocols. AOMDV and AODV have shown the highest Average End-to-End delays in velocity and density diagrams respectively while the DSR routing protocol plays a role in between according to both diagrams.

Normalized Routing Load: Normalized routing load (NRL) is defined as the number of routing packets transmitted per data packet arrived at the destination. Figure 7 depicts the NRL values associated with mentioned routing protocols. It turns out that the DSR routing protocol has the best NRL value in comparison with other routing protocol, followed by DSDV routing protocol in velocity diagram and AODV and AOMDV routing protocol in density diagram. AOMDV owns the highest NRL value in speed diagram while DSDV has shown the highest NRL value in density diagram.

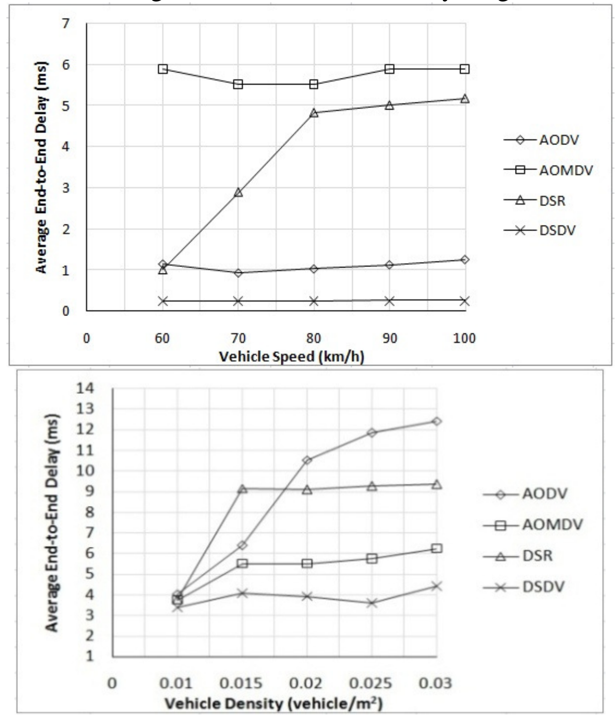

Figure-6
Average End-To-End Diagrams Based on Variety Of Velocity and Density of Vehicles

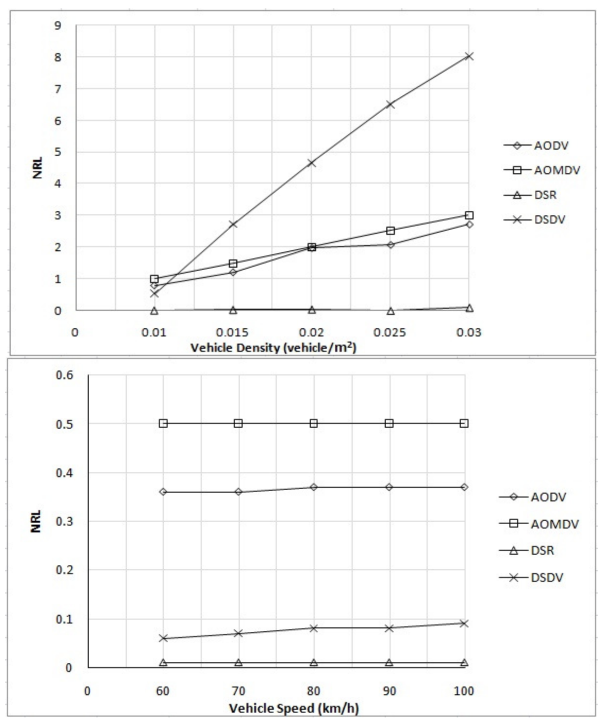

Figure-7
Normalized Routing Load Values in Terms of Vehicle Velocity and Density

Number of Dropped Packets and Packet Loss: Some certain circumstances may cause packet loss event such as corrupted packets, link disruption, insufficient bandwidth, experiencing buffering overloading and many security clearance issues. In such conditions, packets will be dropped either deliberately by the intermediate hops such as buffer overloading or some security clearance issues or unintentionally due to avoid propagation of corrupted packets. Figure 8 and figure 9 represent the related diagrams to both packet loss event and the number of packets dropped associated with mentioned routing protocol, respectively.

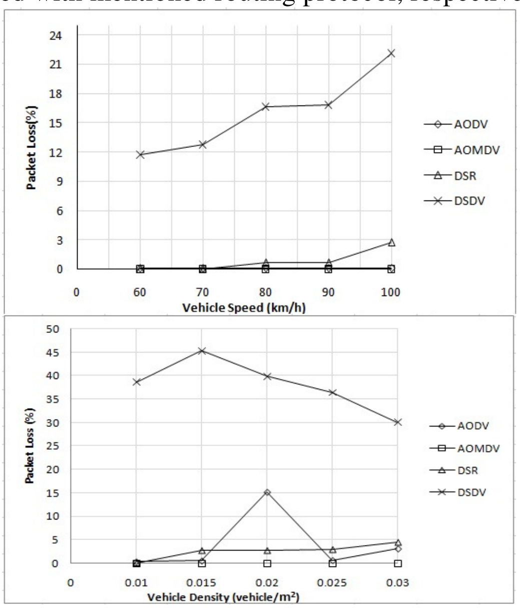

Figure-8
Percentage of Packet Loss Ratio as the Vehicle Velocity and Vehicle Density Increase

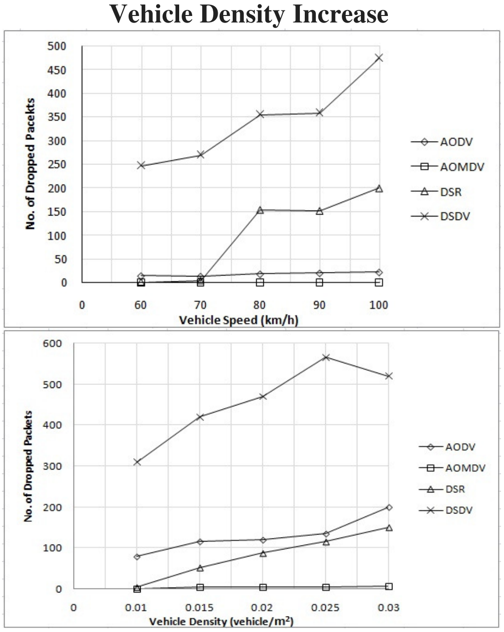

Figure-9
Number of Dropped Packets as Per Variety of Vehicle Velocity and Vehicle Density

Conclusion

This paper reveals the performance analysis of reactive routing protocols AODV, AOMDV and DSR in comparison with proactive routing protocol DSDV. Reactive routing protocols represent some similarities in terms of PDR, packet loss and number of dropped packets. However disparities among reactive routing protocols themselves are undeniable due to the different approach of routing storage and maintenance. Significant disparities between DSDV routing protocol and other reactive routing protocol makes this traditional routing protocol highlighted. Large amount of packet loss as well as a large number of dropped packets compels network administrations to revise on applying DSDV routing protocol on delay sensitive networks. Simulation of fundamental yet major parameters such as PDR, Average End-to-End delay, NRL, Packet loss amount and number of dropped packets based on variety of velocity and density for some reactive and proactive routing protocols in VANET results in some useful information. The simulation results reveal the fact that although MANET routing protocols could be applied on VANET but when the velocity and density of vehicles increase, in most of the time, the performance of both reactive and proactive routing protocols will decrease and this makes utilizing MANET routing protocols in vehicular ad hoc networks a major issue which requires tangible improvements.

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