Efficient Routing Protocol for Vehicular Ad Hoc Networks

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***Abstract*—Vehicular Ad hoc Network (VANET) is a special type of Intelligent Transport System (ITS), The design of routing protocols in VANETs is important and necessary issue for support the smart ITS. The key difference of VANET and MANET is the special mobility pattern and rapidly changeable topology. Existing routing protocols of MANET are not suitable for VANET. This paper proposes SD-AOMDV as VANET routing protocol. SD-AOMD improves the most important on demand multipath routing protocol AOMDV to suit VANET characteristics. SD-AOMDV add the mobility parameters: speed and direction to hop count as new AOMDV routing metric to select next hop during the rout discovery phase. Simulation results show that SD-AOMDV achieves better performance.**

***Keywords- VANET; AOMDV; MANET; Intelligent Transport System*.**

I. INTRODUCTION

A Vehicular Ad-Hoc network is a form of Mobile ad-hoc Networks MANETs, to provide communication among nearby vehicles and between vehicles and nearby fixed equipment i.e. roadside equipment as in figure 1. The main goal of VANET is providing safety and comfort for passengers. Besides safety applications VANET also provide comfort applications to the road users. For example, weather information, mobile e-commerce, internet access and other multimedia applications. The vehicles of a VANET are equipped with the DRSC (Dedicated Short Range Communication) [1]. Vehicles can move along the same road way and transmit information or receive information. Each vehicle equipped with VANET device will be a node in the Ad-hoc network and can receive & relay other messages through the wireless network. VANET is one of the influencing areas for the improvement of ITS in order to provide safety and comfort to the road users. Collision warning, Road signal arms and in place traffic view will give the driver essential tool to decide the best path along the way.

The similarity between MANET and VANET is characterized by the movement and self organization of nodes. Also the difference between these ad hoc networks is that MANET nodes cannot recharge their battery power where VANET has no power constraint for nodes.

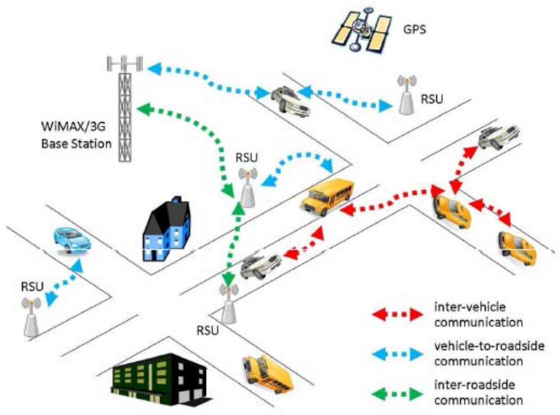

Fig. 1: VANET communication

The design of effective vehicular communications poses a series of technical challenges. Guaranteeing a stable and reliable routing mechanism over VANETs is an important step toward the realization of effective vehicular communications. One of the critical issues consists of the design of scalable routing algorithms that are robust to frequent path disruptions caused by vehicles' mobility. Existing routing protocols, which are traditionally designed for MANET, do not make use of the unique characteristics of VANETs and are not suitable for vehicle-to-vehicle communications over VANETs.

Topology-based and position-based routing are two strategies of data forwarding commonly adopted for multi-hop wireless networks [2]. Topology-based protocols use the information of available network links for packet transmission. Every node has to maintain the routing table. Position-based protocols assume that every node is aware of the location of itself, the location of neighbouring nodes, and the location of the destination node. With the increasing availability of GPS-equipped vehicles, Position based Protocol is getting more convenient. However, the position-based protocols developed for mobile ad-hoc networks may not directly be applied to vehicular environments, due to the unique vehicular network characteristics.

One good way of data forwarding in VANET is to modify MANET routing protocols and make it suitable for vehicular environment. There are many routing protocols for ad hoc networks [3], [4], [5]. One of the most important of them is AODV [6], [7], [8], [9]. Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV) protocol is an extension to AODV protocol for computing multiple loop-free and link disjoint paths [10]. These papers improve AOMDV protocol and make it useable for VANET with high performance.

The remainder of this paper is structured as follows. Section II surveys the variety of related researches being conducted in enhancing MANET routing protocols for V2V communication. Section III introduces the proposed schemes of this paper and the routing protocol. Section IV simulates the proposed scheme, followed by results and discussions. This paper is concluded in Section V.

II. RELATED WORKS

AOMDV protocol is an extension based on Ad hoc on demand Distance Vector (AODV). However, the performance of AOMDV is much better than AODV [11], [12]. AOMDV can find node-disjoint paths and link-disjoint paths when discovering routes. Because the conditions of node-disjoint paths are much stricter than that of link-disjoint paths, the number of node-disjoint paths is less than that a link-disjoint paths. Thus link-disjoint policy is used more popular.

After multiple paths are found, AOMDV will store the paths in routing table. The source node will select one established path according to the timestamp. The first selected forward path is the earliest established one. For route maintenance, when a route failure is detected, packets can be forwarded through other paths. To ensure the freshness of routes, timeout mechanism is adopted. The HELLO messages are broadcasted to eliminate expired routes.

As well as AODV, AOMDV is an on-demand routing protocol. When a source node needs a route to a destination, and there are not available paths, the source node will broadcast RREQ routing packet to initiate a route discovery process. Other nodes may receive duplicate RREQ packets due to flooding. When this case occurs, other nodes will establish or update multiple reverse paths according to different first hops of RREQ packets. However, AODV will establish a reverse path using the first RREQ packet and other duplicate RREQ packets are discarded.

After reverse paths establishing, intermediate nodes will search their routing tables for an available forward path to destination node. If the path exists, an RREP packet will be sent back to source node along a reverse path and the RREQ packet will be discarded. If the path does not exist and the intermediate node does not forward other duplicate RREQ packets, the RREQ packet will be broadcasted. When destination node receives RREQ packet, it will establish or update reverse paths, too. However, destination node will reply with looser policy to find multiple link disjoint paths. According to the reply policy, the destination node will reply all RREQ packets from different neighbours although the RREQ packets posses same first hop. Different RREP packets will be sent back through different neighbours, which can ensure link-disjoint path establishment. After passing by different neighbours, RREQ packets will be sent to source node along link-disjoint reverse paths.

When intermediate and source nodes receive RREP packets, they will establish loop-free and link-disjoint paths to destination node according to different first hops of RREP packets. For intermediate nodes that are shared by different link-disjoint paths, they will check if there are unused reverse paths to the source node. If so, one reverse path will be selected to forward the current RREP packet; otherwise, the packet will be discarded.

Simulation results for some existing ad hoc routing protocols (AODV, DSDV, DSR, TORA) found in numerous papers [13] [14] have concluded that AODV is one of the best ad hoc routing protocols with overall better performance in terms of three metrics: packet delivery ratio, routing overhead and path optimality. AOMDV is a good routing protocol for scenarios with high mobility and the performance of AOMDV is much better than AODV [10]. There are many improvements added to AODV and AOMDV protocols to suit V2V communication.

In [15] a modification on AODV as MANET routing protocol to make it adaptive for VANET is proposed. It used three mobility parameters: position, direction and speed to select the next hop for routing. In that method, direction was used as most important parameter to select next hop during a route discovery phase. With respect to mobility model, if a node has same direction with source and/or destination nodes, it might be selected as a next hop. Position is another parameter that was used for next hop selection.

S-AOMDV routing protocol proposed in [16] combining the routing metrics hop and speed to make routing decision. S-AOMDV protocol is compared with AOMDV minimum hop-count metric. The simulation results show better performance achieved by S-AOMDV in general. Especially with high load (8 packet/s), the performance metrics of NRL and Average End-to-End Delay are reduced by 11.11% and 11.92%, respectively.

In RAOMDV routing protocol proposed in [17], a routing metric combining hop counts and retransmission counts at MAC layer is proposed with consideration of link quality and delay reduction. Based on that routing metric, a cross-layer Ad hoc On-demand Multipath Distance Vector with retransmission counts metric (R-AOMDV) routing protocol is designed to make use of advantages of multi-path routing protocol, such as decrease of route discovery frequency.

III. PROPOSED SD-AOMDV ROUTING PROTOCOL

Proposed SD-AOMDV improves AOMDV to suit VANET characteristics. SD-AOMDV adds the mobility parameters:

speed and direction to hop count as new AOMDV routing metrics to select next hop during the rout discovery phase.

When a source node wants to send a packet to destination node, first, routing protocol gets direction and speed of source node. Then, it gets direction and speed of destination node. Based on direction and speed of both source and destination, intermediate nodes that can be participating in route between source and destination are specified. Because of using Manhattan mobility model, nodes can move in same direction of source and destination, direction of source, or direction of destination.

As nodes in VANET move with high speed, their route stability is less than MANET. In other hand, if two nodes that are moving in different direction communicate together, their link breaks sooner than state which these node move in same direction. Therefore, if source and destination are moving in same direction, the protocol must only selects intermediate nodes that move in same direction with source and destination. However, if source node and destination node are moving in different direction, the protocol must only selects intermediate nodes that move in source or destination direction. The protocol also tries to select intermediate nodes that are moving in appropriate speed between source and destination. All intermediated nodes have minimum difference between its speed and average speed of source and destination ensuring more path stability.

A node can be selected as next hop in route between source and destination under two conditions:

A. Intermediate node that moves in same direction with source and/or destination.

B. Intermediate node that have minimum difference between its speed and average speed of source and destination.

SD-AOMDV combines mobility information with hop count routing metric selection in routing selection as follows:

- For each intermediate node in a disjoint path, the difference between its speed and average speed of source and destination is calculated.
- For each disjoint path, speed metric is the maximum of the differences calculated in step 1.
- For all disjoint paths, the forward path is the path with the minimum speed metric. With equal speed metrics values, the path with minimum hop count is selected.

The path satisfies the following condition will be selected to forward packets:

Minimum (Maximum (difference between (Node speed, Average speed of source and destination) [k]), hop count). Where K is the number of disjoint paths to destination node D.

A. *Mobility Model and Direction Calculation*

SD-AOMDV selects Manhattan mobility model [18], [19] as it is one of the most important mobility models for VANET.

In Manhattan mobility model, several horizontal and vertical streets co-exist in the simulation field and mobile nodes are moving on the lanes of the streets.

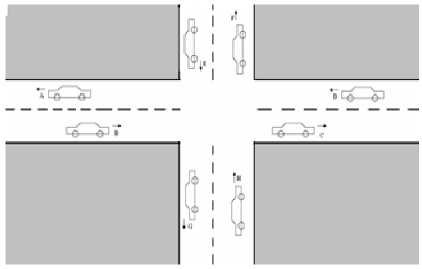

Fig. 2: Manhattan map

Each street has several lanes in both directions. (Users can also define a street with only one direction). The lanes are not supposed to overlap. However, the vertical and horizontal streets may cross with each other at the intersection. In figure 2, Manhattan has a vertical and a horizontal street with an intersection. Each street has two directions be made of a lane. If one direction of a lane has positive value 1, then the lane on the opposite direction must have the negative value -1. Each street has the maximum and minimum allowed velocity (V_{min}, V_{max}).

To determine vehicle's direction in SD-AOMDV, vehicles are classified into four different directions based on changes in X, Y coordinates while movement figure 3. If the change in X, Y values are positive, then vehicle is considered to have direction 1 (0^0-90^0). If the change in X is negative and in Y is positive, then vehicle is considered to have direction 2(90^0-180^0). If the change in X is negative and in Y is negative, then vehicle is considered to have direction 3(180^0-270^0). If the change in X is positive and in Y is negative, then vehicle is considered to have direction 4(270^0-360^0).

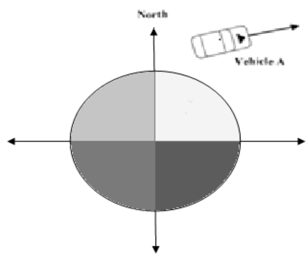

Fig 3: vehicle direction.

B. *SD-AOMDV Data Structure*

SrcDir, SrcSpeed and SpeedMetric are added as new fields into original RREQ packet structure specified in AOMDV [10], [11] as shown in table 1.

TABLE 1: RREQ PACKET STRUCTURE OF SD-AOMDV

Source sequence number	SrcDir
Hop Count	SrcSpeed
Destination sequence number	SpeedMetric

Where SrcDir = source direction, SrcSpeed = source speed and SpeedMetric = speed metric that equal to zero when node send request packet.

SrcDir, AvgSpeed, SpeedMetric and DestDir fields are added as new fields into original RREP packet structure specified in AOMDV [10], [11] as shown in table 2.

TABLE 2: RREP PACKET STRUCTURE OF SD-AOMDV

Source IP address	Hop Count
Destination IP address	SrcDir
Destination sequence number	AvgSpeed
Last_hop	SpeedMetric
first_hop	DestDir

Where AvgSpeed = average speed of source and destination, SrcDir, DestDir = source and destination direction, SpeedMetric = speed metric of RREP packet.

In routing table entry structure, AdvertisedSmetric, DestSpeed and DestDir fields are added as new fields into original routing table entry structure specified in AOMDV [10], [11] as shown in table 3.

TABLE 3: ROUTING TABLE ENTRY STRUCTURE OF SD-AOMDV

Dest	destspeed
Seqno	destdir
advertised_ Hop Count	Advertised speedmetric
Route List { list of available paths }	

Where DestSpeed = destination speed , DestDir = destination direction and AdvertisedSmetric = Advertised speed metric.

as a node accepts and maintains multiple routes as obtained by multiple route advertisements. Different routes to the same destination may have different SpeedMetric, a node must be consistent regarding which one of these multiple SpeedMetric is advertised to others. It cannot advertise different SpeedMetric to different neighbors with the same destination sequence number. For each destination, we restrict that multiple paths maintained by a node have the same destination sequence number. With this restriction, a loop freedom invariant similar to AODV is maintained. Once a route advertisement containing a higher destination sequence number is received, all routes corresponding to the older sequence number are discarded. However, as in AODV, different nodes (on a path) may have different sequence numbers for the same destination. It as advertisedhopcount for hopcount metric.

In route list that have list of paths for destination, we add Speedmetric field that have speed metric for each path, as shown in table 4.

TABLE 4: ROUTE LIST ENTRY DATA

hopcount	lasthop
nexthop	Speedmetric

C. SD-AOMDV Design

SD-AOMDV is an on-demand routing protocol as AOMDV. When a source node needs a route to a destination, and there are not available paths, the source node will initiate a route discovery process.

1) Rout Discovery Processing

Source node S broadcasts RREQ routing packet, as source nodes do in AOMDV after setting values to new fields as follows:

- SrcDir = current direction of node S
- SrcSpeed = current speed of node S
- SpeedMetric =0

-When other nodes receive RREQ packets, they will establish or update the reverse paths to source node S according to SD-AOMDV routing metric (speed metric and hops count). These other nodes can be classified into two types: intermediate node I and destination node D.

-If it is an intermediate node I then it establishes a reverse path I~S, searches the routing table for an available forward path I~D to destination node D.

If path l~D exists then node I checks wether it has the same direction of source and/or destination. If TRUE node I discards RREQ packet and RREP packet is sent back to S along the reverse path after filling new fields in RREP packet as follows:

- SpeedMetric = updated speed metric field of selected forward path in routing table entry.
- SrcDir = SrcDir field in RREQ packet.
- DestDir = DestDir field in routing table entry.
- AvgSpeed= average speed of source speed field in RREQ packet and destination speed in routing table entry.

-If it is an intermediate node and I~D doesn't exist then node I will rebroadcast RREQ packet after updating SpeedMetric field of RREQ packet .

-If destination node D receives RREQ packets, it will also establish reverse paths to source node S. Node D will send RREP packets to node S after filling the new fields in RREP packet as follows:

- SpeedMetric = 0
- SrcDir = SrcDir field in RREQ packet.
- DestDir = Destination direction.
- AvgSpeed = average speed of source speed field in RREQ packet and speed of node D

2) RREP Packet Processing

If RREP packet is received by intermediate node I then it checks wether it has the same direction of source and/or destination. If false, node I drops RREP packet, else an RREP packet is sent after setting SpeedMetric field of RREP packet as follows:

- Speed metric = max (speed metric, Diff (speed metric, speed of current node)).

-If node I is shared by different link-disjoint paths, it will check if there are unused reverse paths to node S. If such reverse paths exist, one will be selected to forward the

RREP packet; otherwise, the RREP packet will be discarded.

-When node S receives RREP packet, SpeedMetric field of RREP packet will record the maximal difference to average speed of source and destination along path D~S. And node S will select forward path that have minimum SpeedMetric and hop count.

IV. PERFORMANCE EVALUATION

This section presents the performance evaluation of SD-AOMDV relative to AOMDV using NS2.34 [20]. VanetMobisim [21] as a validated vehicular traffic generator is used. Manhattan is used as Mobility Model. 802.11 is used as MAC layer protocol with transmission range of 250 meters of each node. Traffic pattern consists of several CBR/UDP connections between randomly chosen source-destination pairs. Two scenarios one for city scenario and another for highway are presented. Results are averaged for five simulation runs. Three main important performance parameters are considered:

Packet delivery ratio (PDF): Ratio of data packets received to the packets sent by the traffic sources.

Normalized Routing load (NRL): ratio of total routing control packets to the total of data packet received.

End to end delay: It computes average delay in receiving correct data packets generated by the sources. This includes all possible delays caused by buffering during route discovery, queuing delay at the interface, retransmission delays at the MAC, propagation and transfer times.

A. City scenario

Simulation is conducted in a 2000 x 2000 meter square areas with 70 nodes for 400sec. speed of vehicles are varying from 10km/h to 90 km/h. A snapshot of the mobility is shown in Fig. 4.

1) Varying Packet Generation rate :

To compare the routing performance with different load, packet generation rate is set to 1 packet/s, 2 packet/s, 4 packet/s, and 8 packet/s, respectively for 20 sessions (connections) and Packet size of 512 Bytes. For packet generation rate of 8 packet/s, the load is rather heavy. Results are averaged for five simulation runs. Performance of SD-AOMDV is improved compared to AOMDV.

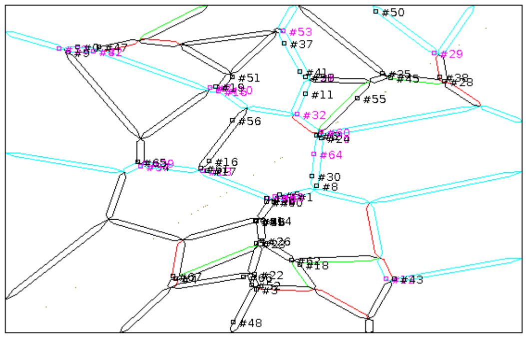

Fig. 4: A snapshot of the city scenario mobility

Fig 5.a shows that average end-to-end delay is decreased by 71.5%. Average end-to-end delay is reduced in SD-AOMDV specially with high packet rate since more available valid and stable paths exist in SD-AOMDV due to considering directions in routing decision, and also much more data packets will be delivered to destinations without waiting for route discovery latency. With increasing number of packets per second, the with low packet rates, a new route discovery is needed for almost every data packet that is generated because previously discovered route(s) will likely break by the time next data packet arrives at the source. This is evident from the higher route discovery frequency and routing overhead at the lowest packet rate (1 packets/s). So as the packet rate increases gradually, performance improvements also become higher with SD-AOMDV (e.g., notice the performance differences from 1 to 8 packets/s).

Fig. 5.b shows that packet delivery ratio is increased by 11.47%.However fig 5.c shows that NRL with SD-AOMDV has been increased by 76.2 % due to the increasing of RREQ and RREP routing packet sizes especially with low traffic. With increasing simulation time or packet rate, NRL percentage is decreased.

2) Varying Connections:

As SD-AOMDV performance is improved with increasing number of packet generation rate, SD-AOMDV performance is evaluated at constant packet rate of 8 packet/s and variable increasing session's number: 10, 20, 40, and 60 session.

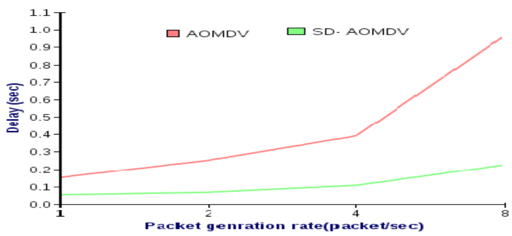

Fig. 5.a: end to end delay

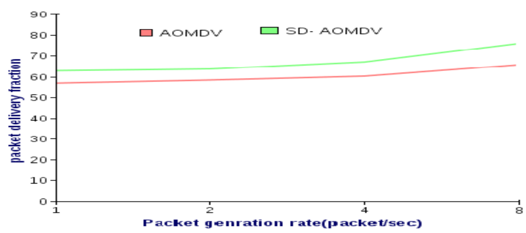

Fig. 5.b: PDF

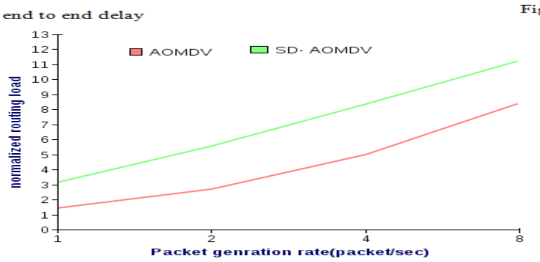

Fig. 5.c: NRL

Fig. 5: Performance evaluation with varying packet generation rate in city scenario

Fig. 6.a shows that delay has been decreased by 79.47% while it is decreased by 11.92 in S-AOMDV [16]. Fig. 6.b shows that PDF has been increased by 11.92%. However NRL with SD-AOMDV has been increased by 29.4% as shown in fig. 6.c.

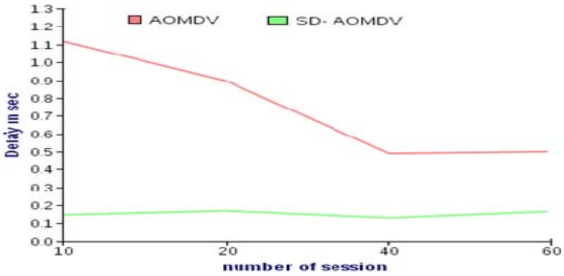

Fig.6.a: end to end delay

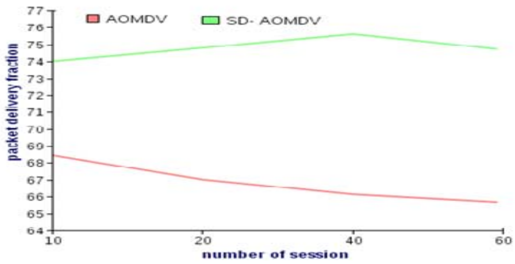

Fig.6.b: PDF

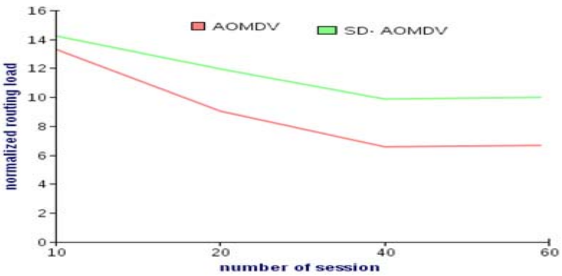

Fig.6.c: NRL

fig.6: performance evaluation with varying connections in city scenario

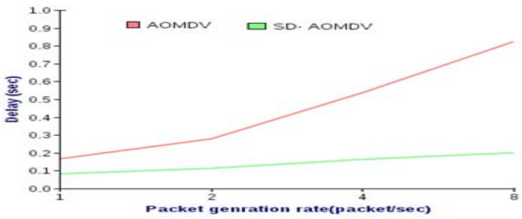

Fig.7.a: end to end delay

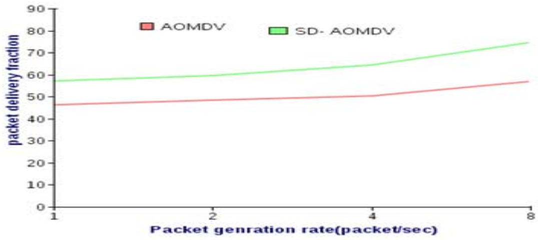

Fig.7.b: PDF

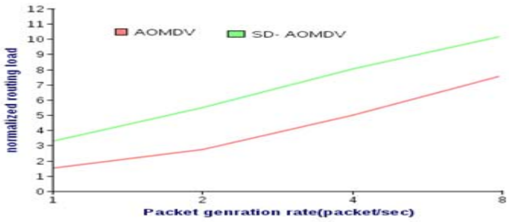

Fig.7.c: NRL

Fig.7: Performance evaluation with varying packet rate in highway scenario

Performance evaluation with varying packet rate in highway scenario

The performance for PDF of both protocols degrades with increasing number of connections. SD-AOMDV has a better ability to handle the stress of routing with large number of connections by discovering multiple stable paths.

B. Highway Scenario

To investigate the efficiency of SD-AOMDV in high speeds. Simulating highway scenario is conducted with 60 vehicles in 2000 x 2000 meter square area. Speeds of vehicles are varying from 60km/h to 120 km/h. Packet size is 512 Bytes for 25 sessions.

To compare the routing performance with different load, packet generation rate is set to 1 packet/s, 2 packet/s, 4 packet/s, and 8 packet/s, respectively for 30 sessions (connections) and Packet size of 512 Bytes. Results are averaged for five simulation runs.

Fig. 7.a and fig. 7.b show that performance of SD-AOMDV is also improved in highway scenario as in city scenario.

Fig.7.a shows that delay has been decreased with 63.06%. Fig.7.b shows that PDF has been increased with 26.33%. However NRL has been increased with 74.88% as shown in fig.7.c. This proves that SD-AOMDV has a better ability to handle high mobility of vehicles in highway by finding much more stable paths than AOMDV

II. Conclusion

This paper proposes SD-AOMDV as VANET routing protocol. SD-AOMD improves the most important on demand multipath routing protocol AOMDV to suit VANET characteristics. SD-AOMDV add the mobility parameters: speed and direction to hop count as new AOMDV routing metric to select next hop during the rout discovery phase. SD-AOMDV is designed, implemented, and compared with AOMDV. Simulation results show that SD-AOMDV has outperformed AOMDV in city and highway with different traffic scenarios. In future work, we will investigate the effect of adding vehicle's number of stops times as additional parameter for SD-AOMDV routing metric to select next hop during route discovery phase.

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