Institute of Advanced Engineering and Science

International Journal of Information and Network Security (IJINS)
Vol. 2, No. 3, June 2013, pp. 207 – 214
ISSN: 2089-3299

Intelligent Driver Mobility Model and Traffic Pattern Generation based Optimization of Reactive Protocols for Vehicular Ad-hoc Networks

Vaibhav Godbole*
*Assistant Professor, Department of Information Technology, Fr. Conceicao Rodrigues College of Engineering, Bandra (W), Mumbai: 400050

Article Info

Article history:
Received January 03, 2013
Revised January 22, 2013
Accepted February 15, 2013

Keyword:
VANET simulation
Intelligent Driver Mobility Model (IDM)
clustering
throughput
energy (fuel) consumption
AODV
AOMDV

ABSTRACT

Vehicular Ad-hoc Network (VANET) is the special type of MANET (Mobile Ad Hoc Network) where the mobile nodes are vehicles that move on roads at very high speed following traffic rules; they provide communication between vehicle and vehicle (V2V) and Vehicle and Road side infrastructural unit (V 2 I). A number of mobility models have been presented and their impact on the performance on the routing protocols has been tested by the researchers. In this paper vehicle to vehicle communication is analysed by integrating clustering of different areas and traffic lights into the Intelligent Driver Model with Intersection Management (IDM-IM). The performance of above model using AODV and AOMDV protocols with different traffic patterns is evaluated using VanetMobisim and NS-2.

Corresponding Author:
Name: Vaibhav Godbole
Affiliation: Assistant Professor
Address: Fr. Conceicao Rodrigues College of Engineering, Bandra (W), Mumbai: 400050, India
Phone:+91-22-09869331965
Email: vai.godbole@gmail.com

1. INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) are a special case of Mobile Ad-hoc Networks (MANETs) [3] and consist of a number of vehicles travelling on urban streets, capable of communicating with each other without a fixed infrastructure. VANETs are expected to benefit safety applications, gathering and disseminating real-time traffic congestion and routing information, sharing of wireless channels for mobile applications etc. One key component of VANET simulations is the movement pattern of vehicles, also called the mobility model. Mobility models determine the location of nodes in the topology at any given instant, which strongly affects network connectivity and throughput. The mobility models also contain a number of other characteristics that affect the wireless communication in real life e.g. cross roads, traffic lights, node (traffic) density, speed variations etc. [5] With the help of these mobility models it is possible to represent the actual scenario of a particular area. For example, a newly planned city may consists of separate area for residence, industry. entertainment hub etc. This newly planned city may get connected with outside world with highways. Hence the speed of the traffic may get restricted at different areas. Hence these mobility models can be used to simulate existing scenario of vehicular traffic. These mobility models can also be used to analyse the traffic before finalizing the layout of a city.

In this paper we have analysed effects of clustering and traffic lights on IDM-IM and then obtained the performance of AODV and AOMDV protocols with this mobility model with different traffic patterns. The rest of this paper is organized as follows. Section 1 presents related work. Section 3. illustrates the description of reactive routing protocols used for simulation. The description of the mobility model used for simulation of VANETs is presented in section 4.. In section 5. the result analysis is presented. Finally a conclusion is drawn in section 6..

2. RELATED WORK

Several studies specific to VANETs have been published comparing the performance of routing protocols using different mobility models. One of the first comprehensive studies was done by the Monarch project [4]. This study compared AODV, DSDV, DSR and TORA and introduced some standard metrics that were then used in further studies of wireless routing protocols. A paper by Das et al. [7] compared a larger number of protocols. However, link level details and MAC interference are not modeled. Another study [13] compared the same protocols as the work by Broch et al. [4], yet for specific scenarios as the authors understood that random mobility would not correctly model realistic network behaviours, and consequently the performance of the protocols tested. Globally, all of these papers concluded that reactive routing protocols perform better than proactive routing protocols.

Following the developments started with scenarios-based testing, it also became obvious that, as scenarios were able to alter protocol performances, so would realistic node-to-node or node-to-environment correlations. This approach became recently more exciting as VANETs attracted more attention, and a new wave of vehicles-specific models appeared. The most comprehensive studies have been performed by the Fleetnet project [10]. In a first study [11], authors compared AODV, DSR, FSR and TORA on highway scenarios, while [12] compared the same protocols in city traffic scenarios. They found for that AODV and FSR are the two best suited protocols, and that TORA or DSR are completely unsuitable for VANET. Another study [17] compared a position-based routing protocol (LORA) with the two non-position-based protocols AODV and DSR. Their conclusions are that, although AODV and DSR perform almost equally well under vehicular mobility, the location-based routing schema provides excellent performance. A similar results has been reached by members of the NoW project [8], which was their major justification for the design of Position-based forwarding techniques. Suman Kumari and others compares AODV DSDV, OLSR protocols for VANETs based on Freeway Mobility Model and TCP traffic [6]. Muhammad Alam et al. proposed Integrated Mobility Model (IMM) [2] for VANETs which is an integration of Manhattan Mobility Model, Freeway Mobility Model, Stop Sign Model and Traffic Sign Model and some other characteristics. R. Pomplun et al. [13] studied the performance of the AODV protocol considering different distances between the source and destination vehicles based on Intelligent-Driver Model. S. Vodopivec et al. [19] presents an overview of clustering algorithms for use in VANET. These clustering algorithms mainly minimizes the power consumption.

3. DESCRIPTION OF ROUTING PROTOCOLS

3.1. Ad-Hoc on Demand Distance Vector (AODV)

The Ad-hoc On-demand Distance Vector routing protocol[6] enables multi-hop routing between the participating mobile nodes wishing to establish and maintain an ad-hoc network. AODV is a reactive protocol based upon the distance vector algorithm. The algorithm uses different messages to discover and maintain links. Whenever a node wants to try and find a route to another node it broadcasts a Route Request (RREQ) to all its neighbors. The RREQ propagates through the network until it reaches the destination or the node with a fresh enough route to the destination. Then the route is made available by unceasing a RREP back to the source.

The algorithm uses hello messages (a special RREP) that are broadcasted periodically to the immediate neighbors. These hello messages are local advertisements for the continued presence of the node, and neighbors using routes through the broadcasting node will continue to mark the routes as valid. If hello messages stop coming from a particular node, the neighbor can assume that the node has moved away and mark that link to the node as broken and notify the affected set of nodes by sending a link failure notification (a special RREP) to that set of nodes.

3.2. Ad Hoc On-Demand Multipath Routing Protocol (AOMDV)

AOMDV [16] is one of the most popular on-demand multipath protocols. It is an extension of a single-path routing scheme AODV and it allows to compute multiple loop-free and link-disjoint paths between any source and destination nodes. AOMDV extends the AODV protocol by computing multiple paths during route discoveries. To keep track of multiple routes, the routing entries in intermediate nodes contain a list of the next-hop nodes towards the destination node, and the corresponding hop counts. Additional information is required to ensure loop freedom and to compute node-disjoint and link-disjoint paths. In AOMDV, different instances of RREQs are not discarded by intermediate nodes, because they may provide information about potential alternate reverse paths: if a new RREQ instance preserves the loop free condition and comes from a different last-hop node, then a new reverse route towards the source node is logged in the intermediate node. If the intermediate node knows one or more valid forward paths to the destination, a RREP packet is produced and forwarded back to the source along the reverse path. If possible, the intermediate node includes in the new RREP a forward path that was not used in any previous RREP, for this RREQ. The intermediate node re-broadcasts the new RREQs to neighbor nodes. When the destination receives more RREQ instances, in order to get multiple link-disjoint routes, it replies with multiple RREP messages. Node-disjointedness may be computed from link-disjoint paths simply preventing intermediate nodes from having more than one path passing through them.

4. INTELLIGENT DRIVER MODEL

In simulating mobile systems, it is important to use a realistic mobility model. Mobility model has major effects on the simulation results. Random waypoint (RWP) model [14], which is broadly used for MANET simulations, is unsuitable for VANET simulations as the mobility patterns underlying an inter-vehicle network are rather different. In order to model realistic vehicular movement Advanced Intelligent Driver Model has been used. It is the extension of Intelligent Driver Model(IDM). This section discusses the clustered integrated approach to this Intelligent Driver Model.

4.1. Our System Model

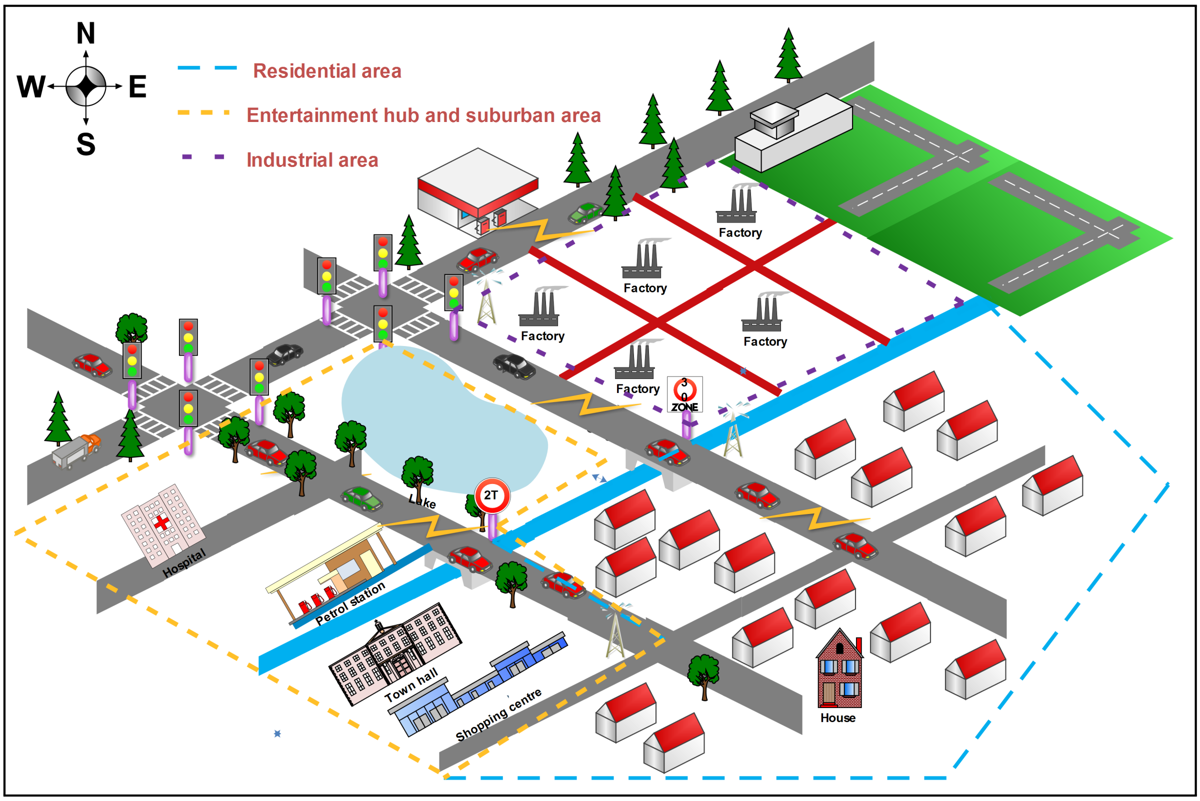


Figure 1. Representation of mobility model used for simulation

Figure 1 shows our integrated approach to the Intelligent Driver Model. As shown in this figure, this model is roughly divided into three clusters, *residential*, *industrial* and *suburban*. Table 1 shows cluster description of our model.

Table 1. Custer Description

Cluster description	% occupancy	Speed limit in Km/hr.
Residenceial	50	40
Indusrial	30	60
Suburban	20	80

Apart from this cluster approach our model also consists of 10 *traffic lights*. The *green light length* is 15 seconds and the *red light length* is 10 seconds.

5. SIMULATION PARAMETERS AND RESULTS

This section presents the simulation and results for evaluating the performances of AODV and AOMDV protocols. Extensive simulations have been carried out to evaluate and compare the performances of the protocols in VANETs by using the network simulator NS-2 [1] in its version 2.34. The movement traces of vehicles as per model presented in section 4.1. are generated using VanetMobiSim tool [9]

5.1. Simulation Parameters

Table 2. Simulation parameters

Parameter	Value
MAC Type	IEEE 802.11
Channel Type	Wireless
Mobility Model	As explained in section 4.1.
Simulation Area	1000 X 1000 m^2
Traffic Type	CBR
Packet Size	512 bytes
No. of Vehicles	50
Traffic Source	10 40
Vehicle Speed	10 - 80 Km/hr
Packet Rate	4 packets / sec
Routing Protocols	AODV, AOMDV

5.2. Performance Merits

[18] describe a number of quantitative metrics that can be used for evaluating the performance of MANET routing protocols. We have used the following metrics for evaluating the performance of routing protocols (AODV and AOMDV):

1. **Routing overhead:** It is the total number of control or routing (RTR) packets generated by routing protocol during the simulation. All packets sent or forwarded at network layer is consider routing overhead

   $$\text{Overhead} = \text{number of RTR packets}$$

2. **Normalized routing load:** It is the number of routing packets transmitted per data packet delivered at destination. Each hop-wise transmission of a routing is counted as one transmission. It is the sum of all control packet sent by all vehicles in the area to discover and maintain route.
3. **Average End-to-End Delay (second):** This includes all possible delay caused by buffering during route discovery latency, queuing at the interface queue, retransmission delay at the MAC, propagation and transfer time. It is defined as the time taken for a data packet to be transmitted across VANET from source to destination.

$$D = (T_r - T_s)$$

Where T_r is receive Time and T_s is sent Time

4. **Throughput (kb/second)** It is the rate at which network send or receive data. It is rated in term of number of bits per seconds.It is the sum of data rates that are delivered to all vehicles in VANETs

5. **Routing Cost:** It is the ratio of routing bytes to CBR bytes.

$$\text{Routing Cost} = N_{route}/N_{cbr}$$

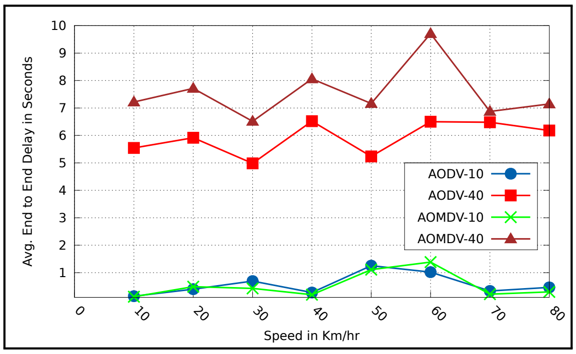
6. **Packet Delivery Ratio (PDR):** It is the ratio of data packets delivered to the destination to those generated by the sources. It is calculated by dividing the number of packet received by destination through the number packet originated from source

$$PDR = P_r/P_s$$

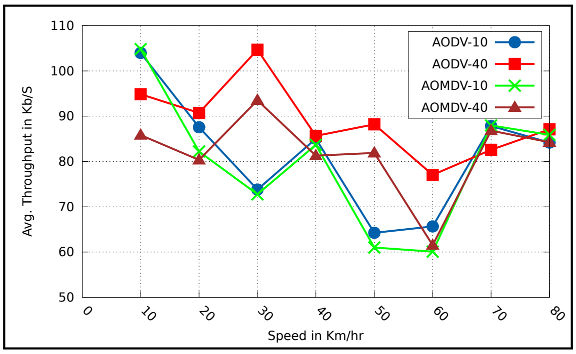
Where P_r is total Packet received and P_s is the total Packet sent.

7. **Energy (fuel) Consumption:** It is the percentage energy (fuel) consumed by the vehicles during their movement and during packet transmission. We have used energy-model in ns-2 which can be directly mapped into the energy (fuel) consumption of the vehicles.

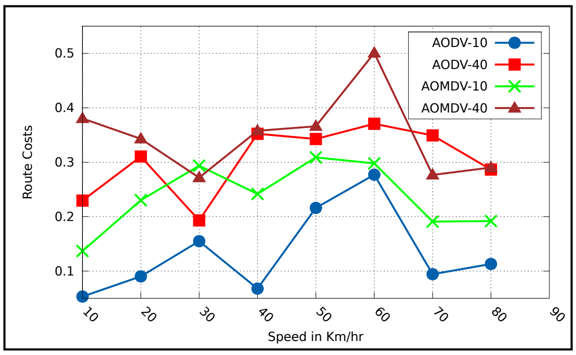
5.3. Results and Discussion



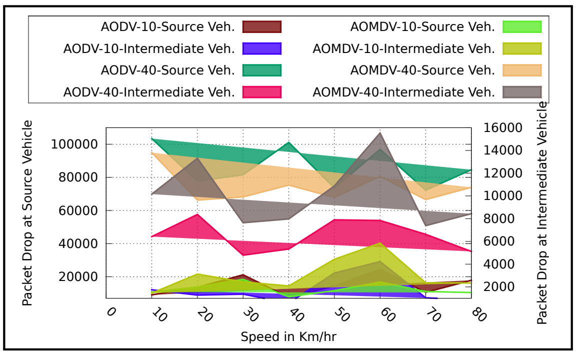
(a) Avg. end to end delay Vs. Vehicle speed



(b) Avg. throughput Vs. Vehicle speed



(c) Route cost Vs. Vehicle speed

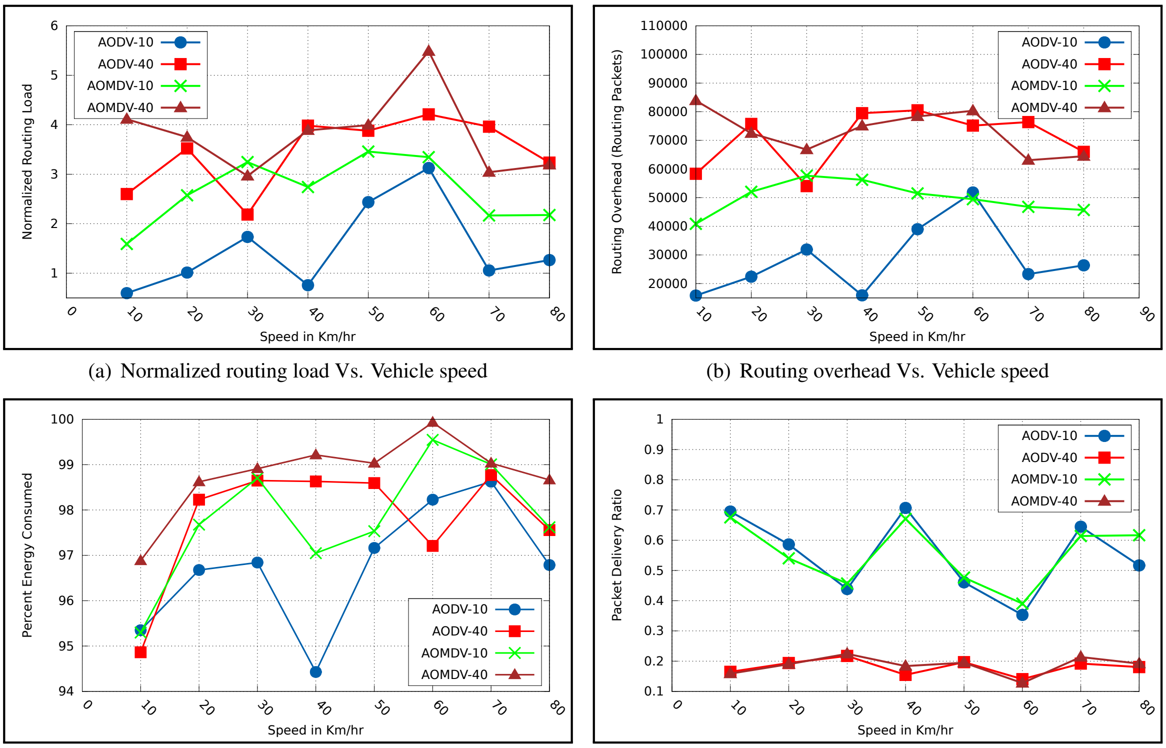


(d) Number of lost packets at source vehicles and intermediate vehicles Vs. Vehicle speed

Figure 2. Different performance merits obtained from our simulation - 1

- From Figure 2(a) we can see that avg. end to end delay is high with AOMDV-40 (40 traffic sources) when avg. vehicle speed is 60 Km/hr. and it is low with AODV-40 when avg. vehicle speed is 30 Km/hr. The delay is even less than 2 seconds when number of sources are equal to 10 for AODV and AOMDV protocols. Hence we can say that for lower end to end delay with high traffic AODV protocol can be used.

- From Figure 2(b) we can see that avg. throughput is high with AODV-40 when avg. speed is 30 Km/hr. and it is less with AOMDV-40 and AODV-10. when avg. speed is about 60 Km/hr. The avg. throughput is about 100 Kb/s when number of sources are equal to 10 for AODV and AOMDV protocols. Hence for high traffic and high traffic AODV protocol can be used with avg. speed of about 30 Km/hr.
- From Figure 2(c) we can see route cost is less with AODV-10 when avg. speed is about 40 Km/hr. and it is high with AOMDV-40 when avg. speed is about 60 Km/hr. When number of sources are equal to 40 route cost is less with AODV protocol when speed is about 30 Km/hr.
- From Figure 2(d) we can see that packet drop at source node with AODV-40 is maximum when avg. speed is equal to 10 Km/hr. It reduces and becomes stable after 20 Km/hr. for AODV-40 but increases afterwards. Packet drop at intermediate nodes is maximum with AOMDV-40 when avg. speed is about 60 Km/hr. For high traffic the packet drops at intermediate nodes are less with AODV as compared with AOMDV protocol. Also for high traffic the packet drops at source vehicle are less with AOMDV as compared with AODV protocol.



(a) Normalized routing load Vs. Vehicle speed

(b) Routing overhead Vs. Vehicle speed

(c) Energy (fuel) consumption Vs. Vehicle speed

(d) Packet delivery ratio Vs. Vehicle speed

Figure 3. Different performance merits obtained from our simulation - 2

- Figure 3(a) we can see that normalized routing load is almost negligible with AODV-10 when avg. speed is 10 Km/hr. It increases sharply for AODV-10 when speed increases beyond 40 Km/hr. When number of sources are high route cost is less with AODV as compared with AOMDV when the avg. vehicle speed is about 30 Km/hr. The route cost is very high with AOMDV-40 when the avg. speed is about 60 Km/hr.
- From Figure 3(b) we can see that routing overhead is almost negligible with AODV-10 when the avg. speed is about 10 Km/hr. and 40 Km/hr. When number of sources are high routing overhead is less with AODV as compared with AOMDV when vehicle speed is about 30 Km/hr.
- From Figure 3(c) we can see that energy (fuel) consumption with AODV-10 is less when the avg. speed is about 40 Km/hr. The energy (fuel) consumption with AODV-40 is almost equal to 100% and it is about 97% with AOMDV-40 when the avg. speed is about 60 Km/hr.

- From figure 3(d) we can see that the graphs of packet delivery ratio when the number of sources are equal to 10 and 40, are almost parallel to each other with AODV and AOMDV protocols. We can also say that packet delivery ratio for high traffic is less as compared with low traffic.

6. CONCLUSIONS AND FUTURE WORK

In this paper the performance of two routing protocols namely AODV and AOMDV for vehicular ad-hoc networks using Intelligent Driver Mobility Model with Intersection Management (IDM-IM) is obtained by integrating clustering of three different scenarios like *residential*, *industrial* and *suburban* with traffic lights placed at 10 places. These two protocols were tested for vehicle to vehicle communication with two different traffic patterns and with avg. vehicle speed ranging from 10 Km/hr. to 80 Km/hr. It is concluded that AODV outperforms AOMDV in terms of end to end delay with high density (40) of traffic source for an avg. speed of 50 Km/hr. It is because AOMDV is a multi-casting based protocol. For low density traffic source (10) the end to end delay for AODV and AOMDV protocols is less than 2 seconds. Higher throughput can be obtained using AODV protocol when density of traffic source is high and speed is about 30 Km/hr. At this speed the route cost is also very less for AODV as compared with AOMDV protocols. The packet drops at intermediate node are less with AODV protocol when density of traffic source is very high.

The energy (fuel) consumption for both the protocols is between 94% and 100% of the total energy. This is a very high value. In order to minimize this energy consumption Carbon Footprint/Fuel Consumption Aware Variable Speed Limit (FC-VSL) traffic control scheme [15] can be integrated with IDM-IM. This scheme reduces average vehicular fuel consumption, and hence carbon footprint, while obeying traffic constraints.

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