Performance Comparison of Different Routing Protocols in Vehicular Network Environments

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Abstract. Due to mobility constraints and high dynamics, routing is a more challenging task in Vehicular Ad hoc NETworks (VANETs). In this work, we evaluate the performance of the routing protocols in vehicular network environments. The objective of this work is to assess the applicability of these protocols in different vehicular traffic scenarios. Both the position-based and topology-based routing protocols have been considered for the study. The topology-based protocols AODV and DSR and position-based protocol LAR are evaluated in city and highway scenarios. Mobility model has significant effects on the simulation results. We use Intelligent Driver Model (IDM) based tool VanetMobiSim to generate realistic mobility traces. Performance metrics such as packet delivery ratio and end-to-end delay are evaluated using NS-2. Simulation results shows position based routing protocols gives better performance than topology based routing protocols.

Keywords: VANET, Routing Protocols, AODV, DSR, LAR, City Scenario, Highway Scenario, Intelligent Driver Model.

1 Introduction

Vehicular ad hoc network is important technology for future developments of vehicular communication systems. Such networks composed of moving vehicles, are capable of providing communication among nearby vehicles and the roadside infrastructure. Modern vehicles are equipped with computing devices, event data recorders, digital map, antennas, and GPS receivers making VANETs realizable. VANETs can be used to support various functionalities such as vehicular safety [1], reduction of traffic congestion, office-on-wheels, and on-road advertisement. Most of the nodes in a VANET are mobile, but because vehicles are generally constrained to roadways, they have a distinct controlled mobility pattern [2]. Vehicles exchange information with their neighbors and routing protocols are used to propagate

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information to other vehicles. Some important characteristics that distinguish VANETs from other types of ad hoc networks include:

- High mobility that leads to extremely dynamic topology.
- Regular movement, restricted by both road topologies and traffic rules.
- Vehicles have sufficient power, computing and storage capacity.
- Vehicles are usually aware of their position and spatial environment.

Unlike conventional ad hoc wireless networks a VANET not only experiences rapid changes in wireless link connections, but may also have to deal with different types of network topologies. For example, VANETs on freeways are more likely to form highly dense networks during rush hours, while VANETs are expected to experience frequent network fragmentation in sparsely populated rural freeways or during late night. High and restricted node mobility, sort radio range, varying node density makes routing a challenging job in VANETs.

A number of routing protocols have been proposed and evaluated for ad hoc networks. Some of these are also evaluated for VANET environment, but most of them are topology based protocols. Position based protocols (like Location Aided Routing (LAR) [3] [4]), which require information about the physical position of the participating nodes, have not been studied that much and require more attention. The results of performance studies heavily depend on chosen mobility model. The literature shows that the results of many of performance studies are based on mobility models where nodes change their speed and direction randomly. Such models cannot describe vehicular mobility in a realistic way, since they ignore the peculiar aspects of vehicular traffic such as vehicles acceleration and deceleration in the presence of nearby vehicles, queuing at roads intersections, impact of traffic lights, and traffic jams. These models are inaccurate for VANETs and can lead to erroneous results.

In this paper performance evaluation of Ad Hoc OnDemand Distance Vector (AODV) [5], Dynamic Source Routing (DSR) [6], and LAR in city and highway traffic environments under different circumstances is presented. To model realistic vehicular motion patterns, we use the Advanced Intelligent Driver Model which is the extension of Intelligent Driver Model (IDM) [7]. We evaluate the performance of AODV, DSR, and LAR in terms of Packet Delivery Ratio (PDR) and End-to-End Delay (EED).

The rest of the paper is organized as follows: Section 2 presents related work, while section 3 briefly depicts the mobility model for VANETs. Section 4 presents simulation methodology and describes reported results. Finally, in section 5, we draw some conclusion remarks and outline future works.

2 Related Work

Routing protocols can be classified in two broad categories: topology based and position based routing protocols [8] [9]. Topology based approaches, which are further divided into two subcategories: reactive and proactive, use information about links to forward the packets between nodes of the network. Prominent protocols of this category are AODV, and DSR. Position-based routing (e.g. LAR) requires some information about the physical or geographic positions of the participating nodes. In this protocol the routing decision is not based on a routing table but at each node the routing decision is based on the positions of its neighboring nodes and the position of the destination node.

Several studies have been published comparing the performance of routing protocols using different mobility models, and different traffic scenarios with different performance metrics. A paper by Lochert et al. [10] compared AODV, DSR, and Geographic Source Routing (GSR) in city environment. They show that GSR which combines position-based routing with topological knowledge outperforms both AODV and DSR with respect to delivery rates and latency. A study by Jaap et al. [11] examined the performance of AODV and DSR in city traffic scenarios. Another study presented by Juan Angel Ferreiro-Lage et al. [15] compared AODV and DSR protocols for vehicular networks and concluded that AODV is best among the three protocols. LAR is described in [3] is to reduce the routing overhead by the use of position information. Position information will be used by LAR for restricting the flooding to a certain area called request zone. Authors found that LAR is more suitable for VANET.

3 Mobility Model

Simulation is a popular approach for evaluating routing protocols; however the accuracy of the results depends on the mobility model used. Mobility model has significant effects on the simulation results. Random waypoint (RWP) model, which is widely used for MANET simulations, is unsuitable for VANET simulations as the mobility patterns underlying an inter-vehicle communication are quite different. The mobility model used for studying VANETs must reflect as close as possible, the behavior of vehicular traffic. In this work, we discuss the Intelligent Driver Model (IDM).

3.1 The Intelligent Driver Model

The Intelligent Driver Model (IDM) [12] is a car-following model that characterizes drivers' behavior depending on their front vehicles. Vehicles acceleration/deceleration and its expected speed are determined by the distance to the front vehicle and its current speed. Moreover, it is also possible to model the approach of vehicles to crossings. Another advantage of the IDM is that it uses a small set of parameters that which can be evaluated with the help of real traffic measurements. The instantaneous acceleration of a vehicle is computed according to the following equation:

$$\frac{dv}{dt} = a\left[1 - \left(\frac{v}{v_0}\right) - \left(\frac{S^*}{S}\right)^2\right] \quad (1)$$

Where v is the current speed of the vehicle, v_0 is the desired velocity, S is the distance from the preceding vehicle and S^* is the desired dynamical distance to the vehicle/obstacle, which computed with the help of equation (2).

$$S^* = S_0 + \left[v\,T + \left(\frac{v.\Delta v}{2\sqrt{ab}}\right)\right] \tag{2}$$

Where desired dynamical distance S^* is a function of jam distance S_0 between two successive vehicles. T is the minimum safe time headway. The speed difference with respect to front vehicle velocity is Δv. a and b are maximum acceleration and maximum deceleration.

4 Experiments and Evaluations

Extensive simulations have been carried out to evaluate and compare the performances of LAR, AODV, and DSR in VANETs by using the network simulator NS-2 [13] in its version 2.32. It is freely available and widely used for research in mobile ad hoc networks. The movements of nodes are generated using VanetMobiSim tool. The awk programming is used to analyze the simulation results. It is assumed that every vehicle is equipped with GPS receiver and can obtain its current location.

4.1 System Model

Vehicles are deployed in a 1000m*1000m area. A Manhattan grid like road network is assumed to have eight vertically and horizontally oriented roads and 16 crossings. The vehicle moves and accelerates to reach a desired velocity. When a vehicle moves near other vehicles, it tries to overtake them if road includes multiple lanes. If it cannot overtake it decelerate to avoid the impact.

Table 1. Mobility model parameters

Parameter	Value
Maximum Acceleration	$0.9\ m/s^2$
Maximum Deceleration	$0.5\ m/s^2$
Maximum safe deceleration	$4\ m/s^2$
Vehicle Length	5 m
Traffic light transition	10s
Lane change threshold	$0.2\ m/s^2$
Politeness	0.5
Safe headway time	1.5 s
Maximum congestion distance	2 m

When a vehicle is approaching an intersection, it first acquires the state of the traffic sign. If it is a stop sign or if the light is red, it decelerates and stops. If it is a green traffic light, it slightly reduces its speed and proceeds to the intersection. The other mobility parameters are given in table 1.

Table 2. Simulation parameters

Parameter	Value
Simulation time	1500 seconds
Simulation area	1000m x 1000m
Transmission range	250m
Node speed	30 km/hr (city) and 100 km/hr (highway)
Traffic type	CBR
Data payload	512 bytes/packet
Packet rate	4 packets/sec
Node pause time	20 s
Bandwidth	2 Mbps
Mobility model	IDM based
Interface queue length	50 packets
No. of vehicles	10 to 80
MAC and Channel Type	IEEE 802.11, Wireless Channel

Vehicles are able to communicate with each other using the IEEE 802.11 DCF MAC layer. The transmission range is taken to be 250 meters. The traffic light period is kept constant at 60 seconds. Simulations are repeated varying the speed, that is, 30 km/h (city) and 100 km/h (highway) and varying the node density. The other simulation parameters are given in Table 2. Only one lane case is taken for city scenario. However, in highway scenario, first one lane case is considered and later it is generalized to multiple lanes.

4.2 Results and Discussion

The protocols are evaluated for packet delivery ratio and average end-to-end delay at varying node densities (10 to 80 vehicles). Hereafter the terms node and vehicle are used interchangeably.

4.2.1 Packet Delivery Ratio (PDR)

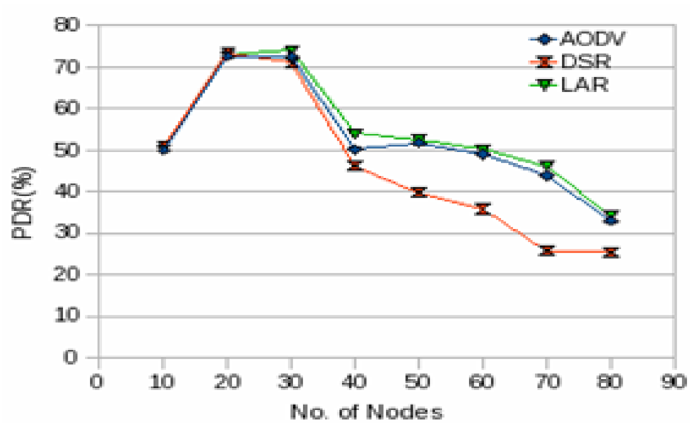
Packet delivery ratio is defined as the ratio of data packets received by the destinations to those generated by the sources. Mathematically, it can be defined as:

$$PDR = \frac{S_a}{S_b} \tag{3}$$

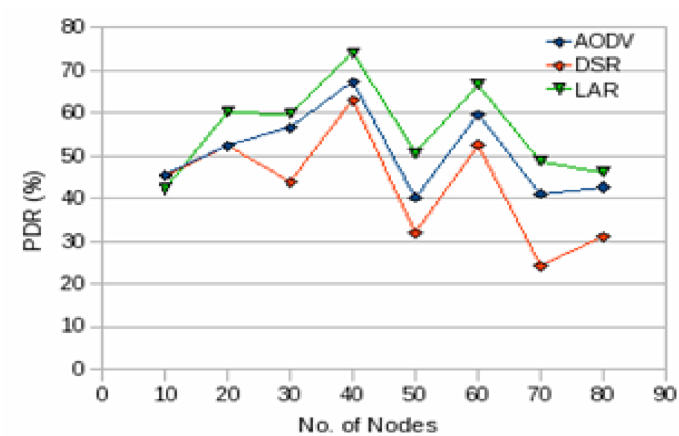
Where, S_a is the sum of data packets received by the each destination and S_b is the sum of data packets generated by the each source.

Fig. 1 depicts the fraction of data packets that are successfully delivered during simulations time versus the number of nodes. In city scenario, all the three protocols exhibit good performance for low node densities as shown in Fig. 1(a) and none of the protocols clearly outperforms the others. But with the increase in density, performance of the protocols decreases. It can be observed that the performance of the DSR reduces drastically while LAR is slightly better among the three.

In highway scenario all the protocols show relatively better performance as depicted by Fig. 1(b) and position based routing protocol clearly outperform the topology-based routing protocols with LAR exhibiting best results. Though, PDR again decreases with increasing density, but it is not that much low as observed in city scenario. Fig. 1(c) and Fig. 1(d) show that performance of the protocols degrades in highway scenario with lane changing (LC). It further slightly degrades with increase in the number of lanes. Again DSR is the worst and LAR has a slight edge over the other protocols.

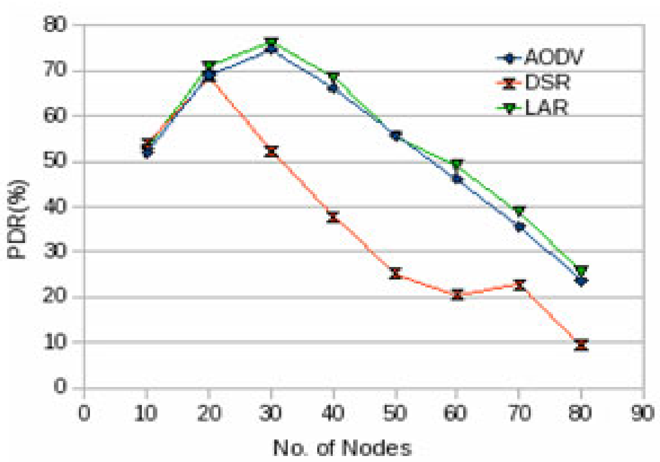


(a) City Scenario using IDM-IM

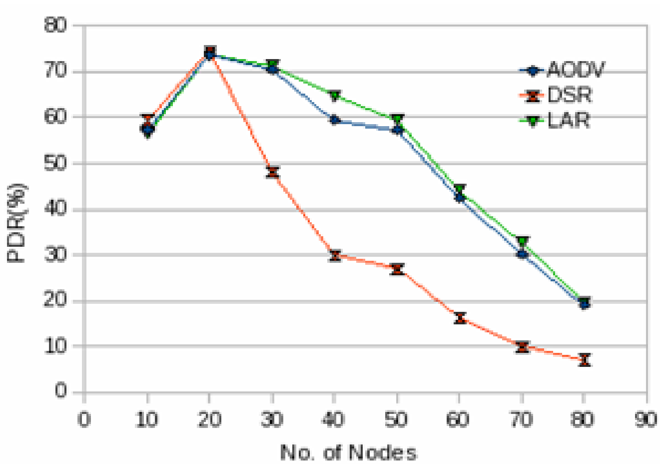


(b) Highway Scenario using IDM-IM

Fig. 1. PDR as a function of node density



(c) Highway Scenario using IDM-LC (lane=2)



(d) Highway Scenario using IDM-LC (lane=4)

Fig. 1. (*continued*)

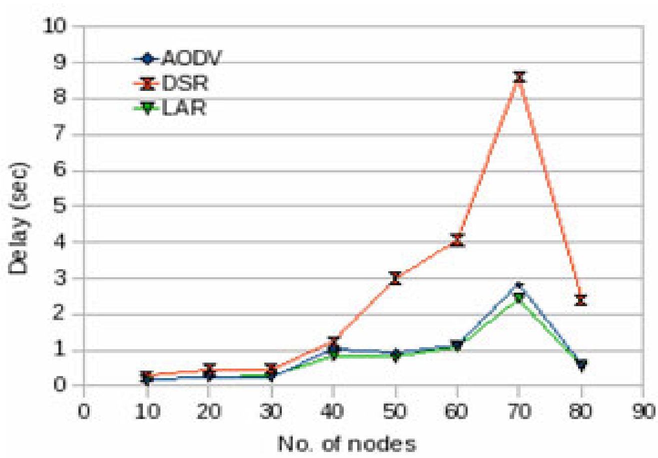
4.2.2 Average End-to-End Delay (EED)

The average time it takes a data packet to reach the destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delay at MAC, and propagation delay. This metric is calculated by subtracting time at which first packet was transmitted by source from time at which first data packet arrived to destination. Mathematically, it can be defined as:

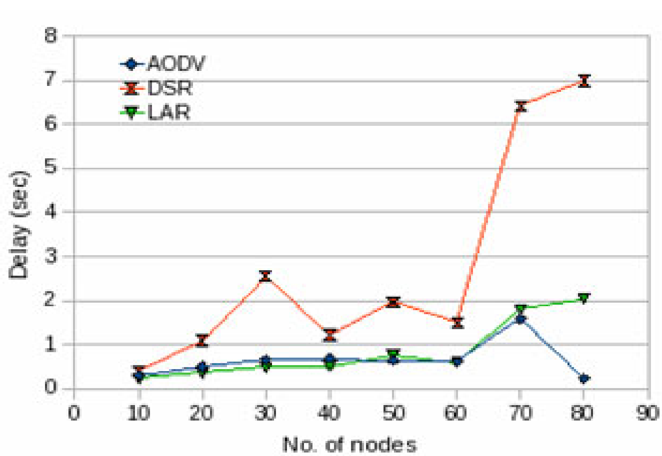
$$\text{Average EED} = \frac{S}{N} \tag{5}$$

Where S is the sum of the time spent to deliver packets for each destination, and N is the number of packets received by the all destination nodes.

Finally, Fig. 2 summarizes the variation of the average latency by varying node density. Average latency increases with increasing the number of nodes. DSR consistently presents the highest delay. This may be explained by the fact that its route discovery process takes a quite long time compared to other protocols. LAR has the lowest delay though compared to DSR and AODV it is low only slightly. In city scenario the position-based routing protocol exhibit lower delay compared to AODV especially at higher densities. Delay of all the protocols clearly increases in highway scenario with lane changing.

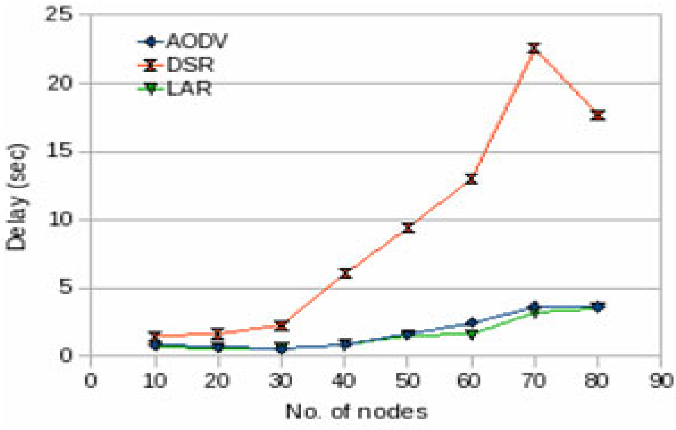


(a) City Scenario using IDM-IM

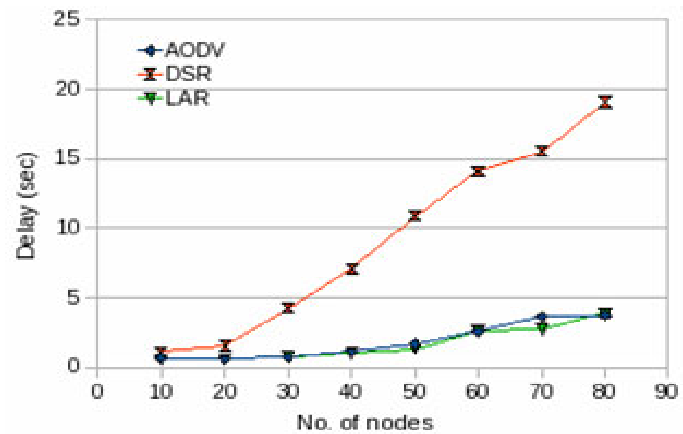


(b) Highway Scenario using IDM-IM

Fig. 2. Delay as a Function of Node Density



c) Highway Scenario using IDM-LC (lane=2)



(d) Highway Scenario using IDM-LC (lane=4)

Fig. 2. Delay as a Function of Node Density

Overall, it can be concluded that LAR showed the best performance in the simulated scenarios with highest PDR. Moreover, it has the highest throughput and shown the lower delays also. We can say that DSR is not a suitable protocol for VANET whether it is city scenario or highway scenario. AODV also showed the good performance with better PDR and lower delays.

5 Conclusion and Future Work

In this paper, performance of three routing protocols AODV, DSR, and LAR were evaluated for vehicular ad hoc networks in city and highway scenarios. We used

Advanced Intelligent Driver Model to generate realistic mobility patterns. The three protocols were tested against node density for various metrics. It is found that position based routing protocol (LAR) outperforms topology based routing protocols (DSR and AODV) in different VANET environment. For most of the metrics LAR has the better performance.

Overall, it can be concluded that position based routing protocol gives better performance than topology based routing protocols in terms of packet delivery ratio and end-to-end delay for both the vehicular traffic scenarios. For future work, we want to study the impact of traffic signs, traffic lights and transmission range on the performance of the routing protocols. Future work will also include the evaluation of other position based routing protocols as they are more suitable in vehicular traffic environment.

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