NS3-based Performance Assessment of Routing Protocols AODV, OLSR and DSDV for VANETs

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Abstract. A self-organized ad hoc network termed as Vehicular Ad hoc NETwork (VANET) allows each vehicle to take part in routing by sending safety-related and non-safety messages to other vehicles. VANETs have captivated many researchers' focus as an emerging research field as it has several challenges to be addressed. The dynamic nature of mobile nodes, network latency because of link failure, and the often changing topology, adds challenges while designing a delay-efficient routing protocol in VANETs. Our study analyzes the network performance of AODV, OLSR, and DSDV routing protocol for an urban VANET scenario using the SUMO and NS3 network simulator for our university campus is presented and analyzed. To evaluate the network performance we use Packet Delivery Ratio (PDR), Packet Loss Ratio (PLR), Average Throughput (AT), Average Goodput (AG), Average End-to-End Delay (AEED), and Average End-to-End Jitter (AEEJ) as routing metrics.

VANET, Routing Protocols, AODV, DSDV, OLSR, Performance Analysis

1 Introduction

VANETs can provide inter-vehicle communication with or without the aid of infrastructure to guarantee road safety and avoid potential accidents [1] as shown in Fig. 1. VANETs are groups of vehicles that are outfitted with wireless transceivers, known as OBUs, to exchange safety-related or non-safety messages to other vehicles. In VANETs, every vehicle has the capability to interact using Vehicle-to-Vehicle communications (V2V) or another piece of static infrastructure named as Road Side Unit (RSU) using Vehicle-to-Infrastructure communications (V2I). This architecture provides three types of vehicular communications — V2V, V2I and hybrid (both V2V and V2I) [2]. The standard for vehicular communication is prescribed by Dedicated Short Range Communication (DSRC) service popularly known as IEEE 802.11p.

Few distinctive features of VANET includes: (i) High dynamic topology - As vehicles move at different speeds, the topology of the VANET rapidly changes. (ii) Frequent network disconnections – Because of the rapid movement of vehicles, VANETs will not always be operational with continuous connectivity. Due to these reasons, finding an efficient routing mechanism for V2V communication is a challenge. For any network, routing defines dissemination of data following specific and predefined mechanism depending on the network behavior. In case of ad hoc network, the communication between two vehicle nodes can take place if they are available in each other's radio range and without involving the infrastructure considering the feasibility, availability and security into account. The primary objective of routing algorithm is to find a competent route between the transmitting and the recipient vehicle to make more reliable message delivery. The five available categories of routing protocols [3], [4], [5], [6], [7] is presented in Fig. 2. Among which the topology-based routing is divided into: proactive, reactive, and hybrid.

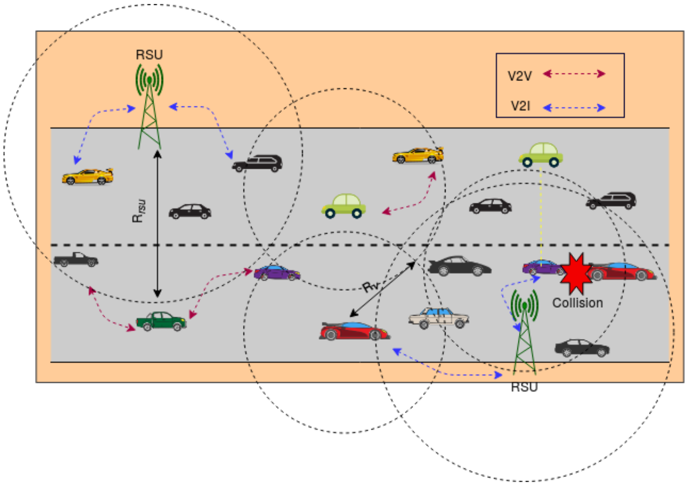

Fig. 1. Architecture of VANET

In case of proactive routing, all potential paths are discovered in advance. A vehicle must regularly deliver control messages in order to preserve accurate route information. The key benefit of the proactive method is that each node maintains routes to all potential destination nodes using a routing table. As a result, the path to destination can be quickly determined. Unfortunately, this results in network overhead and inefficient utilization of bandwidth. Examples of this sort of protocols are Destination-Sequenced Distance-Vector Routing (DSDV) and Optimized Link State Routing (OLSR). On the other hand, reactive routing are also known as on-demand routing. Dynamic Source Routing (DSR) and Ad Hoc On-Demand Distance Vector (AODV) are examples of reactive routing. Instead of broadcasting all of the vehicles' addresses, it just updates the pertinent nearby vehicle(s).

The hybrid routing protocol separates the network into local and global zones, to lessen the routing overhead and latency brought on by the route discovery process. It does this by fusing together local proactive and global reactive routing methods [8]. We restrict our discussion in this paper to topology-based routing strategies. The performance of AODV, OLSR, and DSDV in a VANET highway and urban environment is assessed in this paper using NS3 simulation. The remainder of this paper's description is presented and shown below: In section II, the existing works which are related to our study are briefly outlined. The discussion of routing protocols is covered in section III. The performance analysis of the utilised routing protocols is shown and discussed in Section IV. The work is concluded and future works are discussed in Section V.

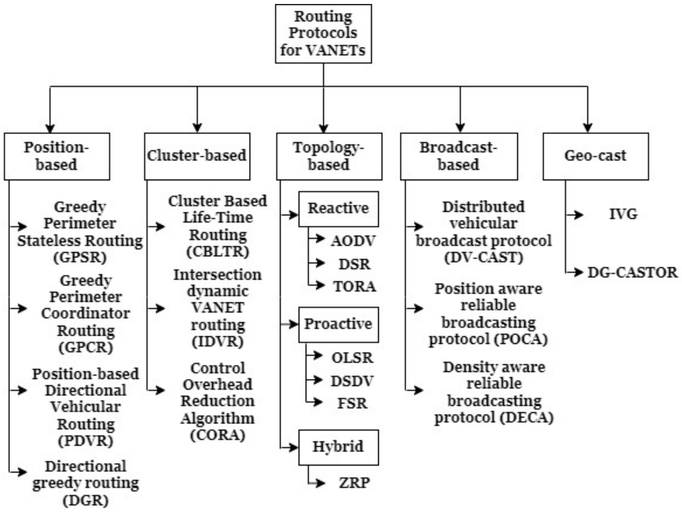

Fig. 2. Classification of Routing Protocols

2 Related Work

The efficiency of routing methods for VANETs between automatic and manual cars in Madinah city was evaluated by authors in [9] under various traffic conditions. AODV, DYMO, and DSDV are three ad hoc routing protocols that were used in two application scenarios to analyse different traffic distributions and densities. The simulation was based on an extracted map of Madinah city and carried out using SUMO and OMNET++. The output of the simulation parameter average trip time shows that choosing a scenario with fully autonomous cars saves travel time for vehicles by around 7.1% in busy areas. On-demand routing methods also cause the least amount of latency. Thus, authors concluded that automatic vehicles significantly reduce trip time.

Authors in [10] compared AODV, DSDV, DSR and GPSR by varying the traffic load. Only two simulation metrics have been used for this comparison such as PDR and routing overhead. The simulation outcome shows that AODV has the maximum PDR, whereas, DSR has the least routing overhead as compared to other routing protocols.

Similar kind of comparison is shown in [11] among four routing protocols like AODV, DSDV, OLSR, and DSR considering AT, overhead, transmission power, AEED, PDR, and energy consumption in terms of node mobility and pause time. The outcomes of the simulation are not described properly to understand in which scenario which routing protocol performs better than the others. A comprehensive, in-depth taxonomy of routing protocols in VANETs is proposed in [12], along with the benefits and shortcomings of each category. Additionally, the methods used by routing protocols are defined depending on the location of the vehicles and the network structure. The traffic scenario of Oujda city is simulated using SUMO and NS3 for AODV, OLSR, DSDV, GPSR and GPCR to study the benefits involved from the perspective of PDR, AT, AEED, and routing overhead.

Authors in [13] used SUMO, and NS-3 to analyze the performances of AODV, DSDV and DSR in terms of AT by considering two types of packet delivery — TCP and UDP. The simulation outcomes demonstrate that DSDV produces less packet delivery rate. As the network's bandwidth is limited, AODV assists in allowing packets to be sent at a suitable rate. DSR shows the minimum throughput among all.

Using ns-3, the routing protocols OLSR (Proactive) and AODV (Reactive) are compared in [14] under various traffic scenarios. The fundamental premise of the scenario is the intersection of similar geographical topology. They considered two types of mobility densities: high and low. The throughput, PDR, and latency are used for all assessment criteria. The outputs show that for the scenario with less traffic during the course of the simulation, OLSR outperforms AODV in terms of AT, PDR, and AEED by 17.4%, 7%, and 5%, respectively. In dense network, OLSR also outperforms the AODV by 7.9%, 6.5%, and 4%. Additionally, when congestion develops, OLSR is still superior to the other routing mechanisms targeted by this research.

AODV is an enhancement of DSDV but with a completely different insight for route discovery. AODV is on demand routing protocol. Now, OLSR is an improvement of link state protocol which is also a proactive protocol like DSDV but comparatively a bit advanced one than DSDV. We have taken these three different genre of routing protocols and rigorously analysed in terms of nearly 7 different performance metrics for comparison.

3 Routing Protocols

For this current study, two primary types of topological routing protocols for VANETs are considered: proactive and reactive. Proactive routing protocols always keep up-to-date routing tables updated by regularly distributing routing information over the entire network. OLSR and DSDV are two different proactive routing protocols which are considered for the performance evaluation. In case of reactive routing protocol, the routing information is not required to be stored in case the nodes need no communication along the way. Path discovery is only required when there's a need of inter-vehicle communication. However, reactive procedures have a large route discovery delay. AODV falls under this kind of routing protocol. Two proactive (OLSR and DSDV) routing protocols and one reactive (AODV) routing protocol are described along with their advantages and disadvantages below.

3.1 AODV

Description It is an improvement of the previously mentioned DSDV algorithm. AODV is an on-demand routing protocol and acts when packet transmission is required. AODV creates routes only when required, thereby reducing the number of broadcasts. The node selection is done only if the node falls into a selected route or else the nodes are not engaged in routing.

The source vehicle starts a path-finding process to find the target vehicle. This path-finding process starts with broadcasting of a route request (RREQ) packet to the available neighbours. These neighbors forwards these RREQ packets to it's own neighbors and so on until and unless the RREQ packet finds the destination. In response to the RREQ, the target or an intermediary vehicle unicasts a route reply (RREP) packet to the neighbour it initially received from. Vehicles on this path create forward route entries for the vehicle from which the RREP originated in their route tables. The forward route listed in these entries is the one that is currently in use [15].

Advantages Low connection setup latency [16] is a benefit of this protocol, and it has lower overhead than other protocols as the transmitted packets only need to store the information of the destination address. Only the destination IP address and sequence number are transmitted in an AODV RREP. Additionally, because a vehicle only needs to retain the next hop information, there is reduced memory overhead. The support for multicast that AODV offers is an additional benefit.

Disadvantages The drawback is an increase in control overheads brought on by several route reply messages for a single route request, as noted by the authors in [16]. Additionally, AODV cannot be used where there are asymmetric links since it needs symmetric links between nodes [15].

3.2 OLSR

Description It is a link state routing protocol enhancement. The issue with such protocol is the multiple receptions of the same link state (LS) advertisement, which adds unneeded network overhead. The purpose of OLSR is to prevent the transmission of duplicate LS advertisements.

Because OLSR is proactive, routing tables are updated regularly. Due to the lack of a route discovery procedure, considerable initial latency is not necessary. New routes can quickly determine which offers the best routing efficiency because of constantly updated routing tables. To preserve the routing table information, topology control messages are periodically sent, consuming more network resources. As a result, more bandwidth is used. OLSR is appropriate for large, dense and highly mobile ad hoc networks. It is even appropriate for applications that are time-sensitive and safety-related [17].

Advantages The benefits of OLSR include optimization over pure link state routing, a decrease of needless LS advertising for retransmission, less initial latency and applications relating to safety, and the ease with which new routes can be found to increase routing efficiency [17].

Disadvantages The following are OLSR's shortcomings: It requires a lot of network resources, creates routing overhead, consumes a lot of network bandwidth, and burdens the network [17].

3.3 DSDV

Description The protocol uses a table-driven algorithm, based on the conventional Bellman-Ford routing algorithm. The elimination of loops in routing table is one of the enhancements made. Every mobile node in the network keeps track of all potential network destinations and the hop count required to reach them in a routing table. Each item is identified by a sequence number provided by the destination node. The mobile nodes can discriminate between new and old routes thanks to the sequence numbers, preventing the formation of routing loops. The network is routinely updated with routing table modifications to ensure consistency of the tables [15].

Advatanges DSDV is one of the early algorithms available. It is a table-driven routing algorithm and appropriate for finite number of vehicles with less velocity. Additionally, the latency for route discovery is low [18].

Disadvantages It requires huge volume of control messages, and a regular update of its routing tables [16].

4 Performance Evaluation

Performance of AODV, OLSR and DSDV is compared using 7 different performance metrics which are elaborately defined in the following subsection IV.A. The experiment is simulated jointly using SUMO, NS3 and Open Street MAP(OSM) and a detailed simulation setup is described in subsection IV.B. The analysis of the outcomes of the simulation is presented in subsection IV.C.

4.1 Simulation Metrics

The eight different performance metrics and their corresponding equations are presented below. An overview of this comparisons of three routing protocols can be observed in Table 1 for vehicle density as 100.

Table 1. Comparison of Routing Protocols

Metrics	*AODV*	*OLSR*	*DSDV*
AT (Kbps)	1.86	2.04	1.50
AG (Kbps)	12.73	13.71	10.45
PDR (%)	86	81	51
PLR (%)	13	18	48
AEED (ms)	51	16	30
AEEJ (ms)	36	17	25
Overhead	0.46	0.34	0.46

AT The amount of bits that are delivered successfully to the destination vehicle per unit active network time is termed as AT and is computed using Equation (1).

$$AT = \frac{\beta_{at}}{\tau_{active}} \times \frac{1}{\vartheta} \tag{1}$$

where, β_{at} is the received number of bits by the receiver vehicle, τ_{active} is the time interval during which network is active, and ϑ is total number of simulation turn. τ_{active} is computed using Equation (2).

$$\tau_{active} = \tau_l - \tau_f \tag{2}$$

where, τ_l represents the moment when the last bit is received and τ_f represents the moment when the first bit is received.

AG The number of useful bits (excluding retransmitted and overhead bits) transmitted by the source vehicle to the destination vehicle per unit time is referred to as goodput and is computed using Equation (3).

$$AG = \frac{\beta_{ag}}{\tau_{active}} \times \frac{1}{\vartheta} \tag{3}$$

where, β_{ag} denotes the cumulative received bytes at the receiver vehicle, τ_{active} is the time interval during which network is active, and ϑ is total number of simulation turn.

PDR It is determined by the ratio of the number of data packets successfully received η_r by the destination vehicles by the total number of data packets initiated η_t by the source vehicles and is computed using Equation (4).

$$PDR = \frac{\eta_r}{\eta_t} \times 100 \tag{4}$$

PLR It is the ratio of the difference between the total packet transmitted by the source vehicle and packet received by the destination vehicle to the total number of packets transmitted. PLR computation is shown using Equation (5).

$$PLR = \frac{\eta_t - \eta_r}{\eta_t} \times 100 \tag{5}$$

where, η_r and η_t is the total number of received and transmitted packets.

AEED It demonstrates the required time needed to transmit the data from source to destination node. It includes queuing delay, propagation delay, transmition delay, MAC retransmission delay, and buffering delay during route identification. AEED is computed using Equation (6).

$$AEED = \frac{\sum_{i=0}^{n}(\tau_{ri} - \tau_{si})}{n} \tag{6}$$

where, τ_{ri} and τ_{si} is the time at which i^{th} packet was received by the receiver vehicle and was sent by the source vehicle. The total number of sent packet is denoted by n.

AEEJ It is a term used to describe the difference in dealy between packet flows from source to destination.

$$AEEJ = \frac{\delta(P_n) - \delta(P_{n-1})}{n} \tag{7}$$

$\delta(P_n)$ is the delay occurred for n^{th} packet transmission, $\delta(P_{n-1})$ is the delay occurred for $(n-1)^{th}$ packet transmission, and n is the total number of packets sent.

Overhead It is defined as how many extra bits is needed to be transmitted in order to deliver a safety message from source vehicle to destination vehicle. It is computed using Equation (8).

$$Overhead = \frac{\beta_{total} - \beta_m}{\beta_{total}} \tag{8}$$

where β_{total} is the total number of bits transmitted in order to send a safety message which includes control messages, route request and route reply messages as well. β_m is the number of bits presents in the safety message required to be delivered from source to destination.

4.2 Simulation Setup

The VANET routing protocols were simulated using NS3. In order to predict the road environment and vehicle traffic in the real world, a $3000m \times 1000m$ simulation area of our university with two RSUs was derived using Open Street Map (OSM). The mobility model building tool named SUMO and the city road map file are used to create the mobility trace file for the vehicles. Realistic mobility traces are gathered from SUMO and fed as input into NS-3 for simulation. The parameters used for this simulation are outlined in Table 2.

Table 2. Simulation Metrics

Metrics	**Values**
Simulation area	$3000m \times 1000m$
Number of vehicles	$20 - 100$
Number of RSUs	2
Vehicle velocity	$0 - 20m/s$
Packet size	200 bytes
Routing protocol	AODV, DSDV and OLSR
Mobility Model	Random Waypoint
Pause Time	0s
MAC	IEEE 802.11p
Loss Model	Two-Ray Ground loss model
Transmit power	20dBm
Transmission Range	145m
Simulation time	300 sec

4.3 Result Analysis

The simulation results and analysis of the routing protocols for VANET are presented in this section. The simulation result for PDR is shown in Fig. 3. PDR

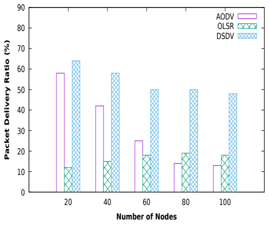

Fig. 3. Impact on PDR with varying vehicle density

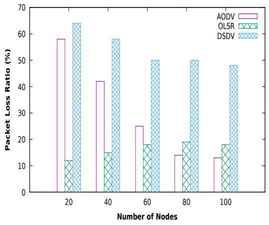

Fig. 4. Impact on PLR with varying vehicle density

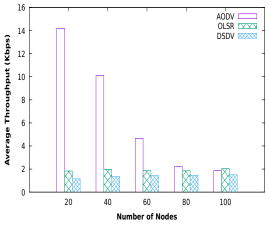

Fig. 5. Impact on AT with varying vehicle density

for DSDV is more as compared to AODV and OLSR with increasing number of vehicle density. Fig. 4 presents the simulated results for PLR. The results demonstrate that PLR is more for DSDV whereas, PLR for AODV reduces and PLR for OLSR increases with increasing number of vehicles. Fig. 5 presents the simulated results for AT. The results show that the AODV routing protocol shows better AT for less number of vehicles but the AT keeps decreasing with the increasing number of vehicles whereas the AT seems to be quite constant for OLSR and DSDV with the increasing number of vehicles. Fig. 6 presents the simulated results for AG where AODV performs better with the increasing number of vehicles. However, AG is less for DSDV than the other two protocols. Fig. 7 presents the simulated results for $AEED$. The results show that AODV routing protocol has an increasing $AEED$ with the increasing number of vehicles.

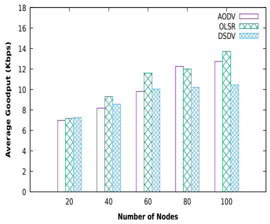

Fig. 6. Impact on AG with varying number of vehicle nodes

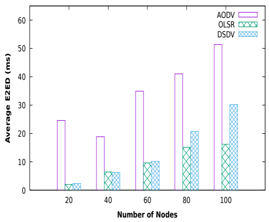

Fig. 7. Impact on AEED with varying vehicle density

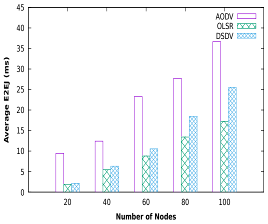

Fig. 8. Impact on AEEJ with varying vehicle density

Fig. 8 shows that AODV routing protocol has an increasing $AEEJ$ with increasing number of vehicles. Fig. 9 presents the outputs for number of vehicles vs MAC/Phy overhead. The results show that DSDV has more overhead for sparsely populated vehicles and shows decrease in overhead for 60 vehicles and

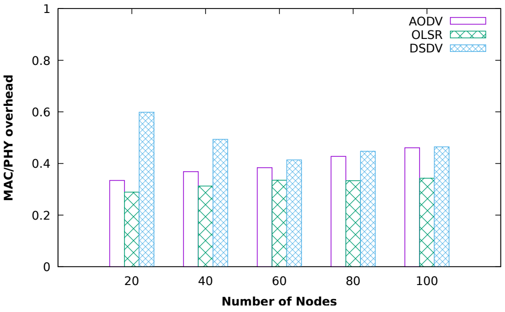

Fig. 9. Number of vehicle Nodes vs. MAC/Phy Overhead

then increases slowly with increasing number of vehicles. AODV shows increasing overhead with increasing number of vehicles. In this situation, OLSR performs better than AODV and DSDV.

5 Conclusion

In this study, the three routing protocols-AODV, OLSR and DSDV are compared and analyzed in VANET environment simulated using NS3 combined with SUMO and OSM. It is observed that AODV poorly performs with respect to $AEED$ with rise in vehicle density as compared to DSDV and OLSR. AODV may be used for sparse VANETs but does not seem to be good enough for dense network. DSDV has more PLR as compared to OLSR and AODV. The results show that PLR for AODV decreases with the rise in vehicle nodes. In contrast to $AEEJ$, which rises with rise in vehicle nodes, AT for AODV falls as the number of vehicles rises. OLSR shows better result for AG than that of AODV and DSDV. This comparison can be further enhanced by incorporating different mobility models along with the routing protocols and a rigorous analysis can be carried out.

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