INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ORIGINAL ARTICLE

OPEN ACCESS

Received: 29/08/2024

Accepted: 10/05/2025

Published: 30/05/2025

Citation: Mahajan PM, Patil GM (2025) Performance Analysis of GPSR, DSDV, and AODV Routing Protocols in VANET with respect to Area and Node Scalability. Indian Journal of Science and Technology 18(20): 1578-1589. https://doi.org/10.17485/IJST/v18i20.2796

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN

Print: 0974-6846

Electronic: 0974-5645

Performance Analysis of GPSR, DSDV, and AODV Routing Protocols in VANET with respect to Area and Node Scalability

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Abstract

Objectives: To investigate the performance of GPSR, DSDV, and AODV routing protocols in scalable vehicular ad hoc networks with varying node densities. **Methods**: The simulation utilizes OpenStreetMap generated Mumbai Map Network for the study in SUMO 1.8.0 with OMNeT++ 5.6.2 and Veins 5.2 for analysis purposes. **Findings**: According to the simulation experiment results, AODV gives better performance than DSDV and GPSR in terms of average throughput (highest 96.3kbps), low packet loss ratio (min. zero), low average end-to-end delay (lowest 0.532 ms), and high packet delivery ratio (highest 100%). **Novelty**: The simulation is performed for the real-world map containing the most challenging mobility model – the Random Way Point mobility model (Mumbai Map). This paper illustrates how different routing protocols perform in the case of PLR, PDR, average end-to-end delay, and average throughput over varying network area sizes and node density, which can be important for network planning and protocol selection.

Keywords: AODV; DSDV; GPSR; ITS; OBU; RSU; TA; VANET; V2I; V2V

1 Introduction

Many individuals consider automotive technologies to be among the most promising areas for further study. Automotive technology is impacted by improvements in human well-being. Car networks have recently come into focus due to traffic congestion in major cities and auto accidents. Important traffic information, including warnings for turning, pedestrian crossings, speed, road conditions, and status, is conveyed to drivers via vehicle networks [1].

Recently, a number of countries have widely deployed 5G technology, automotive networks, and fog computing into their transportation systems to increase driver safety and better handle increasingly unpredictable traffic patterns [2]. In the context of networked automobiles, intelligent transportation systems (ITS) use wireless devices mounted in vehicles (referred to as On Board Units, or OBUs) to collect, process, and share traffic data [3].

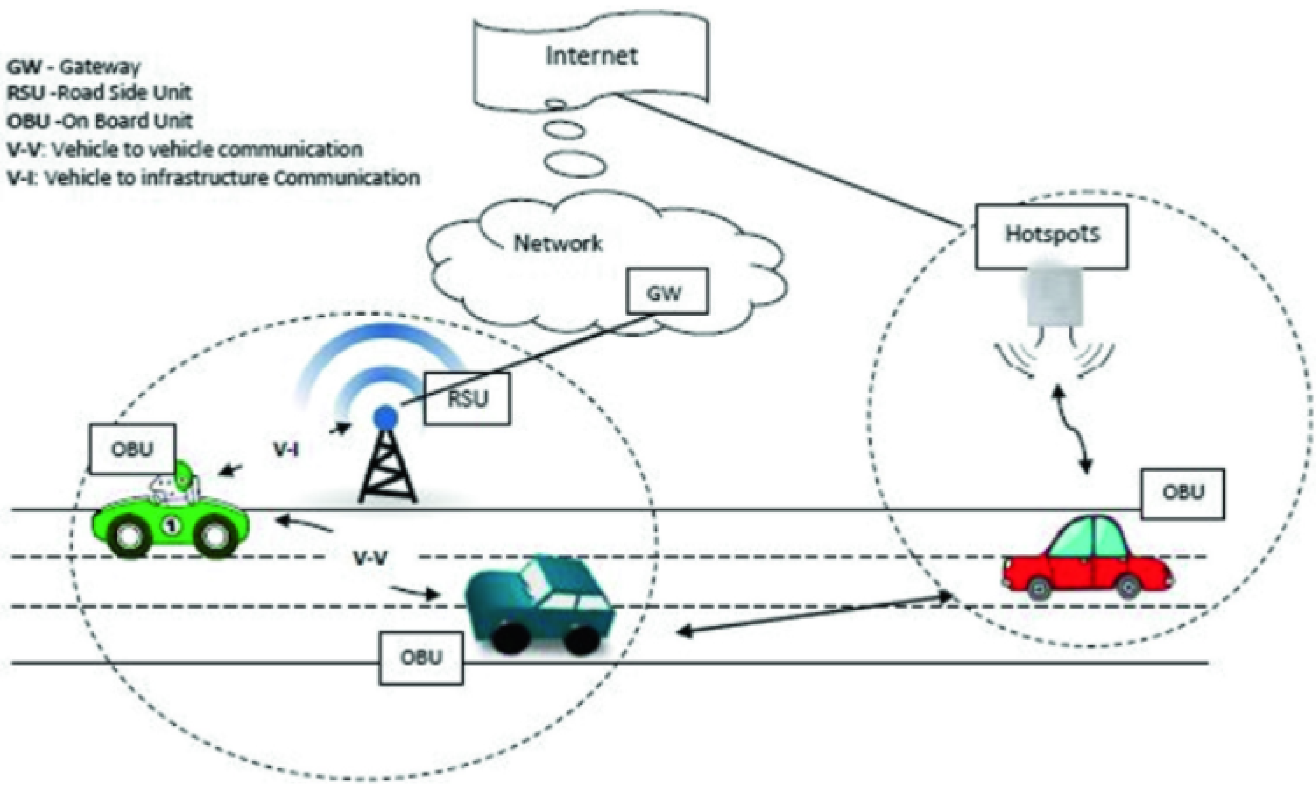

Fig 1. VANET Environment

As a subclass of Mobile Ad Hoc Networks (MANETs), Vehicular Ad Hoc Networks (VANETs) use moving cars as nodes to enable wireless network connectivity and information exchange. It contributes to the development of ITS, which is essential for providing drivers with safety and comfort [4]. While there are some parallels between VANETs and MANETs, they also exhibit certain distinct behaviors. These unique qualities include fast vehicle movement on the road, frequent connections and disconnections of the network architecture, limitless power supply, higher processing capacity, and enhanced latency constraint difficulties for many applications [5].

A typical VANET system consists of three primary components, as illustrated in Figure 1 the trusted authority (TA), roadside unit (RSU), and on-board unit (OBU). The TA, the center for OBU and RSU registration, is responsible for administering and maintaining the whole network infrastructure. An intermediate node between TA and OBUs, the RSU is a base station (e.g., WiFi, WiMAX, etc.) that is placed next to the road and controls multiple authentication processes. VANET uses OBUs and RSUs to facilitate communication between vehicles (V2V) and infrastructure (V2I). Due to the high cost of real-world VANET deployment and prototyping, simulator studies are used in most current VANET research to evaluate system performance and behaviour [6].

2 Routing Protocols

A number of routing protocols have been proposed to increase the effectiveness and dependability of VANET routing. The goal of these protocols is to increase throughput while decreasing packet loss [2]. Because of the high node mobility in VANETs, which creates a dynamic network topology frequently resulting in link disconnections, routing protocols are a challenging and complex task. In this instance, the routing protocol selection is heavily influenced by the network's properties. As a result, no single routing protocol can meet the needs of every kind of network [7].

Three different protocol types—Proactive-DSDV, Reactive-AODV, and Position-Based-GPSR—have been simulated in this research.

2.1 Literature Review

The performance of the Vehicular Ad hoc Network (VANET) can be measured in terms of various performance metrics also known as Quality of Service (QoS) metrics [8]. The popular QoS metrics used for performance measurement are like Packet Delivery Ratio (PDR), Packet Drop Rate, End-to-End Delay, Network Routing Load (NRL), Average Throughput etc [9].

Table 1 shows the Literature Review of the related works based on performance improvement of the VANET.

Table 1. Literature Survey of Related Works based on Performance Improvement of VANET

Protocol / Method	Advantages	Limitations	Performance Measures
CORFA [10]	This method finds the best possible route with the minimum transmission of packets, which ensures enhanced QoS. In this protocol model Vehicles request the pre-cached route and use them for data transmission. This protocol model forms multiple routes during route discovery to handle link failure scenario.	In absence of a pre-cached route, the fittest vehicle from each hop is selected as next forwarder for packet transmission. This process consumes more power. Two ray ground propagation model. For large area network it gives high Packet Loss Ratio (PLR) about 32.4%	-
FSSA [11]	This method provides assured lifespan to the network through less power consumption when data transfer in MANET.	Not applicable for VANET due to high mobility frequency. Two ray ground propagation model.	Encryption time = 10ms Decryption time = 13ms
ODMRP [12]	It ensures the authenticity of the messages in VANET. High packet delivery ratio and throughput.	The problem of coordination between the RSU in a range that there is prevention.	-
ASCII-ECC [13]	Ensure authenticity of messages. High PDR and Throughput.	Discarding the request messages leads to high PLR.	-
Mo-AODV [14]	High PDR, delay, NRL, and throughput and also control message overhead.	In case of VANET, node's residual energy can't be used for DF estimation.	-
DDSRC [15]	Sends data to the destination through a shortest route efficiently. Low PDD.	In case of traditional VANETs, PDD is high. Two ray ground propagation model	Packet Delivery Delay (PDD) = 0.77s
IHS [16]	High Packet Delivery Ratio (PDR) and has less overhead.	High delay in case of high mobility of the network. Two ray ground propagation model.	PDR = 48% Delay = 0.4s
TURBO [17]	Low overhead, low propagation delay, smaller the packet loss rate, higher the coverage percentage.	High MAC layer collisions with high traffic density. Applicable for two-ray ground propagation model.	End-to-End delay = 0.15s
ACARP [18]	High PDR and throughput. Low communication delay, communication overhead, and CO2 emissions.	With an increased number of vehicle density, the performance decreased.	Average throughput = 187.25 kbps PDR = 90.92%, Delay = 0.1147s
Optimal broadcasting algorithm [19]	Low Packet Loss Ratio. Give preference to long-distance communication	Uncontrolled message broadcasting over several hops may lead to a message storm.	-
D_BH_AODV [20]	High PDR, low overhead ratio, low avg. delay.	Low mobility speed. Two ray ground propagation model.	Avg. delay ranging from 100ms to 300ms Very low PDR with node scalability ranging from 40% to 50%.

Continued on next page

Table 1 continued

Scalable Block- chain for Data Management [21]	High Throughput, low latency, efficient use of bandwidth and storage.	High node density degrades the performance.	-
Metaheuristic PSO algorithm [22]	Low E2E delay, High PDR, Low control overhead, Low PLR.	Applied for low density area.	E2E delay = 25ms PDR = 65%
Intelligent IDS [23]	Detects both known and unknown attacks. Improve the detection time of the various attacks.	Performance optimization required.	-
NOVEL TWO STAGE APPROACH [24]	Detect Sybil and Dos attacks. Central authority and vehicle certification are also not required to detect attacks.	Low Packet Delivery Ratio.	PLR = 93.5% PDR = 6.5%

2.2 Problem Statement

From the Table 1 it can be observed that VANET suffers challenges like Packet drop, Packet Delivery Delay etc. resulting in degradation of VANET performance. It is necessary to find out the efficient solution that can improve the VANET performance.

For this research work, it is necessary to check the performance of the existing VANET routing protocols through the simulation experiments.

2.3 Ad-Hoc on Demand Distance Vector (AODV) Routing Protocol

The AODV protocol is classified as a reactive protocol, and it uses sequence numbers to ensure route change and uniqueness. This routing protocol is scalable making it loop-free. A two-way path between the source and the destination is maintained using the AODV protocol. As an AODV routing protocol does not maintain routes to nodes that are not communicating, it is particularly effective in highly dynamic networks.

When the need arises, a source node will send a Route Request (RREQ) message in accordance with the AODV protocol's procedure. Intermediate nodes will deliver this Route Request (RREQ) message while recording the ID of the querying node until a route is found or the destination is reached. If the route is already known until the source node, an intermediary or destination node uses a temporary route to the requesting node and provides a route back reply through an RREP message.

2.4 Destination-Sequenced Distance-Vector (DSDV)

DSDV makes the use of routing table to determine the shortest path to the destination. The routing table consists of the following information about each node in the network:

- Destination Address
- Next hop route Address
- Sequence number generated by the destination, which is used to guarantee a loop-free path

Figure 2 shows the network structure, and Table 2 provides details on node A's routing table and how it controls the routes between neighbors.

Table 2. Node A's Routing Table Information

Source	Destination	Next Hop	Hop Count	Sequence Number
A	B	B	1	B000
A	C	C	1	C100
A	D	D	1	D200
A	E	B	2	E300
A	F	B	3	F400
A	G	D	3	G500
A	H	D	2	H600

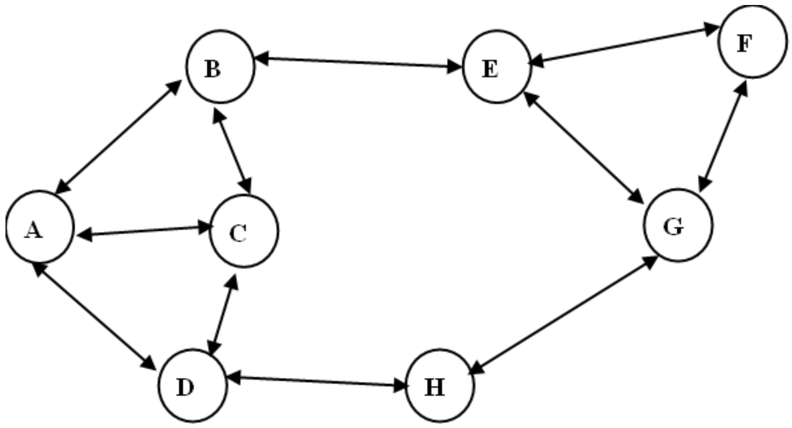

Fig 2. Network Structure

Every node keeps this table updated by occasionally sharing all routing tables with every other node in the same network. Figure 3 shows a real-world OMNET++ application. By sending hello messages to each other, nodes find each other.

As shown in Figure 4, the procedure is repeated for each node until the network topology is produced. After that, the source can readily get to the destination.

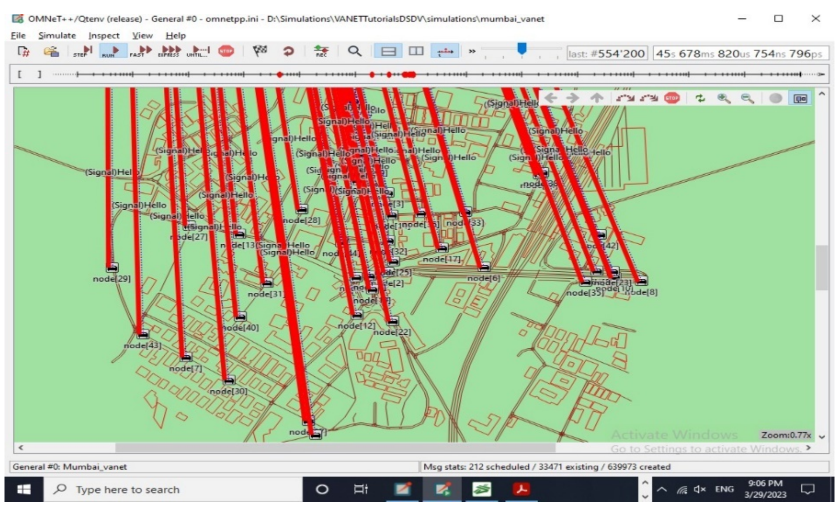

Fig 3. DSDV messages exchange

2.5 Loop Free Prevention

When two nodes' connections break, loop free occurs, such as the connection between nodes Y and Z in Figure 5. Node Y wants to inform other nodes that a link is broken after realizing it. However, Node X updates the table to Node Y more quickly than Node Y. Node Y transmits its update table to X after determining that there is a link to Z from X with a hop count of 2. The two nodes in this case will cycle endlessly and fail to recognize the network link that is broken.

2.6 Greedy Perimeter Stateless Routing (GPSR) Protocol

GPSR is a geo-routing technique that finds routes without the use of routing tables. When the topology is constantly changing, GPSR utilizes local topology information to quickly determine new routes.

This is how GPSR operates:

1. Each node learns both its own and its neighbors' positions through broadcast messages.

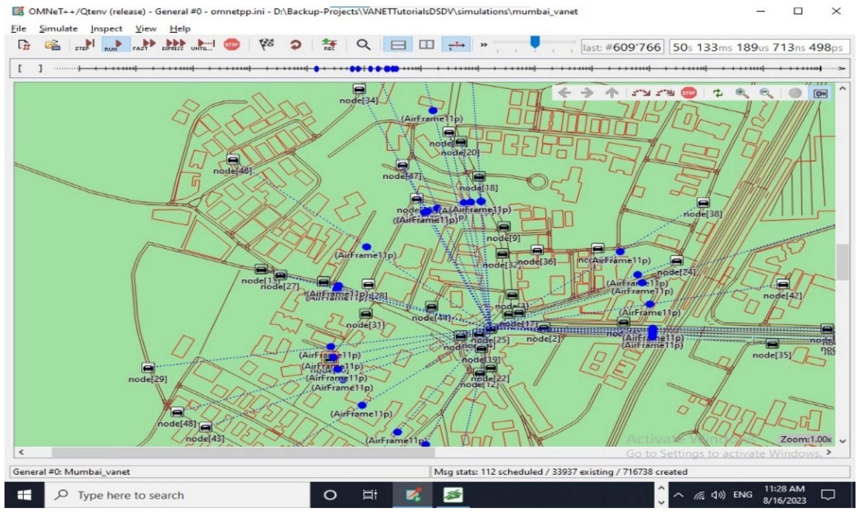

Fig 4. Network topology completed and routing tables built after exchanging messages

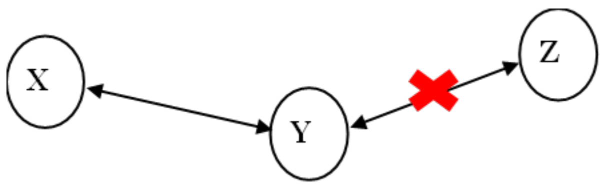

Fig 5. The infinite loop problem

2. Coordinates, not a specific recipient, receive data packages.
3. Packages are sent to the node closest to the coordinates.

During the route discovery step, the source node of an ad hoc network looks for a path to a destination node. The discovered path is used by the source node for all communications until it turns out invalid.

The source node receives a response describing the network nodes and process cycles as part of the GPSR route discovery process.

2.7 QoS Metrics

Quality of Service (QoS) metrics in Vehicular Ad Hoc Networks (VANETs) are essential for evaluating the efficiency and reliability of communication protocols. Key QoS metrics include Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR), End-to-End (E2E) Delay, and Average Throughput. PLR measures the percentage of packets lost during transmission, while PDR indicates the success rate of packet delivery. E2E Delay reflects the time taken for data to travel from source to destination, which is critical for real-time applications. Throughput quantifies the amount of data successfully transmitted over the network in a given time. Together, these metrics help assess how well a protocol supports safety, infotainment, and navigation services in highly dynamic vehicular environments.

1. **Packet Loss Ratio (PLR):** Packet Loss Ratio defines the total number of lost packets over total number of transmitted packets by all nodes in the network. It is defined as,

$$Packet\ Loss\ Ratio\ (PLR) = \frac{Total\ No.\ Packets\ Sent - Total\ No.\ of\ Packets\ Received}{Total\ No.\ of\ Packet\ Sent}\%$$

2. **Packet Delivery Ratio (PDR):** The packet delivery ratio can be calculated by dividing the total number of data packets that have reached their destinations by the total number of packets that have been delivered from sources. It is defined

as,

$$Packet\ Delivery\ Ratio\ (PDR) = \frac{Total\ No.\ of\ Packets\ Received}{Total\ No.\ of\ Packet\ Sent}\%$$

3. **Average End-to-End Delay (Avg. E2E):** Average End-to-end delay is the amount of time it takes for a packet to travel from its source to its destination across the network. The mean end-to-end latency of all successfully delivered messages can be used to calculate the average end-to-end delay. As a result, the packet delivery ratio influences end-to-end delay to some extent. The probability of a packet dropping rises with distance between source and destination. The average end-to-end delay incorporates all potential network delays, including as propagation and transmission delays, retransmission delays at the MAC, and buffering and route discovery latency.

   Average End-to-end delay is defined as,

$$Avg.\ E\ 2\ E\ Delay = \frac{1}{n}\sum_{i=0}^{n} T_{r_i} - T_{s_i} * 1000\ ms$$

   Where,

   i= Packet Identifier

   T_{r_i} = Reception Time

   T_{s_i} = Send Time

   n = Number of packets successfully delivered

4. **Average Throughput:** It represents the mean throughput value. Alternatively, it is expressed in packets per Time Interval Length units.

   Mathematically it can be defined as,

$$Avg.Throughput = \frac{recvdSize}{stopTime - startTime} \times \frac{8}{1000}\text{Mbps}$$

   Where,

   recvdSize = Received packet's size

   stopTime = Simulation stop time

   startTime = Simulation start time

3 Simulation Experiment and Results

The overall transmission efficiency is computed using combined simulation in OMNET++ and SUMO based on OMNeT++ wireless package with the CBR of 1 bps [25]. We have compared AODV, DSDV and GPSR for performance metrics such as Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR), Average End-to-End Delay (Avg. E2E Delay) and Average Throughput [26]. Table 3 summarizes the parameters used in the simulation experiment. The purpose of the simulation is to analyze the communication process of AODV, GPSR and DSDV protocols and the advantages as well disadvantages of concerned protocol for the following scenarios:

1. Node Scalability
2. Area Scalability
3. Mobility Model Scalability

The simulation process includes:

1. Network generation of selected map in SUMO using appropriate mobility model.
2. Apply one of the three protocols to the generated network in OMNET++.
3. Simulation of Combined data transfer through vehicle to RSU and vehicle to vehicle communication using balanced distance and vehicular speed assigned to compute efficiency.

Table 3. Parameters used for simulation experiment

Parameters	Values
Protocols	AODV, DSDV, GPSR
Number of Nodes	**10, 20, 30, 40, 50, 100, 150, 200, 250, 300**
Map	Mumbai, Mohali
Simulation Time	2500 seconds
Traffic Pattern	CBR
Routing protocol	AODV, DSDV, GPSR
Transmission Range	2600 m
Mobility Model	**Random Waypoint, Manhattan**
Simulation area	**10000m X 10000m, 20000m X 20000m**
Node Speed	max 22.22 m/s (80 km/hr)
Delay Time	00 sec
Interface Type	Queue
Mac Protocol	IEEE 802.11p and IEEE 1609.4 DSRC/WAVE
Packet Size	512 MB
Queue length	50
Radio Propagation Model	Two-Ray Interference model
Obstacle Model	simple obstacle shadowing model

Table 4. QoS metrics reading of AODV, DSDV and GPSR routing protocols based on Node Scalability

No. of Vehicles	AODV				DSDV				GPSR			
	PLR	PDR	Avg E2ED	Avg. Throughput	PLR	PDR	Avg. E2ED	Avg. Throughput	PLR	PDR	Avg. E2ED	Avg. Throughput
10	0.375	4.000	32.625	1.692	3.000	4.000	81.560	8.302	0.125	4.000	36.125	3.062
20	0.667	6.286	27.000	3.300	5.286	4.667	41.810	8.000	0.375	4.200	32.625	2.452
30	0.944	7.800	26.500	9.091	6.800	7.389	15.170	7.704	1.000	7.800	11.840	2.162
40	1.500	7.861	11.857	14.920	6.861	8.500	11.130	7.518	1.214	8.375	11.510	2.078
50	2.571	11.676	11.143	12.398	10.676	9.571	9.240	3.692	2.250	11.100	10.375	1.811
100	3.371	11.893	10.778	18.482	10.893	11.314	7.460	3.267	3.200	11.893	9.294	1.620
150	4.526	13.744	8.895	28.687	12.744	12.211	4.810	3.216	5.364	13.793	8.250	0.900
200	3.714	18.669	5.457	39.473	16.720	15.014	3.490	2.622	6.211	18.922	7.703	0.623
250	5.733	17.720	3.967	40.352	17.669	17.167	3.410	2.391	6.604	20.188	7.450	0.394
300	5.757	23.338	3.814	41.972	22.338	17.714	3.280	2.337	6.699	20.555	6.612	0.256

Scenario I – Node Scalability

For this simulation based on node scalability, we considered the vehicle density starting from 10 upto 300 as mentioned in Table 3. According to Table 4, AODV routing protocol maintains the lowest Packet Loss Ratio (PLR) up to about 200 vehicles, then slightly increases. This implies that AODV routing protocol is the most resilient to PLR under increasing load. DSDV routing protocol shows the highest PLR, increasing significantly with the number of vehicles. DSDV routing protocol performs poorly in dense networks, possibly due to outdated routing tables in high-mobility scenarios. GPSR routing protocol has a moderate, stable PLR.

AODV routing protocol consistently achieves the highest Packet Delivery Ratio (PDR), peaking at 300 vehicles. This indicates that AODV routing protocol is highly reliable in PDR. GPSR follows closely behind AODV routing protocol. As GPSR routing protocol benefits from geographic routing, doing better than table-based DSDV routing protocol. DSDV routing protocol remains lower than both, though it improves as vehicle count increases.

As shown in Figure 6, AODV and GPSR routing protocols start with relatively high Average End-To-End Delay (E2ED) at low vehicle numbers but stabilize and remain low as density increases. So, it can be said that AODV and GPSR routing protocols are more adaptable, especially in denser scenarios. DSDV routing protocol starts with very high E2ED and drops

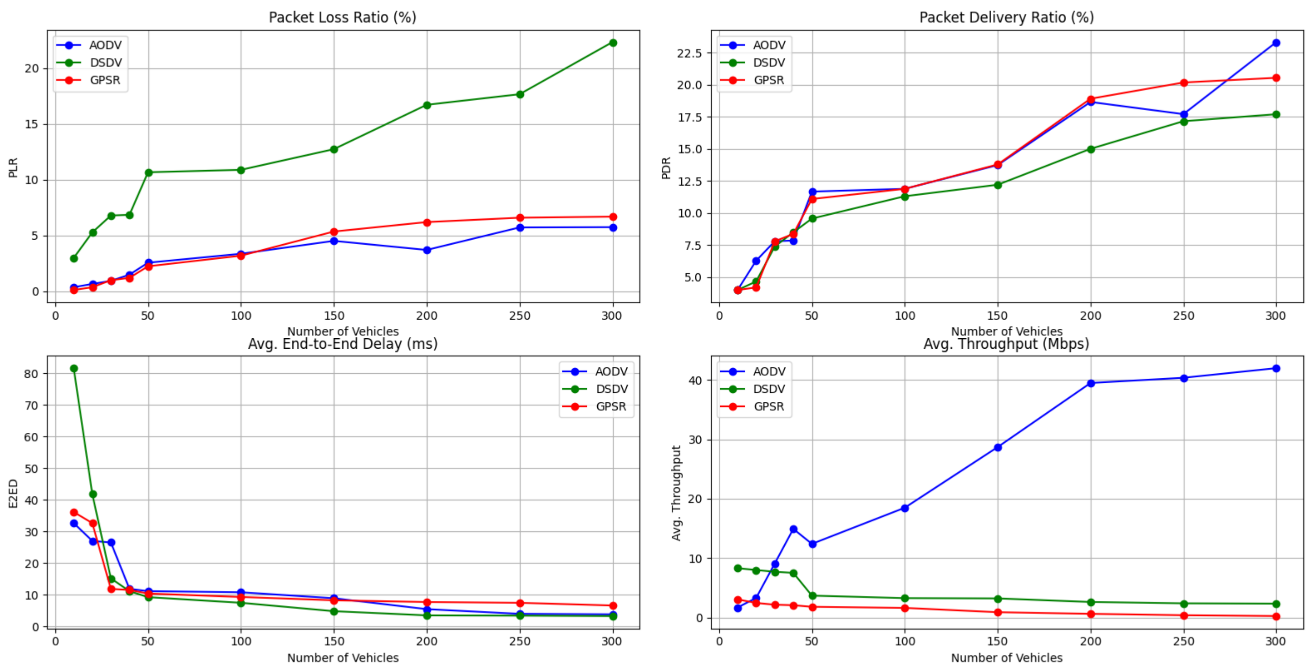

Fig 6. Comparison of GPSR, DSDV, and AODV in terms of PLR, PDR, E2ED and Avg. Throughput based on Node Scalability

sharply, indicating poor performance in sparse networks. In sparse networks, proactive protocols like DSDV routing protocol struggle due to slow convergence.

AODV routing protocol significantly outperforms the others, with average throughput increasing dramatically with more vehicles as shown in Figure 6. It is observed that AODV routing protocol is more efficient in utilizing bandwidth and managing data transmission at scale. GPSR and DSDV routing protocols show a decline in avg. throughput as vehicle numbers increase. GPSR and DSDV routing protocols face bottlenecks or overhead that reduce effective avg. throughput.

Scenario II – Area Scalability

Table 5. QoS metrics reading of AODV, DSDV and GPSR routing protocols based on Area Scalability

Metrics	AODV		DSDV		GPSR	
	10000m X 10000m	20000m X 20000m	10000m X 10000m	20000m X 20000m	10000m X 10000m	20000m X 20000m
PLR	2.235	2.210	12.744	22.338	3.200	6.699
PDR	97.765	97.790	87.256	77.662	96.800	93.301
E2E Delay	0.583	1.822	4.810	3.280	9.294	6.612
Avg Throughput	96.096	9.554	3.216	2.337	1.620	0.256

In the Scenario-II of the simulation experiment, the used simulation area was 10000m X 10000m and 20000m X 20000m. As shown in Table 5, AODV routing protocol maintains very low Packet Loss Ratio (PLR) in both cases. AODV routing protocol scales well in larger areas, maintaining reliability. DSDV routing protocol suffers from high packet loss ratio, which worsens drastically in the larger area. This shows that DSDV routing protocol is highly sensitive to network size, likely due to stale routing tables in larger topologies. GPSR routing protocol shows moderate PLR, increasing slightly with area size.

From Figure 7, it is observed that the AODV routing protocol has the highest Packet Delivery Ratio (PDR), remaining near 100% even in the larger area. This implies that AODV routing protocol is most reliable for successful packet delivery ratio (PDR) across varying geographical sizes. DSDV routing protocol experiences a significant drop in packet delivery ratio in the larger area. GPSR routing protocol maintains high PDR but shows a slight drop in larger areas.

AODV routing protocol has the lowest Average End-To-End Delay (E2ED) in both cases. AODV's reactive nature ensures efficient route discovery. GPSR routing protocol has the highest E2ED, especially in the smaller area. GPSR routing protocol

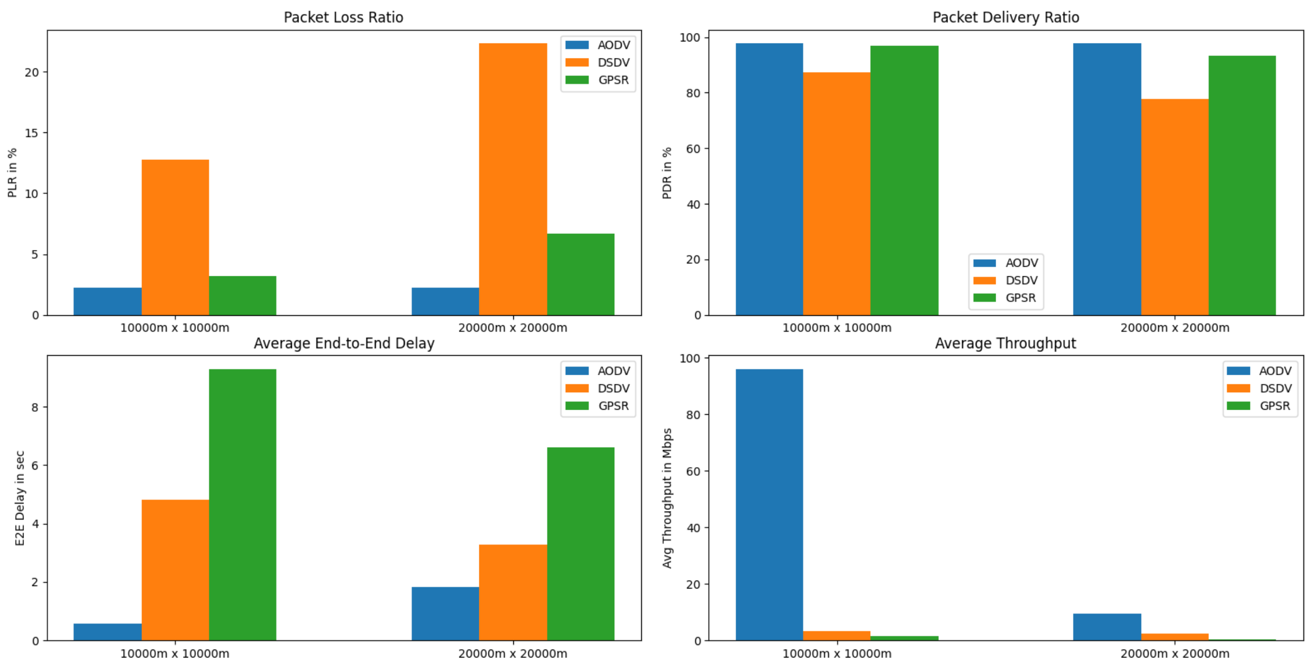

Fig 7. Comparison of GPSR, DSDV, and AODV in terms of PLR, PDR, E2ED and Avg. Throughput based on Area Scalability

may incur longer E2ED due to geographical forwarding and potential path sub optimality. DSDV routing protocol falls in the middle but improves slightly in the larger area.

AODV routing protocol demonstrates very high average throughput in the smaller area (95 Mbps) but drops significantly in the larger area. AODV routing protocol performs well in dense, smaller-scale networks. Its avg. throughput degrades in large-scale scenarios, possibly due to increased routing overhead. DSDV and GPSR routing protocols both show consistently low throughput regardless of area. GPSR and DSDV routing protocols are less effective in bandwidth utilization.

Scenario III – Mobility Model Scalability

Table 6. QoS metrics reading of AODV, DSDV and GPSR routing protocols based on Mobility Model Scalability

Metrics	AODV		DSDV		GPSR	
	RWP	Manhattan	RWP	Manhattan	RWP	Manhattan
PLR	22.338	11.3375	5.7571429	5.671429	6.698885	11.45
PDR	23.338	21.31667	17.714286	16.83333	20.55513	21.28333
E2E Delay	328.79	256.2	38.4	35.2	66.11	25.62
Avg Throughput	41.972	54.02	23.3700000	25.26	25.6	11.19

The graphs shown in Figure 8 presented comparison of the performance of three routing protocols — AODV, DSDV, and GPSR under two different mobility models and urban scenarios: Mumbai- Random Waypoint (RWP) mobility model and Mohali- Manhattan Grid mobility model as mentioned in Table 3. These graphs evaluate Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR), Average End-to-End Delay (E2ED), and Average Throughput for each protocol in both scenarios.

According to Figure 8, AODV routing protocol shows very high Packet Loss Ratio (PLR) in Mumbai (RWP) but improves in Mohali (Manhattan). AODV routing protocol may suffer in highly dynamic, less structured mobility (RWP). DSDV routing protocol has consistently low PLR in both scenarios. GPSR routing protocol performs better than AODV routing protocol in Mumbai but has slightly higher PLR in Mohali. GPSR routing protocol is moderately robust across both mobility models.

AODV routing protocol has the highest Packet Delivery Ratio (PDR) in both cities, slightly higher in Mumbai. AODV routing protocol is reliable in delivering packets despite higher PLR, possibly due to better route recovery. DSDV routing protocol has the lowest PDR, especially in the Manhattan scenario. DSDV's proactive nature may limit its performance in grid networks with frequent topology changes. Though GPSR routing protocol has slightly low PDR, it remains close to AODV routing protocol.

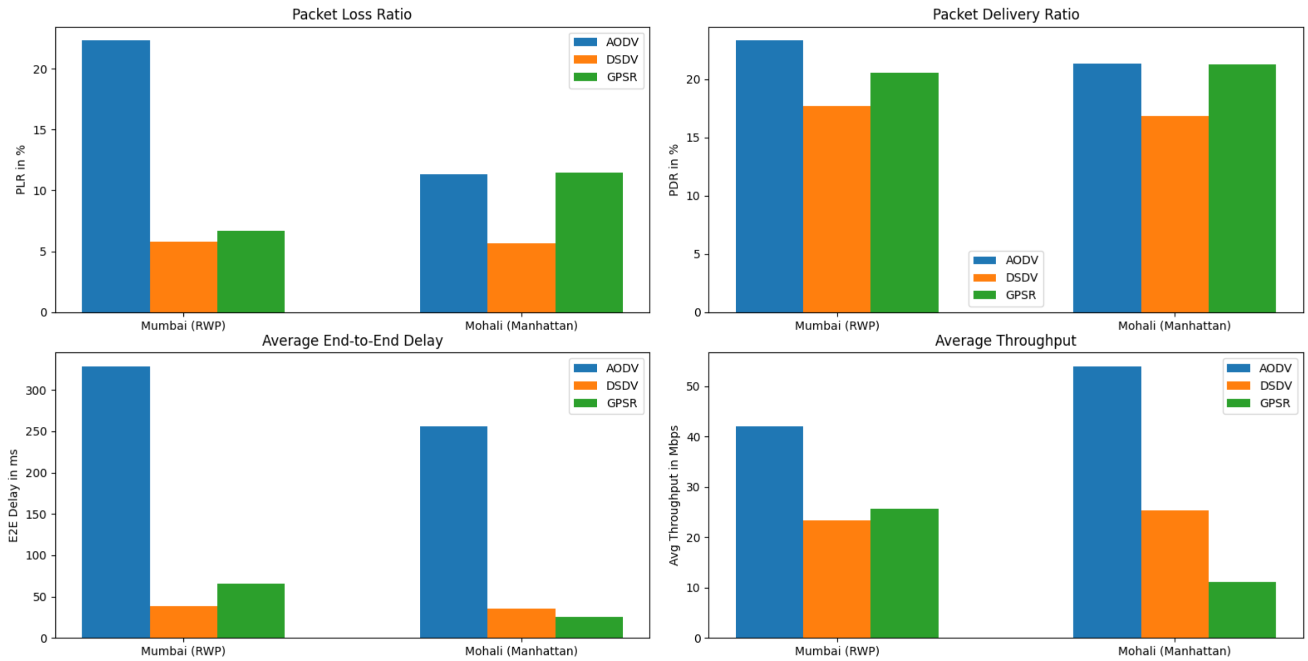

Fig 8. Comparison of GPSR, DSDV, and AODV in terms of PLR, PDR, E2ED and Avg. Throughput based on Mobility Model Scalability

AODV routing protocol suffers from high E2ED in both environments, especially in Mumbai. AODV's reactive route discovery leads to increased latency. DSDV and GPSR routing protocols have significantly lower E2ED, with GPSR routing protocol being slightly higher than DSDV routing protocol. DSDV and GPSR routing protocols provide quicker route availability, contributing to lower E2ED.

AODV routing protocol achieves the highest avg. throughput in both scenarios, especially in Mohali (Manhattan). AODV routing protocol is efficient in data transmission despite its high E2ED. DSDV and GPSR routing protocols deliver comparable avg. throughput in Mumbai, but GPSR's avg. throughput drops in Mohali. GPSR routing protocol may struggle with consistent avg. throughput in structured grid-like environments.

4 Conclusion

This study shows a simulation of a real-world road maps. SUMO 1.8.0 and OMNeT++ 5.6.2 were used to analyze the various scenarios such as node scalability, area scalability and mobility model scalability. The simulation lasts for 2500 seconds and produces a result file with scalar and vector data for various parameters. The result analysis carried out by observing the graphs.

Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR) and Average throughput rise proportionally with increasing number of vehicles. Average End-to-End Delay (E2ED) decreases with increasing number of vehicles for all scenarios.

AODV routing protocol shows superior overall performance, especially in high-density vehicular networks. GPSR routing protocol performs moderately well due to its position-based logic, while DSDV routing protocol struggles with scalability and latency.

AODV routing protocol remains the most efficient and scalable protocol across all metrics and area sizes. While GPSR routing protocol shows reasonable performance, particularly in PDR, its E2ED and avg. throughput are less favorable. DSDV routing protocol performs poorly as network size increases, making it unsuitable for large-scale or dynamic VANET scenarios.

Overall, AODV routing protocol leads in terms of avg. throughput and PDR, making it ideal for data-intensive applications even though it suffers from higher E2ED. DSDV routing protocol is consistent and low-latency but may not deliver as much data or adapt quickly in dynamic topologies. GPSR, being a geographic protocol, maintains moderate performance and shows strength in lower delays, though it may falter in throughput in structured environments like Manhattan.

Each protocol's effectiveness depends on the mobility model and network demands, with AODV routing protocol being the strongest overall performer when avg. throughput and Packet Delivery Ratio (PDR) are prioritized.

4.1 Future Work

The data dissemination is a promising application for VANETs. This research work shows that although all the existing models and protocols improve QoS, the performance of the VANET is affected with high vehicle mobility, high vehicle density and varied layouts (varied mobility models). Also, AODV routing protocol faces the problem of increased Avg. End-To-End Delay. For future work, it aimed to overcome problems like network crash due to accident events, various attacks, including black hole, eavesdropping, and wormholes etc. In future work, a new technique or model will be developed for the performance improvement and efficient data accessibility in the VANET through a sustainable data management scheme.

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