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Performance Evaluation of Data Dissemination Protocols for Connected Autonomous Vehicles

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ABSTRACT An overwhelmed number of vehicles has wrecked the current system of transportation due to rapid growth in population. Smart cities are the novel innovation that is inevitable to curb the problems of traffic jams, unorganized traffic, environmental pollution, and slow response rate to emergency situations. The intelligent transportation system (ITS) is an integral part of smart cities allowing communications and interaction among vehicles. An autonomous vehicle is the key element of ITS and the mass implementation of this emerging technology is the solution to traffic problems linked to the current transportation system. Autonomous vehicles lead to the need for efficient and reliable external vehicular communications particularly through vehicular ad hoc networks (VANET). However, utilizing a suitable routing protocol to provide stable routing and efficient performance for vehicular communications in autonomous vehicles is a key factor. Routing protocols are particularly important for establishing vehicular to vehicular and vehicular to infrastructure (V2X) communication, which is incredibly challenging due to the movement of nodes. The quality of inter-vehicular communications is widely affected by numerous factors such as routing protocols, traffic environment, and traffic density. This article presents a detailed evaluation of three commonly used protocols, i.e., Ad-hoc On-demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), and Destination-Sequenced Distance-Vector Routing (DSDV) under three different traffic environments. To investigate the performance of these routing protocols under diverse environments, simulations are extended further by using the varying density of vehicles. This study aims at finding the best routing protocol for efficient and reliable packet dissemination among vehicles under different scenarios.

INDEX TERMS Connected autonomous vehicles, data dissemination protocols, future internet, smart cities.

I. INTRODUCTION

In the present times, the need for building smart cities has become more important. As the cities are growing rapidly in size, the problems of environmental pollution, overpopulation, and traffic congestion are a routine now. It is undeniable that the transportation system has a huge impact on the urban sustainability, economic development, and social welfare. The transportation system currently prevailing in the world poses environmental, social, and economic challenges with urgent need to cut back on carbon emissions and environmental pollution, mitigate road incidents, conserve energy, and relieve congestion [1], [2]. Smart cities are the potential and contemporary solution to all these problems [3]–[6]. The concept of smart cities will make the cities more efficient, livable, environment friendly, and less noisy, improving the quality of life [7].

Advances in technology introduces autonomous vehicles that offer great promise to address the everyday problems of traffic and have the potential to bring revolutionary changes

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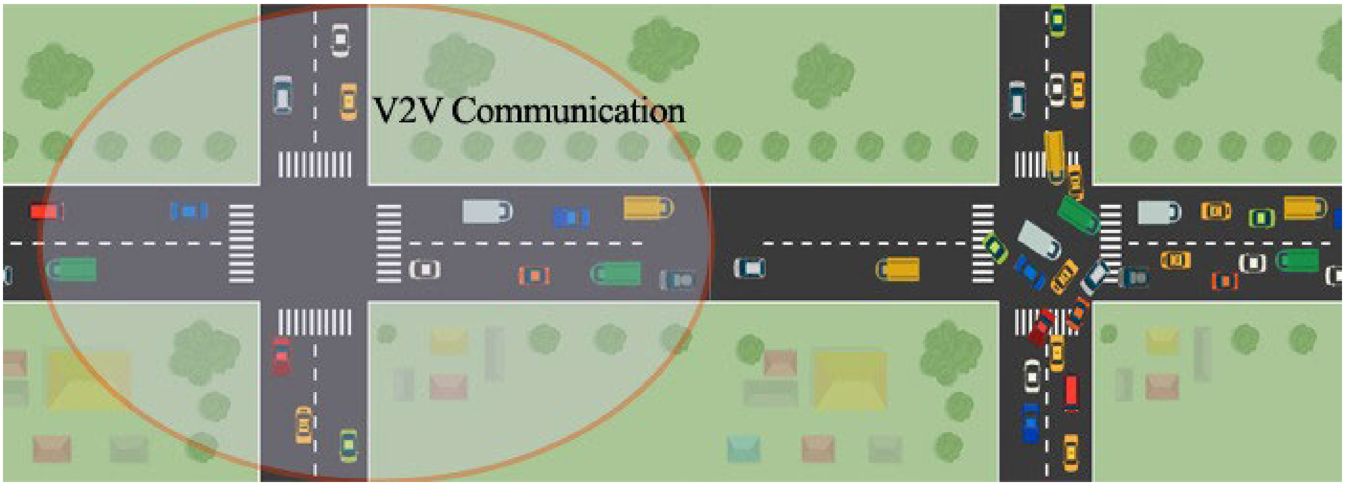

FIGURE 1. Traffic condition with and without VANET.

to the future transportation systems [8]. The V2X communication is the key aspect of the ITS, which is getting significant attention due to its role in building safe, fast, and congestion-free cities [9].

Autonomous vehicles have the capability to tackle the widely faced problems of traffic congestion, unorganized traffic, and delay in case of accidents. This fully automation of vehicles will bring a substantial decline in the number of incidents on roads. Apart from it, autonomous vehicles are capable of controlling environmental pollution by emitting lesser amount of gasses and consuming fewer amount of fuel.

In recent years, autonomous vehicles become the emerging field of research to ensure road safety through inter-vehicular communications [10]. Vehicles on roads are continuously increasing in number due to the increase in population. This increasing number of vehicles gives the motivation to design and implement a super-efficient and fast traffic system [11]. The main aim of ITS is to introduce an efficient and safe traffic system via V2X communication that reduces environmental pollution, travel time, traffic jams, and enhances traffic safety meanwhile making vehicles well aware of their surrounding through on-road real-time communications [12], [13]. Figure. 1 shows two scenarios: one with V2V communication and the other without V2V communication.

The real traffic scenario generation is a very expensive and complex task in terms of planning, design, and implementation. The alternative solution to this problem is the simulation of the road network. There are various simulation tools available that are flexible, simple, and generate the required scenarios for traffic evaluation.

Various routing protocols are available for vehicle-to-vehicle (V2V) communications that are used to send a message from the source to the sink. The VANET protocols are categorized into three types: Proactive, Reactive, and Hybrid. In proactive routing protocols, every node is required to identify the next hop towards the sink and the total hops it is away from the sink node, i.e., hop count for the destination. All this information is maintained in a routing table in which each record represents the next node towards the destination. In this way, the need for route discovery is eliminated as the route towards the destination is always available in the routing table. The reactive protocols, on the other hand, set up on-demand routes whenever a node is required to establish a communication with a node it wants to connect with.

To achieve the aim of the efficient, fast, and safe traffic system, the experts need to figure out an efficient and reliable routing protocol. This needs an evaluation of various routing protocols by carrying out simulations. In this article, three different routing protocols have been evaluated in three different traffic scenarios with a varying density of vehicles. The routing protocols AODV, DSDV, and DSR are selected. These three are the most popular and commonly used routing protocols used in simulations of vehicular communications as given in some of the studies [14].

This work considered a wide number of scenarios to find out the best routing protocol for inter-vehicular communications. Three major road scenarios are chosen for simulation, namely a city environment, a highway, and a grid topology. These three scenarios are the key elements of any transport system. To assure the smooth flow of traffic, the major components of the transport system must be improved.

The remainder of this article is structured as: The services and benefits of AVs are described in Section II, Section III contains the related studies, Section IV discusses the routing protocols and their types, Section V illustrates the problem statement, Section VI describes the simulations setup and experiments of the proposed solutions, Section VII contains the results of the simulation, and Section VIII concludes the study.

II. AUTONOMOUS VEHICLES: DRIVING TOWARDS A BETTER FUTURE

The AVs are equipped with super efficient computational power and huge data storage in order to run the autonomous

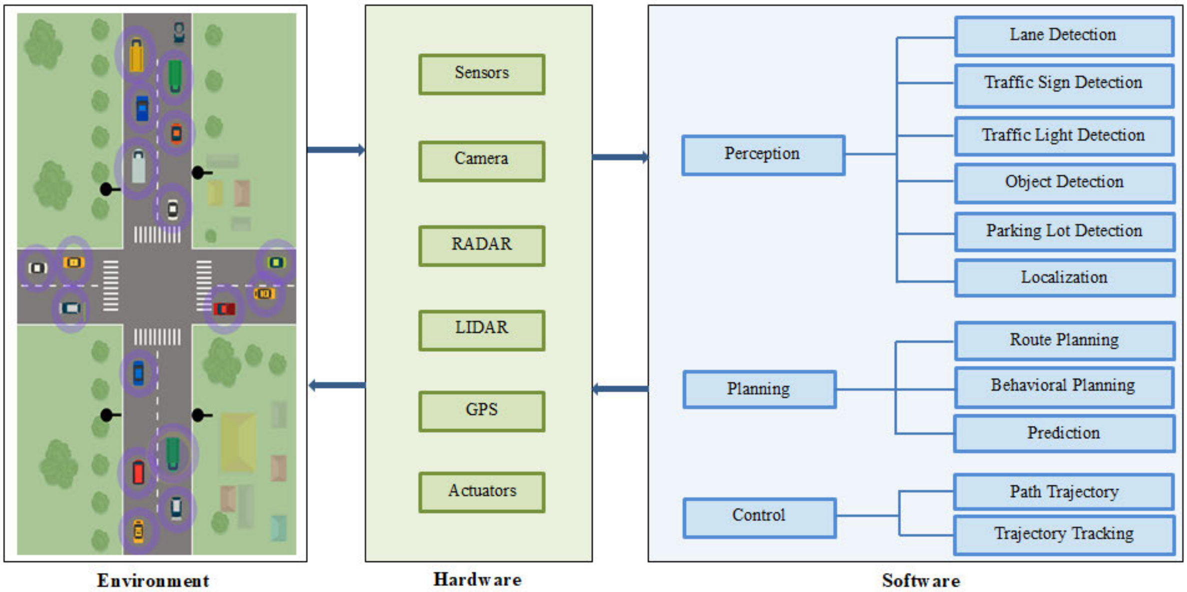

FIGURE 2. An intelligent transportation system (ITS) presented by autonomous vehicles.

vehicle's driving algorithms [15]. All the functions such as sensory, perception-related, processing, and control that have historically the responsibility of the driver become the domain of the on-board system of the AVs. The on-board system senses and understands the surrounding of the vehicle it is mounted on, and takes the most appropriate action. To gather information from the surrounding, the V2X communication takes place through the hardware components such as sensors, cameras, RADAR, LIDAR, GPS etc [16], [17].

The data achieved is in raw form and is converted into meaningful structured information by the perception system. This information is then used by the planning system to create driving behaviors. The planning components do high-level route planning, behavior planning telling what next action the vehicle should take, and prediction about the other objects on the road. The control system at the end ensures that the vehicle must follow the path presented by the planning system without any error. The control system issues commands for the safe driving that includes acceleration, steering, and brake commands. The working of AVs is shown in Figure 2.

The future is very bright for the AV technology that will lead the world to a revolutionary transportation system [18]. There is a huge number of services that can be attained by implementing the technology of AVs at a wider scale. Some of these services are discussed below.

A. SAFETY

The feasibility of the AVs is directly proportional to the level of safety it ensures. The car crashes on roads can be significantly reduced by equipping the vehicles with adaptive headlights, anti-lock brakes, air bags, head-protection side air bags, lane departure warnings, forward collision warning, adaptive headlights, and blind spot assistance. The AVs are capable of preventing an appreciable number of these accidents, eventually mitigating a majority of all traffic delays [19].

B. DRIVERLESS TAXIS AND CAR-SHARING SCHEMES

The AVs provide the services of driverless taxis that eliminate the cost of cabdriver's time and services. These driverless taxis have a number of advantages such as availability to multiple persons on demand, less costly, and are more suitable for household uses.

C. ROAD'S CAPACITY

The AVs have the ability to cruise at higher velocities while keeping shorter distances. These vehicles are equipped with finely tuned braking system while monitoring the surrounding environment precisely at the same time. The shorter distances among the AVs will not compromise the safety of the vehicles. This leads to the platooning of AVs on roads, eventually increasing the road's capacity.

D. AVs AND ELECTRIC VEHICLES

The electric vehicle (EV) uses batteries instead of fuel tanks used in conventional vehicles. The EVs are more efficient in performance in terms of lesser emission in hazardous gases, lesser cost of running, and lesser dependence on imported oil [13]. Apart from these potential benefits, EVs suffer from some drawbacks, such as limited travelling capacity that depends upon the durability and size of the batteries. This limits the EVs to the short-range travel distances. This problem can be resolved through the fleet of AVs. This fleet of AVs can resolve charging time management, short range anxiety, and the anxiety of finding a charging station.

E. ENVIRONMENT FRIENDLY

The AVs support the concept of eco-driving. The eco-driving causes lesser consumption of fuel and lesser emission of gases. Apart from it, AVs increase the travel capacity of roads and reduce the amount of fuel wastage during the times of traffic congestion, making them environment friendly [20], [21].

F. TIME SAVING

The AVs free drivers from involving in mental and physical actions linked to the driving. The drivers can use this time in other useful activities.

III. RELATED WORK

The performance of three different routing protocols was evaluated for a highway traffic scenario in [22]. The simulation tools used are OMNET++ and SUMO. The routing protocols used are CBF, ASTAR, and GPCR. These protocols were evaluated using the routing overhead, latency, and packet delivery ratio. Results show that CBF performs excellently well. When the simulations were repeated using varying speed, then A-STAR depicted an improved performance.

In [23], the performance evaluation of AODV, AOMDV, and DSDV had been performed. The results show that AOMDV outperforms AODV and DSDV for packet loss and PDR. Whereas, AODV was found to be efficient than AOMDV and DSDV for the throughput. The DSDV proved to be better than AODV and AOMDV in case of latency. The analysis showed that AODV performed better when it comes to the lower density of nodes. In order to show the importance of efficient and fast traffic flow, [24] carried out experiments using CBR. The results obtained showed that the CBR outperforms the GPSR, AODV, and the DSR protocols in terms of PDR and the message overhead. It showed a 10% improved performance than other protocols.

An architecture is proposed in [25] that consists of pure vehicle to vehicle (V2V) communications. The experiments had been carried out using OPNET simulator on two scenarios: one with RSU and the other on without RSU. To perform the simulations, two different numbers of vehicles had been used. The routing protocols used are AODV, GPR, DSR, and OLSR. The results showed AODV protocol depicts good performance in terms of load, delay and re-transmission attempts. As far as other KPI's are concerned, other protocols depicted better results than AODV. The reason behind it is that AODV needs to update the shortest path frequently.

In [26], the performance of eight VANET protocols namely AODV, DSR, FSR, DSDV, OLSR, ZRP, GPSR, and DYMO were compared. The experiments were performed on an urban environment using realistic node mobility. The Vanet-MobiSim was used to generate the traffic. The authors selected PDR, latency, throughput, and the routing cost as performance metrics. The result analysis showed that the geographic routing protocols performed better than the rest of the protocols. The reason is such that this type of protocol uses the information of the node's position proving it suitable for this kind of network. The performance of AODV, OLSR, and DSDV protocols was evaluated in [27] using NS-3 and BonnMotion. The results showed that in case of low-density and low-speed scenarios, DSDV and OLSR performed better than AODV. It was analyzed that OLSR outperformed the other two protocols on increasing the density or speed of nodes.

The AODV, DSDV, and DSR were evaluated in [28] where the performance metrics used were throughput, PDR, and Normalized Routing Load (NRL). The analysis of results showed that AODV proved to be better than DSDV and DSR for PDR and throughput. Whereas, DSDV performed more efficiently in case of NRL. The AODV and DSDV had been evaluated in terms of PDR, jitter, and delay.

Results showed that DSDV depicted better performance for TCP reno traffic type for transferred throughput and PDR, while the AODV found to be good in throughput on increasing the CBR source nodes exponentially. The DSDV protocol performed better for the UDP traffic for jitter, transferred throughput, and latency, whereas the AODV proved to be better for generated throughput and PDR. The AODV and OLSR were evaluated in [29]. The OLSR proved to be better both for low-density and high-density crossroad scenarios.

In [30], five routing protocols were considered for simulations, namely AODV, DSDV, GPSP, OLSR, and GPCR. The results showed that the OLSR performed better in terms of throughput and PDR. On the other hand, the GPSR and GPCR proved to be more efficient in case of overhead and latency. The simulations were performed using AODV and MAODV in the NS-2 environment. The results showed that the MAODV performed more efficiently than the AODV in terms of PDR. Moreover, it was observed that the MAODV protocol was appropriate for high networks where route failure is observed very often. Therefore, the MAODV found to be more efficient than the AODV for VANET networks. The AODV and DSR were compared in [31] using PDR, throughput, average end-to-end delay, and jitter. The results showed that the AODV outperforms DSR. Moreover, the performance was affected more by varying the area size as compared to the density of nodes.

The mobility model based on varying speed of nodes was simulated in [32] in which the DSDV was used as the routing protocol. The performance was evaluated based on PDR and throughput. The analysis of results showed that when the speed of nodes was increased, both metrics declined which gave poor performance of DSDV in case of the high speed of vehicles. The AODV, DSDV, and DSR were compared in [33] in which the analysis of the results showed on-demand protocols AODV and DSR performed better in case of fast mobility of nodes. Moreover, it was observed that the lesser routing load was created by DSR as compared to AODV.

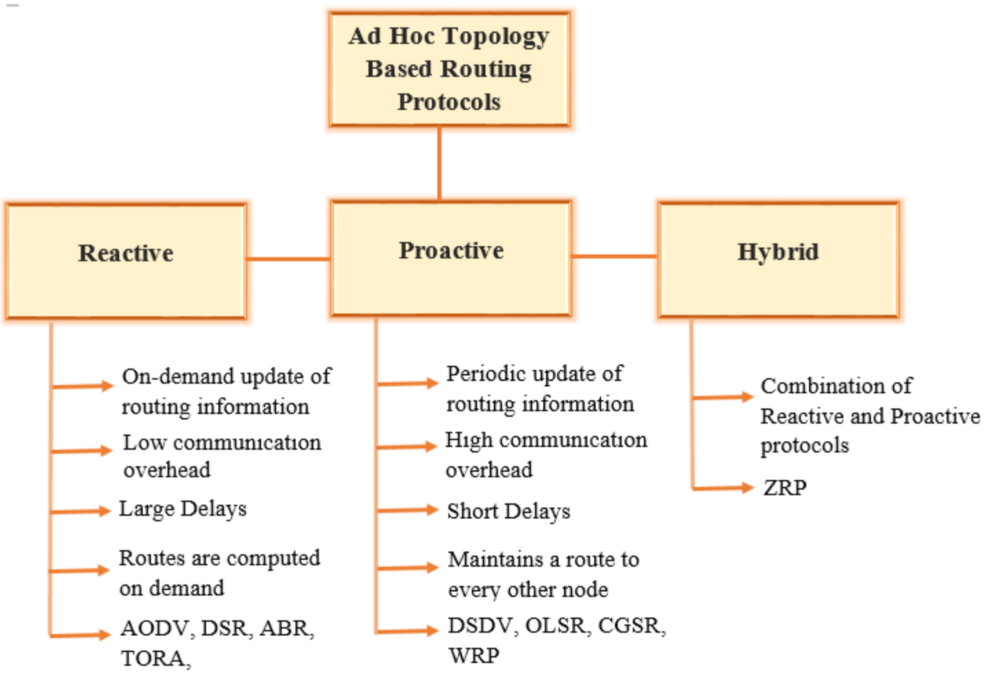

FIGURE 3. Ad hoc routing protocols and their characteristics.

In [34], DYMO and OLSRv2 were simulated to evaluate their performance using throughput, average jitter, delay, and PDR. In terms of PDR and throughput, DYMO proved to be a better choice than OLSRv2. For average jitter and delay, OLSRv2 performed more efficiently. The performance evaluation of four protocols, i.e., Intersection-based Distance and Traffic-Aware Routing (IDTAR), Greedy Traffic-Aware Routing (GyTAR), Anchor-based Street and Traffic-Aware Routing (A-STAR), and Geographic Source Routing (GSR) was performed. The results showed that the IDTAR caused minimum latency and maximum PDR due to its attribute of dynamic selection of anchor-based on curve-metric distance and traffic density.

The AODV, DSR, and DYMO were evaluated in [35]. The DYMO proved to be better than the other two protocols due to its low latency and large throughput. The AODV depicted better performance in case of latency. It was concluded that the cities and highway environments are the most suitable environments for VANET applications [36]–[38]. The feasibility of applications of the three routing protocols had been evaluated in [39]. The results showed that the GPR performed efficiently than the OLSR and AODV for bandwidth utilization. Under voice traffic, it performed efficiently for delay, overhead, and throughput. The OLSR depicted the best average results for latency due to its proactive nature.

It is observed that OLSR and DSDV are better than AODV for low-speed and low-density scenarios. For the high-speed nodes, AODV and DSR perform better than DSDV. Moreover, MAODV is more efficient as compared to AODV. It is observed that the performance of the routing protocol depends on multiple factors, such as road network, node's density, and node's mobility. Apart from these factors, the impact of evaluation metrics on the performance of each protocol cannot be denied.

IV. AD HOC ROUTING PROTOCOLS

One of the most important aspects of VANETs is the routing protocols used to transmit information. There are several types of protocols in VANETs, which can be classified into three types, i.e., Reactive, Proactive, and Hybrid [40], [41], as shown in Figure 3.

A. REACTIVE PROTOCOLS

Reactive protocols [42] do not require to keep the routing information updated for improving the use of resources. Nodes do not share topological information with other nodes. A route generation mechanism will establish a route on demand by a node that requires to transmit the data. Initially, route discovery is carried out before transferring data packets. Once a reply is received, nodes start exchanging information.

1) AD HOC ON-DEMAND DISTANCE VECTOR ROUTING (AODV)

The AODV [43] establishes and maintains routes for communication when the end-user has data packets to be transmitted. Whenever data needs to be transmitted, a route request (PREQ) packet is transmitted by the source node to the destination. The nodes that receive this PREQ packet checks if they have a route to the destination. If any node has that route, it replies with the (PREP) packet. If none of these nodes has a route towards the destination, then the PREQ packet is broadcasted further to the nearby nodes.

If a link break happens among the nodes, then a route error packet (PERR) is created and broadcasted back to the source.

2) DYNAMIC SOURCE ROUTING PROTOCOL (DSR)

The DSR [44] determines and maintains routes dynamically ensuring quick response services by delivering data packets successfully. When data is sent from the source node, a route discovery mechanism works and the PREQ is transmitted to all nodes in its neighbour. Each of these nodes then adds its unique identifier to the PREQ message. A PREP message is generated when the data reaches its destination. The copy of the packet is stored by the nodes on the buffer. When a route failure occurs, the nodes generate a PEER message and the buffer is updated.

B. PROACTIVE PROTOCOLS

In proactive protocols, one or multiple tables are kept by each node in order to preserve the routing information towards all other nodes. This is the reason these protocols are also called table-driven protocols. The information in these tables is updated consistently so that the consistency can be retained as the status of the network changes. This information is passed onto every node that exists in the network.

1) DESTINATION SEQUENCED DISTANCE VECTOR ROUTING PROTOCOL (DSDV)

In DSDV, the routing tables are broadcasted by the nodes to their neighbors with a sequence number [45]. The sequence number is updated with every packet broadcast. There are two tables maintained by every node. One table is helpful when the packets need to be transmitted further. Whereas, the other table is for advertising incremental routing packets. On receiving an updated packet, the information is extracted from the packet and a routing table is updated.

C. HYBRID PROTOCOLS

Hybrid protocols contain the characteristics of both reactive and proactive protocols. It intends to reduce the message control overhead seen in reactive protocols and the delay experienced in proactive protocols [28].

V. PROBLEM STATEMENT

To design an intelligent transport system, it is very important to consider all the major traffic scenarios for simulations. The previous studies focus only on a single environment that only deals with a specific area of ITS, such as in [30], [31], the simulations are performed in a city environment. In [29], a small crossroad is considered for experiments and in [32], a highway is considered for simulations. Based on it, we have included all these traffic scenarios in the experiments so that the performance of protocols in each of these scenarios can be investigated and to assure the QoS of VANETs.

This study provides an efficient and reliable road-map for the designers and researchers to carry out simulations to tackle the poor condition of today's traffic. Firstly, to maintain a piece of updated information for the sake of research and design of ITS, we have considered the most recent articles, i.e., from the span of 2017-2020, assuring up-to-date information. Secondly, we have considered three different traffic scenarios, i.e., a city scenario, a highway scenario, and a Manhattan grid scenario. Thirdly, the good or bad situation of traffic depends mainly on the density of vehicles on these roads that keep on varying.

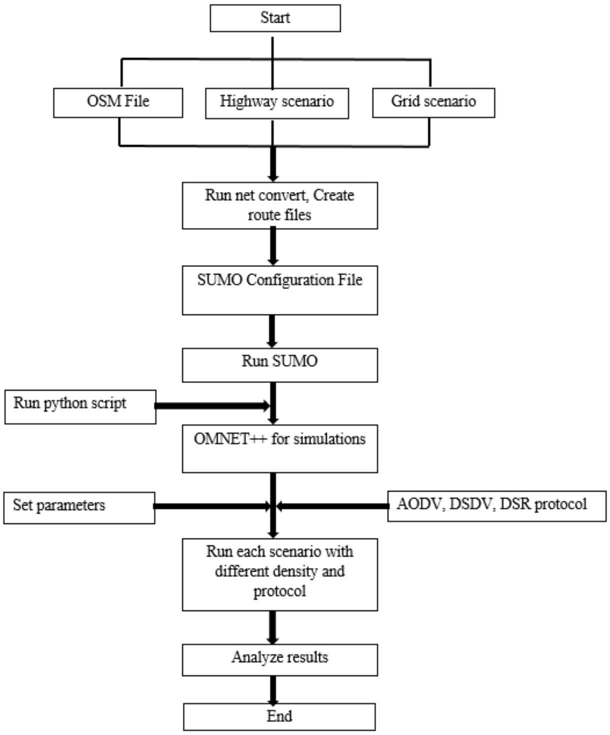

FIGURE 4. Research methodology for performance evaluation of data dissemination protocols for connected autonomous vehicles.

To deal with this problem, we performed the simulations on the varying density of vehicles. Fourthly, to find out the most efficient protocol for each scenario, we have considered both reactive and proactive protocols for simulations. To achieve this aim, the QoS performance evaluation of three commonly used and most popular routing protocols is carried out to find the most efficient protocol with minimum latency and maximum throughput.

VI. SIMULATION ENVIRONMENT AND SETUP

A. MOBILITY MODEL

To simulate a VANET network, several mobility models have been developed to meet the requirements of the real-world traffic environment. Choosing an efficient mobility simulator is an important factor in carrying out simulations that are close to reality. In this article, three different mobility scenarios are simulated using SUMO-0.30.0, which is efficient and close to the reality multi-modal mobility simulator [46]. Figure 4 shows the flow of the methodology to perform simulations.

B. NETWORK SIMULATOR

The simulation tools used for vehicular communications are OMNET++ 4.7.1 with the INETMANET-3.x framework [47]. The network communication and message dissemination are carried out through OMNET++, which is a discrete simulation library [48]. The wireless network is based on the commonly used IEEE802.11p standard. IEEE 802.11p is an improved version of the IEEE 802.11 to facilitate wireless access among vehicles. This amendment enhances 802.11 that is required to support the applications related to ITS. The simulations are performed using a mobility simulator, network simulator, and a connection between the two. The simulation parameters are defined in Table 1.

TABLE 1. **Simulation configuration for network parameters.**

Parameter	Value
Network Simulator	OMNET++
Mobility Model	Veins Inet Mobility
Simulation Scenarios	Real World, Highway, Manhattan Grid
Routing Protocol	AODV, DSDV, DSR
Number of Nodes	50, 150, 250, 350, 450
Transport Protocol	UDP
Packet Size	100Bytes
MAC Protocol	IEEE802.11p
MAC Bitrate	6Mbps
Transmission Power	100mW
Transmission Range	250m
Radio Propagation Model	Two-Ray Ground

C. SIMULATION SCENARIOS

To define an efficient model, three different traffic environments are considered for simulations:

- **Real World:** A real-world traffic scenario of a famous intersection of the city of Lahore is extracted using an Open Street Map (OSM) which is then imported in the SUMO [31], as shown in Figure 5. It is a busy intersection where an abrupt flow of traffic is seen often. The vehicular speed is set to be the maximum speed allowed by each lane.
- **Highway Scenario:** A highway with two lanes for traffic is considered. The traffic pattern for the highway scenario is different as compared to the urban scenario and needs a separate analysis. The maximum speed for the two lanes of the highway is 50 km/h. This scenario is shown in Figure 6.
- **Manhattan Grid**: A 5 × 5 Manhattan grid is a mobility model that consists of the vertical and horizontal roads. The city of Islamabad is developed on this structure of roads network. The vehicles in grid scenario move with maximum speed allowed by each lane. Figure 7 shows the Manhattan grid scenario in SUMO.

D. PERFORMANCE METRICS

The performance metrics selected for performance evaluation are given below:

- **Throughput** is the number of packets delivered successfully for a specific time. The network efficiency and the throughput are directly proportional to each other, which means a higher value of throughput shows higher performance.
- **Latency** is the time taken by each data packet sent by a node to reach its destination. This consists of all the possible time delays triggered by the route discovery, waiting at the interface queue, time consumed in propagation and transmission, and the re-transmission delays. The network efficiency and the latency are inversely proportional to each other.

FIGURE 5. **A realistic scenario of the city of Lahore.**

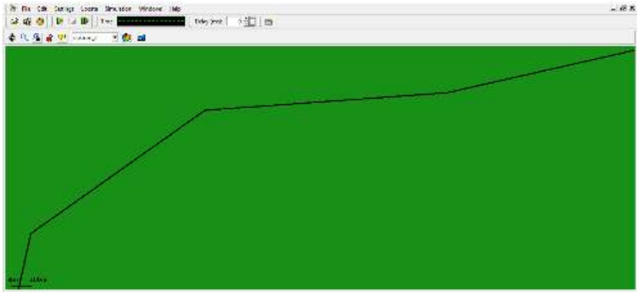

FIGURE 6. **A two-lane highway scenario generated in SUMO.**

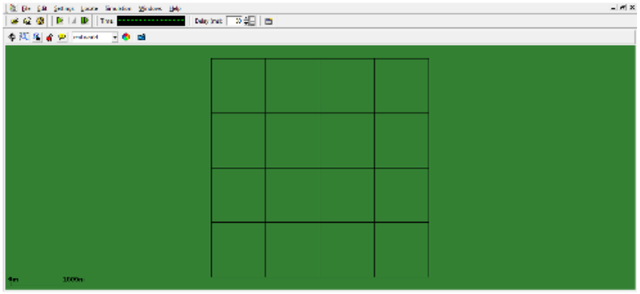

FIGURE 7. **A manhattan grid scenario.**

VII. SIMULATION RESULTS

In this section, the analysis of the results for each of the three scenarios is presented.

A. RESULTS ANALYSIS FOR THE CITY OF LAHORE

The results analysis of a city model shows that the DSR outperforms the other two protocols. when the node's density is 50, DSR and AODV show good performance with AODV slightly lagging behind DSR. When the node's density is set to 100, the throughput for all the three protocols increases. When the node's density is set to 150, the performance of AODV and DSR almost becomes equal. As the number of vehicles increases, the DSR shows an increase in the throughput surpassing AODV. The DSDV being the proactive protocol shows the minimal throughput for all densities of vehicles. On setting the number of vehicles to 250, the DSDV shows a sudden decrease in performance. When the density of vehicles is increased further, an improvement in the throughput of DSDV is observed. Whereas, AODV and DSR show consistency in throughput with the increase in node's density.

In the case of latency, the DSR shows minimal latency as compared to AODV and DSDV and maintains its good performance throughout the simulations. At the beginning of simulations, a significant difference in latency of DSR and the other two protocols is observed. When the node's density is set to 150, the latency for DSR increases touching the value of the latency for DSDV. When the node's density is increased further, the latency in the case of DSR decreases maintaining an efficient performance than the AODV and DSDV. When the node's density is set to 300, a sudden increment in the latency of all the three protocols is observed.

The AODV depicts maximum latency than DSR and DSDV, whereas the DSDV performs better than the AODV. It is observed that AODV and DSDV depict efficient performance with the increase in the node's density in terms of latency, showing a minimum increment in their latency with the increase in the node's density. As far as the overall performance is concerned, DSR maintains a good latency from minimum to the maximum density of nodes. Figures 8 and 9 show the throughput and latency for the city scenario, respectively.

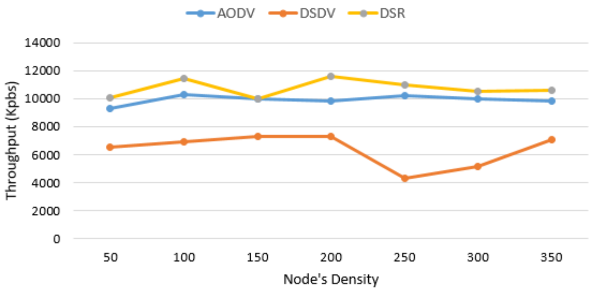

FIGURE 8. Throughput for real model of Lahore City.

B. RESULTS ANALYSIS FOR HIGHWAY

The data analysis of simulations performed for highway scenarios shows when the node's density is low, the DSR depicts the maximum throughput with AODV slightly lagging. When the node's density is set to 250, the throughput for DSR is decreased suddenly. The DSR maintains its performance again when the node's density is increased further. The DSDV, on the other hand, shows good performance for the increased value of the node's density. The AODV shows a minimal change in the performance on increasing the node's density to 350. It is observed that for the highway scenario, AODV and DSR are more efficient than DSDV, but when the density of the nodes is expanded, the DSDV performed efficiently showing a greater value of the throughput. The throughput for AODV and DSR shows very little improvement with the increase in the node's density.

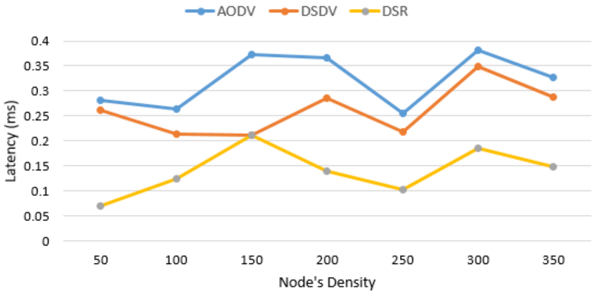

FIGURE 9. Latency for real model of Lahore City.

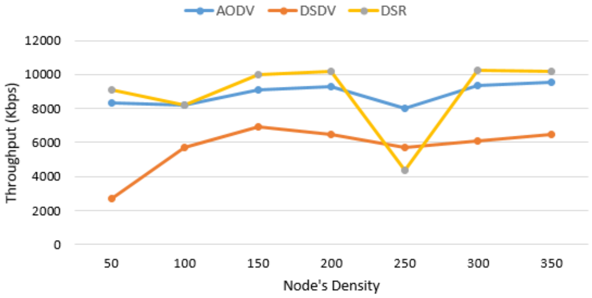

FIGURE 10. Throughput for highway scenario.

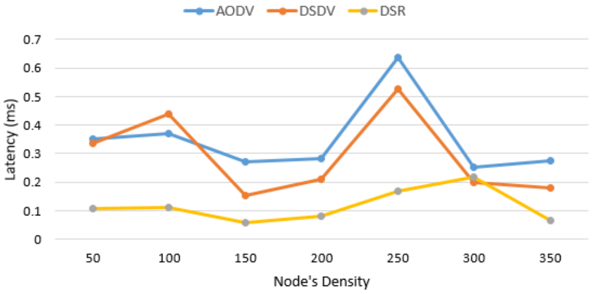

FIGURE 11. Latency for highway scenario.

In the case of latency, AODV and DSR show a minimum impact of node's density on the performance showing lesser latency, as compared to DSDV. At the beginning of simulations, DSR shows the lowest latency as compared to AODV and DSDV, whereas AODV and DSDV show a significant value of latency. The AODV and DSDV show an almost similar pattern of change in throughput as the number of nodes is increased. For AODV, a minimum impact of change in the node's density is observed for the node's density 200. When the density is increased further, both the AODV and DSDV shows an increase in latency. It is again decreased when the node's density is set to 300, showing excellent improvement in the performance of AODV and DSDV. The DSR maintains a good latency throughout the simulations. Figures 10 and 11 show the throughput and latency for the highway scenario, respectively.

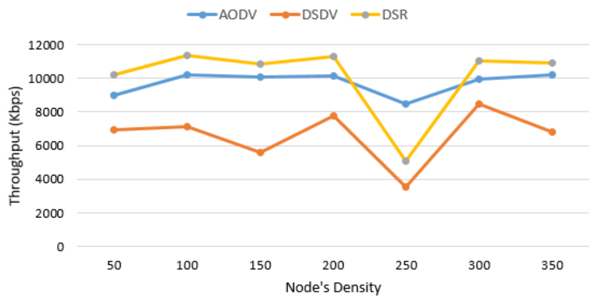

FIGURE 12. **Throughput for the scenario of Manhattan grid.**

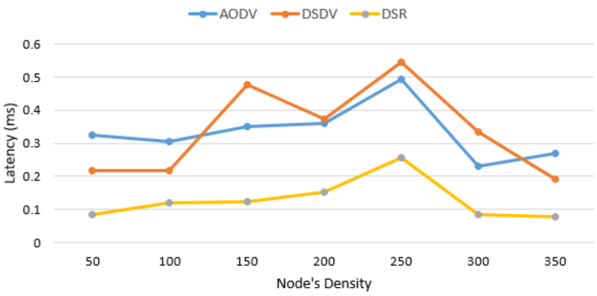

FIGURE 13. **Latency for the scenario of Manhattan grid.**

C. RESULTS ANALYSIS FOR MANHATTAN GRID

The performance analysis of the grid scenario shows DSR performs efficiently with the maximum throughput. The AODV and DSR maintains a good throughput, showing the minimum impact of the node's density on their performance.For the first four values of node's density, the DSR shows excellent performance, but a sudden decline in its throughput is seen for the node's density 250, making the AODV more efficient than DSR at this point. The DSDV shows the minimal throughput throughout showing a consistent performance with the incline in the vehicle's density.

In the case of latency, the AODV shows poor performance as compared to the other two protocols. The DSDV shows better performance as compared to AODV but not better than DSR. At the start, the DSDV lags behind AODV, but for the node's density 150, 200, 250, and 300, the DSDV shows an increase in latency making it surpass the latency for AODV. When the node's density is set to 350, the DSDV shows a fast decrease in the value of latency making it better than the AODV again. The DSR performs efficiently throughout with the latency of 0.078 when the vehicle's density is set to 350. The performance for grid scenario is shown in Figures 12 and 13.

VIII. CONCLUSION

The growth in the density of vehicles around the world drives researchers and designers to improve road safety by finding an efficient and fast solution. In this study, different routing protocols that can be used for communications among autonomous vehicles have been investigated. The results show that the DSR depicts efficient performance overall as compared to AODV and DSDV. It shows maximum throughput for the scenario of real-world and Manhattan grid. In case of the highway, the AODV performs efficiently as compared to DSDV in terms of throughput. The latency for DSR in the case of all three scenarios is the minimum, whereas the AODV depicts the maximum latency for the real-world and the grid scenarios.

It is observed that the DSR has the minimum impact of the node's density on its performance both in terms of throughput and latency. This study helps in prescribing an efficient routing protocol for each specific environment we have considered. Different factors impact the performance of routing protocols, such as road network and density of vehicles on roads, i.e., DSR depicts a good throughput in case of the real-world map and the Manhattan grid, whereas its performance deteriorates in the case of the highway. Future work directions will be to carry out the evaluation of these protocols using a varying range of transmission range and a varying speed using various other parameters such as packet loss and overhead.

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