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Design and Evaluation of Improvement of GPSR-Based Routing Techniques for Intelligent Transport Systems using Vehicular Ad Hoc Networks

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ABSTRACT: As topology has become extremely fast, VANETs (vehicular ad-hoc networks) have become increasingly complex, creating new routing protocols for geographic routing. A GPSR-enhanced system (E-GPSR) is presented in this paper, which includes extended capabilities that select the best route and bypass previous vehicles delivering such packets. The E-GPSR protocol also prevents packets from being sent to neighbours similarly, thus eliminating packet routing loops. Road accidents and dead-end roads are unavoidable reasons for link breakage, which the E-GPSR protocol helps to resolve. Simulation of Urban Mobility (SUMO) and Network Simulator-version 3 (NS-3.33) platforms were used to compare E-GPSR with traditional GPSR and Maxduration-Minangle GPSR (MM-GPSR). GPSR and MM-GPSR have better packet loss ratios (PLR) and packet delivery ratios (PDR) than the proposed E-GPSR protocol.,

Keywords: Intelligent Transport Systems, Vehicular Ad Hoc Networks, GPSR, IoT

1. INTRODUCTION

An emerging technology known as a Vehicular Adhoc Network (VANET) can communicate between vehicles, connect to the Internet seamlessly, and provide essential alerts and entertainment that can be accessed within the vehicle [1], [2]. Multihop routing allows vehicles to communicate even when they are out of sight. It is similar to MANET in that nodes self-organize; however, it differs from MANETs in that nodes are highly mobile, topologies change frequently due to restricted roads and patterns, and bandwidth is limited because of the lack of a central coordinator when objects between communicating nodes fragment the network and cause signal fading, disconnection occurs [3], [4]. The characterization of VANETs is partly motivated by the network's unique characteristics and the popularity of GPS, availability of traffic data, and applicant number and type of application [5].

A low vehicle density area like a highway may have propagation potential; for example, two vehicles may communicate within communication range. It is possible to induce connectivity in urban environments by combining wireless technology with cellular networks.

Routers have to deal with changing topologies and node limitations within VANETs. Nodes and destinations are selected based on their locations when GPR (Greedy Perimeter Stateless Routing) is used to forward packets [6]. When topologies change frequently, GPSR offers the advantage of quickly adjusting the routes [7]. This protocol combines the proactive and reactive characteristics of Zone Routing Protocol (ZRP) [8]. Furthermore, it addresses inefficient floods in reactive protocols and excess bandwidth in proactive routing. ZRP maintains an updated topology of zones by using

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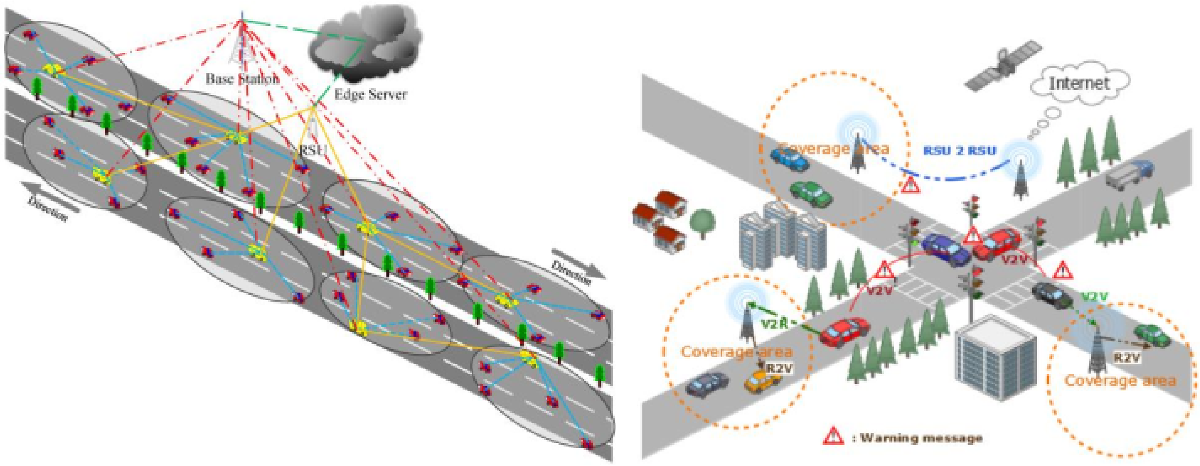

FIGURE 1. Topology of urban and highway networks.

nodes. A zone's routing information is immediately available through this mechanism. ZRP utilizes a route discovery method for destinations outside the zone, which is more efficient than the local routing information of the zones.

It allows drivers to communicate with each other to avoid any acute situations, like accidents on the road, roadblocks, and speed limits, ambulances being able to pass unhindered, and concealed obstacles. Vehicles exchange a variety of information through these communication variants. VANETs are, therefore, dependent on information propagation. It is key to propagate information in VANETs so that topology, position, clustering, geocasting, and broadcasting are all considered [9], [10]. The paper [8] proposes a route selection protocol using PA-GPSR to reduce packet loss and delay between nodes in recovery mode. The PA-GPSR protocol is based on position-based routing.

Virtual area networks can be routed stateless with Geographic Perimeter Stateless Routing. In the paper [11], the author minimized hop count, end-to-end delay, and packet loss in VANETs by selecting the most optimal path and avoiding neighbours seeking local maximums on their paths. Using onboard and roadside units (RSU), VANET can connect various vehicles into a network spanning several kilometres. Wireless transceivers in vehicles can use the electricity from the vehicle. Batteries and other energy sources can power cell phones, speed sensors, and road transceivers for vehicular communication. The distribution of messages between vehicles in urban areas is more challenging due to energy efficiency and reliability issues. Messages can be broadcast by moving vehicles in some networks, reducing energy consumption [12]. Vehicle ad-hoc networks might experience deadlocks during routing. Nodes can't forward RREQ packets because they are stuck in a deadlock [13].

It is important to improve clustering efficiency and connection stability as much as possible to gain the most valuable insights from vehicular clustering research. Cluster dynamics are maintained by network lifetime since changes in network topology frequently affect vehicular clusters, or vehicles can join or leave the cluster at any time [3], [4]. The adaptability of networks to road structures and the challenges of network formation have not been systematically explored. There is a need to pay more attention to the effects of high road dynamics, such as lane changes and vehicle departures, on network sustainability and possible overhead incurred in network recovery. As a result, road parameters such as road capacity have not been considered about the cluster size that can effectively fit on the road, whether the road is a highway or a city.

2. LITERATURE

In VANETs, routing protocols have been examined by many researchers. It was greedy perimeter stateless routing (GPSR), developed as the first geographical routing protocol for VANETs [14]. Packets are forwarded according to their distance from the destination using this protocol. Urban scenarios with frequent interruptions are not compatible with perimeter forwarding. Therefore, several enhancements to GPSR have been proposed in urban scenarios. By measuring link lifetimes between neighbours, Stable Connected Routing Protocol (SCRP) is one of the most popular set-based routing protocols [13]. Each SCRP node maintains a routing table for forwarding packets. Through SCRP, junction roads can be linked to nodes along a forwarding path.

VANET applications are also degraded by short communication links between vehicles [15]. Since VANET vehicles depend on the Global Positioning System to determine their locations, geographical routing protocols are more convenient. Since routing protocols affect the entire network's performance, a stateless algorithm such as the Geographic Perimeter

Routing Protocol (GPSR) is considered the baseline for the Internet [16]. Positions of neighbour nodes are used to forward packets. In his GPSR+Predict protocol, Houssaini proposes identifying the best neighbour and forwarding the packet to that node based on its approximate future position [17]. A protocol named GPCR [18] takes advantage of the fact that packet loss rates are much lower when nodes closer to the junction are chosen. To achieve this to improve the GPCR protocol, GPSRJ+ [19] emphasizes the planar nature of road maps in recovery mode. The author [20] investigated speed, direction, and density as parameters of greedy forwarding to improve packet forwarding accuracy. As packets are forwarded between neighbour nodes, Greedy Curvemetric Routing Protocol uses curve-metric distances between them to calculate their geographic locations [12].

The author used a DSR and ad hoc routing protocol to analyze the ZRP [21]. Ad hoc On-Demand Distance Vectors (AODV) to effectively account for way attainment delays and rapid way reconfigurations throughout link failures. End-to-end delays are increased as a result. Throughput and packet reception decreased due to this. The proposed work can reconfigure routes quickly through selective border casting mechanisms in case of a link failure. Query message packets are controlled to reduce the acquisition delay, reducing control overhead [21]. A new algorithm has been proposed that minimizes the time it takes to receive the first packet, resulting in a higher throughput. At the destination, more bytes and packets will be received.

With the RSU (Road Side Unit), the author [22] provides a more reliable and efficient method of communication between vehicles. A server-based method can be used for data dissemination to reduce the delay with maximum throughput by using RSU and DSDV routing protocols. It will, therefore, be easier to communicate.

To reduce packet loss in VANET, the author [22] has developed a GPSR routing protocol. The work proposes a second route to reduce the ratio by sending the same packet twice. SUMO, OMNET++, and Veins were used in the experiment. As a result of simulations using the improved GPSR model, packet delivery is superior to the existing GPSR model [23]. The GPSR method he proposed is an optimized version of GPSR based on comparisons with GPSR and MM-GPSR. Two new expansion tables in NT are used to avoid packet loops and retrieval modes specific to specific nodes. A dense urban environment was simulated with the NS-3. The proposed algorithm performs better regarding network productivity, packet loss rate, and delay than the current GPSR and MMGPSR, based on comparisons with the current GPSR and MMGPSR [24].

According to the authors, Greedy Perimeter Stateless Routing (GPSR) can be made secure and enhanced [25]. Two modules comprise this protocol: (i) To minimize delay in transfer and control messages by utilizing GPSR routing protocol. The improved Diffie-Hellman algorithm has been combined with a hash function-based security scheme for authenticating and verifying GPSR packets' integrity with a hash function-based Message Authentication Code (MAC) [26]. The proposed solution meets the security requirements of AVISPA based on an automated validation of Internet security protocols and applications. AVISPA evaluates security protocols and applications for their integrity.

3. METHODOLOGY

GPSR protocol can be improved by implementing the following enhancements to reduce neighbor relationship instability and path redundancy in greedy forwarding.

3.1 GREEDY FORWARDING: IMPROVING THE INSTABILITY OF THE NEXT HOP

Using two parameters for greedy forwarding, T and Q improve neighbour relationships by dealing with the instabilities in neighbour relationships. An example of a small circle represents a vehicle, as shown in Figure 2. S finds the nearest vehicle to D when it tries to send packets. Vehicle B is the closest vehicle to the destination, as shown in Figure 2. The distance from B to D can be used to calculate a maximum hop distance. Choosing the most stable next-hop vehicle from the neighbouring vehicles of S is based on comparing cumulative and stable communication durations.

Using the coordinates of S and D, S and D send a packet to each other $(x_S,\ y_S)(x_D,\ y_D)$. When a source vehicle transmits packets greedy forwarding, that vehicle looks up the nearest neighbour list of D and finds the nearest neighbour is B, with coordinates $(x_B,\ y_B)$. According to Eqn. (1-2), B is distanced from D and d_{SB} is distanced from S. Eqn. (3) Compute d_{max} as the maximum distance allowed for communication. The allowed communication area is defined as the area where two circles with a center D and a radius d_{max} overlap, and another with a centre S and a radius maximum communication distance, we call it Q. There are vehicles in Q that are close to the destination vehicle D, and those vehicles are also within the communication range of vehicle S so that they can be selected as the next hop vehicle.

$$d_{BD} = \sqrt{(x_D - x_B)^2 + (y_D - y_B)^2} \tag{1}$$

$$d_{SB} = \sqrt{(x_S - x_B)^2 + (y_S - y_B)^2)} \tag{2}$$

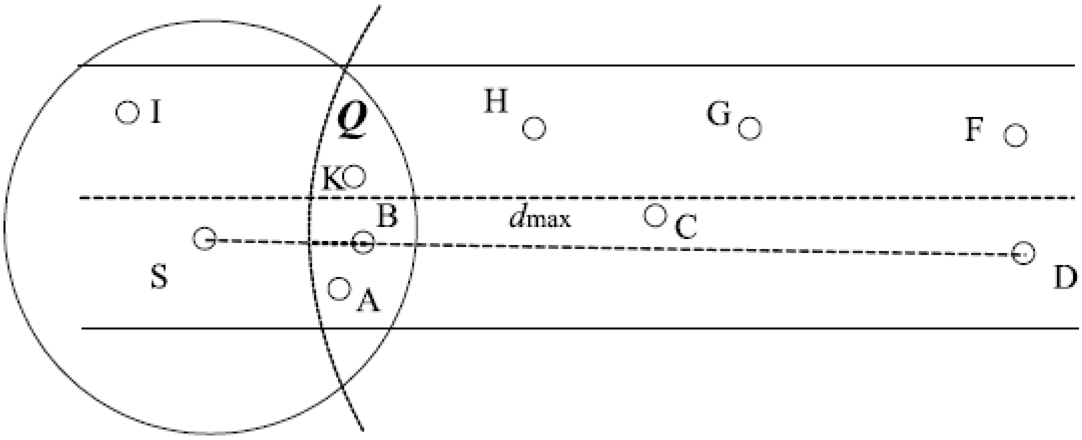

FIGURE 2. **Greedy forwarding procedure graph.**

$$d_{max=d_{BD}} + \lambda \times d_{SB} \tag{3}$$

In (3), $\lambda \in [0.1]$. Q's size appears to be affected by λ. When λ is too large, Q becomes larger. The vehicle near S can be selected as the next hop in Q. Still, it will take longer for this vehicle to reach D. As λ decreases, Q becomes smaller, and the next hop in Q will likely be the vehicle near D, which could lead to a longer distance between S and this vehicle, causing packet loss. Experiments have shown that 0.3 is a good threshold for greedy forwarding.

Between three neighbouring vehicles, the cumulative time it takes for communication to occur, S, is intended as shown in Figure 3, where Q is composed of A, B, and K, and then by (4).

$$T_i = T_{i-1} + t_i - t_{i-1} \tag{4}$$

It's defined like this: T_i is the current cumulative time for communicating, T_{i-1} is the last cumulative time for communicating, T_i currently, hello is being received at this time, and T_{i-1} hello has come to an end. It is, first of all, set the initial conditions, $T_1 = 0$ and is the moment when the first packet is received. A, B, and K have different t_i values so that we can choose the vehicle with the maximum t_i to reach S destination, S will take this vehicle as the next hop. It can reduce the risk of communication links breaking and create a more efficient packet forwarding system.

3.2 PERIMETER FORWARDING WITH IMPROVED PATH REDUNDANCY

Improved perimeter forwarding can resolve path redundancy by considering neighbouring vehicles' positional relationships. S has three neighbours, A, B, and K, as shown in Figure 3. S uses the right-hand rule to decide what hop to go to next due to greedy forwarding failing. In other words, we are looking for a vehicle that does not deviate from D when picking a next-hop vehicle. The angle formed by the ray through D and the ray through the neighbour vehicle will be the angle name θ, which is the angle formed by the ray through D. Analyzing all of S's neighbour s' θ can help us select an optimal next hop.

N_1, with coordinates $(x_{N_1},\ y_{N_1})$, is in the first quadrant next to the neighbour vehicle N. θ_{right} is calculated by using (5), (6) using SD and SN_1.

$$cos\theta_{right} = \frac{y_{N_1} - y_S}{\sqrt{(x_{N_1} - x_S)^2 + (y_{N_1} - y_S)^2}} \tag{5}$$

$$\theta_{right} = arccos\left(cos\theta_{right}\right) \tag{6}$$

N_2, with coordinates $(x_{N_2},\ y_{N_2})$, is in the first quadrant next to the neighbour vehicle N. θ_{left} is calculated by using (7), (8) using SD and S_{N_2}.

$$cos\theta_{left} = \frac{y_{N_2} - y_S}{\sqrt{(x_{N_2} - x_S)^2 + (y_{N_2} - y_S)^2}} \tag{7}$$

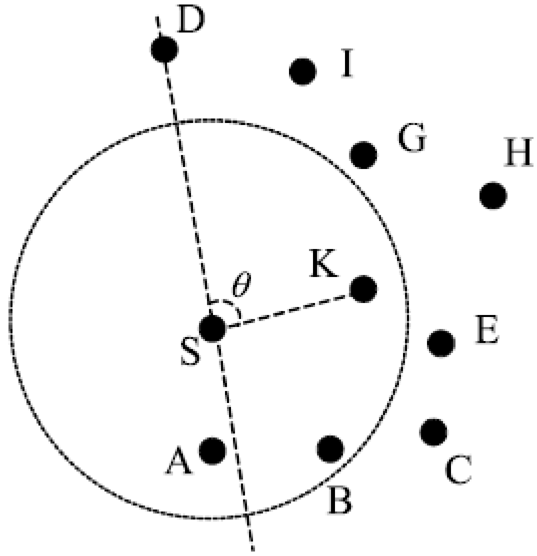

FIGURE 3. Enhanced perimeter forwarding graph.

$$\theta_{left} = arccos(cos\theta_{left}) \tag{8}$$

N_3, with coordinates $(x_{N_3},\ y_{N_3})$, is in the first quadrant next to the neighbour vehicle N. θ_{left} is calculated by using (9), (10) using SD and SN_3.

$$cos\theta_{left} = \frac{y_{N_3} - y_S}{\sqrt{(x_{N_3} - x_S)^2 + (y_{N_3} - y_S)^2}} \tag{9}$$

$$\theta_{left} = \pi - arccos\left(cos\theta_{left}\right) \tag{10}$$

N_4, with coordinates $(x_{N_4},\ y_{N_4})$, is in the first quadrant next to the neighbour vehicle N. θ_{left} is calculated by using (11), (12) using SD and SN_4.

$$cos\theta_{right} = \frac{y_{N_4} - y_S}{\sqrt{(x_{N_4} - x_S)^2 + (y_4 - y_S)^2}} \tag{11}$$

$$\theta_{right} = \pi - arccos\left(cos\theta_{right}\right) \tag{12}$$

In (13), all of S's neighbours are compared to determine the minimum θ.

$$\begin{cases} \theta = \theta_{\text{left}}, & \text{when } \theta_{\text{left}} \leq \theta_{\text{right}} \\ \theta = \theta_{\text{right}}, & \text{when } \theta_{\text{left}} > \theta_{\text{right}} \end{cases} \tag{13}$$

With improved perimeter forwarding, the next hop vehicle for S will be selected from the next neighbour vehicle with minimum angle θ, greatly reducing path redundancy.

3.3 THE IMPROVED E-GPSR PROTOCOL

There is a proposal in this paper to enhance greedy forwarding and perimeter forwarding by using a new enhanced GPSR protocol (E-GPSR). A vehicle determines the next hop by identifying the communication area and then calculating and comparing the cumulative communications of neighbouring vehicles. By calculating and comparing neighbouring vehicles' angles, perimeter forwarding determines which neighbour has the lowest angle when forwarding packets. E-GPSR is described in Algorithm 1.

Algorithm 1: GPSR E-Procedure

Initialization:

$neighbor \leftarrow NULL$
$d_{min} \leftarrow d_{C \leftarrow D}$
$neighbor_{min} \leftarrow NULL$
$T_{max} \leftarrow 0$
$d_{max} \leftarrow 0$
$node_{next} \leftarrow NULL$
$\theta_{left} \leftarrow \pi$
$\theta_{right} \leftarrow \pi$
$\lambda \leftarrow 0.3$
C: Current vehicle.
P: Data packet.
D: Destination vehicle.
set_C: Set of neighbour vehicles of C.
$d_{neighbor \leftarrow D}$: Distance between D and its neighbour.
$d_{neighbor}$: Time spent communicating with neighbours cumulatively.
$\theta_{neighbor}$: Angles between neighbours.
$Plane_{right-half}$: Connection between C and D creates the right-half plane.
Q: Areas where communication is allowed.

while (C receive p)
    if C ==D **then**
        Finish transmitting p;
    else
        If C meet the greedy forwarding method, **then**
            for each neighbor $\in set_C$ **do**
                Calculate $d_{neighbor \rightarrow D}$ by (1);
                if $d_{neighbor \rightarrow D} < d_{min}$ **then**
                    $d_{min} \leftarrow d_{neighbor} \rightarrow D$;
                    $neighbor_{min} \leftarrow neighbor$;

```
            end if
        end for
        Calculate d_C → neighbor_min by (2);
        d_max ← d_min + λ × d_C → neighbor_min ;
        Determine Q;
        for each neighbour in Q, do
            Calculate T_neighbor by (4);
            if T_neighbor > T_max then
                T_max ← T_neighbor;
                node_next ← neighnor;
            end if
        end for
        Update p and then forward p to node_next;
    else
        for each neighbor ∈ set_C do
            if a neighbour in plane_right-half then
                Calculate d_neighbor→D by (6) or (12);
                if θ_neighbor < θ_right then
                    θ_right ← θ_neighbor;
                    node_right ← neighbor;
                end if
            else
                Calculate d_neighbor→D by (8) or (10);
                if θ_neighbor < θ_left then
                    θ_left ← θ_neighbor;
                    node_left ← neighbor;
                end if
            end if
        end for
```

```
            if θ_left ≤ θ_right then
                node_next ← node_left;
            else
                node_next ← node_left
            end
            Update p and then forward p to node_next;
        end if
    end if
end if
```

In a wide scenario, as mentioned earlier, many studies neglect to consider the various traffic and network conditions concurrently occurring. This paper extends the IEEE 802.11 [27] and IEEE 802.11p performance analyses and compares scenarios in which different traffic conditions are considered under GPSR, E-GPSR and IEEE 802.11p MAC/PHY standards.

4. RESULT ANALYSIS & DISCUSSION

We examine the simulation environment and network traffic scenarios to evaluate the proposed routing protocol. A road network of 1000 m x 1000 m is used to evaluate the performance of the E-GPSR protocol. There are eight traffic signals and four two-way lanes on this road network. In this case, 30 to 110 cars are used as vehicle types. Random trips were created by the tool/traceExporter 2021 (tool/traceTrips.py) to determine the movement of vehicles on the roads. SUMO generates trace files compatible with NS-3.23 (Tools/Trip 2021). A random number of cars are initially distributed along the road network, following the random waypoint (RWP) mobility model and street movement. A speed of not more than 250 mph was achieved by the vehicles. For traffic simulations, 100 seconds are used as the simulation time. The size of packets, transmission range, and number of vehicles are modified depending on the scenario. There is a 1-second interval between Hello packets. A unidirectional antenna is installed on each vehicle, whose communication range is between 200 and 300 meters. MAC layer characteristics are modelled using IEEE 802.11p, and wireless channel fading characteristics are computed using a two-ray ground radio propagation model. Ten CBR connections with different vehicle densities were used to evaluate the network's existing traffic. Each simulation group consists of a random pair of source-destination pairs. Furthermore, vehicles use a precise location service to determine their position coordinates.

4.1 PERFORMANCE METRICS

MM-GPSR and GPSR were compared using the following performance metrics.

A. Average end-to-end delay

CBR source vehicles send packets to application agents at CBR destination vehicles at the end of the transmission cycle. You can determine the delivery time at the destination vehicle by dividing it by the number of packets received.

$$Average\ E2E\ Delay = \left(\left(\sum_{i=1}^{n} \sum_{j=1}^{R_i} RT_{ij} - ST_{ij}\right)\right) \tag{14}$$

j^{th} packets are transmitted from the i^{th} source to the destination sent by source i at time ST_{ij}, and they are received at time RT_{ij}.

B. Average Throughput

A communication channel's efficiency is determined by the number of messages effectively delivered. In other words, throughput measures how many packets are received at a destination compared to how many packets are transmitted by sources. Kbps is the unit of measurement [28]. To calculate throughput, use the following equation:

$$Throughput = \left(\sum Pkt_{Ri}/Sim_{Time}\right) \times Pkt_{size} \tag{15}$$

This $\sum Pkt_{Ri}$ Indicates how many packets have been received at destinations, Pkt_{size} how many CBR packets Sim_{Time} have been received at destinations, and how long has the simulation taken to complete.

C. Packet Loss Ratio (PLR)

Using the packet loss ratio, you calculate how many packets were lost compared to all packets sent at the source. The equation below can calculate the packet loss ratios [29].

$$PLR = \left(\sum Pkt_{Li} / \sum Pkt_{S\,j}\right) \times 100 \tag{16}$$

Here, $\sum Pkt_{Li}$ indication of how many packets have been lost in total $\sum Pkt_{S\,j}$, counts how many packets were sent by all sources combined.

D. Packet delivery ratio (PDR)

In this simulation, we can calculate PDR by comparing the number of packets received at CBR destinations with the total number of packets sent by all CBR sources. Calculating PDR involves percentages. The equation below can be used to calculate it:

$$PDR = \left(\frac{\sum Pkt_{Ri}}{\sum Pkt_{S\,j}}\right) \times 100 \tag{17}$$

Here, $\sum Pkt_{Li}$ indication of how many packets have been lost in total $\sum Pkt_{S\,j}$ counts how many packets were sent by all sources combined.

4.2 EXPERIMENTAL ANALYSIS

Comparing E-GPSR with state-of-the-art protocol, the figure shows a significant effect on vehicle speed. Our proposed protocol has a lower average end-to-end delay compared to state-of-the-art protocols. Compared to GPSR and MM-GPSR, the proposed protocol has the advantage of being more efficient, as there is an end-to-end delay of roughly 1–3.5 seconds when considering the range of vehicle speeds. Rather than using a single parameter for routing decisions, the E-GPSR uses multiple parameters to determine whether the best vehicle is in a safe area or unsafe area. Since GPSR's average end-to-end delay increases as vehicle speeds increase, especially after 150 mph, GPSR's end-to-end delay increases.

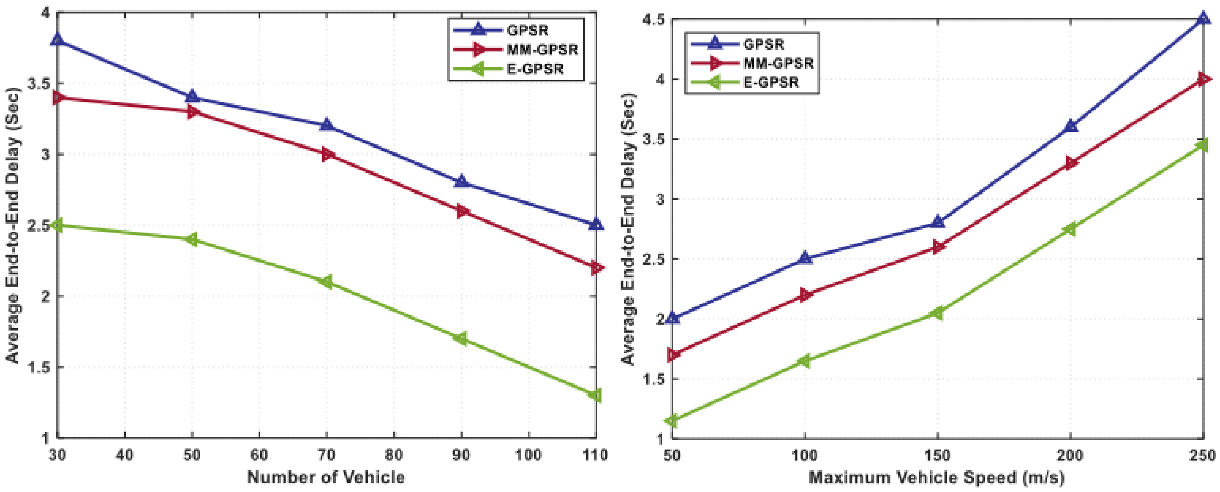

FIGURE 4. **Average end-to-end delay (sec) versus number of vehicles and vehicle speed (m/s), respectively.**

Figure 5 analyzes the average VANET network throughput based on the number of vehicles and their speeds. An increase in vehicles results in an increase in throughput, whereas an increase in speed results in a decrease. Only minor changes were observed during the experiment compared to the existing algorithms graph. The E-GPSR protocol appears to improve network performance relative to a state-of-the-art protocol (Figure 5). The throughput of E-GPSR is also increasing with the increasing number of vehicles, as it is relatively stable compared to the state-of-the-art protocols. E-GPSR has a throughput between 25 and 50 kbps for vehicle density, while GPSR and MM-GPSR have throughputs between 18 and 35 kbps. By avoiding unreachable vehicles that lead to packet loss and retransmission, E-GPSR reduces the need for retransmission. The proposed protocol makes routing decisions based on different metrics to reduce packet loss. Because of this, E-GPSR provides a higher network throughput than existing technology.

Security issues are now at the forefront of our attention. We compare the packet loss number and packet loss ratio under different scenarios to evaluate the effects of vehicle speed on network performance. Figure 6 shows how many packets per hundred are lost in an average packet loss ratio. The packet loss ratio increases with vehicle speed. The speed of the

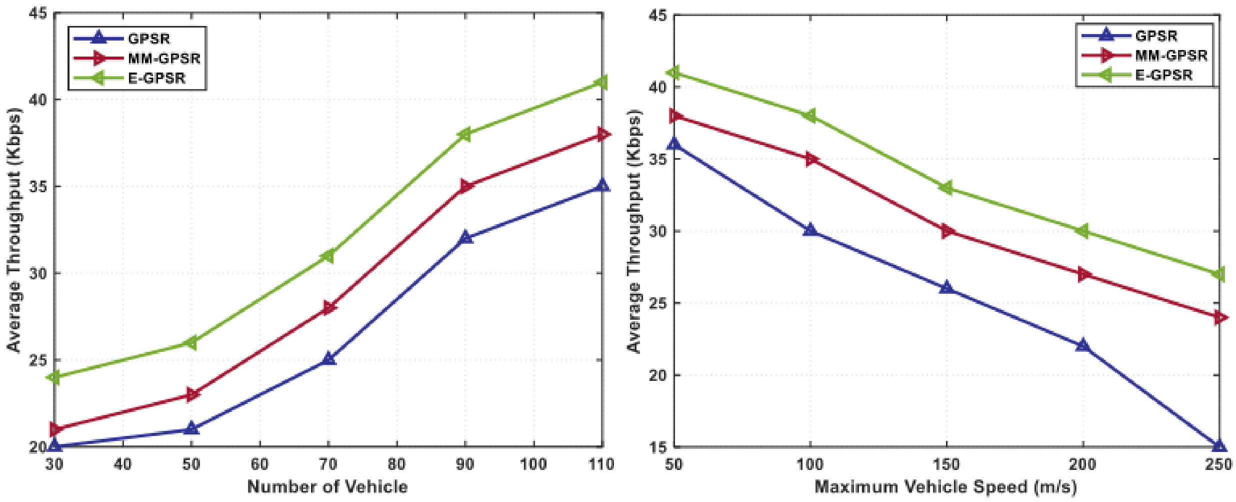

FIGURE 5. **Average throughput (Kbps) versus number of vehicles and vehicle speed (m/s), respectively.**

vehicle affects packet losses. Increasing speed led to a more frequent change in location for the vehicle in this case. This results in packets being sent directly to blackhole vehicles, with higher packet loss rates. According to the Random Way Point (RWP) model, vehicles are moved predictably and collectively. Thus, the RWP model reduces the chance of packet loss by minimizing route changes. Accordingly, E-GPSR is a promising and effective approach to network security under the RWP mobility model, as it offers enhanced security for networks.

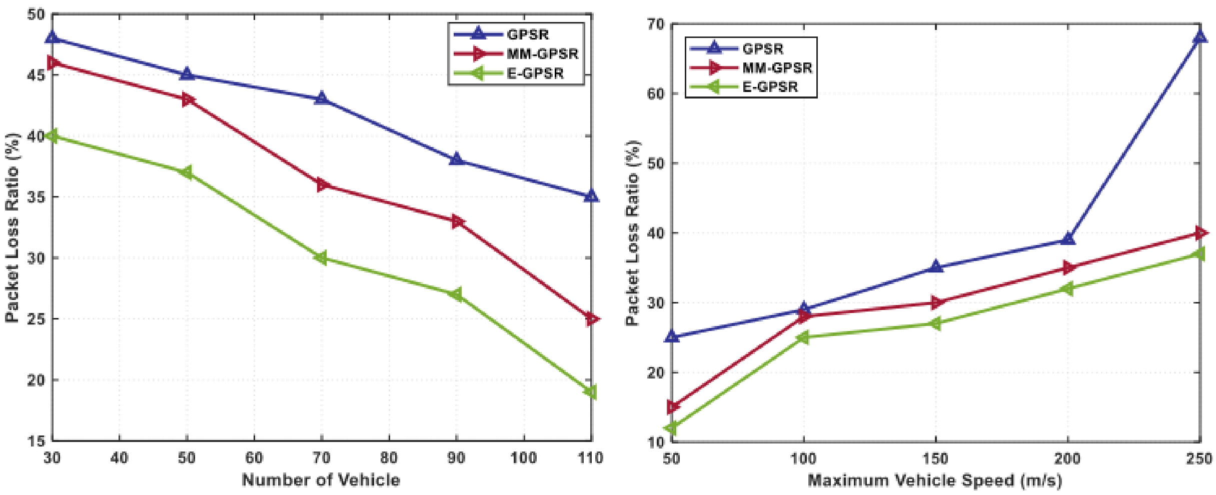

FIGURE 6. **Packet Loss Ratio (%) versus number of vehicles and vehicle speed (m/s) respectively.**

Figure 7 compares packet delivery ratios (PDRs) with vehicle speeds. With increasing vehicle speed, the PDR decreases. As the vehicle speed increases, packet loss may occur because the network becomes more unstable due to the dynamic movement of the vehicle. While E-GPSR is considerably more robust than existing GPSR and MM-GPSR protocols, the level of PDR remains significantly higher. Thus, PDR proved most reliable with the proposed E-GPSR protocol. A high PDR is also demonstrated by the proposed E-GPSR protocol coupled with the RWP mobility model.

5. CONCLUSION

Since VANETs have highly dynamic topologies and unpredictable behaviours, routing them is difficult. With VANETs' changing topologies and vehicles' high speeds, designing a new routing protocol is challenging because each vehicle's radio range is limited and the network's topology changes often. When selecting one-hop forwarding vehicles, we exploit

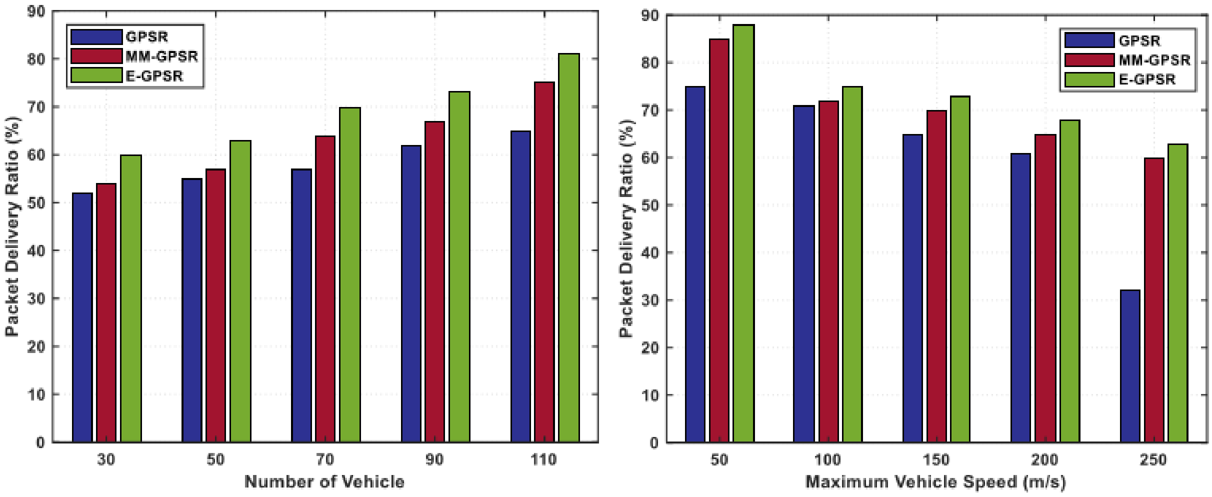

FIGURE 7. **Packet Delivery Ratio (%) versus thenumber of vehicles and vehicle speed (m/s) respectively.**

information about neighbours' vehicles in this modification to the GPSR protocol. Our paper illustrates the effectiveness of GPSR routing protocol enhancement mechanisms for urban and highway scenarios. Two of the most widely used VANET routing protocols, GPSR and MM-GPSR, are compared to this routing protocol's performance. In most cases, E-GPSR enhances the routing protocol, outperforming the other tested protocols.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

REFERENCES

[1] P. Rani, N. Hussain, R. A. H. Khan, Y. Sharma, and P. K. Shukla, "Vehicular Intelligence System: Time-Based Vehicle Next Location Prediction in Software-Defined Internet of Vehicles (SDN-IOV) for the Smart Cities," in *Intelligence of Things: AI-IoT Based Critical-Applications and Innovations* (F. Al-Turjman, A. Nayyar, A. Devi, , and P. K. Shukla, eds.), pp. 35–54, Springer International Publishing, 2021.

[2] N. Hussain and P. Rani, "Comparative studied based on attack resilient and efficient protocol with intrusion detection system based on deep neural network for vehicular system security," *Distributed Artificial Intelligence*, pp. 217–236, 2020.

[3] N. Kumar, P. Rani, V. Kumar, P. K. Verma, and D. Koundal, "TEEECH: Three-Tier Extended Energy Efficient Clustering Hierarchy Protocol for Heterogeneous Wireless Sensor Network," *Expert Syst. Appl*, vol. 216, pp. 119448–119448, 2023.

[4] N. Kumar, P. Rani, V. Kumar, S. V. Athawale, and D. Koundal, "THWSN: Enhanced energy-efficient clustering approach for three-tier heterogeneous wireless sensor networks," *IEEE Sens. J*, vol. 22, no. 20, 2022.

[5] J. Bernsen and D. Manivannan, "Routing Protocols for Vehicular Ad Hoc Networks That Ensure Quality of Service," in *The Fourth International Conference on Wireless and Mobile Communications*, pp. 1–6, IEEE, 2008.

[6] B. Karp and H. T. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," *Proceedings of the 6th annual international conference on Mobile computing and networking*, pp. 243–254, 2000.

[7] P. Rani and R. Sharma, "Intelligent transportation system for internet of vehicles based vehicular networks for smart cities," *Comput. Electr. Eng*, vol. 105, pp. 108543–108543, 2023.

[8] N. Beijar, "Zone routing protocol (ZRP)," *Netw. Lab. Hels. Univ. Technol. Finl*, vol. 9, no. 1, pp. 12–12, 2002.

[9] H. Kaur, "Analysis of VANET geographic routing protocols on real city map," *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, pp. 895–899, 2017.

[10] A. Rasheed, S. Gillani, S. Ajmal, and A. Qayyum, "Vehicular ad hoc network (VANET): A survey, challenges, and applications," *Vehicular Ad-Hoc Networks for Smart Cities: Second International Workshop*, pp. 39–51, 2016.

[11] A. Silva, K. N. Reza, and A. Oliveira, "An adaptive GPSR routing protocol for VANETs," *2018 15th International Symposium on Wireless Communication Systems (ISWCS)*, pp. 1–6, 2018.

[12] M. Huang, B. Yang, X. Ge, W. Xiang, and Q. Li, "Reliable energy-efficient routing algorithm for vehicle-assisted wireless ad-hoc networks," *2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC)*, pp. 1219–1224, 2018.

[13] J. J. Crespo, J. L. Sánchez, F. J. Alfaro-Cortés, J. Flich, and J. Duato, "UPR: deadlock-free dynamic network reconfiguration by exploiting channel dependency graph compatibility," *J. Supercomput*, vol. 77, pp. 12826–12856, 2021.

[14] M. A. Togou, A. Hafid, and L. Khoukhi, "SCRP: Stable CDS-based routing protocol for urban vehicular ad hoc networks," *IEEE Trans. Intell. Transp. Syst*, vol. 17, no. 5, pp. 1298–1307, 2016.

[15] A. K. Ali, I. Phillips, and H. Yang, "Evaluating VANET routing in urban environments," *2016 39th International Conference on Telecommunications and Signal Processing*, pp. 60–63, 2016.

[16] A. Vigilia and J. Suseela, "Survey on Unicast, Multicast and Broadcast Routing Techniques in Vehicular Ad-hoc Networks - Present and Future," *Br. J. Math. Comput. Sci*, vol. 13, no. 4, pp. 1–26, 2016.

[17] Z. S. Houssaini, I. Zaimi, M. Oumsis, and S. E. A. Ouatik, "GPSR+Predict: An Enhancement for GPSR to Make Smart Routing Decision by Anticipating Movement of Vehicles in VANETs," *Adv. Sci. Technol. Eng. Syst. J*, vol. 2, no. 3, pp. 137–146, 2017.

[18] C. Lochert, M. Mauve, H. Füßler, and H. Hartenstein, "Geographic routing in city scenarios," *ACM SIGMOBILE Mob. Comput. Commun. Rev*, vol. 9, no. 1, pp. 69–72, 2005.

[19] K. C. Lee, J. Härri, U. Lee, and M. Gerla, "Enhanced perimeter routing for geographic forwarding protocols in urban vehicular scenarios," *2007 ieee globecom workshops*, pp. 1–10, 2007.

[20] D. Xiao, L. Peng, C. Asogwa, and L. Huang, "An improved GPSR routing protocol," *Int. J. Adv. Comput. Technol*, vol. 3, no. 5, pp. 132–139, 2011.

[21] S. R. Raju, K. Runkana, and J. Mungara, "ZRP versus AODV and DSR: A Comprehensive Study on ZRP Performance on MANETs," in *2010 International Conference on Computational Intelligence and Communication Networks*, pp. 194–199, IEEE, 2010.

[22] R. Vijayakarthika and V. Banumathi, "Efficient data dissemination for secured communication in VANET," *Second International Conference on Current Trends In Engineering and Technology-ICCTET*, pp. 313–320, 2014.

[23] A. Benmir, A. Korichi, A. Bourouis, M. Alreshoodi, and L. Al-Jobouri, "An enhanced gpsr protocol for vehicular ad hoc networks," *Computer Science and Electronic Engineering (CEEC)*, pp. 85–89, 2019.

[24] A. Silva, N. Reza, and A. Oliveira, "Improvement and performance evaluation of GPSR-based routing techniques for vehicular ad hoc networks," *IEEE Access*, vol. 7, pp. 21722–21733, 2019.

[25] M. Houmer, M. Ouaissa, M. Ouaissa, and M. Hasnaoui *SE-GPSR: Secured and enhanced greedy perimeter stateless routing protocol for vehicular ad hoc networks*, 2020.

[26] P. Rani, P. N. Singh, S. Verma, N. Ali, P. K. Shukla, and M. Alhassan, "An implementation of modified blowfish technique with honey bee behavior optimization for load balancing in cloud system environment," *Wirel. Commun. Mob. Comput*, vol. 2022, pp. 1–14, 2022.

[27] P. Rani and R. Sharma, "An Experimental Study of IEEE 802.11n Devices for Vehicular Networks with Various Propagation Loss Models," in *Advanced IoT Sensors, Networks and Systems* (A. K. Dubey, V. Sugumaran, , and P. H. J. Chong, eds.), vol. 1027, pp. 125–135, Springer Nature, 2023.

[28] K. K. Rana, S. Tripathi, and R. S. Raw, "Analytical analysis of improved directional location added routing protocol for VANETS," *Wirel. Pers. Commun*, vol. 98, pp. 2403–2426, 2018.

[29] R. S. Raw, M. Kumar, and N. Singh, "Security challenges, issues and their solutions for VANET," *Int. J. Netw. Secur. Its Appl*, vol. 5, no. 5, pp. 95–95, 2013.