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# W-GPSR Routing Based on Mobility Prediction for Vehicular Ad-Hoc Network (VANET)

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**Abstract**
***In recent years, Vehicular Ad-Hoc Networks (VANETs) innovation has been regarded as a significant research area. This is owing to the increasing popularity of vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications in the area of Intelligent Transportation System (ITS) to improve traffic management, safety, CO2 emission mitigation, and other applications. A variety of routing protocols for VANETs are being recently developed. More specifically, geographic-based routing algorithms such as Greedy Perimeter Stateless Routing (GPSR) have provoked the most interest in VANETs due to their compatibility with a regularly changing network structure and the highly unsteady nature of automobile nodes. This paper proposes an efficient weight based mobility method in VANET to improve the mechanism of the GPSR protocol through optimizing the greedy forwarding strategy; which is so called O-Greedy Mode. Therefore, the key goal is to achieve the optimal data forwarding paths. The next hop is determined by estimating the neighbors' mobility based on each neighbor's Greedy Link Weight Factor (GLWF). The Weighted GPSR (W-GPSR) based on Mobility Prediction is then evaluated using OMNeT++ simulator with Inet, Veins and SUMO traffic simulator. The results demonstrate the efficiency of W-GPSR in contrast with the traditional existing protocols for essential metrics of Packet Delivery Ratio (PDR), throughput, End-to-End Delay (E2ED), Normalized Routing Load (NRL) and Packet Loss Ratio (PLR).***

**Keywords**
**Ad-Hoc, Mobility, GPSR, W-GPSR, OMNeT++, VANET, Veins, SUMO.**

## I. Introduction

Nowadays, Intelligent Transportation System (ITS) utilizes Vehicular Ad-Hoc Network (VANET) in order to boost road safety. ITS addresses the issue of interoperable networked wireless communications between cars, Road Side Units (RSUs), and personal electronic devices, which are known as Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Vehicle to Everything (V2X) respectively [1, 2]. Therefore, for the deployment of ITS, many wireless communications protocols have been proposed over two decades to find efficient solutions and overcome the challenges of vehicular networks. Vehicles include wireless network interfaces that employ IEEE 802.11g or IEEE 802.11b standards for access media. Notably, they are general-purpose standards that do not adequately address the needs of high-dynamic networks like VANETs. Accordingly, Dedicated Short-Range Communication (DSRC)/ Wireless Access in Vehicular Environments (WAVE) are being implied as the communications standard IEEE 802.11p for VANETs [3].

Basically, ITS services include traffic safety and navigation apps, as well as collision warning and driving assistance. These programs implement public services, including emergency vehicles in urban cities, such as driving autonomous fire engines to the fire location in the fastest, safest, and shortest path feasible while avoiding road blockages and jams. In addition to safety services, you can get information about

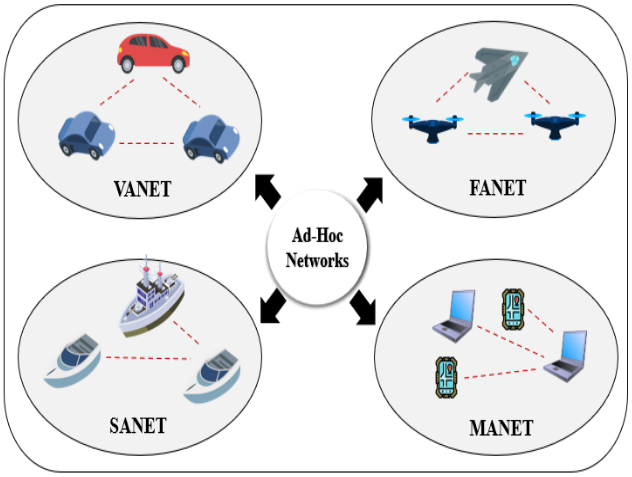



Fig. 1. Ad-Hoc Network Categories.

amenities like gas stations, electronic toll collection, and free Wi-Fi hotspots [4, 5].
On the other hand, VANET is classified as a subtype of Ad-Hoc network along with the other expanded categories, which include Mobile Ad-Hoc Network (MANET), Flying Ad-Hoc Network (FANET), and Sea Ad-Hoc Network (SANET), as illustrated in Fig. 1 [6, 7].

Nevertheless, it is noteworthy that the recent Internet of Things (IoT) concept and its smart connections also provide an innovative approach to establish the Internet of Vehicles (IoV) where multiple services can be delivered via vast sensor capabilities and such communication complements also called IoT based VANET networks [8]. In fact, the major purpose of IoV is to increase network efficiency and safety by providing dependable connections via vehicle networks. Thus, the Internet of Vehicles (IoV) is defined as a new communication standard for smart automobiles and stationary or moving devices like RSUs, pedestrians, infrastructure cellular networks, or sensors via a cloud system and wireless access technologies including Wi-Fi, IEEE 802.11p, 4G, LTE, and 5G [9, 10]. Notably, the efficiency of VANET networks entirely depends on routing protocols, which offer reliable and efficient data transmission. However, many conventional routing protocols fail to adapt to the dynamic nature and scalability of nodes. This may include network challenges, such as link failure due to high nodes mobility; incorrect nodes position awareness, latency and routing load due to the beaconing mechanism. To this end, the vital solution is to design adaptive routing protocols that are mobility-aware in order to discover optimal paths and ensure less routing overhead and high network reliability. In VANET, due to network topology changes and vehicle node mobility, the success rate of data packet transmission cannot be guaranteed. This makes the routing protocol previously applicable to MANET no longer applicable to VANET. Geographic location-based routing protocols are considered more suitable for VANET, as GPS is widely used in vehicles, allowing easy location retrieval through periodic beacons [8, 11, 12]. In this paper, an adaptive weight mechanism for GPSR protocol based on mobility has been developed, so called Weight based GPSR (W-GPSR); for VANET networks. This new W-GPSR is proposed by improving the next hop forwarder in GPSR. The key contributions of this study can be stated as follows:

- The combination between vehicle routing and other network parameters such as source-to-neighbor distance, vehicles speed, and vehicles acceleration is investigated.
- In Greedy Forwarding mode, the weight parameter is adaptively selected in order to determine the best next-hop relay vehicle. This strategy can efficiently estimate the neighbors' mobility based on the neighbor's Greedy Link Weight Factor (GLWF). This is so called Optimized-Greedy mechanism.
- The proposed W-GPSR is successfully evaluated using INET, VEINS and SUMO, and compared to the existing traditional protocols; a geo-routing GPSR and reactive routing AODV.
- The findings show that W-GPSR outperforms both the traditional existing routing protocols using the performance metrics of packet delivery ratio (PDR), throughput, end-to-end delay (E2ED), normal routing load (NRL), and packet loss ratio (PDR).

The rest of the paper is organized as follows: Section II presents some of the recent related works in VANET routing protocols, Section III discusses VANET characteristics and challenges. Section IV describes the main types of VANET routing protocols. Section V views the Geographic-Based routing protocols and Section VI briefly demonstrates the proposed W-GPSR. On the other hand, the VANET simulation software, environment, and QoS metrics are introduced in Section VII and the simulation scenarios are presented in Section VIII. Finally, Section IX concludes the study.

## II. Related Work

Many researches have been carried out in order to improve the routing protocols based on greedy forwarding algorithms in VANET in order to provide a good and reliable communication. To accomplish efficient communication, these solutions have proved flexible methods to the rapid changes in network structure. Nevertheless, these existing routing protocols are still not perfect and they have main shortcomings exist in their performance as follows:

- The existing greedy forwarding algorithm is considered to have local optimal solution when selecting a next-hop node. This strategy depends on the distance between the forwarder-node and the target node with no global consideration.
- The right-hand rule is mainly used when the greedy forwarding strategy fails. This mode has also some delay drawbacks in its implementation.
- In sparse network, this algorithm does not work well, and can easily cause a routing break especially for large scale networks.

Upon these limitations, the following studies have devoted on different approaches of weight-based mobility prediction in the existing routing protocols based on greedy-algorithms. In [13] the authors proposed improved mechanism for the GPSR protocol that takes advantage of neighboring nodes information when selecting a next-hop forwarding node. The proposed technique includes a new field called neighbor trust (NT) to prevent nodes from transmitting packets when in recovery mode. Additionally, in [14] Ye et al. suggested a Mobility-Prediction- Based- Routing-Protocol (MPBRP) using greedy and perimeter forwarding approaches. Instead of a traditional model, MPBRP forecasts vehicle locations based on current data and beaconing intervals. The MPBRP should analyze two parts of the source position information: Firstly, the distance that lies between the destination and the neighboring vehicle. Secondly, the neighbor vehicle's angle is considered compared to the destination. After that, a weight was assigned based on these two factors to find the best path. In 2019, Nadri et al. [15] proposed also an *adaptive beacon* strategy for opportunistic routing in VANET. The scheme is based on two rules; the first is related to estimating the link establishment time between two nodes, and the second is sending an update beacon to neighbors if the consecutively received packet-forwarding set is changed. The aim is to reduce the beacon overhead and maintain the accuracy of the neighbor nodes' topology. The simulation is conducted by using SUMO and NS-3 simulator.

On the other hand, in [16], Li et al., Weighted-GPCR (W-GPCR) technique proposed by constructing a weighted model for Geographic Perimeter Coordinator Routing (GPCR) to assess the best next-hop node. The weight computation approach depends on the interaction between composite parameters in terms of the node pair Euclidean distance, the node orientation, and vehicles density.

Moreover, another weight-aware-GPSR (WA-GPSR) routing protocol has been suggested by Smiri et al. [17]. The upgraded GPSR protocol determines a dependable communication area and picks the next forwarding node based on many routing factors such as, the link lifetime of connection between the sender and the neighbor node, the cumulative communication time of node, nodes density, nodes speed. The idea was assessed and contrasted to Maxduration-Minangle GPSR (MM-GPSR) and standard GPSR utilizing stringent metric analysis. In [18], the GPSR technique was improved by introducing FL-QN GPSR to select the best relay node. A fuzzy logic controller (FLC) is used to select the most suitable next forwarder depending on neighbor nodes as well as the connection quality between nodes. In addition, vehicle direction information is added in beacon message data to increase performance. Recently, in 2023, Zhang et al. [19] have proposed a new Weight based path-aware-GPSR routing protocol; namely W-PAGPSR. It is applied as weight-based geographic routing protocol in VANET environment. The weight scheme considers the network factors such as the node density, distance, cumulative communication duration, and vehicle direction in greedy forwarding; in addition, the packet delivery angle and dependable node density are utilized to construct a perimeter approach. The simulation was carried out using NS3 and SUMO. To the best our knowledge, in this study, a new and efficient GPSR is improved using an analytical approach for selecting the next hop node based on Greedy Link Weight Factor (GLWF). The forward route is established to select the node that has the lowest weight (GLWF) based on the position, speed, and acceleration difference between the source node and its neighbors.

## III. VANET Characteristics and Challenges

In this regard, VANETs are classified into the following categories as per their communication scenarios [9, 20]:

- *Vehicle-to-Vehicle (V2V)*: This type of connection involves direct communication between vehicles within the VANET. Vehicles can exchange information, such as safety messages, traffic updates, or cooperative maneuvers, to enhance road safety, traffic efficiency, and various applications specific to VANETs.
- *Vehicle-to-Infrastructure (V2I)*: V2I connections involve communication between vehicles and fixed infrastructure components. These infrastructure components can include roadside units (RSUs), traffic lights, toll booths, parking lots, or other fixed installations equipped with communication capabilities
- *Vehicle-to-Everything (V2X)*: V2X communication has an expanded accessibility, incorporating both V2V and V2I situations. It refers to a vehicle's capacity to connect with many elements in its environment, such as

other vehicles, pedestrians, infrastructure, bicycles, and even networked equipment.

- *Vehicle-to-Personal Devices (V2P)*: V2P connections refer to the transmission of information between vehicles and pedestrians. V2P can be especially effective in metropolitan areas where automobiles and people interact often.

- *Vehicle-to-Sensors (V2S)*: The interaction between vehicles and sensing devices is referred to as V2S. In this status, the vehicles act as data users, while the sensors give data pertinent to the operation, safety, or other vehicle applications.

- *Vehicle-to-Network (V2N)*: V2N communication involves the interaction between vehicles and external network entities. It enables vehicles to connect to external networks, such as cellular networks or Wi-Fi hotspots, to access internet services, cloud-based applications, or to upload/download data. V2N connectivity is important for various services like real-time traffic updates, navigation assistance, and infotainment services.

These connection types in VANETs as shown in Fig. 2 can support different applications and services, ranging from basic safety messages and traffic information dissemination to advanced features like cooperative collision warning, traffic congestion management, and intelligent routing algorithms. They leverage the wireless communication capabilities of vehicles and infrastructure components to create a connected and cooperative vehicular network.

Specifically, VANET is distinct from the other network categories in a variety of ways such:

• *High Dynamic Network Topology*: Due to the mobility of vehicles, the network topology in VANETs is highly dynamic and changes over time. Thus, connections between vehicles are established and broken frequently.

• *Transmission Power*: Wireless Access in Vehicular Environments (WAVE) restricts transmission power between 0 and 28.8 dBm, corresponding to a coverage distance of 10 m to 1 km [21].

• *Energy Consumption*: Vehicles in VANETs have sufficient energy and computing power for both data storage and processing as compared with MANET.

• *Mobility Model and Prediction*: vehicles nodes in VANETs are continually traveling at different speeds and directions as they are constrained by pre-built highways, roads and streets. This will definitely cause a highly dynamic topology and frequently interrupted connectivity; and consequently the mobility models and prediction are important issues in the design of network protocols for VANETs [18].

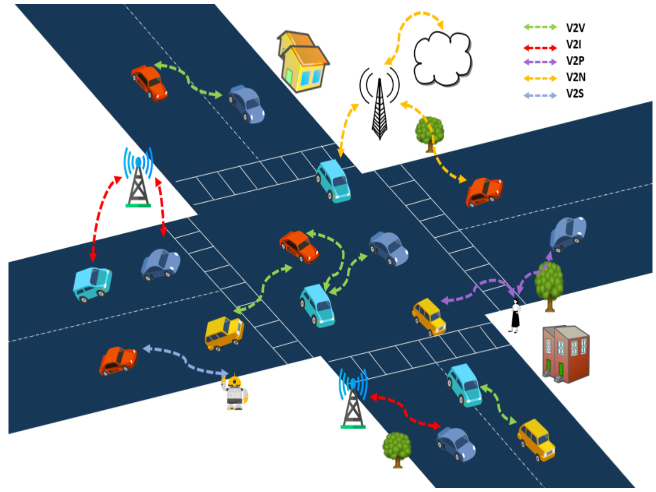


Fig. 2. VANET Classifications.

• *Delay Constraints*: The bulk of communications sent by vehicles have a restricted lifetime beyond which their utility is severely diminished [22]. For instance, safety applications in VANET do not need high data rates but they must maintain low delay constraints.

• *On-Board Unit (OBU)*: Vehicles include on-board sensors that provide data which may be utilized for establishing communication [23].

As a result, the prognosis for other networks cannot be immediately transferred to ITS scenarios such as the routing algorithms [24].

In VANETs, there are two main communication environments: *(i)* Highway traffic scenario, where the mobility model is usually a one-dimensional movement and *(ii)* City traffic scenario, in which the streets are often separated by buildings, traffic lights, trees and other obstacles and hence the mobility model becomes more complex. In this regard, the most critical issue in VANET environment is how to develop an efficient data routing algorithm that can build the best route for data transfer between vehicles with high reliability. Thus, the main aim of such routing algorithms focuses on how to discover and maintain the optimum path for transferring data packets via intermediary nodes [25]. Therefore, certain significant challenges that VANET routing confronts can be summarized as follows [14, 26, 27]:

• *Mobility* : VANETs are highly mobile, resulting in rapid topology changes. The network's dynamic nature makes it difficult to maintain stable and efficient paths. Routing protocols must be able to adapt to fast topology changes while also ensuring timely and reliable packet delivery. In highway traffic environments, the mobility model is typically one-dimensional; however, in city traffic environments, the mobility model becomes significantly more complicated where the roads are frequently segregated by trees, buildings, and other obstacles.

• *Scalability*: In metropolitan environments such as highway and downtown cities, VANETs could consist of a huge number of cars. It is an enormous challenge to increase the number of vehicles while maintaining optimal routing performance. Routing protocols should be designed to reduce control overhead and manage large networks effectively.

• *Limited Network Connectivity*: VANETs often suffer from intermittent connectivity due to the movement of vehicles and obstacles in the environment. Routing protocols need to cope with such challenges and find alternative routes or use store-and-forward mechanisms to ensure message delivery in disconnected scenarios.

• *Security*: VANETs are subject to a variety of security concerns, including attacks on routing protocols. It is a crucial difficulty to provide safe and trustworthy routing in the presence of malicious nodes. Routing protocols must have strong security procedures to protect against attacks and ensure the privacy of sensitive data.

## IV. ROUTING PROTOCOLS IN VANETS

VANET routing protocols are classified into six major categories: Topology-based, Geographic-based, Multicast-based, Hierarchical-based, Geo-Cast-based and Cluster- based routing [7]. The protocol chosen is determined by the VANET application's unique needs, features, and deployment circumstances. Fig. 3 depicts the most commonly used routing protocols in VANET.

Topology-based routing protocols are classified as classic VANET routing protocols that can use routing tables to store source-to-destination information. Topology-based routing protocols are classified into three types: proactive routing protocols, reactive and hybrid routing strategies. In reactive routing, an Ad-Hoc On Demand Distance Vector (AODV) one popular routing protocol designed and developed for wireless and MANET networks by Nokia Research Center, University of California, Santa Barbara and University of Cincinnati, US in 1999. The message types in AODV are Route Request (RREQ), Route Reply (RREP) and Route Error (RERRs). It can create routes through route discovery and maintenance. The routes are implemented as needed throughout the route discovery process to find the path to the destination and Rout Reply occurs along the hops until it reaches the source. Furthermore, the route maintenance is employed to preserve the routes when the topology changes [28, 29]. Although this protocol is loop-free and the most efficient for large scale VANET networks, but it continuously creates many unused routes between a source and destination. So, it might suffer from delay constraints, heavy control overhead when link breakage occurs and unnecessary bandwidth consumption. On the other hand, Geographic-based routing protocols (Position-based) are considered to be more appropriate for VANETs due to their high dynamic nature. These routing protocols can allow the vehicles to know their own positions as well as the positions of their neighbors' vehicles via GPS devices embedded with On-Board Unit (OBU) in each vehicle in order to establish data communication. In 2000, a Greedy Perimeter Stateless Routing (GPSR) routing technique was proposed by Karp and Kung [30] as a Geo-routing mechanism in which data packets are forwarded to the destination based on the node's position which makes it appropriate for VANET communication. GPSR uses greedy and perimeter mechanisms in data forwarding as well as, It uses beaconing method for neighbors discovery [15]. On the other hand, GPSR has limitations that affect network performance, such as Location accuracy, Beaconing, Location error in perimeter mode and routing loop [7, 14].

## V. BACKGROUND ON GEOGRAPHIC-BASED ROUTING PROTOCOLS

Geographic-Based routing protocols are classified into non-delay-tolerant, delay-tolerant Geographic and Hybrid routing protocols. Non-DTN also known as less delay protocols, are suited for use in real-time safety applications since they require an essential reaction during data delivery. The fundamental factor in constructing non-DTN protocols is end-to-end delay time in packet transmission, and the shortest path approach is often used. On the other hand, DTN provides a communication among nodes via a store-carry-forward technique in situation where connectivity between nodes is not guaranteed, in order to avoid network links disconnection. Hybrid protocols employ greedy forwarding and recovery modes for packet delivery [31–34]. Table I summarizes some existing routing protocols.

In VANET, Geographic routing algorithms have lately attracted the attention of researchers due to the accessibility of location-based services such as the Global Positioning System (GPS) [19]. In geo-routing methods, there is no need to establish route management procedure or connection maintenance.

TABLE I.
GEOGRAPHIC-BASED ROUTING CLASSIFICATIONS

| Geographic-Based Routing Protocols | | |
|---|---|---|
| Non-DTN | DTN | Hybrid |
| GPSR | MAXPROP | GEODTN+NAV |
| GPCR | GEOPPS | LARB |
| STBR | VADD | RBVT-R |
| CAR | OPERA | |

Thus, GPSR becomes one of efficient routing protocols

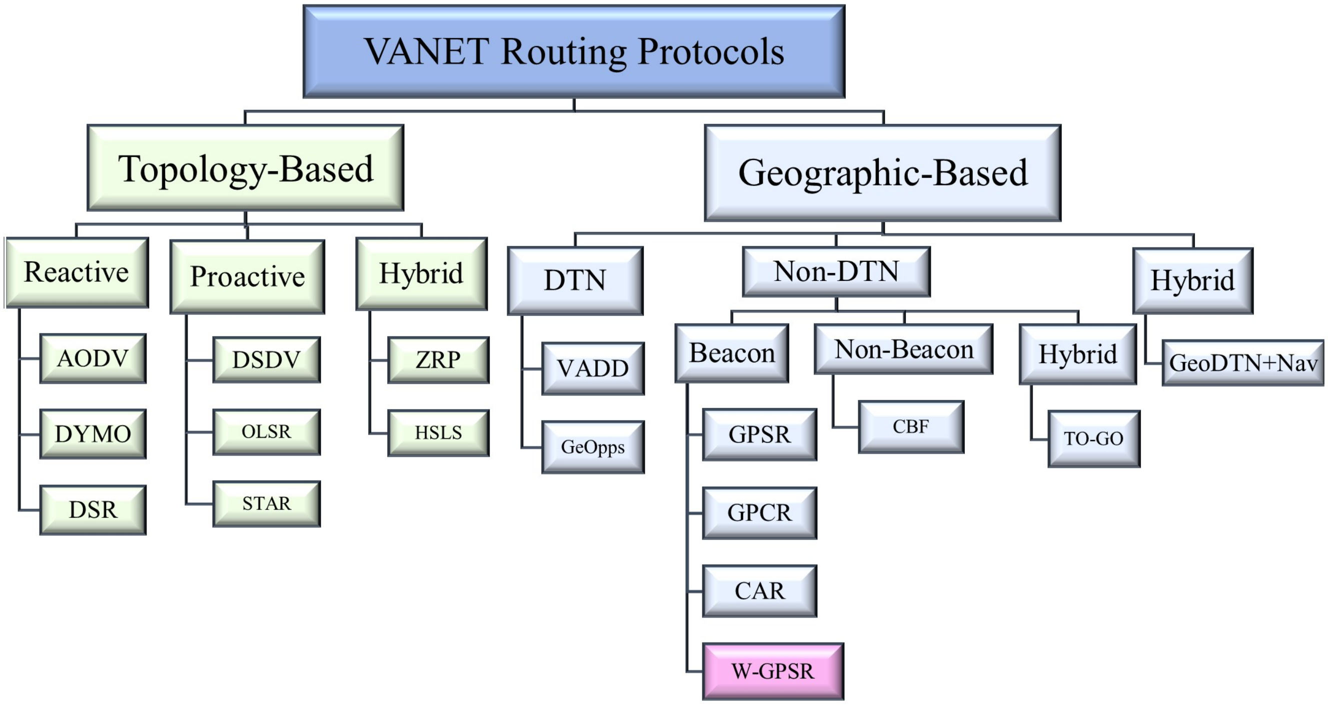



Fig. 3. The Main Routing Protocols in VANET.

for mobile, wireless networks. It can be applied to sensor networks, Rooftop networks, vehicular networks and ad-hoc networks. GPSR is the most dependable geographic-based routing system that can be used in VANET since it uses GPS geographical data for communication between nodes. The source node estimates the destination's position in the packet header to select the next hop node that is the closest neighbor to the destination. Furthermore, it is a stateless protocol in routing since each node in the network only knows about its neighbors and is ill-informed of the rest of the network's nodes. As a result, GPSR protocol employs two forwarding techniques (a) Greedy Forwarding (GF) and (b) Perimeter for packet delivery depending on the state of network nodes as shown in Fig. 4 and illustrated in **Algorithm (1)**. In GF scheme, the next hop rout depends on selecting the nearest neighbor to the destination. Otherwise, If there is no accessible neighbor closer to the destination, the perimeter routing method will work whereas the source declares the region with no nodes to be a void area and then sends the packet around the void area using the Right-Hand-Rule (RHR) [13,14,35,36]. In order to accomplish this, network nodes regularly transmit beacons. Each node broadcasts a beacon packet (Hello Message) with its unique identification number (ID/IP address) and location of the broadcast MAC address.

## VI. Proposed W-GPSR Mechanism

The Weight based Greedy Perimeter Stateless Routing (W-GPSR) method is presented as an upgrade to the original GPSR routing protocol in order to tolerate frequent topology changes in VANET. GPSR is improved by using Optimized Greedy (O-Greedy) Forwarding technique to be dynamic with the vehicle movement by taking the closest node position to the destination in addition to the Greedy Link weight Factor (GLWF). A GLWF is evaluated for each neighbor depending on several dynamic relative factors between the source node and its neighbors to select the next hop. Such factors depend on the received Beacons information from the neighbors including neighbors' position, speed, and acceleration. The following are the principal steps to illustrate the work concept of the proposed methodology:

1. Firstly, the Nodes enter the Simulation area as per the vehicles' movement.
2. Each node is aware of its own geographical coordinates, IP address, speed and acceleration.
3. Each vehicle node sends its Hello Messages to neighbors (i.e., broadcasting beacons).
4. When the nodes receive beacon packets (Hello Messages) from all nodes in their coverage area, they can obtain neighbor information and estimate position factor, speed factor, and acceleration factor.

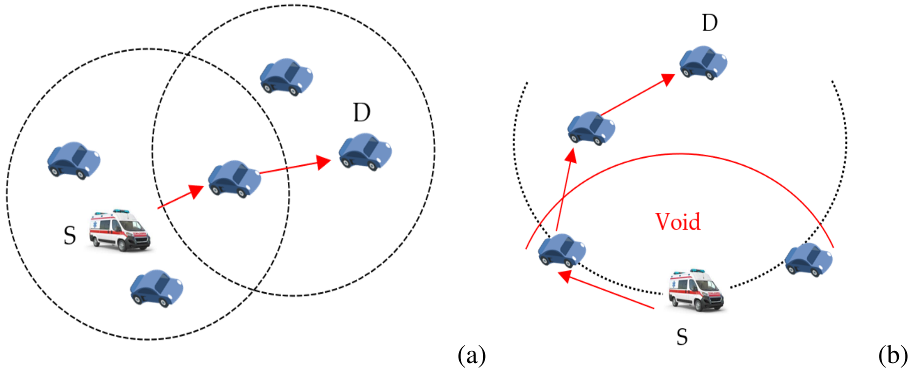



Fig. 4. GPSR Forwarding (a) Greedy (b) Perimeter (RHR).

**Algorithm 1:** Conventional GPSR mechanism

**Input:** Destination IP, Source IP
**Output:** Best Route
**Phase1: Load beacon information**
1. For each node $N$ do
2. Read self-address
3. Read self-position coordinates
4. End For
5. Broadcast Beacons

**Phase 2: Routing**
6. Read for Each $Nn$ (address, position)
7. Update neighbor nodes ($Nn$) table information based on received beacons
8. If $Nn$ is the destination
9. Send the packet
10. Elseif
    $Nn$ closer to the destination than source node
    Switch to Greedy mode and forward the packet
11. Else **Perimeter mode**
    Switch to Perimeter mode and forward the packet
12. Repeat **Phase 1** and **Phase 2** until
    Data Packet reach the destination

5. Estimate GLWF based on position, speed and acceleration factors.
6. Apply the proposed (O-Greedy) forwarding based on neighbor nodes position to destination and GLWF.
7. Employ Perimeter forwarding mode if O-Greedy mode fails to find next-hop node.

The W-GPSR protocol, as previously stated, is based on the original GPSR routing system. The improvements that have been made mostly target the greedy forwarding method. In comparison to the original GPSR routing protocol, the perimeter forwarding technique will stay intact. The optimized greedy approach considers the speed and acceleration of nodes along traffic routes, as well as the distance between the nodes. Furthermore, the proposed W-GPSR mechanism is illustrated in **Algorithm (2)**. In addition, for further details Fig. 5 depicts the flowchart of the W-GPSR protocol structure.

The node depends the hello packet information to build and update the items of its own table and neighbors table information. Each neighbor has a node IP, destination IP, node position (X, Y), node speed and acceleration, as shown in Fig. 6. As well, the neighbor table includes neighbor position, speed, direction acceleration, and GLWF, as represented in Fig. 7 .

The Optimized-Greedy (O-Greedy) mechanism is an improved adaptation of GPSR's common Greedy mode. In this mechanism, besides the distance between neighbor nodes and the destination, other various factors are considered in selecting the next hop. All these mobility factors are jointly utilized to calculate the Greedy Link Weight Factor (GLWF) for each neighbor and then the next hop node will be the neighbor with the lowest GLWF and closer to the destination than the source. The GLWF can be defined as in (1):

$$GLWF = PF + SF + AF \tag{1}$$

where $PF$ denotes to the Position Factor, $SP$ is the Speed Factor, and $AF$ is the Acceleration Factor. Position Factor is evaluated as defined in (2)

$$PF = \frac{W_P \times Distance(S,N)}{R} \tag{2}$$

where $W_P$ denotes the initial Weight for position, $R$ is maximum transmission range and the distance between the source ($S$) and neighbor ($N$) is evaluated as in (3)

$$Distance(S,N) = \sqrt{(X_S - X_N)^2 + (Y_S - Y_N)^2} \tag{3}$$

where ($X_S$,$Y_S$) indicate source coordinates and ($X_N$,$Y_N$ ) are the neighbor coordinates.

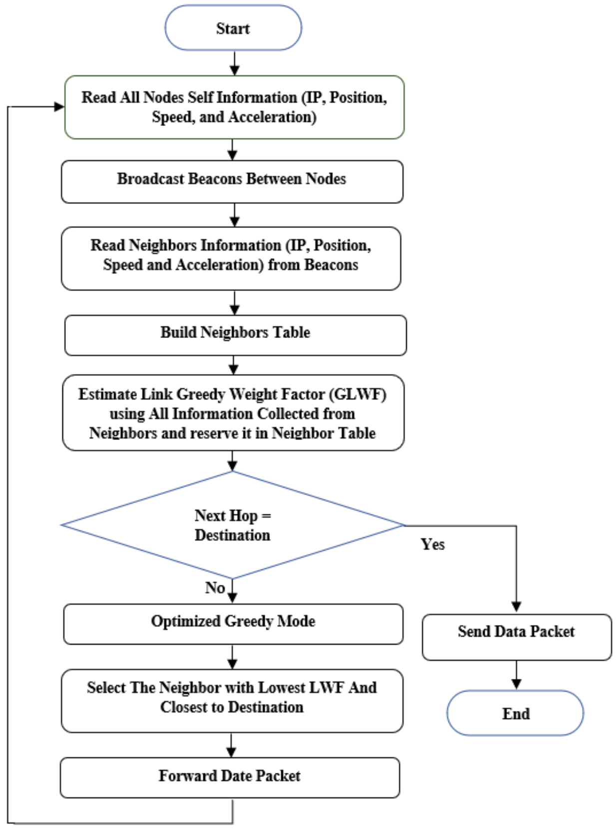



Fig. 5. Flowchart of Proposed W-GPSR.

On the other hand, the Speed Factor between the source and neighbor is evaluated as in (4)

$$SF = \frac{W_S \, |S_S - N_S|}{S_{max}} \tag{4}$$

where $W_S$ is the weight for speed, $S_S$ and $N_S$ indicates to source and neighbor speed respectively while $S_{max}$ is maximum Speed. On the other hand, the Acceleration Factor is also estimated as in (5)

$$AF = \frac{W_A \, |S_A - N_A|}{A_{max}} \tag{5}$$

where $W_A$ denotes the initial Weight for acceleration, and ($S_A$, $N_A$, $A_{max}$) are used to represent the source, neighbor, and maximum acceleration, respectively. Upon the above estimations, the weight values of $W_P$=0.4, $W_S$=0.4 and $W_A$=0.2 can be chosen to achieve the optimal routing performance using the weight formula as in (6). In particular, these values were selected through extensive experimental cases to achieve optimal results.

$$W_P + W_S + W_A = 1 \quad where \quad W_i \xrightarrow{[0 \simeq 1]} \tag{6}$$

**Algorithm 2:** W-GPSR routing mechanism

**Input:** Destination IP, Source IP
**Output:** Best Route based on GLWF
// GLWF=Greedy Link Weight Factor
Initialize GLWF=0
**Phase1: Load beacon information**
1. For each node $N$ do
2. Read self-address
3. Read self-position coordinates
4. Read self-speed
5. Read self-acceleration
6. End For
7. Broadcast Beacons
**Phase 2: Update neighbor nodes ($Nn$) & own tables information based on received beacons**
8. Read for Each $Nn$ (address, position, speed and acceleration)
9. Estimate Position Factor
10. Estimate Speed Factor
11. Estimate Acceleration Factor
12. Evaluate GLWF for each Nn
**Phase 3: Routing**
13. If $Nn$ is the Destination Send the Data packet
14. Elseif
$Nn$ is closer to the Destination than the source node and has the lowest GLWF (O-Greedy) mode
Select Next hop and forward the Date packet
Switch to Greedy mode and forward the packet
15. Else **//Perimeter mode**
16. Switch to Perimeter mode and forward the packet
17. Repeat **Phase 1** and **Phase 2** until
Data Packet reach the destination

## VII. VANET Simulation

There are currently different approaches that are being developed in an attempt to correctly handle the complicated challenge of VANET simulation. The first approach for modeling VANETs involves the use of road traffic simulators capable of creating mobility traces, such as SUMO, MATSim, TRANSIMS, RoadSim, CARISMA, etc., which are then assessed by an existing network simulator that can be utilized used for traffic simulation, protocol estimation, and evaluating the QoS efficiency of simulation scenario. The public availability of several of these network simulators, such as OMNeT++, NS-2, NS-3, and OPNET, is the primary incentive for the success of this technique [37]. Finally, there are models like TraCI, TraNS, and MOVE that are essential for integrating road traffic with network simulators.
Table II represents a comparison of three commonly used road traffic simulators, SUMO (Simulation of Urban Mobility),

| Self Node Table |
|---|
| Source IP |
| Destination IP |
| Self Position (X,Y) |
| Self Speed |
| Self Acceleration |

Fig. 6. The Self Node's Information Table.

| Neighbor Node Table |
|---|
| Neighbor IP |
| Neighbor Position (X,Y) |
| Neighbor Speed |
| Neighbor Acceleration |
| GLWF |

Fig. 7. The Neighbor Information Table.

**Algorithm 2:** W-GPSR routing mechanism

**Input:** Destination IP, Source IP
**Output:** Best Route based on GLWF
// GLWF=Greedy Link Weight Factor
Initialize GLWF=0
**Phase1: Load beacon information**
1. For each node $N$ do
2. Read self-address
3. Read self-position coordinates
4. Read self-speed
5. Read self-acceleration
6. End For
7. Broadcast Beacons
**Phase 2: Update neighbor nodes ($Nn$) & own tables information based on received beacons**
8. Read for Each $Nn$ (address, position, speed and acceleration)
9. Estimate Position Factor
10. Estimate Speed Factor
11. Estimate Acceleration Factor
12. Evaluate GLWF for each Nn
**Phase 3: Routing**
13. If $Nn$ is the Destination Send the Data packet
14. Elseif
$Nn$ is closer to the Destination than the source node and has the lowest GLWF (O-Greedy) mode
Select Next hop and forward the Date packet
Switch to Greedy mode and forward the packet
15. Else **//Perimeter mode**
16. Switch to Perimeter mode and forward the packet
17. Repeat **Phase 1** and **Phase 2** until
Data Packet reach the destination

MATSim (Multi-Agent Transport Simulations), TRANSIMS (Transportation Analysis and Simulation System) [38]. The road traffic simulators provide modeling for the intermodal traffic networks that include automobiles on the roadways, public transportation, and pedestrians.

### A. Network Model: Simulation Environment

The simulation has been performed using the OMNeT++ simulator, the Inet framework Veins, and SUMO as road traffic simulator for 25, 50, 75, and 100 vehicles traveling along (6x6) Manhattan grid with different motion speeds (0-25) mps. The Two Ray Ground propagation model is considered for this network environment. The simulation parameters are specified as in Table III. The SUMO real traffic Manhattan grid is also shown in Fig. 8. Finally, Fig. 9 depicts the VANET simulation structure model.

### B. Simulation Metrics

Quality of Service (QoS) performance of the proposed network has been measured in terms of Packet Delivery Ratio (PDR), End-To-End Delay (E2ED), network throughput, Normalized Routing Load (NRL), as well as Packet Loss Ratio (PLR).

1. PDR: The proportion of packets received by receivers to packets sent by the transmitters. Increased PDR values imply better network performance..

$$PDR = \frac{\sum P_r}{\sum P_s} \times 100\% \tag{7}$$

Where $P_r$ denotes packets received and $P_s$ represents packets sent.

2. Throughput: It is expressed as the number of bits received successfully by the destination over a specified time period measured in bps, Kbps, or Mbps.

$$Throughput = \frac{\sum Receivedbits}{SimTime} \tag{8}$$

3. E2ED: It is the period of time occupied by a packet to travel from the source until it is successfully received by the destination. Its calculation formula is:

$$Avg(E2EDelay) = \frac{1}{n}\sum_{i=0}^{n-1} T_r P(i) - T_S P(i) \tag{9}$$

TABLE II.
ROAD TRAFFIC SIMULATORS COMPARISON

| Criteria | Simulator | | |
|---|---|---|---|
| | SUMO | MATSim | TRANSIMS |
| Category | Open-Source | Open-Source | Open-Source |
| Model | Microscopic | Microscopic | Microscopic |
| System | Continuous | Continuous | Discrete |
| Scope Area | City & Region | City & Region | Region & Country |
| Developer | DLR | Polytechnic of Zurich | NASA |
| 2025 | 2000 | 2006 | — |

TABLE III.
SIMULATION PARAMETERS

| Parameter Description | Value |
|---|---|
| OMNeT++ | V 5.5.1 |
| INET | V 4.2.1 |
| Veins | V 5.0 |
| SUMO | V 1.6.0 |
| Simulation Area (6x6) | Manhattan Grid (2000x2000) $m^2$ |
| Simulation Time | 400 s |
| Routing Protocol | GPSR/ AODV/ W-GPSR |
| Mobility Model | Manhattan Grid |
| Propagation Model | Two Ray Ground |
| Transmission Range | 250 m |
| MAC Protocol | 802.11p |
| Transmission Rate | 2 Mbps |
| Packet Size | 512 B |
| Nodes Density | 25, 50, 75 & 100 |
| Nodes Speed | 10, 15, 20 & 25 mps |

where $n$ is the total successfully sent packets, $P_i$ indicates the $i^{th}$ packet, $T_r$ (Received time), and $T_s$ (sent time).

4. Normalized routing Load (NRL): It denotes the total number of control packets transmitted divided by the total number of correctly received data packets [39].

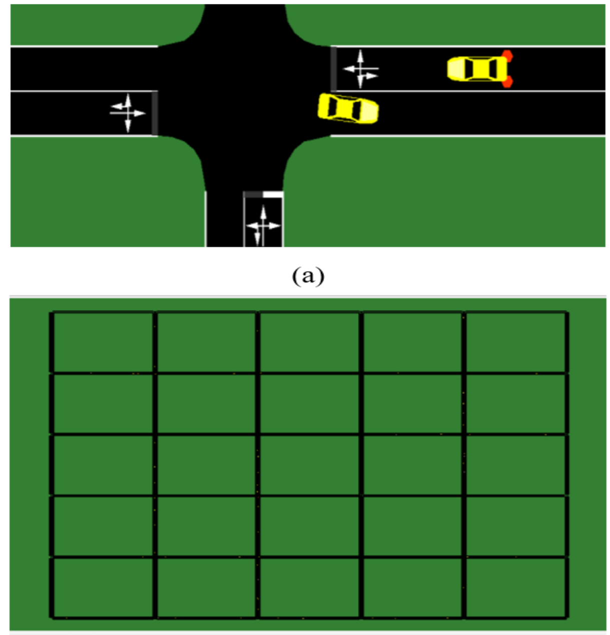
$$NRL = \frac{\sum ControlPackets}{\sum ReceivedDataPackets} \tag{10}$$

5. Packet lose ratio (PLR): It indicates to the total number of drop packets over the total number of sent data packets [40].

$$PLR = \frac{\sum DropPackets}{\sum SentPackets} \tag{11}$$

## VIII. EXPERIMENTAL SCENARIOS

The simulation is executed in simple (6x6) Manhattan map for V2V communication. The performance evaluated by taking two scenarios, first one under different vehicles density (25, 50, 75 and 100) nodes and the other scenario by taking various nodes speed (10,15,20 and 25) mps.


(a)
(b)
Fig. 8. Simulation Area of Manhattan Grid.

### A. Vehicles Density Impact Scenario

In this scenario, network performance was tested in terms of PDR, throughput, E2ED, and PLR using various node density 25, 50, 75, and 100 nodes with a maximum speed of 15 mps. The packet delivery ratio increases dramatically as the density of vehicles increases, as illustrated in Fig. 10, due to better connections, as there are more vehicles accessible for communication and also more intermediary vehicles for data forwarding. The W-GPSR outperforms the traditional GPSR by 8%, 25%, 23%, and 26% for 25, 50, 75, and 100 automobiles, respectively.

Furthermore, throughput increases as vehicle density increases, and W-GPSR surpasses GPSR by 14 %, 38%, 78%, and 45%, respectively, and AODV by 30%, 20%, 17% and 12%, respectively, as shown in Fig. 11.

On the other hand, in Fig. 12, the E2ED obtained from W-GPSR is shorter than the value of standard GPSR because GPSR is roughly stuck in a routing loop between greedy forwarding and perimeter forwarding transmission techniques, while W-GPSR supports the O-Greedy mode. This means that the likelihood of switching to perimeter mode will reduce. In contrast, AODV has the highest E2ED due to the time of the Rout Discovery and Maintenance processes. Furthermore, as

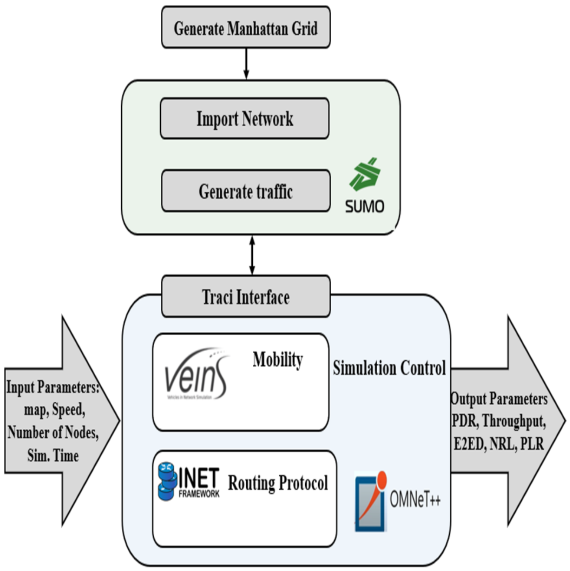



Fig. 9. A Synopsis of Simulation Modeling in VANETs.

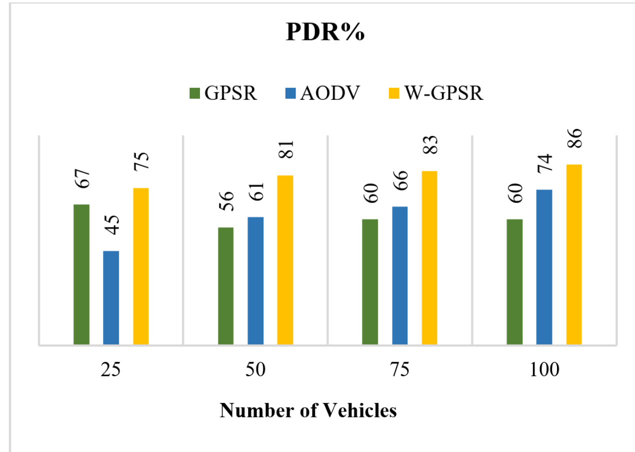



Fig. 10. Packet Delivery Ratio vs Number of Vehicles.

shown in Fig. 13, PLR in W-GPSR is smaller than GPSR and AODV. Because our technique selects a more reliable next relaying vehicle, the probability of packet loss is reduced.
As a result, it can be concluded that the proposed W-GPSR routing protocol can effectively provide the best performance. Fig. 14 shows the average percentage of enhancements achieved by W-GPSR compared to the standard GPSR and AODV routing protocols in the density impact scenario.

### *B. Vehicles Speed Impact Scenario*

The performance of the speed scenario was evaluated by employing speed values of 10, 15, 20, and 25 mps for 50 vehicles. As observed in Fig. 15 and Fig. 16, higher vehicle speeds can cause additional link failures, increasing the potential for packet loss. This has reduced PDR and throughput. The W-GPSR outperformed the traditional GPSR in terms of PDR efficiency (23% on average) and throughput (26%). In addition, the W-GPSR outperforms the AODV by 22% in terms of PDR, and throughput by 39%.
In addition, it is noticed that NRL increases at high moving speeds in Fig. 17 due to the necessity for more frequent routes updates and changes in network topology produced by fast-moving vehicles. In the four moving speeds, W-GPSR outperforms GPSR and AODV because it requires less routing overhead due to its precise routing information and flexibility to vehicle mobility.
As a consequence, it is shown that the packet loss ratio increases because the higher mobility speed leads to higher connection failures in the network. However, as seen in Fig. 18, W-GPSR has a lower PLR than traditional GPSR and AODV. Accordingly, it can be concluded that W-GPSR performance can faithfully prove the efficiency of the proposed O-Greedy mechanism as this W-GPSR can effectively respond to changes in vehicles mobility via reducing the impact of the packet loss ratio. In summary, Fig. 19 shows that the W-GPSR is superior over the standard GPSR and AODV routing protocols in term of the average percentage improvements for speed impact scenario.
Table IV compares the proposed W-GPSR protocol's resilience and efficacy to those of existing, recently upgraded GPSR methods. The results show that the W-GPSR method outperforms the ABOR [15], FL-QN [18], and W-PAGPSR [19] protocols in terms of delivery reliability. But it cost higher E2ED in comparison to ABOR and W-PAGPSR.

## IX. Conclusion and Discussion

Mobility in VANET is considered a crucial challenge in VANET routing which results in link failure owing to variable changes in network topology. As a consequence, a W-GPSR protocol is presented in this paper as an efficient non-DTN Geographic-Based routing protocol for VANET network. A Greedy Link Weight Factor (GLWF) is assigned for each neighbor in order to optimize the Greedy forwarding method. Within this approach, each node can be adaptable with mobility parameters such as speed and acceleration in addition to the nodes position. The aim of O-Greedy method in W-GPSR is to increase the reliability of selecting optimal next-hop forwarder and to mitigate the possibility of switching to perimeter mode. The W-GPSR performance has been successfully tested in two experimental scenarios by varying vehicles density and vehicles speed using OMNeT++ simulator in joint with Inet, Veins and SUMO traffic simulator including the Quality of Service (QoS) performance metrics PDR, Throughput, E2ED, NRL as well as PLR. In the first scenario, W-GPSR outper-

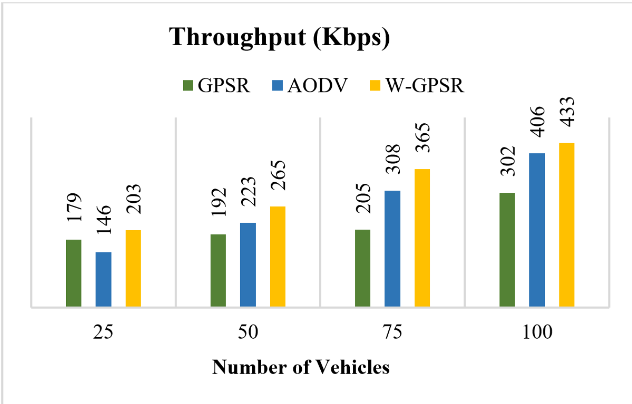



Fig. 11. Throughput vs Number of Vehicles.

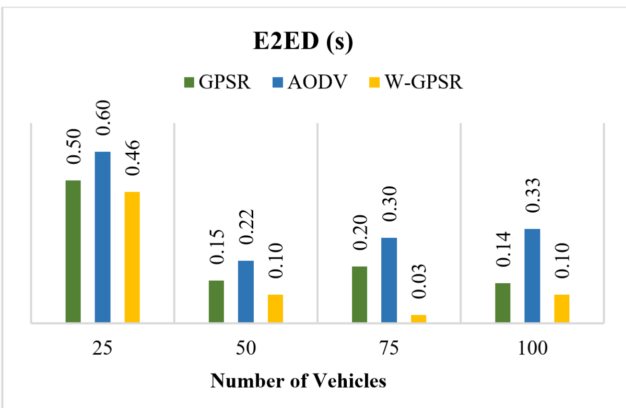



Fig. 12. End to End Delay vs Number of Vehicles.

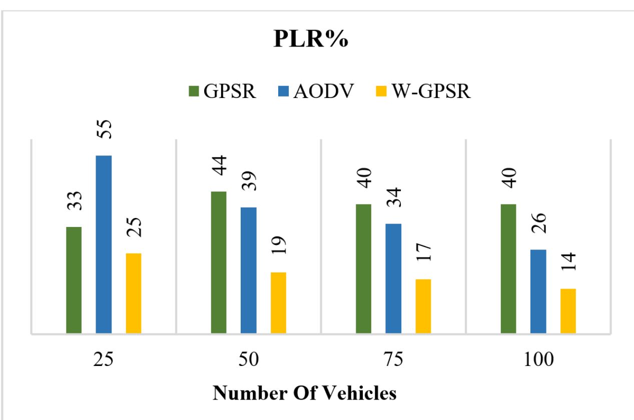



Fig. 13. Packet Loss Ratio vs Number of Vehicles.

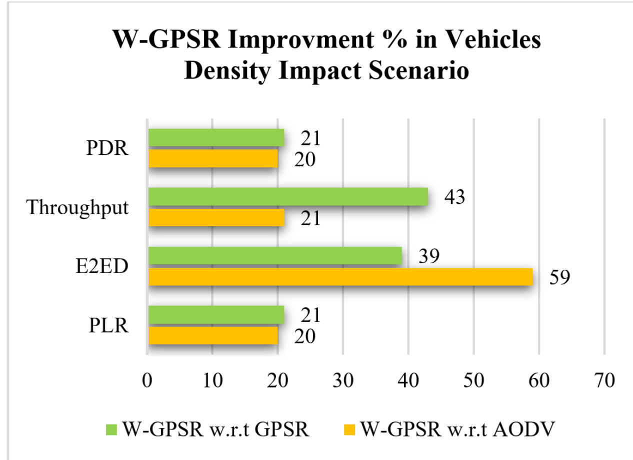



Fig. 14. W-GPSR Improvement % over GPSR & AODV.

forms GPSR and AODV with higher PDR by (21% & 20%) and throughput (43% & 29%) on average respectively, with lower E2ED and PLR with respect to various vehicles density. Meanwhile, in the second scenario, W-GPSR can also efficiently outperform both the conventional GPSR and AODV with regard to different speed values. Since W-GPSR achieved higher PDR by (% & 22%) on average comparing to GPSR and AODV respectively and higher throughput. I addition, W-GPSR reduced the routing cost by (48% and 19%) on average comparing to GPSR and AODV respectively. As a consequence, the suggested W-GPSR method may greatly improve the geographic routing protocol, resulting in a new W-GPSR routing protocol that is effective for VANET communication. In future work, this study can be extended to verify this proposed W-GPSR in highway or urban scenarios. A security issue can also be suggested to avoid the attacks during data routing. Furthermore, to achieve more reliable and scalable routing protocol, W-GPSR can be improved by incorporating an intelligent approach in V2V mode and other VANET communication modes such as V2R and V2X.

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## CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

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TABLE IV.
PERFORMANCE COMPARISON WITH EXISTING WORKS

| Research | 2025 | Routing | Simulator | Network Parameters | Avg. PDR | Avg. E2ED (s) |
|---|---|---|---|---|---|---|
| Nadri et al. [15] | 2019 | ABOR | NS-3 | Data Packet Size 512 B, Node Speed (10-20) m/s, Node Density (100, 150, 200, 250,300). | 74% | 0.46 |
| Aljabry et al. [18] | 2021 | FL-QN | OMNeT++ | Data Packet Size 512 B, Node Speed 10 m/s, Node Density (10, 20, 30 40, 50. | 65% | 1.62 |
| Zhang et al. [19] | 2023 | W-PAGPSR | NS-2.35 | Data Packet Size 512 B, Node Speed 15 m/s, Node Density (30, 50, 70 90, 110. | 62% | .026 |
| Proposed Protocol | 2023 | W-GPSR | OMNeT++ | Data Packet Size 512 B, Node Speed 15 m/s, Node Density (25, 50, 75 , 100). | 81% | 0.172 |

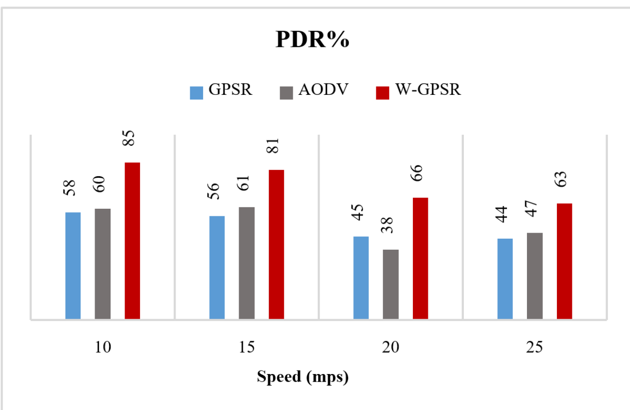


Fig. 15. Packet Delivery Ratio vs Vehicles Speed.

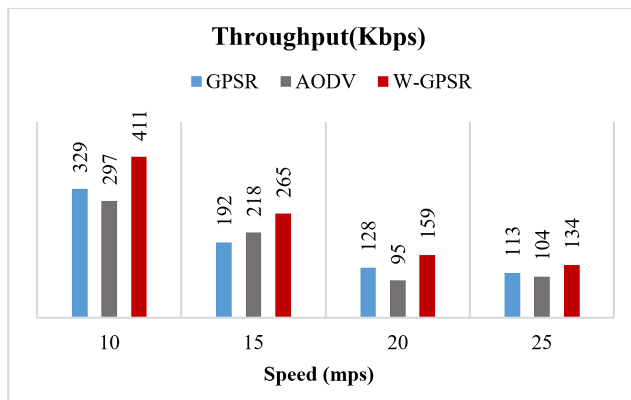


Fig. 16. Throughput vs Vehicles Speed.

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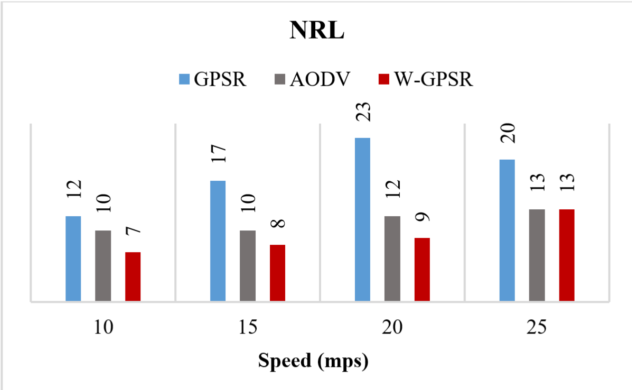


Fig. 17. Normalized Routing Load vs Vehicles Speed.

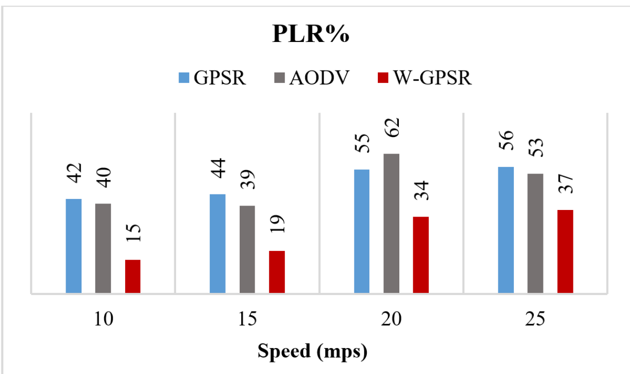


Fig. 18. Packet Loss Ratio vs Vehicles Speed.

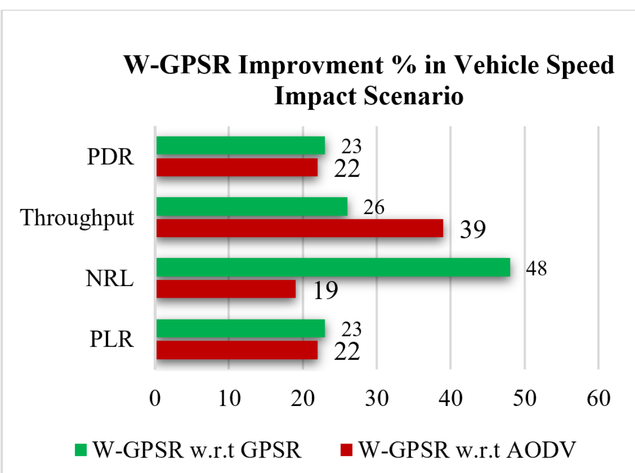


Fig. 19. W-GPSR Improvement % over GPS R & AODV.

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