A Robust Geographical Routing Approach in VANET Using Mobility Metrics

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Abstract- **A robust geographical routing approach in Vehicular Ad Hoc Networks (VANET) is proposed which utilizes mobility metrics, specifically addressing the impact of node acceleration and speed on routing stability and delivery rate. The proposed method is an enhanced version of reactive routing in vehicular ad hoc networks which considers the direction, speed, and position of vehicles in next-hop selection, aiming to improve route stability in high-mobility scenarios. Comparative analysis with traditional geographical routings such as improved AODV and GPSR reveals that the proposed method exhibits fewer broken links and increased Packet Delivery Ratio (PDR). The study further explores the influence of varying node density and speed on route stability and PDR. Results indicate that the proposed approach outperforms AODV in stability and delivery rate, particularly in scenarios with higher node mobility. This research contributes valuable insights into improving VANET routing protocols, emphasizing the importance of incorporating mobility parameters for enhanced performance in dynamic environments.**

Index Terms- VANET, Mobility model, AODV, Geographical Routing

I. INTRODUCTION

The evolution of Vehicular Ad Hoc Networks (VANETs) has spurred intensive research to enhance communication protocols and routing strategies, particularly in the context of high-mobility scenarios. The main challenge in highly mobile ad hoc networks such as VANET is connectivity management. Due to the predictable mobility models in VANET, connectivity

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management processes can use mobility metrics to avoid link and route failure in routing protocols. In addition, deploying VANET in IOT causes heterogeneous nodes that construct Internet of Vehicles (IoV) with different capabilities such as location management system. For example, a vehicle can connect road side unit (RSU) as fog or cloud gateway to get location information[1].

Recent developments in the wireless network have brought a new concept called the ‘internet of things (IoT) in which all objects can communicate with each other, meaning that physical devices, which possess various sensors (e.g., autonomous vehicles, electrical appliances, mobile phones, and the like) and can connect to the Internet, are taken into account. The temporary vehicular ad hoc network is a promising aspect of the intelligent transportation system (ITS) that is of interest to researchers. Vehicles create a self-organized network with a view to supplying superior security traffic and incrementing travel comfort for passengers. Owing to the rapid change and frequent disconnection, it is difficult to establish an efficient routing protocol for routing data between vehicles, vehicle-to-vehicle (V2V), or the communication between vehicles and roadside infrastructures [2].

The internet of vehicles (IoV) is an evolution of VANET, which is a promising technology that is used to control V2V communications. VANET is considered in vehicle-to-infrastructure (V2I) communications in external applications that include road safety and entertainment information; however, V2I can be described as a technology that makes this process possible. Vehicles communicate with each other with or without the use of a roadside unit (RSU) while moving in and out of the network. In addition, RSUs can be classified as another challenge in the network, despite external issues limiting signal attenuation, including buildings and other obstacles. Further, meeting different demands (quality of service) in IoV is an important challenge. Vehicles connected to the future network are expected to play an important role as mobile data collection and processing centers in everyday human life. Therefore, the IoV must be able to respond to distinct service requests with different service quality requirements. Thus, it is necessary to develop such systems since they can take advantage of the existing developments to accelerate the movement of traffic at intersections due to traffic problems. V2I communication area and mobility management and control on VANET are still considered as a challenge in this respect.

The existing routing protocols for VANET are inefficient for responding to traffic scenarios. Hence, the design of an efficient routing protocol has received much attention. According to various studies, the mobility challenge is identified as one of the most fundamental issues of the VANET network, which reduces the quality of service in IoT. Accordingly, the use of motion-based methods creates a stable path in the routing of inter-vehicle networks, which increases the quality of service; because the unique features of

IoV include high computability, high-speed communication, predictable mobility and variable network density [3]. IoV differs from temporary VANET networks by having centralized management that is suitable for its security application. According to the Federal Communications Commission frequency allocation, two main classes of applications can be enumerated for VANETs. The first category is to improve the safety level in roads, while the second one, which is predicted to rapidly grow in the near future, is commercial services (i.e., comfort applications). In both of these categories, related (i.e., safety or comfort) messages should be exchanged between vehicles. In this regard, routing is essential for satisfying the goals in VANET.

In VANET, the topology is highly changing due to its high mobility and dynamics; thus, the main problem is the frequent failure of routes. Interferences also occur due to the movement of nodes in routing protocols due to frequent topological changes. It seems evident that, due to the mobility, the links are not sustainable, leading to the interruption of the routes and an increase in the routing overhead. Therefore, there is a frequent need for routing [4].

This article addresses the challenges associated with traditional routing approaches in VANETs, specifically focusing on the Ad Hoc On-Demand routing to improve connectivity using mobility parameters. Proposed mobility prediction mechanism in this paper based on the VANET mobility models allow routing protocol to select more stable next hops than traditional position based routing strategies. Through a meticulous exploration of various parameters such as network density, node speed, and acceleration, the proposed method aims to overcome the limitations of existing protocols. Preliminary findings reveal that increasing the number of nodes in the network intensifies broken links, primarily attributed to an augmentation in the number of steps within routes. Notably, the proposed method demonstrates superior performance by predicting movement patterns, guiding next-hop selections based on speed, direction, and vehicle positioning. Comparative analyses with traditional AODV and its variants underscore the enhanced stability and efficiency of the modified on-demand routing, particularly in scenarios characterized by high node mobility.

A. RELATED WORKS

Wireless access in vehicular environments WAVE is a set of specific standards developed by the IEEE Research Group for VANETs. Carrier sense multiple access with collision avoidance protocols for medium access control (MAC) are applied by the WAVE standard, which allows for high mobility and dynamic network topology settings. As a result, routing information becomes a challenging task. VANETs deal with two wireless access standards, including IEEE 802.11p, which manages the physical layer and MAC, as well as IEEE 1609, which manages higher layer protocols [1].

In the literature, the multipoint relay-optimized link-state routing (MPR- OLSR) protocol, along with the gravitational search algorithm-particle swarm optimization (GSA-PSO) technique has been proposed to evaluate performance in terms of latency, packet drop, channel usage, packet delivery ratio (PDR), and radio operation capacity [4]. Similarly, a robust architecture in VAVET was introduced for maximum channel utilization and optimal data transmission using the MMPR-OLSR protocol [5]. However, no study has so far considered the effect of the channel model and node velocity. EAACK- MANET performance analysis with fuzzy dynamic cluster routing protocol (FDCRP) and AODV routing protocol (based on cluster and topology) has been evaluated in many studies [6]. Additionally, a position-based routing approach has been studied to analyze the performance of VANETs in terms of PDR, latency, path length, and control overhead with respect to vehicle density [3]. Likewise, comparative studies of routing protocols have been performed to enhance VANET performance without considering the wire- less channel model and the congested traffic scenario. The effect of the channel model, along with the diffusion model and the traffic congestion network scenario should be considered for VANET, where network mobility management represents a significant improvement.

In another study, the MPR-OLSR protocol, along with the GSA-PSO technique was presented to evaluate performance in terms of latency, packet drop, channel usage, PDR, and radio operation capacity. Moreover, using the MMPR-OLSR protocol, a robust architecture in VAVET was suggested for maximum channel utilization and optimal data transmission [6]. Nonetheless, the effect of the channel model and node velocity has not been considered in the studies. Different studies have investigated EAACK-MANET performance analysis with FDCRP and AODV routing protocols based on cluster and topology. In addition, a position-based routing approach has been examined to analyze the performance of VANETs in terms of PDR, latency, path length, and control overhead with respect to vehicle density. VANET-correlated experiments should be performed using IEEE 802.11P/WAVE compatible hardware mounted on vehicles running on real roads. However, due to the prohibitive costs of real-world VANET deployments, most research activities on VANETs focus on simulation-based studies or extremely small-scale test beds [7].

In another study [8], the researchers reviewed routing protocols in VANET with their classification. Proactive routing protocols such as OLSR suffer from a problem of tremendous increases in the size of the routing table by increasing the number of nodes in the network. Further, reactive routing protocols such as AODV suffer from frequent route failure problems and additional time required during the route discovery process. Their findings showed that AOMDV has real-time traffic problems. The position-based routing protocols perform well in a highway environment while suffering in the city environment due to signal blockage and multi-path effects. Greedy perimeter stateless routing (GPSR) suffers from packet losses and routing loops in the perimeter mode. GPSR uses the carry and forward approach but leads to an intermediate node failure problem. CAR suffers from packet overhead problems. They further found that every protocol has some drawbacks, thus it is necessary to design a routing protocol that will address all these problems [8]. Many researchers use a realistic mobility model for the VANET environment; the simulation analysis demonstrated that the performance of the protocol is greatly affected by the mobility model. The performance of an ad hoc network protocol can significantly vary with different mobility models, thus the choice of the mobility model in simulating VANET is highly important. The mobility models for VANET should be most closely matching the expected real-world scenario. In fact, realistic scenarios can significantly aid the development of routing protocols.

In [9] a novel integrated VANET-LTE-A architecture is presented. First, they proposed a new network-based mobile gateway selection scheme with one-hop clustering to efficiently relay the traffic from neighboring vehicles toward the serving SC. The clustering and cluster head selection problem was formulated as a multi-objective binary linear programming problem. Using a linear programming solver, they found that the execution time is relatively short for a realistic number of vehicles per small cell and GW connectivity degree. Then, for seamless mobility of connected vehicles, they proposed a local k-hops anchor-based mobility scheme with three procedures, namely, intra-domain, inter domain, and k-hops inter-domain procedures. Numerical results confirmed the effectiveness of the proposed mobility scheme for reducing the generated signaling load toward the core network.

A centralized routing scheme for end-to-end unicast communication in VANET in [10] is presented. The proposed routing scheme has prediction capability and selects the optimal routing path based on the global information. To adapt to the dynamic changing network topology, this routing scheme can choose either V2I or V2V communication. The researchers simulated the proposed routing scheme with NHPP and compared it with other routing protocols (pure V2I and pure V2V) in VANET. Based on the simulation results, the proposed CRS-MP scheme outperformed other routing schemes in terms of overall vehicular service delay. Moreover, the proposed scheme was more robust with varying vehicle speeds.

Likewise, a mobility prediction-based efficient clustering scheme (MPECS), which benefits from the ability to predict the vehicle's future movement, was suggested to improve the efficiency of VANETs [11]. Initially, MPECS divides the network into different distinct areas using the Voronoi algorithm, and hence, each vehicle can identify its current area. Then, the Gauss-Markov mobility model is used to predict the future positions of a vehicle within its area, followed by applying the polynomial regression model to predict the residual longevity of each vehicle in its current area. Furthermore, the vehicles predict the associated cost of each vehicle which results from selecting that vehicle as the cluster head (CH). The proposed scheme employs predicted vehicle longevity and costs to compute the VLV of each vehicle. Finally, PECS selects the vehicle that has the maximum VLV as the CH in order to form a stable cluster with the minimal cost.

In [12] a new software-defined network (SDN)-based IoV routing protocol for sending data packets via V2V and V2X methods is presented. In the suggested protocol, roads were divided into road sections based on intersections using unique identifiers. The EC kept the road section level navigation in its vicinity. Vehicles shared their information (vehicle speed, direction, road identifier [ID], vehicle ID, and position) with the EC by hello lights. This information was then sent to the SDN controller, respectively.

Additionally, [13] suggested a routing protocol called AGHBI, which uses two basic steps to select the optimal path for sending information in the IoV environment. First, a greedy delivery plan was employed to select the near- est section to the destination, followed by applying a modified hybrid routing scheme using an ABC optimization algorithm to select the highest service quality route and maintain the route with minimal overflow. The simulation results revealed that the AGHBI protocol is scalable in large urban and high- way areas and works better for packet delivery rates of nearly 7, 13.9, and 29.7% and delays of 39, 72, and 61% of VSIM, AODV, and GPSR.

Furthermore,[14] developed a new mobility prediction routing (MPBRP) protocol for neighborhood detection, packet transfer, and route retrieval in VANET using driver intent collected from positioning systems. This study aimed to combine predictive transportation and recovery strategies to identify neighbors and transfer packages, as well as using predicted positions and angles at predefined times while taking into account the driver's intention to select neighboring nodes and discover the transfer route. Similarly, a vehicle mobility prediction module was proposed to estimate RSUs using tracking data collected from a real-world VANET test platform based in Porto, Portugal [15]. A multi-layered cache mechanism was designed to estimate the popularity of the over-the-top (OTT) content to predict the distribution of content requests. In this research, a learning-based algorithm was implemented to actively fetch user content into the VANET cache in the RSU. Further, a prototype was implemented using the Raspberry Pi to simulate RSU nodes to prove system performance. Large-scale Open Stack tests were also performed to confirm the scalability of the system. Extensive experimental results indicated that this system can have benefits for the end-users and OTT service providers that help them optimize the use of network resources and reduce bandwidth consumption.

Greedy perimeter stateless routing (GPSR) is one of the earliest geographic routing algorithms devised for VANETs and is often cited as a benchmark. Position-based methods are preferable to VANETs over topology-based methods, according to research, since geographic routing avoids the operational costs and latency of establishing a forwarding table but rather relies on the geographic position of nodes, which could be derived using a Global Positioning System (GPS) device on a vehicle. Still, there is a research gap present in efficiency improvement in GPS-based VANETs. The Anchor-based Street and Traffic Aware Routing (A-STAR) and Greedy Perimeter Stateless Routing (GPSR) protocols are tested on a normal city map in this research. VANET simulations on real-world map settings produce reliable data and are also valuable for designing and deploying VANETs in the real world. The real-world dynamic model is crucial because that reflects the efficiency of the protocols under consideration in the physical world. Analysis of performance is carried in terms of throughput, packet delivery ratio, packet loss and average delay. However, this model provides moderate results in most dynamic topology[13].

VANET needs constant wireless data transmission among vehicles in order for connectivity to be feasible, and a reliable routing protocol makes this possible. However, the movement of cars has an impact on wireless communication on a broad scale, and the network architecture becomes unstable, necessitating a robust routing protocol design. Researchers compared the traditional Cluster-Based Routing Protocol (CBRP) with an optimized method using the particle swarm optimization (PSO) method in this work. PSO has been used to fine-tune several of CBRP's variables and timing parameters, enhancing the protocol's effectiveness and precision. However, for VANETs, an effective model is essential, which concentrates both in optimal path selection and collision reduction, in order to improve the efficiency of the network [7]. In VANETs, establishing a stable path for distributing packets is difficult due to the speed of vehicles and frequent link interruptions. This research [10] proposes an artificial spider geographic routing in metropolitan VAENTs (ASGR) to address these issues. The methods provide good results in terms of overhead. However, efficiency is moderate when it is applied to the highly dynamic network.

Geographic routing protocols, also known as position-based routing protocols, are much more suitable for fast changing and wireless connections, since they are centered on greedy routing. Unfortunately, in a metropolitan context, this type of protocol confronts a higher difficulty due to radio obstructions, such as towers, trees, and other barriers, that limit channel integrity and packet receiving rate. This work describes the available position-based routing mechanism in depth and introduces the Greedy Curve metric Routing Protocol (GCRP) [4], which uses the curved metric duration instead of the Euclidean distance to pick the next hop. The simulation results show better performance in terms of packet delivery ratio and throughput. However, from the point of view of efficiency, it is moderate.

Whenever possible, the author uses unicast messages in this operation to save network resource consumption. By placing directional antennae in automobiles, we can limit the spread of information. The author created an approach to select the best antenna array for unicasting information, allowing vehicles outside of the message's propagating range to do other things. Furthermore, when information is not obtained after a certain amount of time, each vehicle executes route discovery to nodes that hold information. As a result, pathways are rearranged as needed to accommodate additional vehicles. This method is only suitable for VANETs with less mobility. It is not suitable for networks with huge mobility models [16].

The Intersection-based Geographical Routing Protocol (IGRP) is a category of AODV protocol for VANETs that surpasses existing routing algorithms in metropolitan contexts. The Internet Gateway Routing Protocol (IGRP) is centered on attention for road intersections, through which a signal should traverse to access the Http server. The decision is constructed in such a way that the internet connection between crossing points is guaranteed with a strong likelihood, while meeting quality-of-service (QoS) criteria on acceptable latency, network capacity, and confidence interval. However, it is moderate in terms of efficiency when it is applied to networks with huge mobility [17]. Researchers in [11] suggested a parking-area-assisted spider-web routing protocol (PASRP) for data delivery in urban VANETs. Using remote sensing and GPS techniques with a digital map, PASRP creates a spider-web propagation design based on the parking lot. The transmission path from the source unit to the destination device is determined by sending two control packets, request-spider and confirm-spider, and the route with the shortest latency is chosen as the transmission link. The essential information is then transferred to the route using a multi-mode greedy method, with a dynamic multi-priority concept prioritizing it. This method only concentrates on packet delivery ratio and throughput, others are not investigated.

Under this research, the authors present RSU-assisted Q-learning-based Traffic-Aware

Routing, an innovative routing algorithm for metropolitan VANETs (QTAR). QTAR uses the Q-learning algorithm to study road network traffic statistics, combining the benefits of spatial transportation with fixed road spatial information. A routing method in QTAR is made up of many dynamically determined high-availability connecting road sections that allow payloads to effectively arrive at their destination. To decrease transmission delay and the impact of high-speed traffic flows on path vulnerability, distributed V2V Q-learning combined with Q-greedy geographical forwarding is used for routing packets inside a road segment, while distributed R2R Q-learning (Q-learning occurs between RSU units) is used for packet forwarding at every transitional link. However, this method only concentrates on throughput and delay. Overhead is not calculated [15, 18].

In a Public Transportation System (PTS), GeOpps-N is presented as a novel hybrid routing protocol for communications between buses and procedure control centers. Every thirty seconds, the bus location must be updated. The system can be modeled as a Vehicular Advertising Network that incorporates vehicles and Road-Side Units (RSU). Since the network has a low population density and is frequently congested, data must be relayed. When contrasted to other methods, such as geographic-based routing or storm routing, topology-based routing methods have been found to be more appropriate for low-quantity environments. Rather than seeking the endpoint within the source group, these methods search for the right candidate to deliver the idea to its endpoint. This method is inefficient when it is applied to networks with huge mobility [19]. This research offers a unique routing protocol based on the fuzzy systems that can aid in the coordination and analysis of metrics that are in conflict. To choose the best next-hop for routing packets, the suggested technique considers many parameters, such as position of the vehicle, orientation, network quality, and possible bandwidth. In terms of packet delivery ratio, end-to-end latency, and total network performance, the outcomes of these simulated studies in reasonably congested metropolitan contexts demonstrate significant gains. Still, this type of method produces reasonable performance when applied to a high-speed dynamic network [15].

The designers present a hop greedy routing mechanism in this research that offers a route with the fewest number of intermediate intersection nodes, while considering connection. They also present back-bone nodes, which play an important role in determining connection over a confluence. Aside from that, the backbone nodes permit a payload to be routed in a different path by tracking the position of both the sender and receiver. The suggested routing method has better packet delivery ratio and a lower end-to-end latency, according to numerical simulations. However, this provides moderate results in terms of efficiency [20].

A novel adaptive geographic routing system for enabling simplex VOD broadcast in metropolitan areas is suggested in this study. Instead of one route, a number of random routes between network and host vehicles are established in this system, and the amount is determined by the size of the demanded clip and the lifespan. The connection likelihood of a path is estimated using a shuttered formula, which can then be utilized to pick the greatest linked lines. The optimal path selection is done using this method, which does not satisfy the current drawbacks of VANETs, such as efficiency improvement and collision reduction [21].

Due to the high mobility of nodes and frequent disconnection of links, it is important to apply a high-performance routing algorithm. Choosing the optimal route with a low error rate and repetition in urban environments is a difficult task. It is noteworthy that the probability of packet loss and the number of re-submissions are reduced by considering the parameters that affect the stability of the link. Recently, various protocols have been proposed focusing on reducing traffic to the destination for the next hob vehicles. Most of these protocols have drawbacks such as one-hop consecutive high latency disconnection and low efficiency even at vehicle speed and time in a highly congested vehicle environment. Previous work has not performed well due to the non-consideration of a parameter such as the high mobility of the nodes, which plays a large role in the loss of the path. Moreover, some works have employed greedy methods based on geographical distance, which may not work well in some network conditions because it chooses the local optimal. Therefore, according to the contents of this research, a multiple routing protocol is introduced considering the prediction of mobility in ad-hoc vehicle networks.

The remaining parts of this paper are organized as follows: Mobility models used for this method are described in Section 2. Section 3addresses the main idea of this paper. Finally, in Section 4, our proposed method is evaluated by simulation.

II. MOBILITY MODEL

A VANET mobility model (Freeway or Manhattan) must be utilized since the aim of the study is to improve routing protocols for VANET with high performance.

A. Freeway mobility model

In the Freeway mobility model, several freeways co-exist in the simulation field, and mobile nodes move on freeway lanes. To implement this model, a map according to which the vehicles are moving, is necessary. There are several lanes in both directions for each freeway.

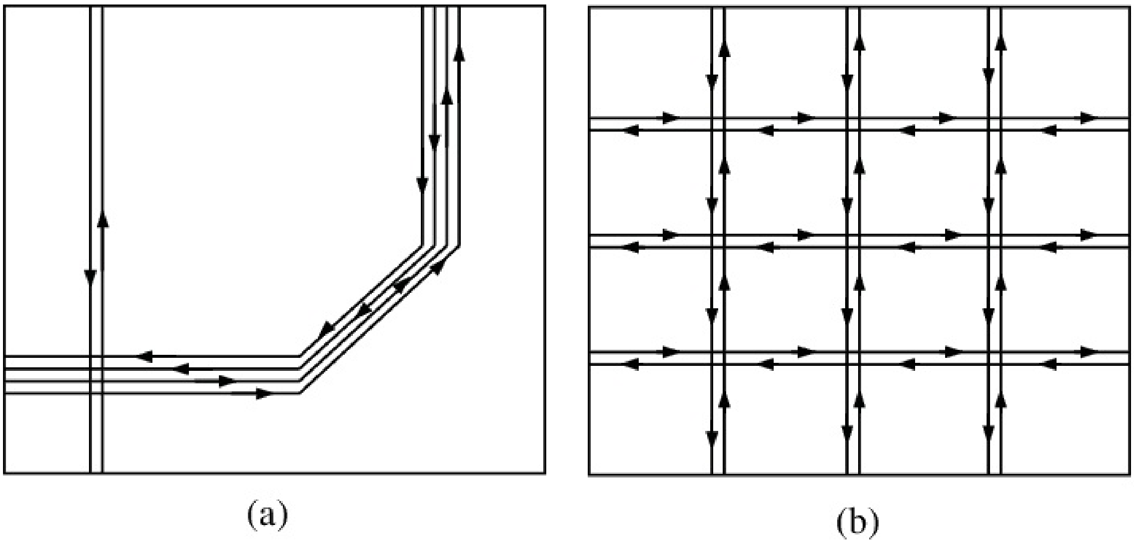

Fig. 1. A map for city mobility models: a) Freeway mobility model and, b) Manhattan mobility model

In this model, each lane should be separated from other lanes by some distance. In other words, when the map file is designed, the lanes are not supposed to be overlapping. This does not have to be a straight line for each lane, thus it may have several phases while each phase is a straight line. By connecting several phases, the users can define a non-straight freeway in the simulation field.

Based on Fig. 1.a, a map for the freeway has two directions, in both of which, there are two phases with two lanes. If one direction of a lane is defined as a positive value (1), the lane in the opposite direction must be defined as a negative value (−1). Each lane per phase has the maximum and minimum allowed velocities ($V_{\min}$ *and* $V_{\max}$). Several phases, lanes, and freeways are defined for each lane, each freeway, and the entire simulation field, respectively. Acceleration is an input parameter in this mobility model. To calculate the next speed of the node, the model uses its acceleration and current speed as Equation (1):

where:

$$v(t) = v(t-1) + \beta^{*} a(t) \tag{1}$$

$-1 < \beta < 1$; If β is less than zero, it means that the node is moving with de-acceleration (negative acceleration); otherwise, it moves with positive acceleration.

If the current speed of the node is greater than the maximum allowed velocity for its lane, the current speed decreases to $V_{\max}$. Otherwise, if it is less than the minimum allowed velocity for its lane, the current speed increases to $V_{\min}$.

If $v(t) > V_{\max}$ Then $v(t) = V_{\max}$

If $v(t) < V_{\min}$ Then $v(t) = V_{\min}$

B. Manhattan mobility model

In the Manhattan mobility model, several horizontal and vertical streets co- exist in the simulation field, and mobile nodes move on the street lanes. Several lanes exist in both directions for each street. Each lane should be separated from other lanes by a distance (i.e., the lanes are not supposed to overlap while designing the map file). However, the vertical and horizontal streets may cross each other at the intersection. The mobile nodes are supposed to move ahead, turn left, or turn right with a certain probability at the intersection.

In Fig. 1.b, Manhattan has a vertical and a horizontal street with an intersection. Each street has two directions consisting of a lane. If one direction of a lane has a positive value (1), then the lane on the opposite direction must have a negative value (−1). The streets of each map have the maximum and minimum allowed velocities ($V_{\min}$ and $V_{\max}$). In addition, acceleration is an input parameter in this mobility model. To calculate the next speed of the node, the model uses its acceleration and current speed as Equation (2):

$$v(t) = v(t-1) + \beta * a(t) \tag{2}$$

where: $-1 \le \beta \le 1$ If β is less than zero, it implies that the node is moving with de-acceleration (negative acceleration). Otherwise, it moves with positive acceleration.

If the current speed of the node is greater than the maximum allowed velocity for its lane, the current speed decreases to $V_{\max}$. Otherwise, if it is less than the minimum allowed velocity for its lane, the current speed increases to $V_{\min}$.

If $v(t) > V_{\max}$ Then $v(t) = V_{\max}$

If $v(t) < V_{\min}$ Then $v(t) = V_{\min}$

As described above, the Freeway and Manhattan mobility models are similar, while differing only when it comes to the intersections. Nodes using the Manhattan mobility model can turn left or right at an intersection, but they cannot do this in the Freeway mobility model.

III. MOBILITY PREDICTION IN VANET

For i and j nodes, if only node i moves, we can generally calculate the time that each node is within the transmission range of the other node, which is expressed as Equation (3):

$$t = \frac{X_{i,j}}{t} \tag{3}$$

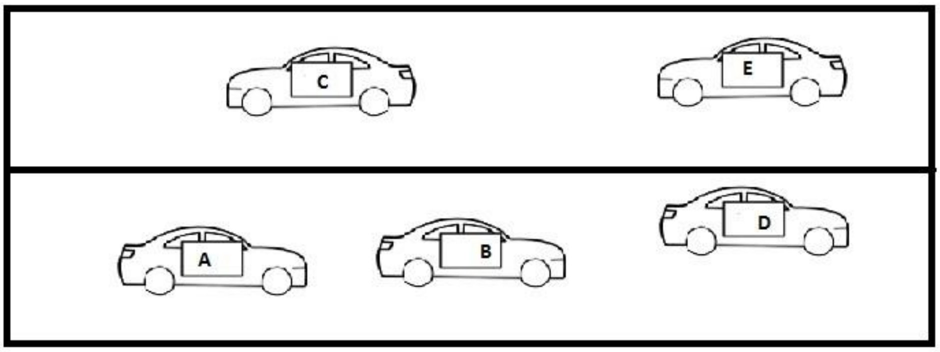

Fig. 2. Nodes Status for LET calculation

where $X_{i,j}$ is the minimum distance that node i is located in the transmission range of node j and vice versa.

If both nodes move, V becomes the relative velocity between them. Herein, the distance between nodes i and j is denoted by $d_{i,j}$, and R denotes the trans- mission range of each node. Further, the velocity of each node is represented by V_i and V_j.

When two nodes move in VANET, they have two situations to each other; they are either in the same street or in two streets. There are two kinds of movements in each situation; they either move toward each other or diverge instead. Each movement and the calculation of the link expiration time (LET) between these two nodes are described as follows.

A. Moving in the same street

First, the concepts of LET are explained with an example. In Fig. 3, suppose that the velocity of each node is as follows:

$$V_A = 30m/s, V_B = 20m/s, V_C = 30m/s, V_D = 40m/s.$$

As shown, nodes A, B, and D move in the same direction, and nodes C and E move in the other direction. Nodes C and D diverge because they move in opposite directions, and have already passed each other. Although nodes D and B move in the same direction, nodes B and D diverge since node D moves in front of node B and has a greater speed. Therefore, there are two kinds of divergence (i.e., divergence by direction and speed). In addition, nodes B and E move in the opposite direction and reach each other (converge). There is another kind of convergence when two nodes such as A and B move in the same direction and the back node (A) moves faster than the other node (B). Similar to the diverging movement, there are two kinds of converge movement (i.e., convergence by speed and direction).

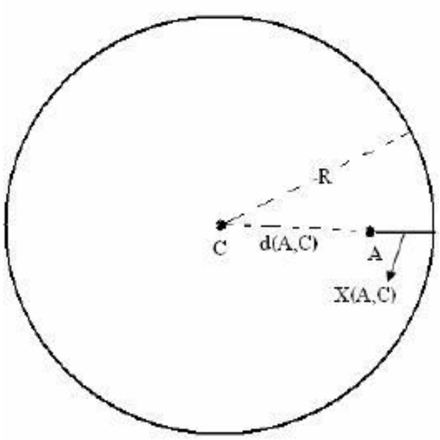

Fig. 3. Diverging movement in the same street

B. Diverging movement in the same street

In Fig. 2, nodes A and C converge by direction. In Fig. 3, they are displayed again based on the transmission range and distance between them.

The distance between two nodes located in the transmission range is expressed as Equation (4):

$$X_{A,C} = R - d_{A,C} \tag{4}$$

Where $d_{A,C}$ is the distance between nodes *A* and *C*. If nodes *A* and *C* move in opposite directions, the relative velocity will be $|V_A + V_C|$. Therefore, LET between nodes *A* and *C* is computed by Equation (5) as follows:

$$LET_{A,C} = \frac{R - d_{A,C}}{|V_A + V_C|} \tag{5}$$

If nodes *A* and *C* move in the same direction, the relative velocity will be equal to $|V_A - V_C|$. Consequently:

$$LET_{A,C} = \frac{R - d_{A,C}}{|V_A - V_C|} \tag{6}$$

C. Converging movement in the same street

(6) When two nodes move toward each other, first, they reach each other and then converge from one another. Fig. 4 depicts this movement based on the transmission range of the nodes where they move in the same direction.

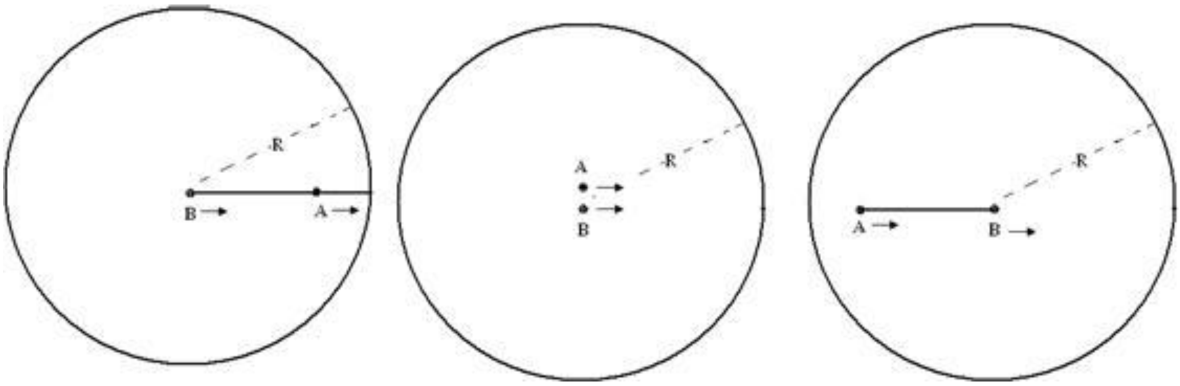

Fig. 4 Nodes moving in the same direction

Thus, the distance between two nodes located within each other’s trans-mission range is longer than when the nodes diverge and equals:

$$X_{A,C} = R + d_{A,C} \tag{7}$$

If the nodes move in the same direction, then LET will be calculated as Equation (8):

$$LET_{A,C} = \frac{R + d_{A,C}}{|V_A - V_C|} \tag{8}$$

If they move in opposite directions, we will have Equation (9):

$$LET_{A,C} = \frac{R + d_{A,C}}{|V_A + V_C|} \tag{9}$$

D. Moving in different streets

When two nodes move in different streets in the Manhattan or Freeway mobility model, they have three situations to each other:

a) They move in the same direction.
b) They move in opposite directions.
c) They have orthogonal directions.

E. Different Streets, Same Direction

In Fig. 5, nodes *A* and *B* move in different streets but the same direction. Considering that

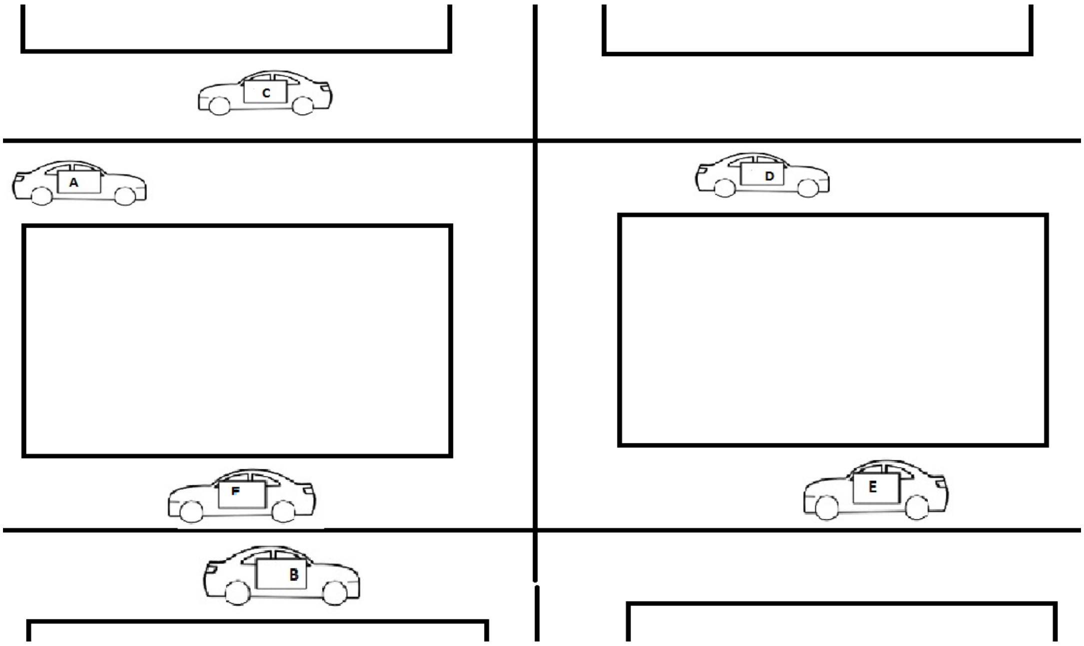

Fig. 5. Different Streets Movements

these nodes move in the same direction, we need to estimate the time that node B needs to exit the transmission range of node A. Accordingly, two parameters are required, including the relative velocity of these nodes and the minimum distance that node B is located in the transmission range of node A, $X_{A,B}$. The first parameter (velocity) is $|V_A - V_B|$.

Given that all nodes use GPS, the coordinates of each node can be obtained, and $X_{A,B}$ can be calculated accordingly (Fig. 8).

First, suppose that the velocity of node B is more than that of node A, and they will diverge accordingly. Using the coordinates of nodes A and B, $X_{A,B}$ can be computed as follows:

$$P = (X_A - X_B) + X_A, \tag{10}$$

$$Y = Y_A - Y_B \tag{11}$$

$$P = \sqrt{R^2 - Y^2} \tag{12}$$

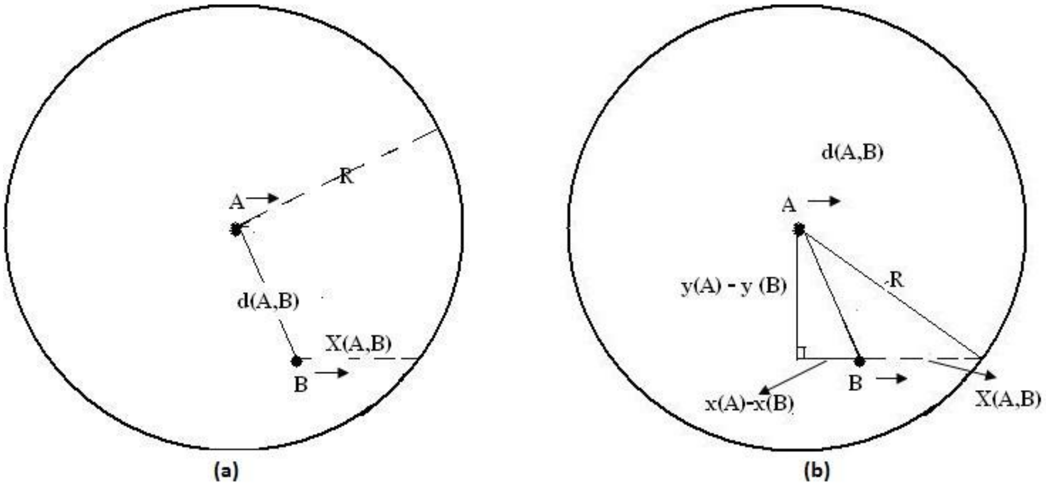

Fig. 6. (a) Different Streets, Same Direction, (b) determining the distance between nodes

$$X_{A,B} = \sqrt{R^2 - Y^2} - (X_A - X_B) \tag{13}$$

Therefore:

$$LET_{A,B} = \frac{\sqrt{R^2 - Y^2} - (X_A - X_B)}{|V_A - V_B|} \tag{14}$$

Fig. 6 illustrates the transmission range of nodes *A* and *B*.

If the velocity of node *A* is more than that of node *B*, they will converge; thus:

$$X_{A,B} = \sqrt{R^2 - Y^2} + (X_A - X_B) \tag{15}$$

Therefore:

$$LET_{A,B} = \frac{\sqrt{R^2 - Y^2} + (X_A - X_B)}{|V_A - V_B|} \tag{16}$$

F. Different Streets, Opposite Directions

If two nodes move in opposite directions (e.g., nodes D and F, as well as A and E for diverging and converging movements, respectively as shown in Fig. 5). The difference occurs in the relative velocity ($|V_D + V_F|$ or $|V_A + V_E|$). Thus, for the diverging movement, we will:

$Y=Y_D-Y_F$

$$LET_{D,F}=\frac{\sqrt{R^2-Y^2}-(X_D-X_F)}{|V_D+V_F|} \tag{17}$$

Moreover, for the converging movement, we will have:

$$Y=Y_A-Y_E \tag{18}$$

$$LET_{A,E}=\frac{\sqrt{R^2-Y^2}+(X_A-X_E)}{|V_A+V_E|} \tag{19}$$

IV. *PROPOSED METHOD*

In our method, the direction of nodes is considered as the pivotal parameter for next hop selection. Another parameter affecting next hop selection is the position of the node, but it is less important than direction. When a source node attempts to send a packet to the destination node, the routing protocol obtains the directions of the source node and the destination node. Then, based on their directions, the protocol recognizes the intermediate node that can participate in the route between the source and destination. Given that the Freeway mobility model is employed in this research, nodes can move only in two situations:

1. The source and destination nodes move in the same direction.
2. The source and destination nodes move in opposite directions.

As mentioned earlier, nodes in VANET move at a high speed, especially if they are moving on the freeway. Therefore, the links between the nodes may be broken, reducing route stability less than MANET because the nodes of MANET have low mobility and move slowly. On the other hand, if the nodes moving in opposite move in the same direction. Hence, if the source and destination nodes move in the same direction, the protocol must select only the intermediate nodes moving in the same direction as that of the source and/or destination move. Contrarily, if the source and destination nodes move in opposite directions, there is no restriction on the direction of the intermediate node.

In the proposed method, it is also attempted to select intermediate nodes moving in suitable positions between the source and destination, and their directions are also important.

Corresponding to the previous description, a node can be selected as the next hop in the route between the source and the destination if:

1. It moves in the same direction as the source and/or the destination.

II. The intermediate node is located between the source and the destination.

Algorithm 1 describes the next hop selection according to the above-mentioned criteria. In this algorithm, the source node, the destination node, and a moving node constitute the input parameters. The algorithm determines whether the node can be selected as the intermediate node in the route between the source and destination nodes. The get-direction function returns the direction of the input node, whereas the get-position function returns the location of any input node.

This algorithm has two steps:

The directions of the source, destination, and input node are determined in step 1. If the direction of the input node is the same as that of the source, destination, or both, then the algorithm moves to step 2.

In step 2, the get-position function first obtains the position of the source, destination, and input nodes. If the input node is located between the source and destination, then the algorithm returns true. This implies that the input node can be selected as the intermediate node in the route between the source and destination. Otherwise, the algorithm returns false to represent that the next node cannot be selected as the intermediate node.

Algorithm 1 Next hop selection

```
    Bool Next Hop (Node, source and destination)
{
    Step1:
    Ds = Get Direction (source);
    Dd = Get Direction(destination);
    Dn = Get Direction (node);
    if ((Dn == Ds)(Dn == Dd))
  {
      Step 2:
      Ps = Get Position(source);
      Pd = Get Position(destination);
      Pn = Get Position(node);
      if ((Ps¡=Pn¡=Pd) (Pd¡=Pn¡=Ps))  return TRUE;
      else return FALSE;
     end if
  }
    else return FALSE;
```

```
end if
}
```

Routes found by this method become more stable and have less overhead compared to the original routing method. Nonetheless, there is a problem; the protocol may not find this type of intermediate node as the next hop.

Algorithm 2 Routing approach with the mobility parameter

```
Attempt=0;Step 1:
if ((Dn==Ds)(Dn==Dd))&&
   ((Pd¡=Pn¡=Ps)(Ps¡=Pn¡=Pd))
{
   Send RREQ packet(node);NR++;
}
 a)      else
   Attempt++;
 b)      end if
if (attempt¡2)
{
   Wait (w t); Go to Step 1;
}
else if ( NR¡Min route thershold)Step 2:
   if ((Dn==Ds)(Dn == Dd))
   {
      Send RREQ(node);NR++;
   }
 end ifend if
```

Thus, our strategy should be modified to solve this problem. Initially, a lower bound is put on the number of discovered routes, and then the algorithm is divided into two steps. In step 1, the protocol searches for the nodes that meet both position and direction conditions. If the protocol satisfies the lower bound of routes after this step, the algorithm is finished without performing the remaining step and continues other routing phases (e.g., the route maintenance and data transmission phase). Otherwise, the algorithm moves to step 2, in which it removes the position condition and selects the intermediate nodes moving in the same direction as the source and/or destination node. These two steps in the route discovery phase are summarized as follows:

Step one:

The nodes can be selected as the intermediate nodes in the route if they move in the same direction as the source or/and destination, and their position is between the source and destination.

Step two:

If the lower bound of the routes is not satisfied, the position condition is removed from the routing restriction, and the only limitation on routing is the direction of the nodes. Therefore, the node can be selected as the intermediate node only if it moves in the same direction as the source or/and the destination. Algorithm 2 summarizes our method.

V. SIMULATION

A. Simulation environment

One simulator for routing protocol evaluation is Glomosim, which is implemented within the GloMoSim library. This library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation language PARSEC. Simulation is performed in a 1000 1000 *m* area and for 700 seconds. The initial placement of nodes is based on the input trace file, and the freeway mobility model is applied for this purpose. The maximum speed is 20*m/s* when the number of nodes represents a change, and acceleration is $5m/s^2$. When the acceleration or speed of the node varies, the number of nodes becomes 40. In addition, the transmission range of each node is 250*m*, and 802.11 is used as the MAC layer protocol. The results are the average of 10 simulation runs. Further, a constant bit rate with a packet size of 5000 bytes is selected as the application for sending, and it is aimed to transmit 10000 packets.

B. Performance parameters

a) Broken links

A route is more stable when it has fewer broken links in any connection. This parameter is employed to indicate route stability. The route is stable if the number of broken links per route is small. Too many broken links lead to the exchange of more control packets and thus more packet loss.

b) Route Expiration Time (RET)

The LET between two nodes is the time that two nodes are directly connected, and each is located within the transmission range of the other one. The calculation of this parameter is provided in the above-mentioned table. RET can be calculated after computing the LET. The RET for a route is the minimum LET that makes that route:

$$RET = \min\{LET_1, LET_2, \dots\dots\dots\dots\dots\dots, LET_n\} \tag{20}$$

c) Packet Delivery Ratio (PDR)

In the study conducted in the VANET, due to the instability of clusters and zoning, it is impossible to deliver all packets. Therefore, in evaluating the search method, it is necessary to pay attention to the PDR (i.e., the proportion of the number of packets received by the destination node to packets transmitted by the source node). Thus, with a view to being an efficient network, the PDR must be as the highest as possible, thereby receiving all the transmitted packets of the source in the destination.

C. Simulation results

New studies have shown that the more efficient routing protocols for VANETs are those which take numerous variables into account while making routing decisions at the relay node. This study is focused on approaches that analyze neighbor nodes using numerous routing parameters and identify the best candidate node to route packets. As a result, we have highlighted some current intriguing suggestions in spatial routing algorithms. The proposed scheme is compared with an improved AODV for VANET [22] and GPSR [8] which both of them are geographical routing protocols.

A. Network density

The effect of network density on broken links is depicted in Fig. 7. As shown, in the improved AODV, as the number of nodes increases, the broken links increases, while the broken links in the proposed scheme and GPSR decrease; however, it has a better performance here and reduces the total number of broken links compared to the original AODV.

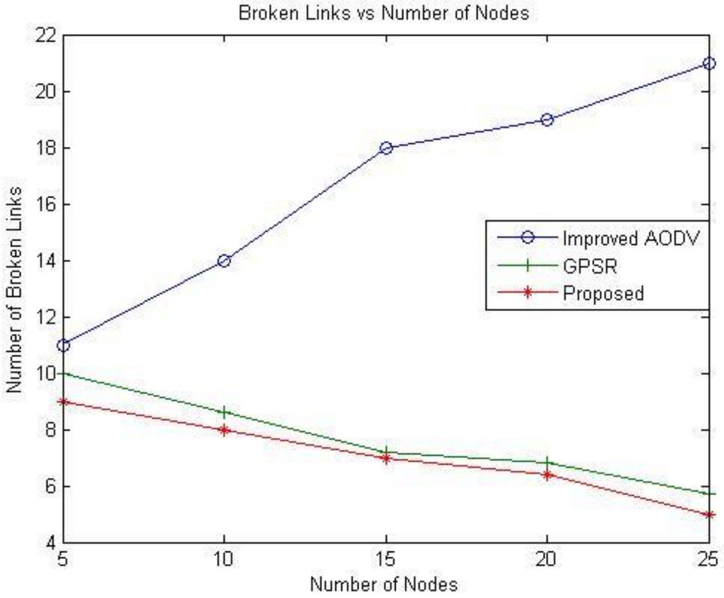

Fig. 7. Broken links vs. the number of nodes

Based on the obtained data, increasing the number of nodes leads to an increase in the number of broken links, which is due to an increase in the number of hops in the routes in all methods. Due to further hops in the path, it is more likely to find the broken links. Moreover, in the proposed method, the number of broken links is less compared to similar methods, which is the reason for predicting the movement performed in routing, and the next step is constantly determined based on speed and direction, the direction of vehicles.

Fig. 8 depicts the RET versus network density. The results indicate that increasing the number of nodes decreases the RET. This is normal, because the number of hops between any source and destination will rise by increasing the number of nodes; therefore, the number of links constructing a route represents an increase. The results further demonstrate that the modified AODV has higher stability in comparison with the improved AODV in route selection. Initially, when 10 nodes exist in the network, all the methods have the same RET. By raising the number of nodes, the difference between these methods increases as well.

Increasing the number of nodes in the network increases the lifetime of the route. Route longevity refers to the average expiration time of all links. In the improved AODV method and GPSR, increasing the number of nodes has a slight effect on improving the expiration time of routes since there is no mechanism to manage the movement of nodes and just uses nodes locations. While in the proposed method, using mobility prediction causes higher route lifetime. In the other words, increasing the number of nodes leads to an increase in path expiration time, which is observed in the proposed method due to the direction in addition to

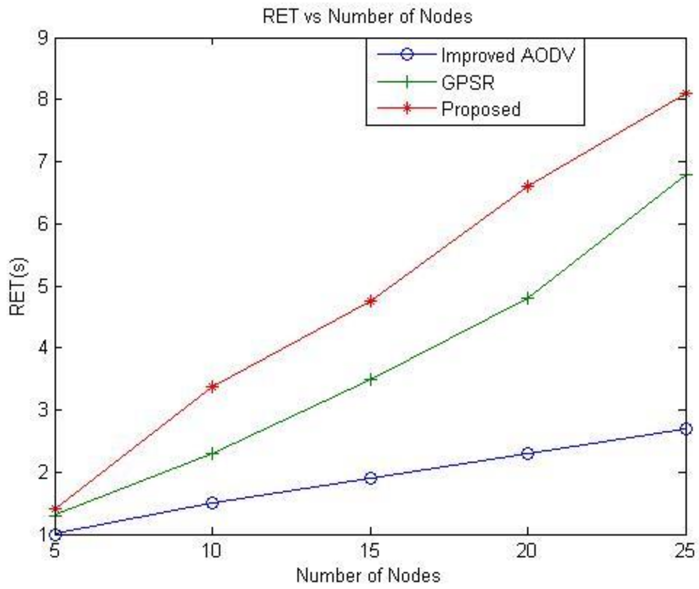

Fig. 8. RET vs the number of nodes

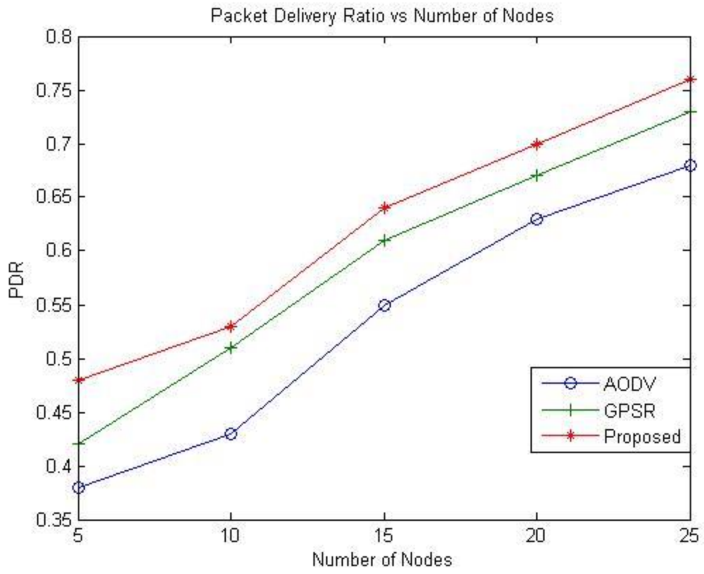

Fig. 9. Packect delivery ratio vs number of nodes

position and better performance speed.

As depicted in Fig. 9, increasing the number of nodes leads to higher data delivery rate. The main reason is finding more stable route in dense situation. Using mobility parameters and mobility prediction assist the proposed method to achieve higher PDR compared two others.

B. Nodes speed

Speed is one of the most important VANET parameters. Fig. 10 depicts the evaluation of the

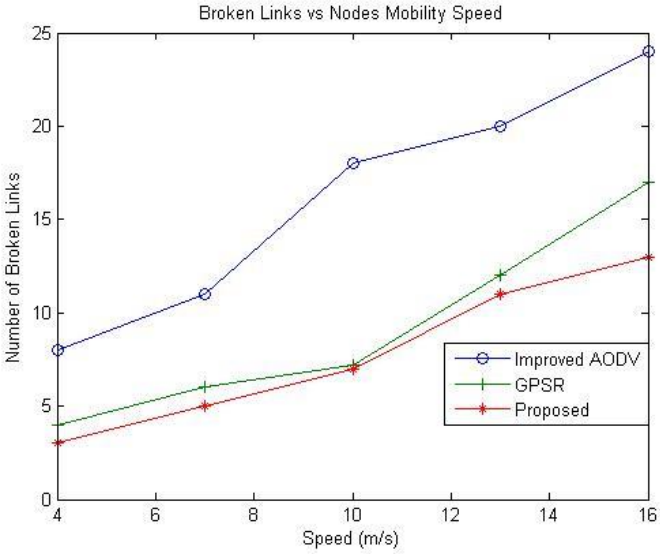

Fig. 10. Broken links vs the speed of nodes

effect of vehicles speed on broken links. As shown, our method selects a more stable route with fewer broken links compared to the other ones. Generally, elevating the speed of the nodes increases the number of broken links regardless of the routing protocol. Nevertheless, the modified routing which uses mobility metrics selects more stable routes, and the stability difference of improved AODV with proposed method and GPSR increases by increasing the speed of the nodes, suggesting that our method is superior to the improved AODV and GPSR in high-mobility scenarios.

The comparison of the effect of node speed on RET is displayed in Fig. 11. When raising the speed of nodes, the RET in all routing methods decrease. Nonetheless, in the proposed method, RET is higher than two otheres due to the mobility prediction capabilities. In addition, selecting more stable routes by using mobility metrics causes less snsitivity to nodes speed in the proposed method at medum speeds. This operation will continue until the vehicle’s speed becomes extremely high, in which case, the RET begins to represent a high reduction in all methods.

Finally, the PDR in different numbers of nodes is compared in Fig. 12. Based on the obtained data, increasing the speed reduces the stability of the routes, and decreasing the stability of the routes leads to a decline in the delivery rate, which is extremely greater in improved AODV without considering the mobility parameters. However, considering more parameters in choosing the next step decreases the effect of speed on the delivery rate because other parameters such as direction and position can compensate for the increase in speed, and the delivery rate does not represent a high decrease.

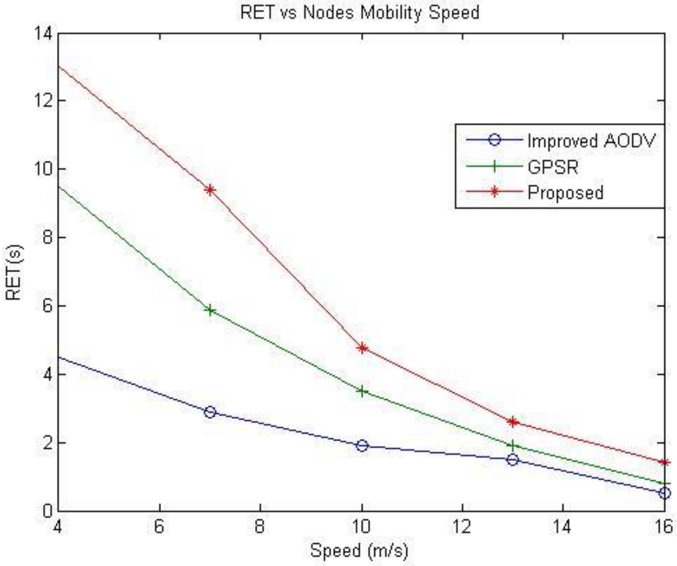

Fig. 11. Route Expiration Time vs speed

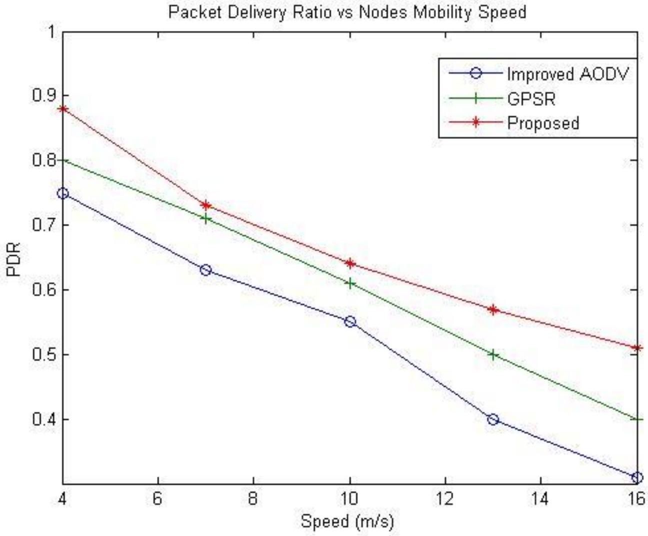

Fig. 12. Packect delivery ratio vs nodes speed

VI. CONCLUSION

In conclusion, the investigation into a Robust Geographical Routing Approach using Mobility Metrics in VANETs has provided valuable insights into the dynamic interplay of network parameters on routing performance. The observed increase in broken links with the rising number of nodes across all methods underscores the challenges associated with scalability. However, the proposed method exhibits a noteworthy advantage by predicting and incorporating movement patterns in routing decisions, resulting in fewer broken links compared to similar methods. The constant determination of the next step based on speed and direction enhances the method's efficacy, addressing the inherent limitations of randomness in traditional approaches like AODV or GPSR based methods. The assessment of network density reveals that the proposed method offers higher stability in route selection compared to the improved AODV and GPSR that just use location information especially in scenarios with increased node density. The observed trends in route longevity further emphasize the method's effectiveness, attributed to its consideration of both position and direction, in addition to enhanced speed performance. Exploring the impact of vehicle acceleration and node speed on broken links highlights the significance of these mobility parameters in routing decisions. The proposed method consistently outperforms the improved AODV, selecting more stable routes and exhibiting increased resilience to higher node speeds. The inclusion of motion prediction techniques in the proposed method represents a leap forward in enhancing route stability, outperforming GPSR in addressing the challenges posed by node speed and direction. The evaluation of Packet Delivery Rate (PDR) under different conditions reinforces the superiority of the proposed method. Notably, the consideration of multiple parameters in selecting the next step compensates for the destabilizing effect of increased node speed, leading to a more consistent and robust delivery rate compared to traditional position-based methods. In summary, the proposed method emerges as a promising solution for high-mobility scenarios in VANETs. The comprehensive consideration of mobility parameters in next-hop selection contributes to improved stability, reliability, and delivery rates. This research underscores the importance of adapting routing protocols to the unique challenges of vehicular environments, paving the way for more resilient and efficient communication strategies in future intelligent transportation systems.

REFERENCES

[1] B. Ji *et al.*, "Survey on the internet of vehicles: Network architectures and applications," *IEEE Communications Standards Magazine*, vol. 4, no. 1, pp. 34-41, 2020.

[2] J. Cheng, J. Cheng, M. Zhou, F. Liu, S. Gao, and C. Liu, "Routing in internet of vehicles: A review," *IEEE Trans. Intelligent Transportation Systems*, vol. 16, no. 5, pp. 2339-2352, Oct. 2015.

[3] C. Ksouri, I. Jemili, M. Mosbah, and A. Belghith, "Towards general Internet of Vehicles networking: Routing protocols survey," *Concurrency and Computation: Practice and Experience*, vol. 34, no. 7, p. e5994, 2022.

[4] M. A. Salkuyeh and B. Abolhassani, "An adaptive multipath geographic routing for video transmission in urban VANETs," *IEEE Trans. Intelligent Transportation Systems*, vol. 17, no. 10, pp. 2822-2831, Oct. 2016.

[5] R. Gasmi, M. Aliouat, and H. Seba, "A stable link based zone routing protocol (SL-ZRP) for internet of vehicles environment," *Wireless Personal Communications*, vol. 112, no. 2, pp. 1045-1060, 2020.

[6] M. Naderi, F. Zargari, and M. Ghanbari, "Adaptive beacon broadcast in opportunistic routing for VANETs," *Ad Hoc Networks*, vol. 86, pp. 119-130, 2019.

[7] G. Abbas, S. Ullah, M. Waqas, Z. H. Abbas, and M. Bilal, "A position-based reliable emergency message routing scheme for road safety in VANETs," *Computer Networks*, vol. 213, p. 109097, 2022.

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

[9] A. S. Chekkouri, A. Ezzouhairi, and S. Pierre, "A new integrated VANET-LTE-A architecture for enhanced mobility in small cells HetNet using dynamic gateway and traffic forwarding," *Computer Networks,* vol. 140, pp. 15-27, 2018.

[10] A. Srivastava, A. Prakash, and R. Tripathi, "QoS aware stochastic relaxation approach in multichannel CR-VANET: A junction-centric geographic routing protocol," *Journal of Ambient Intelligence and Humanized Computing,* vol. 14, no. 8, pp. 11103-11121, 2023.

[11] H. Seo, K.-D. Lee, S. Yasukawa, Y. Peng, and P. Sartori, "LTE evolution for vehicle-to-everything services," *IEEE communications magazine,* vol. 54, no. 6, pp. 22-28, June 2016.

[12] M. T. Abbas, A. Muhammad, and W.-C. Song, "SD-IoV: SDN enabled routing for internet of vehicles in road-aware approach," *Journal of Ambient Intelligence and Humanized Computing,* vol. 11, no. 3, pp. 1265-1280, 2020.

[13] R. Attia, A. Hassaan, and R. Rizk, "Advanced greedy hybrid bio-inspired routing protocol to improve IoV," *IEEE Access,* vol. 9, pp. 131260-131272, 2021.

[14] M. Ye, L. Guan, and M. Quddus, "Mpbrp-mobility prediction based routing protocol in vanets," in *2019 International Conference on Advanced Communication Technologies and Networking (CommNet), IEEE*, pp. 1-7.

[15] I. T. Abdel-Halim, H. M. A. Fahmy, and A. M. Bahaa-El Din, "Mobility prediction-based efficient clustering scheme for connected and automated vehicles in VANETs," *Computer Networks,* vol. 150, pp. 217-233, 2019.

[16] T. L. Willke, P. Tientrakool, and N. F. Maxemchuk, "A survey of inter-vehicle communication protocols and their applications," *IEEE Communications Surveys & Tutorials,* vol. 11, no. 2, pp. 3-20, 2009.

[17] D. Čabarkapa and M. Milićević, "Importance of Realistic Mobility Software Models for VANETs Simulations."

[18] M. T. Abbas and W.-C. Song, "Infrastructure-assisted hybrid road-aware routing and qos provisioning in vanets," in *2017 19th Asia-Pacific Network Operations and Management Symposium (APNOMS), 2017: IEEE*, pp. 370-373.

[19] D. S. Gaikwad and M. Zaveri, "VANET routing protocols and mobility models: A survey," in *International Conference on Web and Semantic Technology*, 2011: Springer, pp. 334-342.

[20] Y. Tang, N. Cheng, W. Wu, M. Wang, Y. Dai, and X. Shen, "Delay-minimization routing for heterogeneous VANETs with machine learning based mobility prediction," *IEEE Trans. Vehicular Technology,* vol. 68, no. 4, pp. 3967-3979, Apr. 2019.

[21] B. Ding, Z. Chen, Y. Wang, and H. Yu, "An improved AODV routing protocol for VANETs," in *2011 international conference on wireless communications and signal processing (wcsp)*, 2011: IEEE, pp. 1-5.

[22] O. Abedi, R. Berangi, and M. A. Azgomi, "Improving route stability and overhead on AODV routing protocol and make it usable for VANET," in *2009 29th IEEE international conference on distributed computing systems workshops*, 2009, pp. 464-467.