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## Movement Direction Algorithm for Geographic Routing Protocol in Vehicular Networks

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*Abstract*—Vehicular ad hoc networks (VANETs) are special type of the wireless network in which communication through other intermediate vehicles on the road. Due to high mobility of vehicles, the design of an efficient routing protocol is one of key issues, which has been considered a challenging problem to deal with such dynamic network in VANETs. The greedy-perimeter stateless routing (GPSR) routing protocol uses the simple greedy forwarding based only on the position information which may fail to find a neighbor closer to the destination than itself. In this paper, we propose a movement direction algorithm under GPSR. It comprehensively takes into account the velocity vector information and underlying link expiration time to recover a local maximum. The simulation outcomes in varying scenarios show that the proposed algorithm enhances the packet delivery and reduces the end-to-end delay, compared to the existing geographic routing algorithms.

*Keywords*—GPSR, Local maximum, Movement direction, Next-hop, VANETs

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### I. INTRODUCTION

Vehicular ad hoc networks (VANETs) are special type of the wireless network in which communication take place through wireless links mounted on each vehicle [1]. Each vehicle within VANETs acts as both, the participant and router of the network. The vehicles communicate through other intermediate vehicle on the road that lies within their own transmission range [2]. The movement direction of vehicles is along roadways, and their mobility is restrained by traffic policies, such as traffic light signals, speed constraints, and road/traffic conditions [3]. The basic target of VANETs is to increase safety of road users and comfort of passengers. VANETs has the unique and critical characteristics, such as: the vehicles may join or leave within one another transmission ranges abruptly or gradually [4], the network topology may change rapidly and unpredictably, the established wireless links between the vehicles may break. As a result of this mobility, the challenges of VANETs will become more serious and the performance of routing protocols could be greatly affected. Due to high mobility and uneven distribution of vehicles, the design of an efficient routing protocol is one of key issues, which has been considered a challenging problem to deal with such dynamic network scenarios [5]. In VANETs, the routing strategy is whether we select an appropriate or undesirable next-hop vehicle from the neighbouring set. The performance still not perform well, if the routing cannot find an optimal next-hop vehicle, as which is essential entity for delivering of the packets from the source to the destination. Therefore, the performance of routing relies on the most suitable next-hop selection mechanism for data delivery among vehicles.

To address these specific requirements of VANETs, greedy perimeter stateless routing (GPSR) [6] is one of the geographic routing protocols that can use the local topology information to find correct new routes quickly and it has been actually designed for dynamic network scenarios [2]. It requires neither regular exchange of the routing information nor broadcast flooding to route requests [3]. It does not need to store routing information; thus it is very effective as a dynamic

network. To select a next-hop neighbor, GPSR uses the simple greedy forwarding based only on the position information. It may choose the next-hop that is the closest to the destination but moving in the opposite direction of the destination vehicle. Therefore, it misses out on some suitable candidates to forward a packet; Moreover, [7] the greedy forwarding may encounter the local maximum or local optimum problem, where the current forwarder is closer to the destination than all its neighbors and the destination still not reachable by one hop communication [8]. For example a vehicle in front may not have any neighbor nearer to it than the final destination vehicle [9]. In such a case, GPSR uses perimeter phase to overcome the situation when the greedy phase meets a local maximum situation [1]. It uses the right hand rule to search routes at the boundary in a direction to route the packet along the perimeter of the local maximum region in a clockwise direction [6]. In VANETs, with the right-hand rule, there may be large number of vehicles on the left side of the road, and the packet may be seen to go further and further away from the target, until the life cycle of the last vehicle is reduced to the end, and then the packet is dropped [1]. The performance of data delivery is degraded, as well as the increase in network delay.

To explore routing features of VANETs, in this paper we propose a movement direction algorithm under the GPSR routing by considering the velocity vector of vehicles. First, instead of perimeter routing to recover the local maximum, we select the optimal next-hop vehicle by considering the number of vehicles that move in the direction of the destination vehicle. Then, we consider the vector projection of each candidate next-hop into consideration to select the optimal next-hop node. Otherwise, we take into account the link-reliability between each neighbor and the destination into consideration based on the link expiration time (LET) information. In our work, we have performed extensive simulation of VANETs based on urban scenario traces generated from VanetMobiSim [10] as the input to the proposed model based on NS-2 network simulation [11]. We have studied the impact of important factors such as number of vehicles and maximum speed of vehicles for comparing its performance with those of the existing geographic routing algorithms. Simulation results clearly show that the proposed is viable and can significantly enhance the packet delivery ratio, reduce end-to-end delay, compared to others.

The remainder of this paper is organized as follows. Related work is reviewed in Section 2. Section 3 introduces the movement direction model. Then, the simulation setup and results are shown in Section 4. Finally, we conclude the paper in Section 5.

## II. RELATED WORK

In VANETs, many algorithms under the geographic routing strategies have been designed to forward the packet from the source to the destination vehicles [12], [13], [14], [15], [16]. GPSR is one of the geographic routing that uses only the neighbor's position information to forward the data packets [6]. In greedy forwarding, upon receiving a data packet with the destination's position information, the source selects a neighbor that is closest to the destination and forward the data packets to that neighbor [17]. During the process of the greedy forwarding, a local maximum occurs, the vehicle would switch to perimeter routing that attempts to route the packet along the perimeter of the local maximum region in a clockwise direction [4]. If during perimeter routing, the packet reaches a vehicle that is closer to the destination than the vehicle at which the routing entered into perimeter mode, the vehicle would resume the greedy forwarding of the received a packet [18]. However, planarization of the graph is very difficult because of the mobility of the VANETs. The recovery strategy of GPSR is inefficient and time consuming especially given the highly dynamic nature of VANETs [9]. The routing with perimeter forwarding in GPSR may lead to wrong directions, and there are too many hops for the packet to be transmitted to the destination which can lead to the packet loss and delay. To improve the GPSR routing protocol, the simplification of perimeter forwarding which is based on GPSR but takes the position information, the speeds and directions of movement of the neighboring vehicles into accounts, to predict the future positions before to forward a packet, and to ensure the reliability of the routing [12]. By considering stochastic characteristics of the distance and speed of vehicles for computing the link-reliability that link with reliability factor greater than a given threshold alone is selected as a next-hop neighbor, when constructing a route from the source to the destination [14]. The performance improvement over the conventional GPSR protocol in terms of the packet delivery ratio and link failure rate is significantly reduced; however the delay slightly increases as compared to the conventional GPSR. Due to the potentially large number of next-hop neighbors, a next-hop selection scheme in [19] uses the optimal stopping theory to choose a suitable next-hop neighbor, while in [20] uses the future position of each neighbor and then selects neighbor vehicle nearest to the next intersection based on predictive location. The predictive location estimates the future location of a vehicle based on its history location and velocity [4], [21]. To predict the probability of the link-reliability between two vehicles, dynamic properties are used in the movement states of vehicles. In the stable state, the mean velocity of vehicles is stable, otherwise, in the unstable stable, the velocity of vehicles is unstable with the acceleration or deceleration [22]. In movement prediction based routing (MOPR) [23], before selecting of a next-hop vehicle each vehicle estimates the link-reliability in its transmission range based on the movement information such as velocity and direction. Then, MOPR will select the next-hop vehicle with the highest the link-reliability to forward a data packet. However, as the vehicle does not know the real location of the target vehicle, it is impossible for it to evaluate the prediction error [4].

Knowledge of the link-reliability is essential for the design of the geographic routing protocols. Recently, there have been certain attempts to analyse the link-reliability in VANETs [22], [24], [25]. In link state aware geographic routing protocol, a routing metric called expected one-transmission advance (EOA) is contrived to improve the greedy forwarding algorithm by diminishing transmission failures [24]. The EOA and link-reliability in [25] are measured using the enhanced the expected transmission count (ETX) metric which is obtained with the assistance of the information (e.g., position and velocity) in the hello message. The calculation of ETX is modified to adapt to the high mobility of the network vehicles. Since the ETX metric depends highly on the value of the hello interval and window size [24].

Researchers have proposed next-hop selection strategies [19], [26], [27]. The selection of next-hop vehicle algorithms resulting in with weak forwarding links. These weak forwarding links may degrade the performance of routing. For stable and reliable routing, the selection of next-hop vehicle is very crucial task. Link and node based metrics have been identified and used in the next-hop vehicle selection algorithm [27]. The node based metrics are localized metrics related to choose a next-hop vehicle whereas link based metrics are depicting the quality of the link between two vehicles. To improve the GPSR routing, a next-hop selection mechanism based on a weighted function which consists of the link-reliability between the source and neighbour vehicles, distance between neighbour and the destination, movement direction angle of vehicles is studied [26]. However, the performance of the proposed protocol is better in some situations. The simplest next-hop selection strategy is to greedily select a neighbour vehicle with the highest geographical progress toward the destination vehicle as a next-hop [22]. A next-hop selection strategy based on the length of the buffer takes not only the distance between next-hop and the destination vehicle [15] but also the available length of the next-hop vehicle buffer into consideration. Thereby reducing the time delay as well as the packet loss which caused by bigger waiting time than the retransmission delay.

All of these routing protocols have proposed various algorithms to improve the performance of the geographic routing in VANETs. A few of them have made an improvement to recover from the local optimum situation. In this paper, we will propose a new recovery method for the greedy forwarding to improve the performance of the GPSR routing protocol in VANETs.

### III. THE PROPOSED ALGORITHM

In Fig. 1 the source S initializes the data communication by sending the data packet to the destination vehicle D, the traditional greedy forwarding of the GPSR protocol defines vehicle N as a next-hop, since vehicle N is clearly the closest neighbor to the destination vehicle D. Here, the vehicle N is closer to the destination vehicle D than its neighbours. In this case, the GPSR protocol declares N as a local maximum to D. The perimeter forwarding mode, where the right-handle rule is used to find a perimeter around the line ND, and the packets are then forwarded from N along the path of the arrows. This forwarding may lead to wrong directions, and there are too many hops for the packet to be transmitted to the destination which can lead to the packet loss and delay.

This section shows the development of movement direction model in next-hop selection mechanism. We analyze the velocity vectors of candidate and the destination nodes. According to the next-hop selection design principles, it requires to comprehensively consider various performances in next-hop selection decision-making, so as to achieve performance balance of routing protocols in aspects of the packet delivery ratio and end-to-end delay. We present a movement direction model. It improves and optimizes the traditional GPSR protocol and mainly takes into account benefits of velocity vector and LET on next-hop selection. During the process of the greedy forwarding, a local maximum occurs, as shown in Fig. 1, the vehicle would not switch to perimeter routing, but firstly select a group of neighbor list based on the movement direction information. It means the node whose movement trend is most close to the destination is selected as a candidate node, and then we utilize the vector projection of each candidate next-hop into consideration to select the optimal next-hop node. Otherwise, we take into account the link reliability between each neighbor and the destination into consideration based on the LET information.

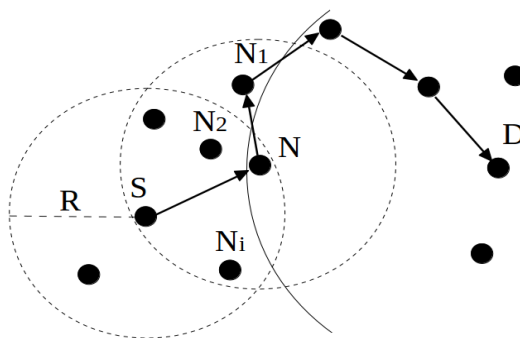


Fig. 1 The local maximum of GPSR

#### A. Assumption

To begin, the following is assumed to be reasonable. Each vehicle in the network can obtain the information of its own and that of neighbor. The vehicles are equipped with global positioning system (GPS) devices that can provide information about vehicle speed, direction, and position, are shown in Table 1. The destination’s information is added in the data packet header in order to be available at the source and neighboring vehicles as shown in Table 2.

TABLE 1

INFORMATION IN THE HELLO PACKET

ID	Position	Velocity vector	Speed	Time
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TABLE 2

INFORMATION IN THE DATA PACKET HEADER

ID	Mode	Source's information	Destination's information
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**B. Movement Direction Model**

Throughout this paper, we will denote  $N_i$  as a neighbor of the source node S for the next-hop forwarder, where  $i=1,2,\dots,n$  is the number of total neighboring nodes. D denotes the destination node.  $\vec{N}_i (V_{x_{N_i}}, V_{y_{N_i}})$  Denotes the velocity vector of node  $N_i$ , similarly,  $\vec{D} (V_{x_D}, V_{y_D})$  denotes the velocity vector of the destination node D.  $\phi_i$  denotes the angle between the movement direction of  $N_i$  and D.  $\phi_i$  and a scalar product of two vectors  $\vec{N}_i$  and  $\vec{D}$  can be calculated by Equations 1 and 2, respectively.

$$\cos(\phi_i) = \frac{\vec{N}_i \cdot \vec{D}}{|\vec{N}_i| |\vec{D}|} \tag{1}$$

$$\vec{N}_i \cdot \vec{D} = V_{x_{N_i}} V_{x_D} + V_{y_{N_i}} V_{y_D} \tag{2}$$

The vector projection of a vector  $N_i$  onto a non zero vector  $\vec{D}$  is a vector parallel to  $\vec{D}$  defined as  $\vec{OH}_i$ , Where  $|\vec{OH}_i|$  is a scalar, called the scalar projection of  $\vec{N}_i$  onto  $\vec{D}$  when  $\phi_i < \pi/2$ , that is defined as Equation 3.

$$|\vec{OH}_i| = \frac{\vec{N}_i \cdot \vec{D}}{|\vec{D}|} \tag{3}$$

According to Equations 1 and 3, when the neighboring node is moving in the direction of the destination  $\cos\phi_i > 0$ , Otherwise, the vehicle is moving in the opposite direction of the destination,  $\cos\phi_i < 0$ . Obviously, when the value of  $\cos\phi_i$  is larger, the scalar projection  $|\vec{OH}_i|$  is larger, as shown in Fig. 2.

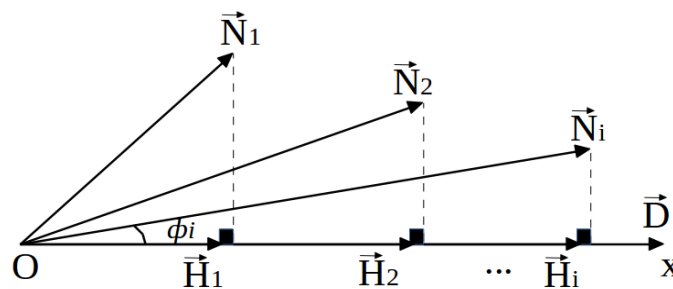


Fig. 2 Movement direction model

**C. Link Reliability Model**

LET is a function of time, it considers the position, velocity vector and speed for estimating the lifetime of communication between two nodes. As shown in Fig. 1, if we consider two nodes  $N_i$  and D with a transmission range of R, the predicted LET is obtained as Equation 4 [28].

$$LET = \sqrt{\frac{(a^2+c^2)R^2 - (ad-bc)^2 - (ab+cd)}{a^2+c^2}} \tag{4}$$

$$a = s_{N_i} \cos\theta_{N_i} - s_D \cos\theta_D \tag{5}$$

$$b = x_{N_i} - x_D \tag{6}$$

$$c = s_{N_i} \sin\theta_{N_i} - s_D \sin\theta_D \tag{7}$$

$$d = y_{N_i} - y_D \tag{8}$$

Where, respectively  $(x_{N_i}, y_{N_i}), s_{N_i}$ , and  $\theta_{N_i}$  denotes the position, speed, and movement direction angle with respect to x-axis of neighboring node  $N_i$ . Similarly,  $(x_D, y_D), s_D$ , and  $\theta_D$  denotes the position, speed, and movement direction angle with respect to x-axis of the destination node D.

**D. Next-hop Selection Algorithm**

In this subsection, the proposed next-hop selection algorithm based on the above movement direction and link-reliability model is described. The algorithm is designed by considering the following two cases of recovery models.

In case 1, when neighboring nodes are moving in the direction of the destination, according to movement direction angle of each arriving neighboring node and the destination node ranges in  $[0, \pi/2[$ , ( $\cos\phi_i > 0$ , according to Equation 1). The neighboring node which has the highest scalar projection and movestoward to the destination, is selected as an optimal next-hop to forward the data packet from the source node to the destination, as shown in Fig. 2.

In case 2, when the movement direction angle between the neighboring nodes and destination node ranges in  $[\pi/2, \pi[$ , ( $\cos\phi_i \leq 0$ ). In this case, we take the link-reliability of each neighbor and the destination node into consideration. The

selection of the best link reliability is made based on the longest lifetime of communication between two nodes. Another key concept is, when a local maximum occurs, all of the neighbors are moving in the opposite or orthogonal direction of the destination, the neighboring node which has the highest value of LET takes the highest priority to be an optimal next-hop node.

Now, let us turn our attention back to the local maximum of GPSR. In Fig. 1, for each neighboring node  $N_i$  we let the scalar projection of  $\vec{N}_i$  onto a nonzero vector  $\vec{D}$  be  $|\overrightarrow{OH}_i|$ , if we choose  $N_i$  as the next-hop forwarder, and the estimation values of  $|\overrightarrow{OH}_i|$  will be obtained. Let node  $N_i$  has the highest value of  $|\overrightarrow{OH}_i|$  among the  $n$  (the total number of neighboring nodes) values. Then, node  $N_i$  will be selected to be the next-hop forwarder and the packets will be forwarded to it. The packet relaying will be repeated hop by hop according to the above process until the data packets will reach the destination. The detailed next-hop selection algorithm of the proposed is given in Algorithm 1. This technique allows an decrease of delivered delay to the destination. Because the packets doesn't attempts to route along the perimeter of the local maximum region that may lead to wrong directions.

**Algorithm 1** Next-hop selection algorithm

```

 $|\overrightarrow{OH}_0| \leftarrow$  the initial value of scalar projection
 $LET_0 \leftarrow$  the initial value of LET
next-hop  $\leftarrow -1$ 
while  $N_i$  do
    /*  $N_i$  the candidate node i
    /* whereas  $i=1,2,\dots,n$  is the number of total neighboring nodes
     $|\overrightarrow{OH}_i| \leftarrow$  the scalar projection of  $\vec{N}_i$  onto  $\vec{D}$ 
     $LET_i \leftarrow$  LET between the candidate node  $N_i$  and destination D
    if  $\vec{N}_i \cdot \vec{D} > 0$  then
        /* the candidate node  $N_i$  moves in the direction of the destination D
        if  $|\overrightarrow{OH}_0| < |\overrightarrow{OH}_i|$  then
             $|\overrightarrow{OH}_0| \leftarrow |\overrightarrow{OH}_i|$ 
            /* loop to find the candidate node with the highest scalar projection
            next-hop  $\leftarrow N_i$ 
        end if
    else if  $LET_0 < LET_i$  then
         $LET_0 \leftarrow LET_i$ 
        next-hop  $\leftarrow N_i$ 
    end if
end while
return next-hop
    
```

**IV. SIMULATION SET UP AND RESULTS**

*A. Simulation Set up*

To determine the performance of the proposed algorithm, we carried out simulations in NS-2 of version 2.35 [11]. We simulated the protocols in a 1500 m x 1500 m rectangle scenario that is generated by the vehicular mobility model generator VanetMobiSim [10], an open source program which can generate more realistic vehicular mobility for NS-2. Vehicles move according to the intelligent driver model with lane changing model support smart intersection management: they slow down and stop at intersections, or act according to traffic lights, if present. Also, vehicles are able to change lane and perform over takings in presence of multi-lane roads. The propagation model used in the simulation is the Two-way Ground model and transmission range of each vehicle is set to 250 m. There are 75 to 135 vehicles randomly distributed initially on the roads. Once the simulation begins, each vehicle moves at a speed ranging from 5 to 10, 15, 20, and 25 m/s. The simulation parameters are summarized in Table 3.

TABLE 3  
SIMULATION PARAMETERS

Parameters	Specifications
Simulation area	1500 m x 1500 m
Transmission range	250 m
Number of nodes	75, 95, 115, 135
Transport protocol	Transmission Control Protocol (TCP)
Simulation time	250 s
Maximum Speed of nodes	10, 15, 20 and 25 m/s

*B. Simulation Results*



This section presents simulation results and describes our observations. We compared the performance of the proposed algorithm to MOPR [23], EOA [24], and GPSR [6]. We conducted extensive simulations based on impacts of vehicular traces with the following performance metrics [3]:

- the packet delivery ratio represents the ratio of the packets delivered to the destinations to those generated by the sources.
- the average end-to-end delay is defined as the average amount of time spent by the transmission of a packet that is successfully delivered from the source to the destination.

1) *Impact of Number of Nodes:*

Fig. 3 shows the packet delivery ratio for varying the number of vehicles with maximum speed 15 m/s. An increase in the number of vehicles slightly decreases the packet delivery ratio. The decrease comes from the fact that the routing topology becomes more dense and unstable when network density increases which makes the network connectivity unstable. Since, EOA metric incorporates the geographic distance and link-reliability and MOPR determines the most stable link-reliability in terms of communication lifetime by selecting the most stable optimal next-hop, which are more successful to deliver the data packets to the destination than the traditional greedy forwarding. Thus, the packet delivery ratio achieved by EOA and MOPR is higher than GPSR. We note that the packet delivery ratio of the proposed approach outperforms MOPR, EOA, and GPSR, which successfully deliver approximately 81.38% of the data packets, while MOPR, EOA and GPSR deliver approximately 72.86%, 72.24% and 69.22%. This is because, the optimal next-hop selection in the proposed approach takes into account the movement direction model to avoid the forwarding of a packet to a wrong next-hop vehicle, which could result in the loss of the data packets. Otherwise, it recovers the local maximum situation with higher LET, compared with that based on the link-reliability and perimeter recovery mode in the EOA, MOPR, and GPSR.

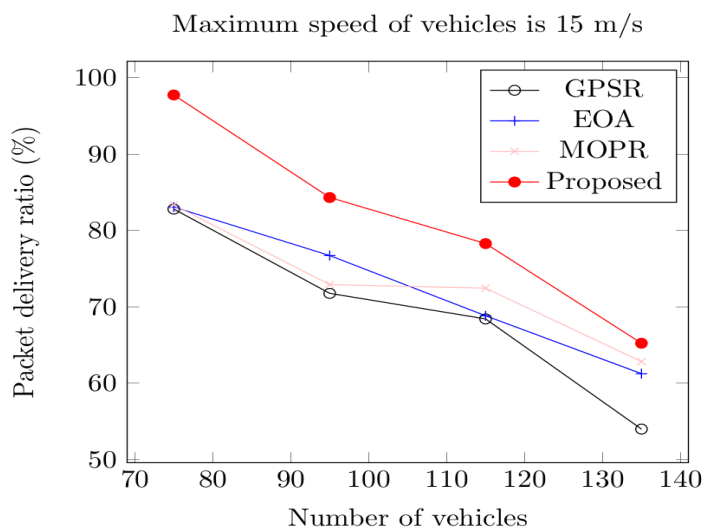


Fig. 3 Packet delivery ratio with different number of vehicles.

Fig. 4 shows the average end-to-end delay for varying the number of vehicles with maximum speed 15 m/s. An increase in network density increases the chances to meet an appropriate next-hop and decreases the distance of vehicles in which the packet delay should be reduced from the source to destination vehicles. Thus, the average end-to-end delay of GPSR and proposed decreases with an increase in the numbers of vehicles. On the contrary, when the density of vehicles is sparse, the connectivity of the network topology affects the end-to-end delay. Thus, if the number of vehicles increases from 75 to 95, the average end-to-end delay quickly increases for EOA and MOPR. In the proposed scheme, the selection process takes less time to find the optimal next-hop, by considering the vehicle which moves toward to the destination, thus, the packet takes less time to reach the destination vehicle, it shows lower average end-to-end delay values than others. Compared with the EOA, MOPR, and GPSR, the proposed decreases the average end-to-end delay by 48.14%, 51.13%, and 54.60% on average, respectively.

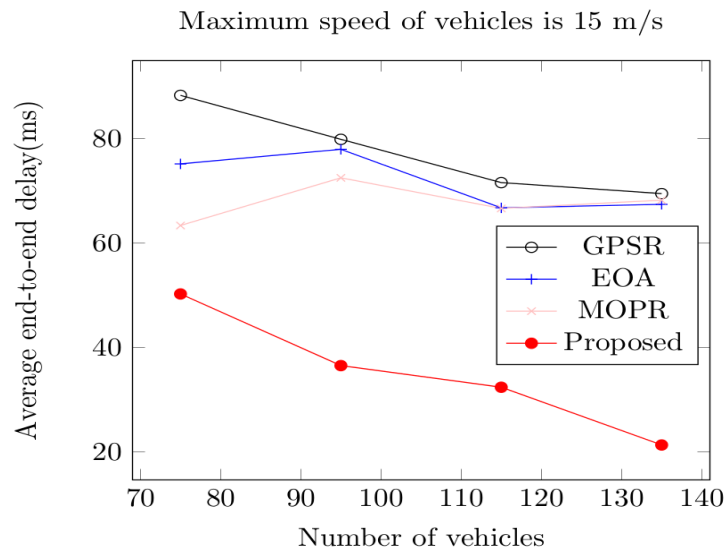


Fig. 4 Average end-to-end delay with different number of vehicles.

2) Impact of Maximum Speed of Vehicles:

In Figs. 5 and 6 we study the impact of maximum speed of vehicles. Fig. 5 shows the performance of the packet delivery ratio for varying maximum speed of vehicles. The packet delivery ratio increases for all the three routing protocols: EOA, MOPR, and GPSR because an increase in the maximum speed of vehicles resulting in an increase in the opportunities for the data packets to find out the optimal next-hop and improves the connectivity of network, which reduces the packet loss. GPSR selects the next-hop only by a simple greedy forwarding technique with the geographic distance based on the position information; thus, a data packet may enter a local maximum and recover through a link with poor quality, resulting in low packet delivery ratio. Compared with the EOA, MOPR and GPSR, the proposed considers the link-reliability based on the velocity vector and LET information to select the optimal next-hop when a local maximum occurs, which outperforms the other routing protocols. On average, the proposed increases the packet delivery ratio by 14.66%, 14.99%, and 15.96%, respectively.

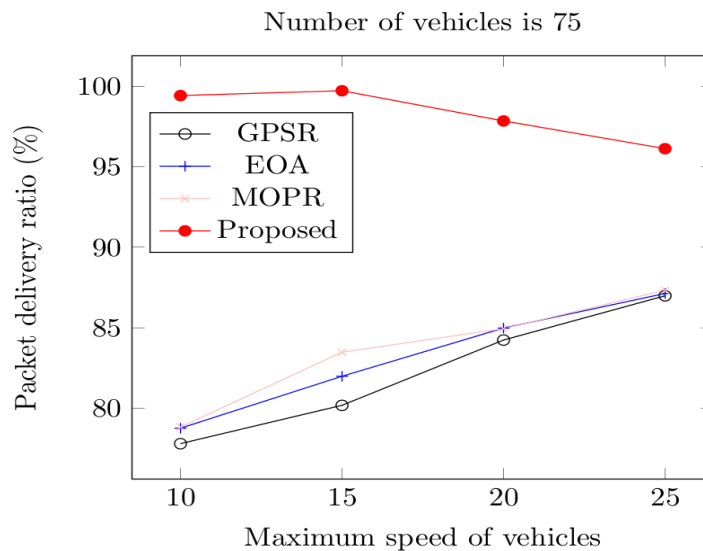


Fig. 5 Packet delivery ratio with different maximum speed of vehicles.

As can be seen from the results shown in Fig. 6, the average end-to-end delay performance of EOA, MOPR, and GPSR dramatically increases, with respect to maximum speed of vehicles increases to 25 m/s. This is due to the highly dynamic network topology and frequent changes cause of a high packet delay and disconnection issues. It is observed that when the maximum speed is 25 m/s, for EOA, MOPR, and GPSR, the end-to-end delay reaches over 175 ms, 172 ms, and 200 ms; in contrast, for the proposed, the delay nearly stays to 70 ms. The proposed shows less end-to-end delay by forwarding the data packet through the optimal next-hop selection based on movement direction model which has high link-reliability. Compared with EOA, MOPR, and GPSR, the proposed algorithm decreases the average end-to-end delay by 43.02%, 48.96%, and 59.42% on average, respectively.

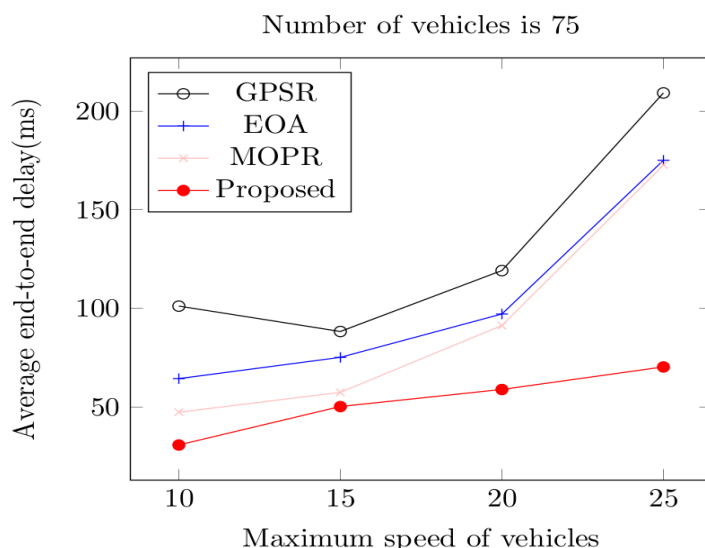


Fig. 6 Average end-to-end delay with different maximum speed of vehicles.

## V. CONCLUSIONS

In this paper, We incorporated the movement direction model and link reliability based on velocity vectors and speeds of vehicles. To recover the local maximum and enhance the performance of the GPSR routing protocol, we take the benefit of a scalar product and scalar projection, which considers the candidate node that moves toward to the destination. Otherwise, we use the link-reliability, which considers the candidate node that has the highest value of LET. Finally, we investigated a comprehensive set of effecting factors, such as number and maximum speed of nodes to compare the proposed approach and existing algorithms. The simulation results reveal that the proposed approach can achieve a better performance in terms of the packet delivery ratio, with an increase of 11.59%, 12.06%, and 14.59%, compared to EOA, MOPR, and GPSR. In the case of average end-to-end delay, the proposed approach performed best and is, 45.85%, 50.05%, and 57.01% lower than EOA, MOPR, and GPSR. Although the proposed algorithm performs better than the other existing algorithms under many configurations, the proposed model is useful only for best effort services in sparse scenarios. In the future work, we will aim to consider the high density network topology to further improve the packet delivery.

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