An Improved GPSR on Similarity Models in Vehicular Networks

Vongpasith Phouthone[a,b,1], Zhu Xiao[a,b,2], Dong Wang[a,3,*], Vincent Havyarimanag[a,c,4]

[a]College of Computer Science and Electronic Engineering, Hunan University, Changsha, 410082, China
[b]State Key Laboratory of Integrated Services Networks, Xidian University, Xi'an, 710071, China
[c]Department of Applied Sciences, Ecole Narmale Superieure, 6983, Bujumbura, Burundi

Abstract — *Due to the highly dynamic network topology of vehicular ad hoc networks (VANETs), using the simple greedy forwarding based only on the position information to select the closest next-hop which may not move toward to the destination vehicle. Thus, the greedy-perimeter stateless routing (GPSR) routing protocol may miss out on some suitable next-hop vehicles to forward a data packet. In this paper, we propose a next-hop selection algorithm for improvement of the GPSR routing. The concept of cosine similarity and speed similarity is adopted, which take into account the the velocity vector and speed information of vehicles into consideration. The vehicle with largest similarity value is chosen as the suitable next-hop to forward a data packet. The performance of the proposed algorithm by simulation demonstrates significant increases of packet delivery ratio and reductions of average end-to-end delay compared to the traditional GPSR routing protocol.*

Keywords — *GPSR, Next-hop selection, Similarity, VANETs.*

I. Introduction

The wireless communication in vehicular ad hoc networks (VANETs) takes place through wireless links mounted on each vehicle [1]. The vehicles communicate through other neighboring vehicle on the road, that lies within their own transmission range [2]. The VANET mobility is restrained by traffic policies, such as traffic light signals, speed constraints, and traffic conditions [3]. The basic target of VANETs is to increase safety of road users and comfort of passengers. In VANETs, the vehicles may join or leave within one another transmission ranges abruptly or gradually [4], the established wireless links between the vehicles may break [5]. As a result of these characteristics, the challenges and performance of VANET routing protocols will become more serious and could be greatly affected.

In VANETs, the routing strategy is to select an appropriate next-hop vehicle, as which is essential entity for delivering of the data packets from the source to the destination. Therefore, the performance of routing relies on the most suitable next-hop selection strategies for data delivery among vehicles [6]. Greedy-Perimeter Stateless Routing (GPSR) [7] 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. To select a next-hop, 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 [8] but moving in the opposite direction of the destination node. Therefore, it may miss out on some suitable candidates to forward a packet. Moreover, [9] the greedy forwarding may encounter the local maximum problem, where the current forwarder is closer to the destination than all its neighbors and the destination still not reachable by one hop communication [10], [11]. To recover the local maximum situation, GPSR uses perimeter forwarding [1] to search routes at the boundary in a clockwise direction [7]. In VANETs, with perimeter techniques, 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.

In this paper we propose a next-hop selection algorithm by considering the velocity vector and speed of vehicles. First, we consider the neighboring vehicles that have a higher cosine similarity to the destination vehicle. Otherwise, we take into account the speed similarity between each neighbor and the destination into consideration. We have performed extensive simulation based on VANET scenarios generated by VanetMobiSim [12] as the input to the proposed algorithm based on NS-2 network simulator [13]. We have studied the impact of important factors such as number of vehicles and maximum speed of vehicles for comparing the performance with those of the existing geographic routing algorithms. Simulation results clearly show that the proposed can significantly enhance the packet delivery ratio, reduce end-to-end delay.

The remainder of this paper is organized as follows. Related work is reviewed in Section 2. Section 3 introduces the proposed next-hop selection algorithm. Then, the simulation set up and results are shown in Section 4. Finally, we conclude the paper in Section 5.

II. Related Work

GPSR is a position based routing protocol, nodes do not find route before sending data and routing table are not saved. The mobile node makes packet forwarding decision directly according to itself, the position information of the neighbor and destination node is added in the hello packet and data packet header. When a source receives a data packet, first it uses the greedy forwarding. If the greedy forwarding fails, it will switch to perimeter forwarding. 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 [14]. During the process of the greedy forwarding, a local maximum occurs, the node 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 node at which the routing entered into perimeter forwarding, the node would resume the greedy forwarding of the received a packet [15]. However, GPSR uses only the position information to consider the next-hop selection for forwarding of the data packets [7]. The perimeter strategy is inefficient and time consuming especially given the highly dynamic nature of VANETs [11]. The routing with perimeter 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.

The GPSR routing protocol has been improved in [4], [16], [17], [18]. In [19], the current position, speed, and direction information are used to predict the future positions of the neighboring vehicles before to forward a packet. In [17], when constructing a route from the source to the destination, the link with reliability factor greater than a given threshold alone is selected as a next-hop neighbor. The performance in term of packet delivery ratio is significantly improved; however the delay slightly increases as compared to the conventional GPSR. Due to the potentially large number of neighbors, a next-hop selection scheme in [20] uses the optimal stopping theory to choose a suitable next-hop, while in [21] and [22] uses the future position of each neighbor and then selects neighboring node nearest to the next intersection based on predictive location. In movement prediction based routing [23], before selecting of a next-hop each node estimates the link-reliability in its transmission range based on the movement information such as velocity and direction. Then, it will select the next-hop with the highest the link reliability to forward a data packet. However, as the node does not know the real location of the target node, it is impossible for it to evaluate the prediction error. 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. Since the ETX metric depends highly on the value of the hello interval and window size [24]. 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 neighboring nodes is studied. However, the performance of the proposed protocol is better in some situations [26]. The simplest next-hop selection strategy is to select a neighbor node with the highest geographical progress toward the destination vehicle as a next-hop [27]. Thereby reducing the time delay as well as the packet loss which caused by bigger waiting time than the retransmission delay [18]. The various algorithms are improved the performance of the GPSR routing in VANETs, by considering the information not only position but speed and direction of vehicles for selecting of the next-hop forwarder and recovering of the local maximum problem. In this paper, we will propose a next-hop selection algorithm using similarity models based on velocity vectors and speeds of vehicles to improve the performance of the GPSR routing protocol in VANETs.

III. Next-hop Selection Algorithm

To design a next-hop selection algorithm, by which the source node could select the appropriate neighboring node as its next-hop. This process continues until the destination node receives the data packets. In Fig. 1, assume that the source node S wants to send a data packet to the destination node D, and D is outside of the transmission range of S. We define $N=\{N_i/i=1,2,\ldots,n\}$, as a neighboring node set of node S, n is the number of total neighboring nodes of sender node S. The source S selects the appropriate neighboring node N_i via the next-hop selection algorithm that is expected to be the optimal next-hop among all the neighboring nodes between source and destination to deliver data packets. The process repeats until the data packet reaches the destination D.

To be reasonable in vehicular networks, we assume that 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 velocity vector and speed information, as 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.

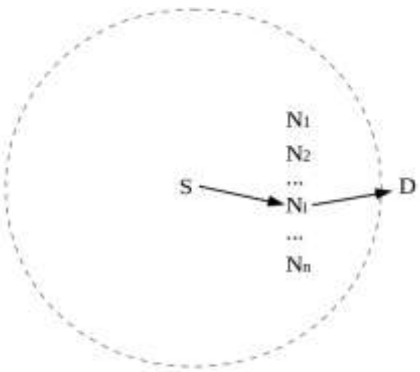

Fig. 1 The next-hop selection process

TABLE I
INFORMATION IN THE HELLO PACKET

ID	Velocity vector	Speed

TABLE II
INFORMATION IN THE DATA PACKET HEADER

ID	Mode	Source's information	Destination's information

A. Cosine Similarity Model

Cosine similarity model is the best metric which is used frequently when trying to determine similarity between two velocity vectors of nodes. By determining the cosine similarity, the angle between the two velocity vectors of nodes is considered. For cosine similarities resulting in a value of ranges in [-1, 0], the velocity vectors nodes do not share any similarities (the nodes move in opposite directions) because the angle between the velocity vectors of noses is larger or equal to 90 degrees. Otherwise, the direction (velocity vectors) of nodes are similar.

$$\cos(\vec{N}_i,\vec{D})=\frac{\vec{N}_i.\vec{D}}{|\vec{N}_i||\vec{D}|} \quad (1)$$

Where

$$\acute{N}_i.\acute{D}=vx_{N_i}.vx_D+vy_{N_i}.vy_D \quad (2)$$

$$|\vec{N}_i|=\sqrt{x_{N_i}{}^2+vy_{N_i}{}^2} \quad (3)$$

$$|\vec{D}|=\sqrt{x_D{}^2+vy_D{}^2} \quad (4)$$

Given a set of nieghboring nodes $N=\{N_i/i=1,2,...,n\}$, n is the number of total neighboring nodes of sender node S. D denotes the destination node. $\vec{N}_i(vx_{N_i},vy_{N_i})$ and s_{N_i} denote the velocity vector and speed of nieghboring node N_i , similarly, $\vec{D}(vx_D,vy_D)$ and s_D denote the velocity vector and speed of the destination node D. The cosine similarity of two vectors $\vec{N}_i$ and $\vec{D}$ can be calculated by Equation (1).

B. Speed Similarity Model

The speed similarity metric is the most suited technique to measures the speed between two vehicular nodes. The speed similarity between two vehicular nodes N_i and D can be evaluated as

$$S_{Speed}(N_i,D)=1-\frac{|s_{N_i}-s_D|}{\rho} \quad (5)$$

When $\rho > |s_{N_i} - s_D|$, Otherwise

$$S_{Speed}(N_i, D) = 0 \quad (6)$$

Where ρ is speed similarity threshold value

C. Next-hop Selection Algorithm

In this subsection, the proposed next-hop selection algorithm based on the cosine similarity and speed similarity models is described. The algorithm is designed by considering the following cases.

In case 1, the neighboring nodes are moving in the direction of the destination, according to cosine similarity of each arriving neighboring node and the destination node ranges in]0, 1]. The neighboring node which has the highest cosine similarity value (the neighboring node which has the most similar velocity vector to the destination), is selected as a next-hop to forward the data packet from the source to the destination node.

In case 2, when the neighboring nodes are moving in the opposite direction of the destination, the cosine similarity of each arriving neighboring node and the destination node ranges in [-1, 0]. In this case, we take the speed similarity of each neighbor and the destination node into consideration. The selection of the best speed similarity is made based on the longest speed similarity of each neighbor and the destination node. Another key concept is, the neighboring node which has the highest value of speed similarity takes the highest priority to be a next-hop node. The packet forwarding will be repeated hop by hop according to the above process until the data packets will reach the destination. The detail of the proposed next-hop selection algorithm is given in Algorithm 1.

Algorithm 1 next-hop selection algorithm

1. $\cos(\vec{S}, \vec{D})$ ← the initial value of cosine similarity
2. Sspeed(S,D) ← the initial value of speed similarity
3. next-hop ← −1
4. **while** N_i **do**
5. /* N_i ← the neighboring node i (i = 1, 2, .., n, where n is the number of total neighboring nodes) */
6. $\cos(\vec{N}_i, \vec{D})$ ← cosine similarity of $\vec{N}_i$ and $\vec{D}$
7. Sspeed(N_i , D) ← speed similarity between the neighboring node N_i and destination D
8. **if** $\cos(\vec{N}_i, \vec{D})$ > 0 **then**
9. /* the neighboring node N_i moves in the direction of the destination D (velocity vectors of N_i and D are similar) */
10. **if** $\cos(\vec{S}, \vec{D})$ < $\cos(\vec{N}_i, \vec{D})$ **then**
11. $\cos(\vec{S}, \vec{D})$ ← $\cos(\vec{N}_i, \vec{D})$
12. /* loop to find the neighboring node with the highest cosine similarity (find the most similar velocity vectors of neighboring node and the destination) */
13. next-hop ← N_i
14. **end if**
15. **else if** Sspeed(S, D) < Sspeed(N_i , D) **then**
16. Sspeed(S, D) ← Sspeed (N_i , D)
17. /* loop to find the neighboring node with the highest speed similarity (find the most similar speed of neighboring node and the destination) */
18. next-hop ← N_i
19. **end if**
20. **end while**
21. **return** next-hop

IV. Simulation Set Up and Results

A. Simulation Set Up

All simulations have been done on two tools; a traffic simulator VanetMobisim and a network simulator NS-2 which both are open source platform. In VanetMobiSim simulation, the scene size is 1500 m x 1500 m with bidirectional road scenario. In the total area there are 4 traffic lights and 75 to 135 vehicular nodes randomly distributed initially in the roads. Once the simulation begins, each node moves at a speed ranging from 5 to 10, 15, 20, and 25 m/s along a path towards a randomly chosen destination. The instantaneous speed of a node depends on nearby cars. To simulate nodes motion using the Intelligent Driver Model with Lane Changing (IDM_LC). We have also considered the network simulation area of 1500 m x 1500 m in NS-2, each source node sends packets at the rate of 1 Mbps with a packet size of 512 bytes. The propagation model used in the simulation is the two-ray ground model and the transmission range of each node is set to 250 m. We set the value of the hello interval as 0.5 s and the window size as 10 s. The simulation parameters for the network simulation are shown in Table 3. In order to understand the effect of the performance of the protocols we varying number of nodes and maximum speed of nodes on the various efficiency metrics, especially packet delivery ratio and average end-to-end delay of the routing protocols.

TABLE III
Simulation Parameters

Parameters	Specification
Simulation area	1500 m × 1500 m
Transmission range	250 m
Number of Vehicles	75, 95, 115, 135
Transport protocol	TCP
Simulation time	250 s
Maximum Speed	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 EOA [24], and GPSR [7]. We conducted extensive simulations based on impacts of vehicular traces with the following performance metrics [28].

- 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 Vehicles

Fig. 2 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 which is more successful to deliver the data packets to the destination. According to the greedy forwarding in GPSR, the neighboring nodes are likely to be on the edge of the transmission range of the source node, and a slight move can lead to a link break. Thus, the packet delivery ratio achieved by EOA is higher than GPSR. We note that the packet delivery ratio of the proposed approach outperforms EOA and GPSR, which successfully deliver approximately 81.45% of the data packets, while EOA and GPSR deliver approximately 72.44% and 69.22%, respectively. This is because, the proposed approach takes into account the similarity models, which could result in the success of the data packets delivery.

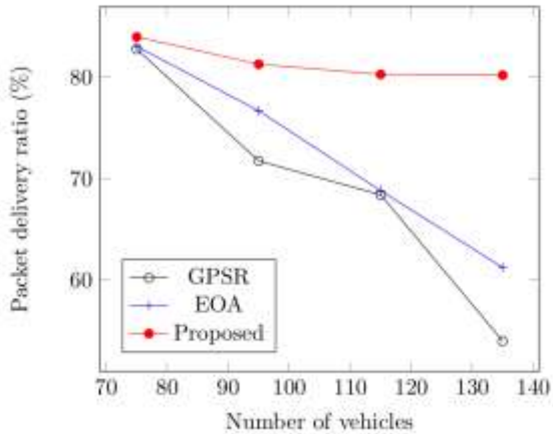

Fig. 2 Packet delivery ratio with different number of vehicles.

Fig. 3 shows the average end-to-end delay for varying the number of vehicles with maximum speed 15 m/s. The average end-to-end delay decreases with an increase in the numbers of vehicles. The reason is an increase in network density decreases the distance of vehicles in which the packet delay should be reduced from the source to destination. 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 begins from 75, the average end-to-end delay is higher for GPSR. EOA achieves lower average end-to-end delay than GPSR. This is mainly because that EOA tends to select a link with higher quality to forward the packet. In GPSR, greedy forwarding takes more time to find the optimal next-hop that is closest to the destination, result in the delay. In the proposed scheme, the selection process takes less time to forward the data packets, by considering the vehicle which has the speed similarity to the destination, thus, the packet takes less time to reach the destination vehicle, it shows lower average end-to-end delay values than EOA and GPSR by 24.90%, and 30.23% on average, respectively.

2) Impact of Maximum speed of Vehicles

In Figs. 4 and 5 we study the impact of maximum speed of vehicles. Fig. 4 shows the performance of the packet delivery ratio for varying maximum speed of vehicles. The packet delivery ratio increases by increasing of the speed, due to an increase in the opportunities for forwarding of the data packets to the destination, which reduces the packet loss. The greedy forwarding technique based on the position information; 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 and GPSR, the proposed algorithm considers the similarity based on the velocity vector and speed information to recover a local maximum situation, which increases the packet delivery ratio by 3.91% and 4.96%, on average, respectively.

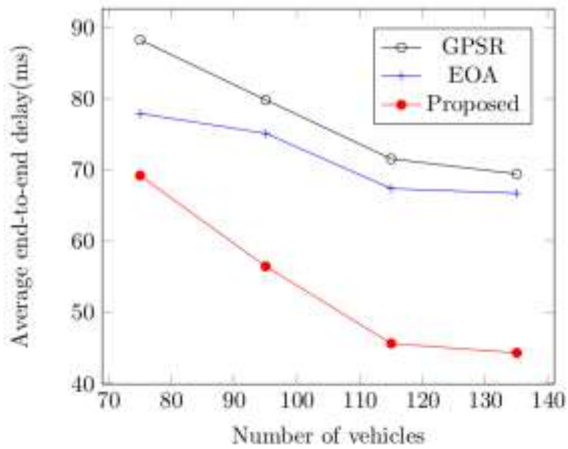

Fig. 3 Average end-to-end delay with different number of vehicles.

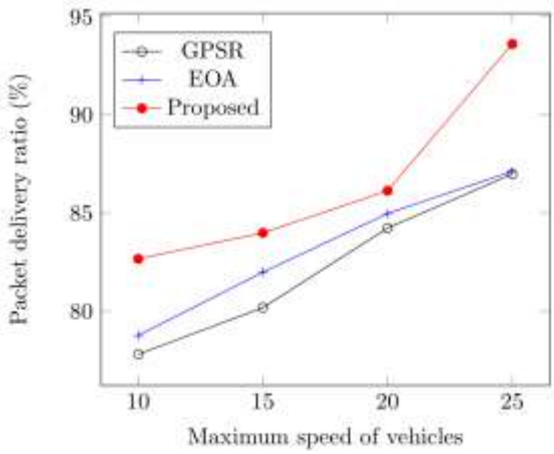

Fig. 4 Packet delivery ratio with maximum speed of vehicles.

As can be seen from the results shown in Fig. 5, the average end-to-end delay performance of EOA 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 and GPSR, the end-to-end delay reaches over 175 ms and 200 ms; in contrast, for the proposed strategies, the delay nearly stays to 80 ms. The proposed shows less end-to-end delay by forwarding the data packet through the next-hop selection algorithm based on similarity models. Compared with EOA and GPSR, the proposed algorithm decreases the average end-to-end delay by 42.13% and 53.08% on average, respectively.

V. Conclusions

In this paper, we proposed the similarity models based on velocity vectors and speeds of vehicles. To enhance the performance of the GPSR routing protocol, we take the benefit of the cosine similarity

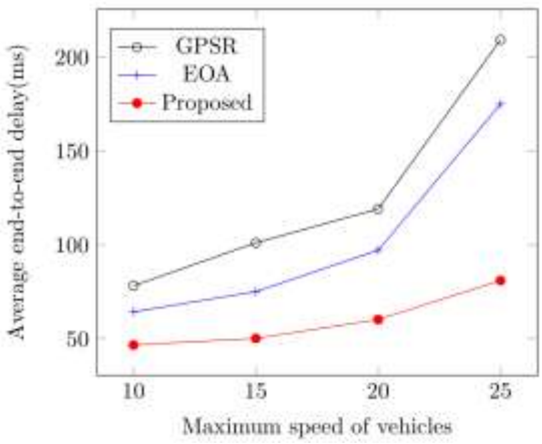

Fig. 5 Average end-to-end dealy with maximum speed of vehicles.

and speed similarity of vehicles into considering of the next-hop selection algorithm. We investigated the number of nodes and maximum speed of nodes as the effecting factors for comparing of the proposed approach and existing algorithms. The simulation results reveal that the proposed approach can achieve a better performance in term of the packet delivery ratio, with an increase of 11.59%, 7.48%, and 9.98%, compared to EOA and GPSR. In the case of average end-to-end delay, the proposed approach performed best and is, 33.51% and 41.65% lower than EOA and GPSR. In the future, we plan to investigate the other effecting factors to make the next-hop selection algorithm more efficient.

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