Density, Speed and Direction Aware GPSR Protocol for VANETs

Amina Bengag, Asmae Bengag, and Mohamed Elboukhari

Abstract Vehicular Ad Hoc Networks (VANETs) comprises vehicles equipped with wireless transceivers. These vehicles could exchange information directly via vehicle-to-vehicle communication (V2V) without the need of implementing any pre-existing infrastructure. However, Routing in VANET network is not the same as routing in Mobile Ad hoc Network (MANET), due to the specific features of VANET like the high dynamic topology caused by the high speed of vehicles. Hence, many VANET routing schemes have already been proposed, but they are not efficient in terms of Packet Delivery Rate (PDR) and throughput or they have a high routing overhead. In this paper, a new position-based routing for VANET has been proposed that is efficient in terms of PDR, throughput and has low overhead. Moreover, the proposed protocol named DVA-GPSR is based upon the classical GPSR routing by taking into account three new metrics in addition to the position of vehicles. Proper vehicle could be selected as a relaying node based on a weight function that includes the proposed metrics, like the angle direction and the speed variation between the sender and the receiver, the density of the next hop and the current location of the destination vehicle. Simulation studies prove that the proposed protocol maximizes the throughput, increases the PDR and decreases routing overhead.

Keywords VANET · Routing protocol · GPSR · DVA-GPSR · Angle direction · Speed · Density · Position-based routing

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A. Bengag (✉) · A. Bengag · M. Elboukhari
MATSI Laboratory, ESTO, University Mohamed 1er Oujda, Oujda, Morocco
e-mail: bengag.amina@gmail.com

A. Bengag
e-mail: asmaebengag@gmail.com

M. Elboukhari
e-mail: elboukharimohamed@gmail.com

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1 Introduction

VANETs consist of a set of intelligent vehicles equipped with an on-board unit (OBU) to exchange information directly with other vehicles by using vehicle-to-vehicle communication (V2V) or via vehicle-to-infrastructure communication (V2I) by using roadside units installed on roads. However, the communication in VANETS that is ensured by routing protocol still suffer from many issues due to the unique features of vehicular networks like the frequently link breakage caused by the high speed of vehicles. Hence, a huge number of researchers have taken a big attention on developing a new enhanced routing protocol that take into account all VAENTs features.

According to [1], we can split routing protocols in VANETs into four categories in case of V2V communication. The category of routing protocols based on the position of vehicles is one of the most widely discussed and used in case of VANETs scenarios thanks to their high packet delivery rate and less control overhead [2, 3]. In the literature, many routing protocols based on GPSR have been proposed like MV-GPSR, E-GPSR and GPSR-2P [4–6]. In this paper, we suggest a novel routing protocol based on the position of vehicles by taking into consideration some new metrics that enhance the efficiency of our protocol. These metrics are the density, the variation speed the angle direction and the distance between the target node and all neighbors of the source node. This routing protocol called Density-Velocity-Aware-GPSR (DVA-GPSR) based on the classical GPSR protocol proves its efficiency in terms of PDR, average throughput and routing overhead in the network in the proposed highway scenario.

The organization of our paper is as follows. The traditional GPSR routing protocol is presented in Sect. 2; in Sect. 3, we describe the novel strategy that enhance the classical GPSR for VANET and its benefits. Section 4 clarifies the performance evaluation of DVA-GPSR that will be compared to the classical GPSR. The conclusion and some future works will be presented in Sect. 5.

2 Overview of the Classical GPSR Routing

GPSR [7] is the most well-known routing protocol based on the position of vehicles. Basically, a source vehicle in GPSR utilizes two techniques for transmitting data packets. The greedy forwarding technique, by transmitting data to the vehicle that has the shortest distance from the destination or the perimeter forwarding technique. In fact, when the source node has no neighbor near to the target node than itself (local maximum problem) the greedy forwarding approach fails. Hence, the perimeter forwarding technique will be applied that is based on the right hand rule.

The original GPSR is based only on the location information to select the next relaying hop that could lead to a wrong decision. Additionally, by applying the greedy forwarding technique the number of hops from source to the target node will be reduced. However, this procedure ignores the quality of the connection link. Moreover, for each link failure a novel route has to be regenerated consequently the transmission process will be postponed until another relaying node is found. As a result, the routing overhead will be dramatically increased that decreases the PDR and throughput.

3 DVA-GPSR Routing Protocol

Our proposed routing protocol adopts that all vehicles in VANET are equipped with a GPS device to get the accurate position of vehicles, and with wireless transceivers for exchanging traffic route information. The proposed protocol named DVA-GPSR is based upon the classical GPSR routing by taking into account three other parameters in addition to the position of vehicles. The next paragraph describes each metric, the formula to calculate it and its benefits.

3.1 Next-Hop Selection Procedure

The process of selecting the next relaying node is very important and is composed of three steps. The first step applied by the source node, by gathering the mobility parameters: the location and the velocity of its neighbors. The second step is using the gathered parameters to calculate the angle direction (Fig. 1), the speed variation between the sender and the receiver in addition to the number of neighbors of the current node. The calculation process is explained below:

1. To calculate the angle direction φ between each next hop candidates and the destination node, we use the following formula (1).

$$\varphi_{AB} = cos^{-1} \frac{((AVelocity.x * BVelocity.x) + (AVelocity.y * BVelocity.y))}{\left(\sqrt{(AVelocity.x^2 + BVelocity.x^2)} * \sqrt{(AVelocity.y^2 + BVelocity.y^2)}\right)} \quad (1)$$

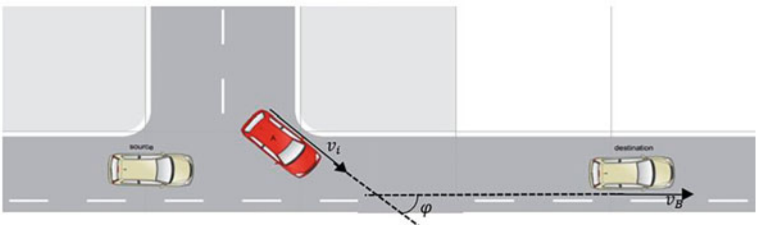

Fig. 1 The angle direction φ

In the formula (1):

- AVelocity is the velocity of the next hop candidate
- BVelocity is the velocity of the destination.

The rational between the concepts of the angle direction is to maintain the connection between vehicles as long as possible by choosing the small value of all calculated φ_{id}.

2. To calculate the distance between the node that has the transmitted packet and the target node, we use formula (2).

$$D_{AB} = \sqrt{(y_A - y_B)^2 + (x_A - x_B)^2} \tag{2}$$

In the formula (2):

- The pair (x_A, y_A) designates the neighbor vehicle position called A
- The pair (x_B, y_B) means the position of the target node.

3. To calculate the speed variation, we use formula (3).

$$S_{AB} = |S_A - S_B| \tag{3}$$

In formula (3):

- S_A is the neighbor node speed called A
- S_B signifies the speed of the target node.

4. The third step consists in using the beforehand calculated metrics to formulate a weighted function (4). This function will be used to specify the link weight for every neighbor of the current node that has the transmitted packet.

$$LWF = \alpha * D_{id} + \beta * \left(\frac{1}{density_i}\right) + \theta * S_{id} + \gamma * \varphi_{id} \tag{4}$$

In formula (4):

- $density_i$ is the number of neighbors for the next hop candidate i. this metrics will be used to determine the connectivity mode in each path.
- α, β, θ and γ are the weighting factors for each metrics.
- $\alpha + \beta + \theta + \gamma = 1$.

3.2 *The Benefits of DVA-GPSR*

The problem of local maximum mentioned in the previous section, occurs in most of cases by applying the classical GPSR caused by the void area issue or the high speed of vehicles. In fact, in our proposed routing we take into consideration the density parameter in the next hop selection process. By implicating this parameter, the vehicle that has the high density (high number of neighbors) increases the probability of being chosen as a relaying node, hence the void area problem will be reduced.

The issue of link breakage caused by the high speed is resolved in DVA-GPSR, by using the variation speed calculated previously in the process of selecting the next hop. Therefore, vehicle that has almost the same speed as the destination will be selected as a next hop that enhance the connection lifetime. Moreover, this technique ensure a longest possible duration of communication between vehicles. Hence, the current vehicle will choose the neighbor that has the lowest value of link weight function (LWF) as a next-hop to get suitable results.

4 Simulation Results and Discussion

In this section, the performance of DVA-GPSR will be evaluated compared to the classical GPSR in terms of PDR, overhead and average throughput by varying the destination number. We have used NS3 [8] as network simulator and SUMO [9] as traffic simulator.

To evaluate the performance, we are based on a highway VANET scenario of 300 m * 1500 m with four lanes in two opposite directions that was created and generated by using SUMO where vehicles move following the real traffic rules. The other simulation parameters are presented in Table 1.

Packet Delivery Ratio (PDR): Fig. 2 shows the results for GPSR and DVA-GPSR protocols in terms of PDR. The PDR for both protocols increases when the number of destination vehicles increases but is very high for the proposed protocols up to 65% while for GPSR does not exceed 57%.

Table 1 Simulation parameters

Parameters	Measures
Number of destination nodes	1, 5, 10
Vehicles number	60
Vehicles speed	Max: 30 m/s
Simulation time	200 s
Mac protocol	IEEE 802.11p
Transmission range	145 m

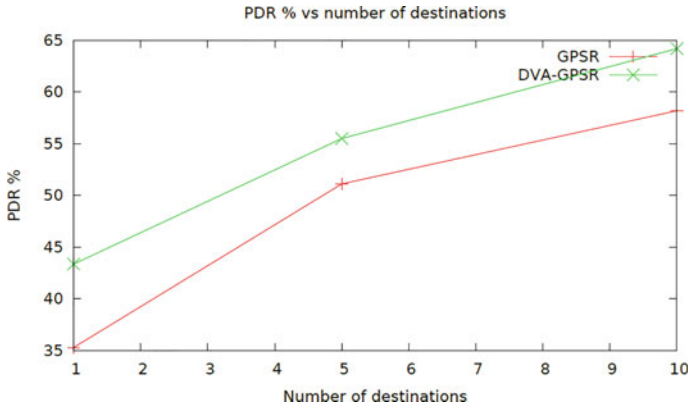

Fig. 2 The PDR vs number of destination vehicles

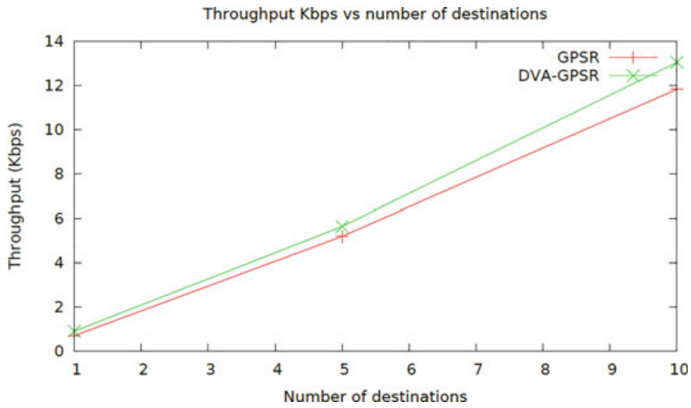

Fig. 3 The average throughput vs number of destination vehicles

Average Throughput: Fig. 3 shows the results for GPSR and DVA-GPSR protocols in terms of the average throughput. The values of throughput increases for both protocols when the number of destination vehicles increases. However, the throughput is increased up to 13.8 Kbps for DVA-GPSR while for the classical GPSR the values do not exceed 11.9 Kbps.

Routing Control Overhead: The graph in Fig. 4 presents the impact of varying the destination number on the routing overhead. The values of overhead for DVA-GPSR is very low comparing to the classical GPSR and does not exceed 27.5%.

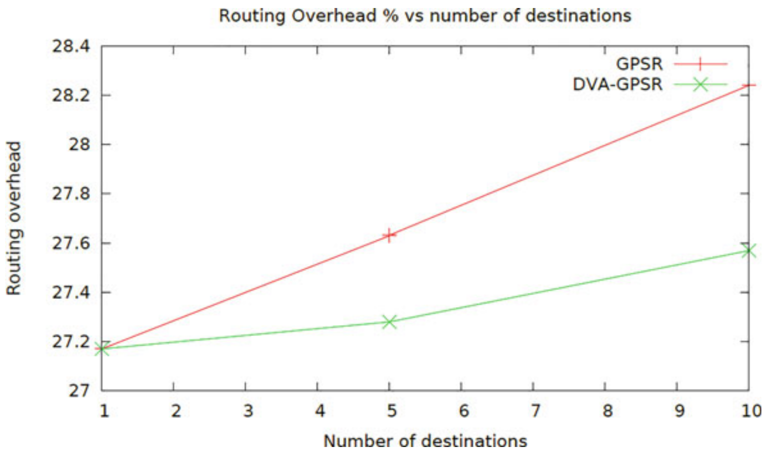

Fig. 4 The routing overhead vs number of destination vehicles

5 Conclusion

In this work, we have suggested a novel routing protocol based on the position of vehicles for VANETs called DVA-GPSR. In this routing, the procedure of selecting the next hop-relaying node is based on three new metrics: density, variation speed and angle direction to be more efficient for VANETs scenarios. The simulation results for a highway scenario, demonstrates that DVA-GPSR outperforms the classical GPSR in case of PDR, average throughput, and has low values in case of routing overhead. As future works, we aim to evaluate our protocol in more complex scenarios. Besides, we look forward to take into account more impacting parameters to enhance the proposed protocol in order to support urban environment.

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