A Cluster Routing Algorithm Based on Vehicle Social Information for VANET

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Abstract. In recent years, with the gradual rise and improvement of autonomous driving technology, research on vehicle ad hoc network (VANET) has gradually been paid attention by researchers. In VANET, the vehicle nodes are networked through a routing protocol and communicate with each other with the established routing. However, the high-speed mobility of vehicle nodes will cause rapid changes in the topology of the network, which can increase the information transmission delay. And as the number of vehicles increases, the probability of information transmission collision in the network will also increase. When the delay and collision reach a certain level, it will cause the loss of information. In order to solve these problems, this paper proposes a cluster routing algorithm based on vehicle social information. The communication source node and the destination node will communicate with each other through these cluster heads. This algorithm is superior to the traditional routing algorithm in terms of VANET communication performance.

Keywords: VANET · Cluster routing algorithm · Vehicle social information

1 Introduction

With the improvement of living conditions, people's requirements for service in the car have become more diverse, and there are more requirements for mobile network access. Therefore, there is an increment in data transmission between vehicles and mobile networks [1, 2]. Because the spectrum resources of the communication system are very precious, the more communication between vehicles and base stations or vehicles and vehicles will cause the waste of precious spectrum resources. It will cause excessive network cost and even cause network link congestion and collapse. Therefore, data aggregation is particularly important, which will make the communication more efficient and greatly improve the utilization of spectrum [3]. Because VANET has the characteristics of high data capacity, low latency requirement, and rapid topology change, the traditional routing protocol in the existing mobile ad hoc network (MANET) cannot meet the needs of the VANET.

Q. Liang et al. (eds.), *Communications, Signal Processing, and Systems*, Lecture Notes in Electrical Engineering 654,
https://doi.org/10.1007/978-981-15-8411-4_71

Ant colony algorithm [4] is an evolutionary algorithm. The algorithm is mainly based on the behavior of the ant colony searching for the shortest path in the foraging process. It can be used to improve existing routing protocols by applying ant colony algorithm. Reference [5] combines ant colony algorithm with dynamic source routing protocol (DSR). Unlike traditional routing algorithms, the most important thing in this algorithm is path discovery and maintenance. This algorithm defines a data packet based on ant colony algorithm, namely forward ants packet and backward ants packet, and estimates the current network status by considering the transit time, hop counts, and Euclidean distance.

Fuzzy logic [6] can reduce the data retransmission rate and improve the transmission efficiency during the communication. Also, it can select a better next node as a relay node. Reference [7] combines the fuzzy logic with ad hoc on-demand distance vector routing (AODV) in the VANET. The sending node will include the current node's direction, speed, and other information in the data packet. The receiving node compares its own information with the data it received. And then, the probability of better route can be calculated through the fuzzy logic system. Only the routes with higher probability values are kept during communication, until the receiving node is the destination.

Reference [8, 9] study cluster-based routing protocol (CBRP). It divides nodes into different clusters, and the nodes communicate through the cluster head. It only maintains the route table of one-hop or two-hop neighbors of the cluster head node. Compared with other routing protocols, its routing table entries are smaller. Meanwhile, CBRP is an on-demand routing protocol, which can reduce the overhead in a certain extent.

Similarly, reference [10] proposes an algorithm named mobility prediction-based clustering (MPBC). This algorithm estimates the relative speed between each node and neighbor nodes when selecting the cluster head, and the node with the lowest ID is set to be the cluster head.

Although these studies have solved the need for low latency, efficient, and stable routing in VANET in a certain extent, we note that the ant colony algorithm has high iteration complexity and high overhead. Also, the rules formulated by fuzzy logic are not applicable all the time. At the same time, the existing cluster routing algorithm only considers one social information, such as the speed, which does not apply to all vehicles on the road.

This paper mainly studies the traditional routing protocols in mobile ad hoc networks, and proposes a cluster routing algorithm based on vehicle social information such as the distance between two vehicles, the speed, the type of vehicles, the number of neighbors, and so on.

2 Cluster Algorithm Based on Vehicle Social Information

In this section, we propose a cluster algorithm based on vehicle social information, which comprehensively considers a variety of social information and elects the cluster head (CH) by calculating the weighted social information count of each node in the cluster. After selecting the CH, the remaining nodes automatically become the cluster members (CM).

The social information of a vehicle is the type of vehicle, the speed of the vehicle, the total distance between a vehicle node, and its neighbors. The specific definitions of these four kinds of vehicle social information are as follows:

Define the type of vehicle C_i as the category of vehicle i. For example, all buses on the road belong to one category, and taxis belong to another category.

Define the number of vehicle's neighbors $N_{i,t}$ as the number of all neighbors of the node i within the set maximum distance threshold th of the cluster at time t. The cluster maximum distance threshold th is the maximum radius distance centered on each node.

Define the total distance between vehicle nodes $D_{i,t}$ as:

$$D_{i,t} = \sum_{i=1}^{n} \sum_{j=1, j \neq i}^{n} \sqrt{\left(x_{i,t} - x_{j,t}\right)^2 + \left(y_{i,t} - y_{j,t}\right)^2} \tag{1}$$

$D_{i,t}$ is the sum of the distance between the node i and its each neighbor node j at t.

Define the speed of the vehicle $M_{i,t}$ as:

$$M_{i,t} = \sqrt{\left(x_{i,t} - x_{i,t-\mathrm{tim}}\right)^2 + \left(y_{i,t} - y_{i,t-\mathrm{tim}}\right)^2} / \mathrm{tim} \tag{2}$$

$M_{i,t}$ is the moving distance of node i within the algorithm execution interval tim at time t.

In this algorithm, first, the vehicle types C_i of all nodes in the scene will be randomly assigned to simulate different types of vehicles on the road. Secondly, set the maximum distance threshold *th* of the cluster. When clustering, the nodes will disconnect with others whose distance exceeds the threshold *th* nor the types of vehicle are different. While others are connected.

After clustering, the node i in the cluster will send a HELLO message to search for all neighbors within the *th* distance of it. The total number of neighbors of node i is recorded as $N_{i,t}$. Then, it will calculate the total distance between node i and all its neighbor vehicle nodes in each cluster, and calculate the speed of node i at time t.

After this, the weighted social information count $w_{i,t}$ of each node at time t can be defined as:

$$w_{i,t} = \lambda_1 \times M_{i,t} + \lambda_2 \times D_{i,t} - \lambda_3 \times N_{i,t} \tag{3}$$

Define λ_i as the normalized weight.

After calculating $w_{i,t}$, the algorithm will compare the count of all nodes in the cluster, and the node with the smallest count will become the CH at that time, and the remaining nodes in the cluster automatically become the CM.

The communication source node in the cluster will regard the CH as a relay node and communicate with the destination node through the CH. After time tim has passed, the cluster algorithm will be executed again and elect the CH and CM at time $t + \mathrm{tim}$.

3 Cluster Routing Algorithm Based on Vehicle Social Information

In this section, we propose a cluster routing algorithm based on AODV and the cluster algorithm in the section above. After getting the cluster information from the cluster algorithm, the source node and destination node will communicate with each other by using the cluster routing algorithm through CH.

The traditional non-cluster routing algorithm AODV has four types of route messages, namely RREP, RREQ, RERR, and HELLO. When the node receives RREQ from the communication source node, it will first establish a reverse routing path, and then, it will check whether itself is the destination node. If it is the destination, it will send RREP directly. If it is the relay node with the route to destination, it will send RREP, or it will broadcast the RREQ.

In the cluster routing algorithm, the destination node will send RREP only in these situations as follows:

(i) The packet it received is from source of RREQ.
The node is CH.
The packet it received is from CH.
(ii) The packet it received is from source of RREQ.
The node is not CH, but the packet it received is from the CH of itself.
(iii) The packet it received is not from the source of RREQ but is in the same cluster with itself.
The relay node which does not have the route to destination will broadcast RREQ only in these situations as follows or it will send RREP directly.
(i) The node is CH.
The packet it received is from source of RREQ.
The source of RREQ is CH.
(ii) The node is CH.
The packet it received is from source of RREQ.
The source of RREQ is not CH but is in the same cluster with itself.
(iii) The node is CH.
The packet it received is not from source of RREQ but is CH.

4 Simulation Results

In this section, we use the cluster routing algorithm based on vehicle social information for communication and compare the results with traditional non-cluster routing algorithms. See Table 1 for the simulation parameters.

Table 1 Simulation parameter settings

Total number of nodes	10, 20, 30, 40, 50
The type of vehicle	3
The minimum speed of vehicle	3
The maximum speed of vehicle	5, 10, 15, 20
Number of communication connections	5, 10, 15, 20, 25

The speed of a vehicle is a random number between the minimum speed and the maximum speed in the table. By comparing the communication performance of cluster routing algorithm and traditional AODV routing algorithm under the same parameters, we can get the characteristics and advantages of cluster routing algorithm proposed in this paper.

From Figs. 1, 2, and 3, we can see that as the number of vehicles on the road gradually increases, the performance also gradually deteriorates. The rate of packet loss and the average transmission delay rise linearly with the increase of the number of vehicles, while the rate of normalized routing cost rises approximately exponentially. The increase in the cost represents that there are more broadcast pathfinding messages in the scene, which means that more vehicles will cause more burden to the pathfinding work. At the same time, the increasing rate of packet loss means that due to the more collision, the route message cannot reach the destination node correctly, which will increase the cost in turn. The average transmission delay represents the average time for the message from the source node to the destination node. When the number of vehicles is increased, the work of the node will also increase, which can cause the rise of average time in transmission.

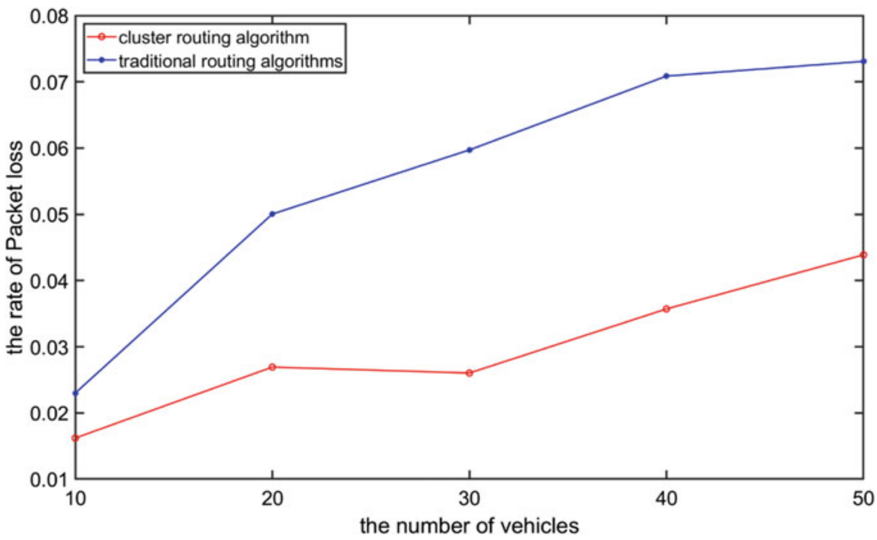

Fig. 1 Rate of packet loss of two algorithms under 15 m/s

However, by comparing the communication performance between these two algorithms, the cluster routing algorithm reduces the rate of packet loss rate by about 3%, and the average transmission delay is reduced by about 0.4 s. The cost of normalized routing cost is also effectively reduced, and the average value reduced is about 0.6. Therefore, we can get the conclusion that this algorithm is superior to the traditional routing algorithm in terms of VANET communication performance.

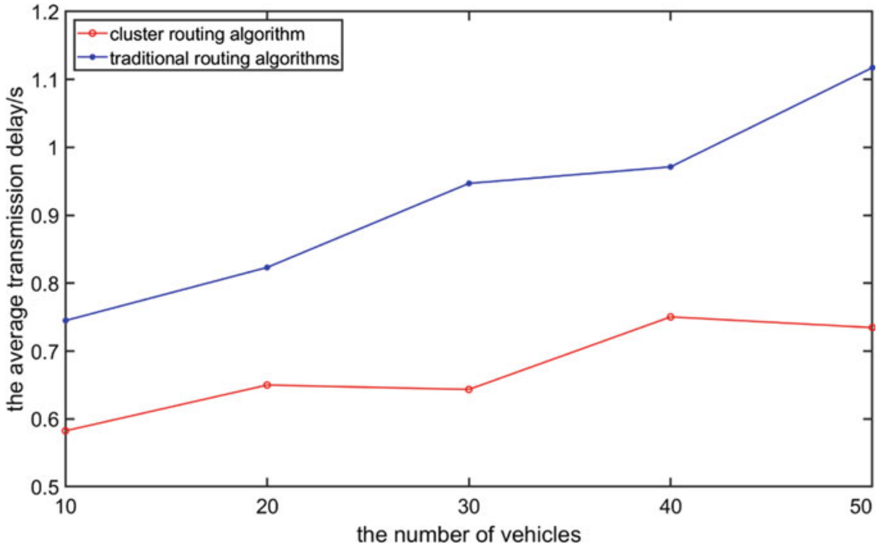

Fig. 2 Average transmission delay of two algorithms under 15 m/s

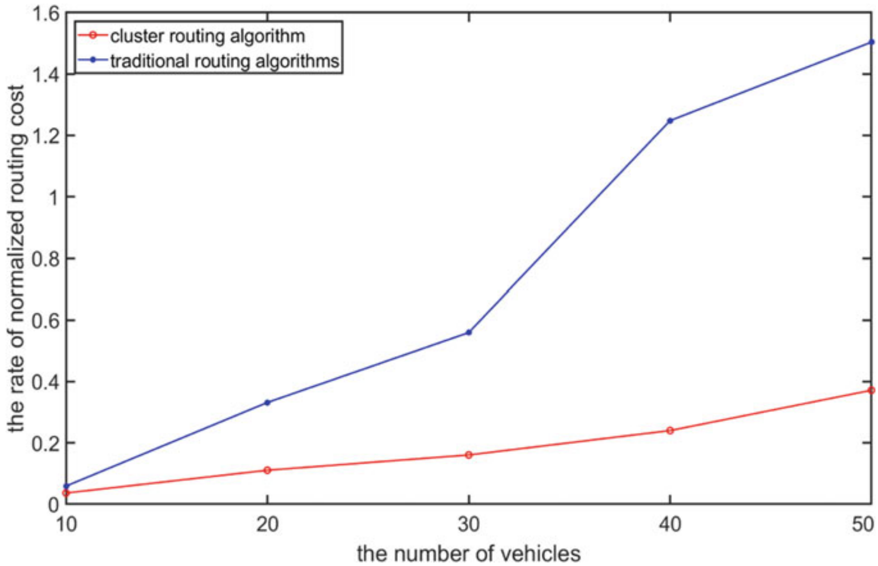

Fig. 3 Rate of normalized routing cost of two algorithms under 15 m/s

5 Conclusions

This paper proposes a cluster routing algorithm based on vehicle social information for VANET to meet the needs of vehicles for the low-latency efficient and stable routing. This algorithm takes full account of various social information of vehicles on the road and elects cluster heads as relay nodes in different clusters by calculating weighted social information count. The source node communicates with the destination node through the cluster head. Compared with the traditional non-cluster routing algorithm, this algorithm has better performance when nodes communicate with each other in VANET.

Acknowledgements. This paper is supported by National Key R&D Program of China (No.2018YFC0807101).

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