An Improved VANET Intelligent Forward Decision-making Routing Algorithm

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Abstract—Routing protocol selection of VANET is crucial for its network performance, which undertakes task to transfer important information. On the basis of comparison and analysis on existing VANET routing protocols, an VANET routing technology based on link quality and velocity vector (LQ-VV-GPSR) was brought out. The method aims at selecting reasonable relay node to convenient forwarding message intelligently. It comprehensively takes into account velocity vector information and underlying link status to determine which next hop data packet will be forwarded. The performance of improved algorithm and GPSR was compared with simulation on NS2. Simulations were performed with different network scenarios and different simulation strategies and results were also provided. The result shows that LQ-VV-GPSR has better robustness and scalability, which is suitable for large scale and heavy traffic network scenarios.

Index Terms—vehicle ad hoc networks, intelligent forwarding, routing protocol

I. INTRODUCTION

Vehicular ad-hoc network (VANET) is specifically designed from communication among vehicles based on mobile ad hoc network technologies. It has many new features different from traditional mobile ad hoc network, which put forward many new requirements on routing technologies. According to features of VANET and various application requirements, the selection of crucial for network performance in that it undertakes task to transfer important information. How to avoid weaknesses of these new features and to design robust, reliable and efficient routing technology meet specific application environment requirement has been placed on more prominent position. In recent years, many researchers have proposed highly effective program, among which the location-based routing protocol shows a good prospect [13, 14]. In all location-based routing protocols, nodes in the network can obtain its location information real-time via navigation system and that of other nodes through location service. Location-based routing methods often use greedy forwarding strategy, namely to select nearest neighbor node to destination node as next hop. The method only uses location information, so the forward node may has not nearer neighbor node to than itself to the destination, which is location optimal problem or local maximum problem. It must be solved with recovery schema. The paper just proposes an intelligent forwarding routing algorithm based on link quality and velocity vector based on existing VANET routing protocol analysis and performs simulation.

The paper is organized as follows: section 2 analyzes on existing VANET routing algorithms; section 3 gives routing protocol based on link quality and velocity vector; section 4 conducts simulation analysis on the proposed protocol and section 5 concludes our work.

II. RELATED WORKS

Routing protocol research on VANET is based on related research results of MANET. The protocols of MANET can be divided into three types [1], namely table-driven or proactive routing protocols, source-driven or reactive routing protocols and position-based information routing protocols.

Many researches show that good-performance routing protocol of MANET are no longer suitable for VANET for different features of VANET from MANET [2]. For high-velocity of mobile host in VANET, table-driven routing protocols as destination sequenced distance vector (DSDV) and wireless routing protocol (WRP) routes that need not to maintain, which will frequently produce large amount of management load to occupy most bandwidth, thus effecting transmission of data stream, so this type routing protocols are not been considered in VANET. Currently, researches of various institutions on VANET routing protocol mainly focus on source drive (non-location-based) routing protocols such as Ad-hoc on demand distance vector (AODV) [3], dynamic source routing (DSR) and GPSR protocols as Greedy Perimeter Stateless Routing and Geographic Source Routing (GSR).

A. On-demand Routing Protocol Analysis

Typical on-demand routing protocol as AODV uses blind flooding to find routes. The shortcomings of blind flooding are that it will generate large amount of redundancy. At the same time, as network scale grows, increasing management load will greatly affect the performance of AODV. AODV+ PGB (Preferred Group Broadcasting) uses broadcast mechanism [4]. PGB divides received broadcast packets into three categories according to perceived signal strength, namely optimal node set, stronger signal node set and weaker signal node set. In case of determining whether a node can be
rebroadcast node, node in PG group has the highest priority. PGB tries to restrict rebroadcast on some node to achieve two targets, reducing redundant transmission so as to reduce control message overhead and obtain more stable routing. Overall, source-driven routing protocol initiates a route finding process by source node before packet transmission and to establish a route sequence. The routing establishment process cause additional delay to the first sent packet. When the network topology frequently changes, route maintenance will generate a lot of network load. In addition, convergence speed of route maintenance will greatly affect quality of data transmission.

B. Location-based Routing Protocol Analysis

In the location-based routing protocols, nodes in the network can obtain its location information real-time via navigation system and that of other nodes through location service. Location-based routing methods often use greedy forwarding strategy, namely to select nearest neighbor node to destination node as next hop. The method only uses location information, so the forward node may has not nearer neighbor node to than itself to the destination, which is location optimal problem or local maximum problem. It must be solved with recovery schema. Typical location-based routing protocols include Greedy Perimeter Stateless Routing (GPSR) [5], Geographic Source Routing (GSR) [6], Anchor-based Street and Traffic Aware Routing (A-STAR) [7], Advanced Greedy Forwarding (GPSR+AGF) [8] and Connectivity-Aware Routing (CAR) [9]. However, GSR, A-STAR and CAR are all perform source routing and need to store entire anchor path information in the header of packet, which has poor scalability and not high efficiency. Compared with GPSR, the GPSR+AGF algorithm only add node mobility, not considering process local maximum problem using perimeter routing of GPSR. In addition, these location-based protocols have not considered about effect of underlying link quality on reliability. For the vehicle number participate in VANET will be very large, routing protocol needs localization to ensure scalability of protocol. In decision-making, vehicle only depends on available information of local neighbor range. Therefore, it is basic part in routing protocol design to notify its existence each other by exchange beacon message with neighbor nodes.

III. ROUTING PROTOCOL BASED ON LINK QUALITY AND VELOCITY VECTOR

As most routing protocols select paths according to minimum hop number. For example, the greedy algorithm in GPSR protocol tends to select a path approximate to straight line that has least hop to destination. But when the connection quality is poor or network congests, the performance of this path may not be optimal. Thus, according to routing protocol design principles, it needs to comprehensively consider various performances in routing decision-making, so as to achieve performance balance of whole network in aspects of packet loss rate, delay, route overhead and throughput. Thus, we present a LQ-VV-GPSR according to these requirements. It improves and optimizes the traditional GPSR protocol and mainly takes into account benefits of link quality and velocity vector on routes selection.

A. Assumptions

To convenient protocol design and simulation implementation, we make the following assumptions:

1. All nodes are equipped with GPS and it always active so that node can access to its own geographical information with GPS, which is the premise of simulation implementation of location-based routing protocol. In the GPSR protocol simulation with NS2, node location and velocity vector information are used as private member of mobileNode class structure to implement bind of Agent and each mobile node, so as to obtain information by call its methods. The own attributes of these mobile node can be directly read from simulation scenario file in the way of variable binding.

2. Node accesses to geographic location information with location service. Location service is an integral part of GPSR protocol, which is not the focus in the paper. We used a simple method to replace the service. The Sink node need to receive data send query packet to some source node with flooding in case of data acquisition needs, where there is location information of this node.

3. Node accesses to its own velocity vector information from sensor and encrypts it with the location information from GPS into hello beacon information, and then periodically broadcast to neighbor nodes. The description is due to the improved protocol LQ-VV-GPSR utilizes velocity vector information of forwarding nodes and neighbor nodes. In this way, each node in the network can obtain location and velocity information of its own and that of neighbor nodes.

4. All nodes are located in two-dimensional space, namely it adapts to GPSR protocol. In the specific realization of GPSR protocol, although the location information is three-dimensional coordinate information, but we can set the Z coordinates to 0 as now only two-dimensional data is used.

B. Design Idea

The LQ-VV-GPSR is also a location-based protocol, which mainly improves on forwarding decision-making of GPSR. When the immediate node sends data to next hop, it does not select the neighbor node closest to destination according to traditional greedy forwarding strategy, but firstly select a group of forward list based on measurement standard of link quality each time, and then select optimal node from them with velocity vector information. It means the node whose movement trend is most close to destination forward this packet, and then selects a set of candidate node, and so on till the destination receives this data packet.

In existing routing protocol, forwarding decision-making does not usually take into account link quality among nodes. Assume that in wire environment there is fixed link among nodes, which can directly communicate and the signal is stable, the effect of this method is very good. However, in wireless networks, due to weather,
signal interference and signal attenuation and other factors, the wireless transmission loss is high. Furthermore, wireless signal has been changing in a wireless network. The optimal path at this moment may be not at another time. As the wireless signal is instability, the data loss is higher. So it is of important to consider link quality in decision-making.

In routing and forwarding, we will refer to useful information of vehicle’s velocity vector to intelligent forwarding. This is to say the routing is based on expected trajectory of the vehicle movement rather than the temporary location so that the vehicle forward data message to more useful neighbor node on the trajectory. It seeks for the most useful node to destination according to current velocity vector. Forwarding decisions should ensure that data packets afterwards closer to the target than the current holder. Otherwise, the message is more likely to tend to be lost. In specific realization, periodical beacons of vehicle piggyback their current velocity vector. Because beacons is the message periodically sent by each vehicle, which can not contain too much information. Otherwise the protocol overhead will increase, leaving lower bandwidth for data information. As lightweight information, the velocity vector can be added to beacons to engage in intelligent forwarding decision. With relative movement information among mobile nodes, we can provide reliable and effective routing scheme.

C. Algorithm Design

As VANET has not energy limit, the GPS location system receiver on node can access needed local location information. Each node periodically flood hello beacons to show its existence. After neighbor node receives hello beacon, it updates one hop neighbor node list maintained itself. If time exceeds, delete the node information, which means the neighbor node is failure. With location service function, it can access to geographical information of destination. On this basis, the nearest node will be determined by comprehensively considering velocity vector information and underlying link quality of all surrounding neighbor nodes.

The specific routing is determined by the following two steps:

Step 1: When a node receives a data packet, it firstly select a candidate node list with better link quality by a certain percentage according to link quality of each arriving neighbor nodes.

Each node maintains a measure Metric for its neighbor nodes to show the link quality from it to neighbor nodes within signal range. The metric is obtained in this way: each node periodically sends a number of Hello packets to adjacent nodes periodically and then computes its transmission success rate $P_r$, which is used as weight of link among them. The weight $P_r$ is link quality metric between it and neighbor node. The node whose metric meet some needs, such as $P_r > 10\%$ will be candidate node.

Step 2: Predict movement trend of each node according to velocity vector information of neighbor nodes in the subset and compute minimum distance to destination. Then, select the neighbor node whose movement trend is the closest to destination as the next hop.

(1) Velocity information computation

Firstly, compute velocity vector information to be used. As shown in Fig. 1, if the nearest distance from current node $C$ to destination $D$ marker as $dC$, set $V_c$ as movement vector of a node to point movement direction of this node. The two point vector from this node to destination is $CD$. The angle between two vectors can be obtained by point product of vectors equal to length of vectors and the cosine of their angle.

Set angle as $\alpha$. From vector $CD$: Vector $V_c = |CD| |V_c| \cos(\alpha)$, we can arrive at $\alpha = \arccos((CD \cdot V_c) / |CD| |V_c|)$

(1)

Set vector $CD = (a_1, b_1)$ and $V_c = (a_2, b_2)$, then vector $CD$ Vector $V_c = a_1 a_2 + b_1 b_2$, then $\cos(\alpha) = (a_1 a_2 + b_1 b_2) / (\sqrt{a_1^2 + b_1^2})(\sqrt{a_2^2 + b_2^2})$

(2)

Figure 1. Forwarding decision vector diagram.

Thus, we can arrive at angle $\alpha$ from (1). The nearest distance from predicted node to destination is $dC = \sin(\alpha) \cdot (CD)$

(3)

If the value of $\alpha$ is equal to or larger than 90 degree, the node moves in the reverse direction to destination. If the value is less than 90, it moves the same direction with destination. It may also be relative static.

(2) Decision rules

After obtained angle value and predicted shortest distance, we can perform route selection according to the forwarding decision as shown in Table 1.

The forwarding decision can be concluded as that node is divided into three different priority based on node status. The priority are same direction > static > reverse in turn.

When the neighbor nodes are high priority, it forwards. When neighbor priority of the node is low, it does not forward. In case of same priority with adjacent node, conduct different process according to different level. If they are all move at same direction, determine whether forward according to predicted shortest distance. If all are static or moves at reverse direction, perform decision depends on actual line distance to destination node. In the routing algorithm, there may be not only candidate target node, namely there are many nodes that has same distance to routing destination node. If the destination node is not sole, select the node with better link quality. In addition, we can also select the node with larger velocity to forward packet.

If it can not select next hop from current adjacent nodes, namely the algorithm is suffered from local
optimal, it indicates that the priority of all adjacent nodes is lower than current forwarding node, the node keep packet in cache and forward it afterwards. Or it can change into surrounding forwarding state of traditional algorithm.

### Table 1

<table>
<thead>
<tr>
<th>Current node</th>
<th>Neighbor node</th>
<th>Forwarding decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>Static</td>
<td>Meet ND&lt;CD</td>
</tr>
<tr>
<td>Static</td>
<td>Reverse</td>
<td>No</td>
</tr>
<tr>
<td>Static</td>
<td>Same direction</td>
<td>Yes</td>
</tr>
<tr>
<td>Reverse</td>
<td>Static</td>
<td>Yes</td>
</tr>
<tr>
<td>Reverse</td>
<td>Reverse</td>
<td>Meet ND&lt;CD</td>
</tr>
<tr>
<td>Reverse</td>
<td>Same direction</td>
<td>Yes</td>
</tr>
<tr>
<td>Same direction</td>
<td>Static</td>
<td>No</td>
</tr>
<tr>
<td>Same direction</td>
<td>Reverse</td>
<td>No</td>
</tr>
<tr>
<td>Same direction</td>
<td>Same direction</td>
<td>Meet dN&lt;dC</td>
</tr>
</tbody>
</table>

**D. Algorithm Flow**

The algorithm flow is shown in Fig. 2.

- Initialization and receive flooding location information from node starSink
- Add target information into data packet
- Select a subset with better link quality
- Select next hop based on velocity vector
- Temporary data packet
- Select successful?
  - Y: Arrive at destination?
    - Y: End
    - N: Update adjacent list
- N: Select successful?

**IV. PERFORMANCE SIMULATION**

To compare performance of traditional GPSR routing protocol and LQ-VV-GPSR protocol, the paper conduct simulation experiments on NS-2.29 on Windows XP+cygwin platform. The GPSR protocol code used GPSRKeLiU_SUNY_Binghamton [12] development kit.

**A. Performance Evaluation Indexes**

There are many performance indexes to measure routing protocol, including throughput, data packet delivery ratio, delay jitter, average end-to-end delay, packet loss, routing overhead and etc. We should select appropriate performance indexes according to design purpose of protocol design and usage situation. The simulation will select the following performance indexes to examine routing protocol performance in VANET network.

1. Network throughput. It is used to represent size of effective data packet that can be transmitted by the system, which is the ratio of bit number in successful data packet to total transmission time, namely average flow rate received by all nodes.
2. Average end-to-end delay. The computation method of average end-to-end delay is ratio of total delay in packet receiving process to number of received packets. It reflects network congestion and efficiency.
3. Packet delivery ratio. The value is ratio of actual received packet number to sent packet number. Packet delivery ratio is the probability that data packet from node been delivered successfully, namely ratio of actual received packet number to total sent packet number. The parameter can reflect loss rate of packet and throughput supported by the network, which is also index to show efficiency of protocol, including correctness, completeness and reliability. Larger is the value, it indicates that more packets are sent to destination, that is, the performance of protocol may be better. On the contrary, the performance of protocol is poor.
4. Routing protocol overhead. Control packet is the data packet generated by protocol, such as hello packet. The routing protocol overhead is ratio of control packet generated in the whole data transmission process to all data packets. This statistics can be used to compare the scalability of different network routing protocol as well as efficiency to adapt network congestion and protocol. As to routing protocol, it should improve its network throughput and data packet delivery rate and decrease overhead as well as average end-to-end delay.

**B. Simulation Scenario Settings**

The paper used highway and Manhattan models [10, 11] to execute simulation. Highway Mobility Model (HW) is one of Map-based Mobility Models, which is also called as Freeway model to describe Freeway scenario on highway [10]. There are many highways in the scenario. Each one consists of several one-way or two-way lanes. The vehicle nodes in it move at random velocity and can be set to certain acceleration changes. It also depends on vehicle in front to keep a safe distance. Node in this scenario has a high time and space dependence, the movement of which is strictly limited by road topology and can not be any turning. Manhattan Mobility Model (MH) model is also a map-based model to describe urban area Scenario [10]. The scenario has many horizontal and vertical cross streets to form a cross-road topology. Vehicles run two-way along the road. When it arrives at an intersection, it selects travel along the original, or turning left or right turn according to some probability. Except for freedom turn of vehicle, the vehicle movement feature is similar to HW model, the velocity of which is also been affected by vehicle in front.
The simulation scenario set in NS-2 is shown in Fig. 3.

![Simulation scenarios in ns2](image)

(a) HW model  
(b) MH model

**Figure 3. Simulation scenarios in ns2.**

### C. Simulation Parameters Settings

Four movement velocities were used in the simulation, respectively 10 m/s, 15 m/s, 20 m/s and 25 m/s. The average of 5 times simulation results was selected to reflect frequent degree of network topology changes. There are 20 sources nodes to send 30 traffic flows in the simulation. In addition, it needs to generate two groups of simulation scenario files, where location and movement of 100 nodes are defined. The file can be input into scenario in the simulation. Each file contains four different velocities. The settings of other simulation parameters are set as Table 2 shows.

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario size (m*m)</td>
<td>1000*1000</td>
</tr>
<tr>
<td>MAC</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Antenna type</td>
<td>Omni-Antenna</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR</td>
</tr>
<tr>
<td>Node transmit distance (m)</td>
<td>250</td>
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<tr>
<td>Channel bandwidth (Mb)</td>
<td>2</td>
</tr>
<tr>
<td>Queue type</td>
<td>PriQueue</td>
</tr>
<tr>
<td>Node velocity (m/s)</td>
<td>10/15/20/25</td>
</tr>
<tr>
<td>Node number</td>
<td>100</td>
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<tr>
<td>Simulation time (s)</td>
<td>200</td>
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<tr>
<td>Propagation</td>
<td>Two-way Ground</td>
</tr>
<tr>
<td>Packet size (Bytes)</td>
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<tr>
<td>Data stream number</td>
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<tr>
<td>Packet send rate</td>
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</tr>
<tr>
<td>Queue capacity</td>
<td>50</td>
</tr>
</tbody>
</table>

**TABLE II. SIMULATION ENVIRONMENT PARAMETERS**

### D. Simulation Result Analysis

1. **Protocol overhead comparison**

The routing overhead comparison of two mobile scenarios is shown in Fig. 4, where Fig. 4(a) is routing overhead in HW scenario and Fig. 4(b) is that in MH. We can see that the routing overhead of two kinds of protocols are almost same in HW model. The reason is that the overhead is mainly caused by each node send hello beacon to local adjacent nodes, which is periodically sent by local node. As velocity increases, routing messages is still a fixed smaller number overhead. But as the beacon adds velocity vector information in LQ-VV-GPSR, the overhead has slightly increased. In the MH model, the routing protocol overhead is still caused by Hello beacon overhead. As the LQ-VV-GPSR added information in beacon, the size of information increases, so the routing overhead has some increase. As the added information is slightly velocity vector information, the additional overhead is not too large.
(2) End-to-end delay comparison
The end-to-end delay comparison of two scenarios is shown in Fig. 5, where Fig. 5(a) is end-to-end delay in HW scenario and Fig. 5(b) is that in MH.

![End-to-end delay comparison](image)

(3) Packet delivery success rate comparison
The packet delivery success rate comparison of two scenarios is shown in Fig. 6, where Fig. 6(a) is packet delivery success rate in HW scenario and Fig. 6(b) is that in MH. We can know that in the HW model, the improved protocol LQ-VV-GPSR has some advantage in the aspect of successful delivery rate because two important affect factors as link quality and velocity vector were considered in the path selection, which is of great importance to select a better route. In addition, as velocity increase, the packet loss of GPSR protocol increases significantly. The improved protocol LQ-VV-GPSR has not been effect too much, which shows good scalability. The urban environment also shows the advantages improved algorithm, packet delivery success rate increase significantly.

![Packet delivery success rate comparison](image)

(4) Throughput comparison
greatly increased network performance. Simulations based on NS-2 show that the protocol to some extent, increased network throughput and data packet delivery rate, reduced the average end-to-end delay, and effectively improved the network performance. It better meets VANET’s need for reliable network quality. But inevitably, it will also bring a certain degree of routing overhead. In the future work, we will focus on how to decrease routing overhead to optimize performance of LQ-VV-GPSR protocol.

REFERENCES


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