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# A Hybrid Routing Protocol Based on GPSR Protocol and LTE in VANET

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## Abstract:

In vehicular ad hoc network, the position-based routing algorithm is considered to be a very promising routing strategy for communication. Greedy Perimeter Stateless Routing (GPSR) is a representative routing protocol of position-based routing algorithm. However, the GPSR protocol is likely to select the wrong next hop forwarding node in the greedy forwarding mode and cannot send data packets on the sparse path. To solve the above problems, we propose a hybrid routing protocol called Predict-LTE GPSR (PL-GPSR)based on the GPSR routing protocol and LTE technology. The PL-GPSR first predicts the position of the neighbor nodesin greedy forwarding mode and selects the neighbor node closest to the destination node within the communication range of the source node as the next hop node. When the greedy forwarding mode fails, the PL-GPSR will use LTE technology. By using the NS-3 and SUMO simulation tools to simulate GPSR and PL-GPSR, the results show that PL-GPSR is superior to GPSR in packet delivery ratio, average end-to-end delay, and throughput.

*Keywords* **—Vehicular ad hoc network, GPSR routing protocol, LTE, NS-3, SUMO.**

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## I. INTRODUCTION

Vehicular Adhoc Network (VANET) represent a rapidly emerging, particularly challenging class of Mobile Ad Hoc Network (MANET)[1]. MANET is characterized by limited computing resources and energy resources[2], and the position of the nodes is unpredictable. Characteristics of VANET are opposite to those of MANET. The node in VANET are not limited by computing resources and energy resources, and the position of the node is predictable within a certain period of time due to the node travels on a fixed road and its speed is measurable.Moreover, nodes in VANET are much faster than nodes in MANET, resulting in more frequent changes in the network topology of VANET[3], which adds many difficulties to the study of VANET routing protocols. Simulation results showed that many routing protocols which were developed for MANET suffer from poor performances in VANET[4].

In addition to V2V communication in VANET, there is also V2I communication. Vehicles can also forward data packets to destination vehicles via roadside units in VANET[5], but from an industrial perspective, the cost of deploying roadside units is relatively high.However, we can use the already mature long-term evolution (LTE)4G technology. LTE possesses natural benefits in providing V2I communications because of its high data rate, high penetration rate, comprehensive QoS supporting, and large coverage[6]-[7]. With the global deployment and commercialization of LTE networks, LTE can be used as a wireless access network to support the adoption of in-vehicle applications. When there is difficulty in V2V communication, vehicles may choose to transmit data packets to the LTE base station, which then transmits the data packets to the destination vehicle.

Routing protocolsare important for mobile networks, and position-based routing algorithm is considered to be a very promising routing strategy for communication in VANET currently[8]. Greedy Perimeter Stateless Routing(GPSR)[9] is a classical position-based routing algorithm.The GPSR protocol includes a greedy forwarding mode and a perimeter forwarding mode. For GPSR, each nodeperiodically broadcasts hello packets to pass its location information that is obtained by GPS to neighbors within one hop. After receiving the information from a new neighbor node, the node will update its neighbor table. In the process of sending data packets, the node uses the greedy forwarding mode firstly, and if the greedy forwarding mode fails, it switches to the perimeter forwarding mode.

Fig. 1 shows a schematic diagram of the greedy forwarding mode. The dotted circle centered on S represents the communication range of S. Ssearches for the neighbor node closest to the distance D in the neighbor table when forwards a data packet to D. At this time, it is found that B is a node that satisfies the condition, and therefore the data packet is forwarded to B. B will also be in greedy forwarding mode until the packet reaches D.

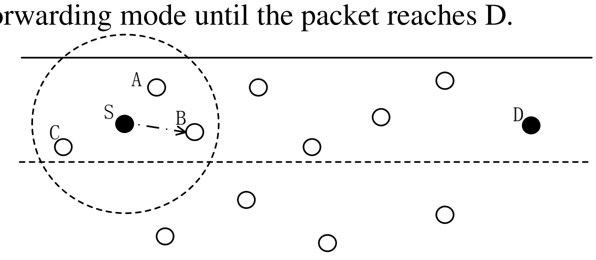


Fig. 1 Greedy Forwarding Mode

Sometimes the node that needs to forward the data packet is closer to the destination than all its neighbors, which means that it encounters a void area as shown in Fig. 2.The node will switch from the greedy forwarding mode to the perimeter forwarding mode. Perimeter forwarding mode will forward data packets with right-hand rules. The right-hand rule means that the data packet is forwarded along the path, and the destination node is always on the right side of the forwarding path. In Fig. 2, the transmission path of the data packet is x→w→v→D.

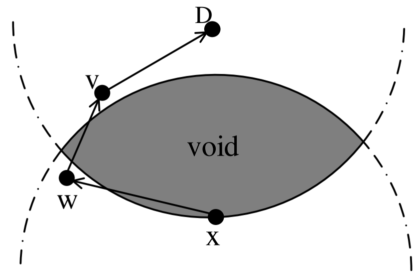


Fig. 2 Perimeter Forwarding Mode

## II. PROBLEM DESCRIPTION

It can be found from the above analysis that the GPSR routing algorithm selects the next hop forwarding by using the position information of the neighbor node, which means that GPSR does not need to maintain the routing table, so the network overhead is small, and the network has good scalability and adaptability to the highly dynamic network topology. However, in the actual traffic environment, GPSR still has many shortcomings and defects. The reasons are as follows:

(1)GPSR protocol only uses the geographical information to select the next hop forwarding nodeand ignores the communication boundary problem [10], which often causes error forwarding. As illustrated in Fig. 3, vehicle S wants to send a data packet to vehicle D. According to the GPSR protocol, S queries the neighbor table which saves the last information of hello packets, and then sends the data packet to F. But in fact, at this moment F has reached F' which has already driven out of the communication range of S, resulting in the loss of the data packet.

(2)In addition, since the hello packet defined by the GPSR does not consider the relative direction between nodes[11], the problem of packet loss is also prone to occur in the VANET environment. As illustrated in Fig. 4, vehicle S wants to send a data packet to vehicle D. According to the GPSR protocol, S sends the data packet to F whose direction of movement is opposite to S. In fact, the F at this moment has reached F' which is not the node closest to the vehicle D. Finally, F will carry the data packet away from D, resulting in the loss of the data packet.

(3)When a sparse road is encountered, as shown in Fig. 5, the neighbor table of the vehicle S is empty at this time. According to the GPSR, because there is no successor node can be selected as the forwarding node, S can only carry the data packet until there is a vehicle that can be forwarded, or the packet is discarded when the carrying time exceeds the set time. Therefore, the sparse condition of the road will decrease the packet delivery ratio as well as increasing the end-to-end delay.

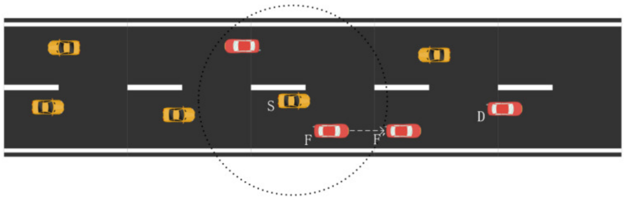


Fig. 3 Communication boundary problem

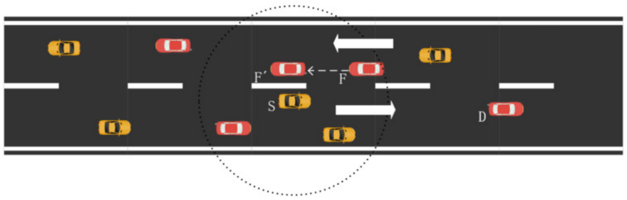


Fig.4 Relative direction problem

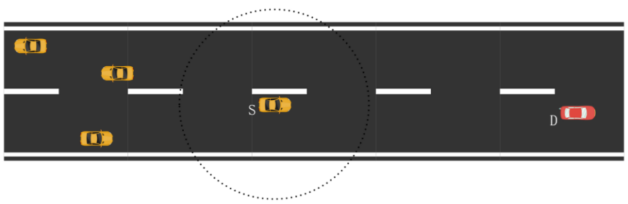


Fig. 5 Sparse road problem

## III. PROPOSED ALGORITHM

In order to solve the problem of error forwarding caused by the greedy forwarding mode in the GPSR protocol and the issue of forwarding data packets on sparse roads, we propose the following improved algorithm named Predict-LTE GPSR(PL-GPSR).

### A. Add Prediction Algorithm

Each vehicle node adds its own speed information when broadcasting Hello packets. The Hello packet format is shown in Table 1.

TABLE I
HELLO PACKET FORMAT

| $id$ | $t$ | $x(t)$ | $y(t)$ | $v_x(t)$ | $v_y(t)$ |
|---|---|---|---|---|---|

In the greedy forwarding mode, the source node S obtains the geographical location $(x_n, y_n)$ and the speed $(v_{nx}, v_{ny})$ of a neighbor node at time $T$ from the neighbor table. With this information, node S can predict the position of the neighbor node at the current moment $T'$ by using Formula (1)-(3).

$$\Delta T = T' - T \quad (1)$$

$$Pre(x_n) = x_n + v_{nx} \times \Delta T \quad (2)$$

$$Pre(y_n) = y_n + v_{ny} \times \Delta T \quad (3)$$

When the node S forwards the data packet, the distance $d_{ND}$ between the predicted location of the neighbor node $(Pre(x_n), Pre(y_n))$ and the location of the destination node $(x_n, y_n)$ is calculated according to Formula (4).

$$d_{ND} = \sqrt{(Pre(x_n) - x_D)^2 + (Pre(y_n) - y_D)^2} \quad (4)$$

$$d_{SN} = \sqrt{(x_S - Pre(x_n))^2 + (y_S - Pre(y_n))^2} \quad (5)$$

$d_{SN}$ represents the distance between the node S $(x_S, y_S)$ and the predicted location of the neighbor node, which can be calculated by Formula (5). It is judged whether or not $d_{SN}$ is larger than the transmission range $D_t$. The neighbor node that is closest to the destination node within the transmission range $D_t$ is taken as the next hop forwarding node.

### B. Utilize LTE Technology

Assume that each vehicle is equipped with an LTE wireless communication device. When the neighbor table of the source node is empty or the appropriate next hop is not found after the prediction algorithm is calculated, the data packets will be sent by the LTE to eNodeB base station. Then the base station will send the data packet to the destination node.

## IV. SIMULATION

The simulation experiment used NS-3.25[12] and SUMO[13]. We generated models of traffic roads and vehicle flows through SUMO. The output file of SUMO was imported into NS-3.25. The simulation of PL-GPSR and GPSR was conducted with different numbers of nodes. The performance metrics of PL-GPSR and GPSR were analyzed from three aspects: packet delivery ratio, average end to end delay and throughput. All simulation parameters were given in Table 2:

TABLE III
PARAMETERS OF SIMULATION

| | |
|---|---|
| Simulation Time | 150 seconds |
| MAC Protocol | IEEE-802.11p |
| Propagation Model | FriisPropagationLossModel |
| Network area size | 2km×2km |
| Data packet size | 512 bytes |
| Transmission range | 250 meters |
| Number of vehicles | 30、50、70、90、130 |
| Data packet type | CBR |
| Packet interval | 2 seconds |

**Packet Delivery Ratio:** Fig. 6 shows the comparison of packet delivery ratio between PL-GPSR and GPSR withdifferent number of nodes. It is clearly shown that, when there are only a few nodes in a mobile scenario, the distribution of nodes is relatively sparse, GPSR gets a very low PDR because it is difficult for GPSR to find the next hop forwarding node. Compared with GPSR, PL-GPSR always obtains relatively high PDR regardless of the number of nodes due to that PL-GPSR predicts the position of neighbor nodes and selects the next hop forwarding node more scientifically. In addition, PL-GPSR uses LTE technology to solve the problem that nodes cannot forward data packets on a sparse road.

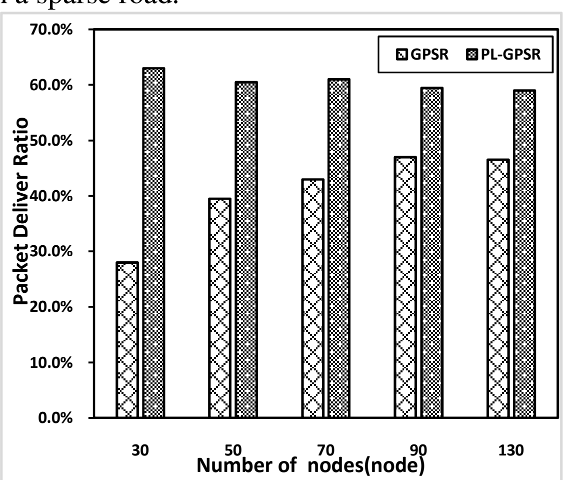


Fig. 6 Packet delivery ratio via number of nodes

**Average End-To-End Delay:** Fig. 7 shows the comparison of average end-to-end delay between PL-GPSR and GPSR with different number of nodes. It can be found from Fig.7 that when the number of nodes is small, the source node may not find the next hop forwarding node in greedy forwarding mode.Then the source node will switch tothe perimeter forwarding mode when the neighbor table is not empty, or the source node carries the data packet until there is a vehicle that can be forwarded. Both of these conditions will result in a relatively high end-to-end delay. On the whole, the PL-GPSR performs better than the GPSR in terms of average end-to-end delay due to that PL-GPSR sends the packet to the destination node via LTE when the greedy forwarding mode fails.

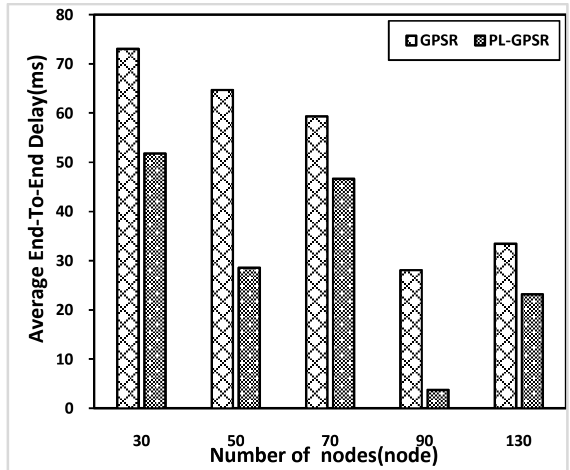


Fig.7 Average end-to-end delay via number of nodes

**Throughput:** Fig.8 shows the throughput of PL-GPSR and GPSR for different number of nodes. As shown in Fig.8, PL-GPSR has a higher throughput than the GPSR in the case of different number of nodes due to good reception of the data packets. PL-GPSR builds a more reliable communication link, which makes communication between nodes better and improves the throughput of the network.

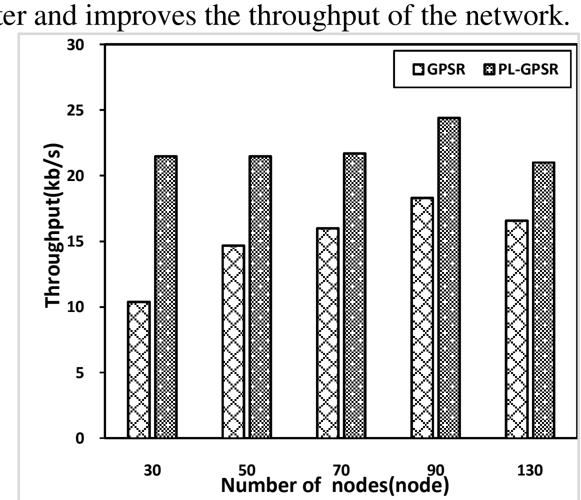


Fig.8Throughput via number of nodes

## V. CONCLUSIONS

Compared with MANET, the network topology of VANET changes more frequently, so the design of routing protocols has many difficulties. In this paper, we delve into the GPSR protocol. By analyzing the problems in GPSR, we proposed PL-GPSR routing protocol based on GPSR and LTE. The main contributions of this paper are as follows:

(1)In greedy forwarding mode, we add the prediction algorithm. By predicting the position of neighbor nodes, the neighbor node closest to the destination node within the communication range of the source node will be selected as the next hop forwarding node. This method avoids relative direction problem, communication boundary problem, etc.

(2)When greedy forwarding mode fails, we use the LTE technology. This method can effectively solve the problem that the source node cannot forward the data packet on the sparse road.

Finally, experiments show that the proposed PL-GPSR has better performance than GPSR in packet delivery ratio, end-to-end delay, and throughput, so it is more suitable for vehicular ad hoc network.

## ACKNOWLEDGMENT

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