An Improved GPSR Routing Protocol

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Abstract

The rapid movement of Vehicles which results in frequent changes in vehicle position and speed, as well as inaccuracies in predicting driver's direction at intersections usually lead to wrong packet forwarding decisions in VANET. Consequently, a routing protocol incorporating vehicle density, moving direction and speed into GPSR in making packet forwarding decisions is hereby proposed. Key data structures were designed and MOVE was used to construct typical Grid map urban simulation scenario. The protocol was simulated using NS-2 under the urban simulation scenario and was compared with AODV and GPSR protocols. Our experimental results indicate that the improved GPSR protocol has better performance when packet delivery rate, average end-to-end delay and average throughput are used as the performance metrics, and is better for VANET under the urban simulation scenario.

Keywords: *VANET, Routing, GPSR, NS-2, MOVE*

1. Introduction

Vehicular Ad hoc Network (VANET) is considered a special type of Mobile Ad hoc Network (MANET). Its importance is particularly observable in the design and implementation of Intelligent Transportation Systems (ITS). Because VANET characteristically has high dynamic topology, strict-delay demanding, high node speed, trajectory predictability, unlimited energy, and accurate positioning etc., its routing algorithms face many challenges.

Presently, position-based routing protocols have become increasingly popular in VANET. This is because position-based routing protocols incorporate fully the advantages of Global Positioning System (GPS), or advanced services provided by Geographic Information System (GIS). Many position-based routing protocols assume that vehicles are equipped with a GPS device.

Greedy Perimeter Stateless Routing (GPSR) [1] protocol is a typical example of the position-based protocol. This protocol forwards packet using the "greedy algorithm" designed by the developer. Here packets are forwarded greedily to the neighbor with the nearest distance to the destination. When the node itself is the nearest one, then GPSR makes use of a recovering strategy— using the Right-Hand rule to solve the problem of local optimum. In Geographic Source Routing (GSR) [2] protocol, the algorithm first receives the digital map through a GPS device, and then uses the Dijkstra algorithm to find the nearest distance from source to destination on the digital map, and forwards the data packets through this path. Greedy Perimeter Coordinator Routing (GPCR) [3] protocol seeks the next-hop node by means of constructing the planarized graphs at street intersection. Anchor-based Street and Traffic Aware Routing (A-STAR) [4] protocol adds auxiliary anchor information to help routing.

[5] has improved the Perimeter part of the GPSR protocol, and proposed the Geographic Perimeter Stateless Routing Junction+ (GPSRJ+) protocol. [6, 7] proposed a lifetime concept to solve the speed factor effect on GPSR protocol, [8, 9] also worked on improving GPSR protocol.

[10] constructed three types of typical urban simulation scenarios by MOVE, then simulated research the performance of three typical routing algorithms (including GPSR protocol) under these scenarios. Their experimental results indicated that vehicle density had a great effect on the routing protocol performance, and in most cases, the performance got better as the vehicle density increases.

Zhao et al proposed the Vehicle-assisted data delivery (VADD) [11] routing protocol. VADD protocol not only needs the basic information provided by GPS, but also needs the statistical traffic information, such as average vehicle density, history of the traffic flow etc. to calculate vehicle's movement, and take forwarding decision towards areas with lower delay. However, in practice, this information is always changing, so the result calculated by statistical traffic information does not always reflect the optimal path and will affect experimental results. In order to solve this problem, [12] proposed a solution to get each road's vehicle density in distributed way. If the density is bigger than the given threshold level, then it can be seen that the section of the road is connected, or the reverse is the case. This protocol also uses the greedy algorithm to forward data. Geocast routing is usually considered as position-based multicast routing, which forwards the data from the source node to all nodes in a so-called Zone of Relevance (ZOR), [15-17] gave several typical geocast routing protocols.

[18] proposed cluster-based routing protocol, it also used the location of the vehicle from GPS device. The difference is that the network is divided into some clusters, and each cluster is made up of one cluster head and other cluster members, each cluster head propagates messages at a certain time to maintain the cluster.

[19] proposed the Epidemic Routing protocol. This protocol works on the principle that when two nodes meet, they will exchange data in the cache which was not yet processed. This protocol has good performance under the delay tolerant network.

[20] proposed a context-aware routing protocol which makes use of pre-defined context information such as traffic density and road topology to vigorously and energetically calculate an optimal path for packet forwarding based on location, speed, and direction to the selected path.

[21] proposed a congestion control for VANET frame work based on a singly prioritized event-driven safety messages.

In this paper, we propose an improved GPSR protocol and redesign it for VANETs. We use MObility model generator for VEhicular network [22-23] (MOVE) and Simulation of Urban MObility (SUMO) [24] to construct a typical urban simulation scenario—Gird map scenario, and TCL scripts will be exported from MOVE then feed these files to the Network Simulator-version 2 (NS-2) [25] for simulation, the improved GPSR protocol will be implemented and compared with Ad Hoc On Demand Distance Vector Routing (AODV) and GPSR protocols under this scenario. Packet delivery rate, average end-to-end delay and the average throughput are used as the performance metrics to evaluate these three routing algorithms. This paper is organized as follows: Section 2 introduces drawbacks of GPSR algorithm and the basic ideas of our work- the improvement on GPSR protocol. Simulation results and analysis are given in section 3. We conclude the work and give suggestion for future works in section 4.

2. The proposed Routing Algorithm

2.1. Drawbacks of the GPSR protocol

In VANET, the effective communication time is always very short due to high speed vehicular movements, which causes performance degradation. GPSR protocol is also affected in a similar manner. As illustrated in Figure 1, all the nodes move along the road in accordance with the direction of the arrows. Suppose that vehicle S can cover five neighboring nodes Q, X, Y, Z and P, if S wants to send a data packet to node D at time t, meanwhile, node Y is going away from node D. However, at time t, node Y is still the node closest to D. According to GPSR protocol, S will forward the data packet to node Y, however, after a short time, node Y will become far away from node D and no longer the closest node to D. Ultimately, the data packet carried by node Y would be discarded. Therefore, without considering moving direction, the GPSR protocol would lead to wrong packet forwarding decisions and increase packet losses.

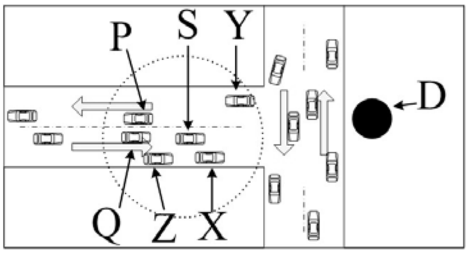

Figure 1. Wrong forwarding in GPSR (1)

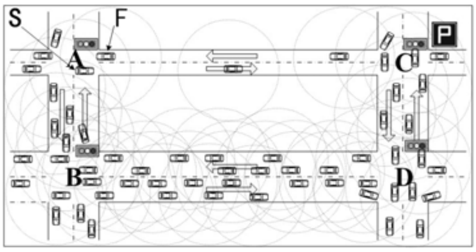

Figure 2. Wrong forwarding in GPSR (2)

Similarly, look at the road condition illustrated in Figure 2. Suppose A, B, C and D represent four intersections, and vehicle S wants to send a data packet to the node in park 'P' in order to get the number of available parking lots. According to the GPSR protocol, data packets will be forwarded to vehicle F along the road AC. However, because the vehicle F temporarily has no successor node to forward data packets to, vehicle F will carry the data packet until it finds a successor node or it will discard the data packet at the expiration of the TTL set time. Therefore, although the vehicle F is the closest node to the destination, the sparse condition of the road also will cause wrong packet forwarding and increase the packet loss rate and end-to-end delay. It is worth to mention that Figure 2 also has the same problem illustrated in Figure 1, because the vehicle F is moving away from destination P. Although vehicle F is moving at high velocity, its speed is still much slower than the speed of wireless signal transmission. Therefore, data packet in VANET should instead be forwarded by wireless transmission than otherwise.

2.2. The improved GPSR algorithm

Supposing all vehicles are fitted with a GPS device, so that each node can obtain necessary geographical information provided by the GPS. Considering drawbacks of the GPSR protocol illustrated in section 2.1, this paper proposes an improvement over GPSR protocol by designing a system to overcome the challenges illustrated in Figure 1 and 2. The main work focuses on improving the greedy forwarding strategy of GPSR by introducing factors such as vehicle moving direction, speed, and traffic density into the packet forwarding decision policy.

2.2.1 Data structure

Packet formats and data structures needed in this algorithm are shown through Table 1 to Table 3.

Table 1. Hello packet format

id	$x(t)$	$y(t)$	$v(t)$	$\rho(t)$

In Table 1, let id, the identity number of the current node, be 4 bytes; $x(t)$, the x coordinate of the current node at time t, take 4 bytes; $y(t)$, the y coordinate of the current node at time t, take 4 bytes; $v(t)$, the speed of the current node at time t, be 2 bytes; $\rho(t)$, the traffic density near the current node at time t, equal 1 byte.

Table 2. Format of neighboring node list

id_n	$x_n(t)$	$y_n(t)$	$\rho_n(t)$	$v_n(t)$	$x_n(t-\Delta t)$	$y_n(t-\Delta t)$

Similarly in Table 2, we assign the id_n, the identity number of the neighboring node, 4 bytes ; $x_n(t)$, the x coordinate of the neighboring node at the time t, 4 bytes ; $y_n(t)$, the y coordinate of the neighboring node at the time t, 4 bytes ; $v_n(t)$, the speed of the neighboring node at the time t, 2 bytes; $\rho_n(t)$, the traffic density near neighboring node at the time t, 1 byte; $x(t-\Delta t)$, the x coordinate of neighboring node at time $t-\Delta t$, 4 bytes ; $y(t-\Delta t)$, the y coordinate of neighboring node at time $t-\Delta t$, 4 bytes.

Table 3. Format of the temporary routing list

id_p	$\rho_p(t)$	$v_p(t)$	$d_p(t)$

Also in Table 3, let id_p, the identity number of candidate node, be 4 bytes; $\rho_p(t)$, the traffic density near candidate node at the time t, be 1 byte; $v_p(t)$, the speed of candidate node at time t, be 2 bytes; and $d_p(t)$, the distance between candidate node and destination node, be 2 bytes.

2.2.2 Routing strategy

Supposing Δt is the period of hello packet and R is the communication range of each node, the detailed routing strategy is as following:

1. Every node obtains its own coordinate information $(x(t), y(t))$ at time t by using GPS and vehicle speed at time t from the speedometer. Besides, each node maintains a variable $\rho(t)$, which is used to store the number of neighboring nodes at time t. Each vehicle can calculate the connectivity between the node itself and its neighboring nodes by receiving periodic hello messages. Finally, it counts the number of connected nodes to update $\rho(t)$ and propagates hello packet in accordance with the format illustrated in Table 1.

2. Once a node receives a hello packet, it updates the neighbor's information immediately as illustrated in Table 2. At this time, $\rho_n(t)$ means the number of neighboring nodes for current neighbor at time t. Existing information are updated every Δt time, upon the detection of a new node, the new neighboring node will be appended to the neighboring node list. Nodes whose beacons were not received after a period are then deleted from the neighboring node list.

3. When to send or forward a data packet, the algorithm works as following:

Step1: Obtain the coordinate of the destination node $(x_d(t), y_d(t))$ from the packet header. Get the coordinate $(x_n(t), y_n(t))$ of each node by traversing the neighboring node list. Calculate the angle θ between the line from current node to destination node and the horizontal axis using Formula (1). Use Formula (2) to calculate the distance (between itself and the destination node) $d(t-\Delta t)$ at time $t-\Delta t$ and $d(t)$ at time t, respectively. Let $\Delta d = d(t-\Delta t) - d(t)$, this node is moving close to the destination node if $\Delta d \geq 0$, and the node is moving away from destination node if $\Delta d < 0$.

$$\theta = \arctan[(y_d(t) - y_n(t))/(x_d(t) - x_n(t))] \tag{1}$$

$$d(t) = \sqrt{(x_d(t) - x_n(t))^2 + (y_d(t) - y_n(t))^2}\,(\cos\theta + \sin\theta) \tag{2}$$

Step2: Create a temporary routing list in accordance with the format illustrated in Table 3. Nodes in neighboring list whose $\Delta d \geq 0$ will be added into the temporary routing list, which become candidate nodes.

Step3: Traverse the temporary routing list to calculate the $D(t)$ at time t for each node according to Formula (3)

$$D(t) = \alpha * [d / v(t)] + (1-\alpha) * [\pi R^2 / \rho(t)], \alpha \in [0,1] \tag{3}$$

where α is a weight coefficient. When the vehicle is moving at low speed or entering sparse roads, α should be relatively big.

Step4: Choose the $D\min$ by traversing the temporary list and comparing the value of $D(t)$, and then get the node's id with $D\min$ as the next hop. This is formally expressed as:

$$D\min = Min\{D(t)\}$$

$$NextHop = D\min -> id\ .$$

If $Min\{D\}$ is not unique, choose the node with smallest $v(t)$ as the next hop. Because smaller the value of $v(t)$ is, slower the node leaves from the covered range; therefore, the communication link can be maintained relatively longer.

3. Simulation Experiment

Our simulation was carried out in NS-2 version 2.29 running on the Linux System.

3.1. Simulation scenario construction

Grid scenario is the most common urban traffic road scenario where there exist many crossroads and corners, which often result in frequent vehicle congestion and accidents. These areas will also have high rate of communication in VANET, so that simulating vehicle communication is greatly significant in Grid scenarios. The snapshot of Grid scenario is shown in Figure 3, where the left side is the panorama, and the right side is the zoomed map for one intersection. Sample in MOVE's manual is used to build a Grid scenario, the simulation topology size is 1000m × 1000m, the maximum road speed is not more than 20m/s, packet size is 200byte, CBR data flow rate is 16Kbps, simulation time is 100s, MAC layer uses IEEE 802.11, and other parameters are mostly consistent with the parameters in the example.

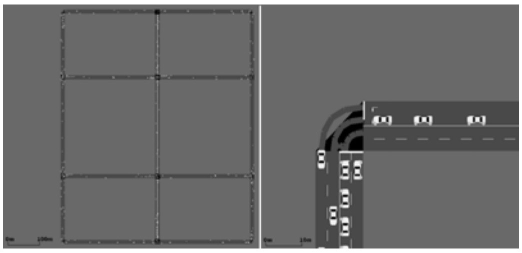

Figure 3. Snapshot of Grid scenario

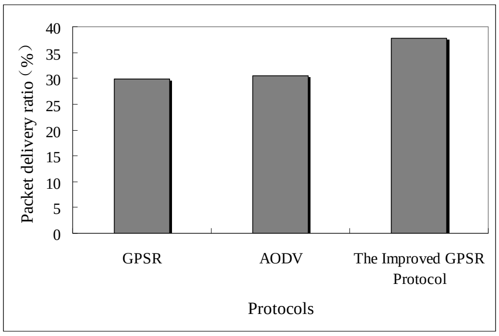

Figure 4. Comparison of packet delivery ratio

3.2. Experimental results

In this simulation, we took $\alpha = 0.5$, and identified some random traffic flows in the Grid scenario generated by MOVE, after that, we randomly chose some node couples to communicate. Running the scripts exported from MOVE into NS-2 and according to the trace file generated by NS-2 for multiple times, we statistically got the performance of our improved GPSR protocol compared with GPSR and AODV, which is shown in Figure 4, Figure 5 and Figure 6.

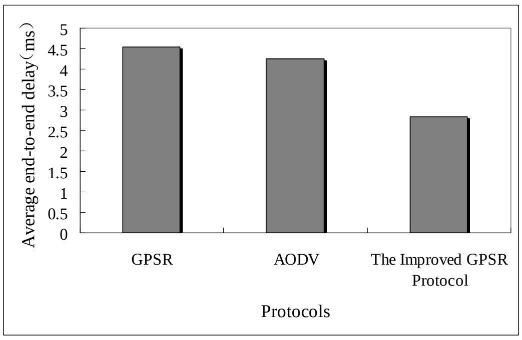

Figure 5. Comparison of average end-to-end delay

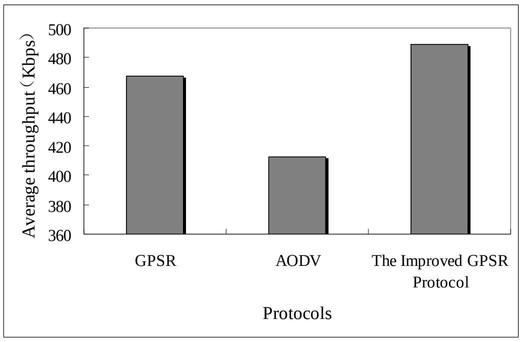

Figure 6. Comparison of average throughput

3.3. Performance analysis

The experimental results indicate that packet delivery ratio improved considerably by about 7-8% compared with AODV and GPSR. Similarly, the average throughput also increased.

Our experiment further shows that the improved GPSR protocol has a good reduction in the average end-to-end delay. This is possible because the packets are now forwarded to the neighbor node which is in the same direction with the destination node, and the ‘potential’ vehicles or nodes which could reach the destination node earlier are now selected as the next hop. Although the path through the high vehicle density may result in detour, it has more candidate successors to choose thereby making it more favorable. Besides, Grid scenario has stronger connectivity at high vehicle density than in sparse conditions. Therefore, the impact of geometric distance will not necessarily lead to increase end-to-end delay.

The results also show that the improved GPSR protocol has shorter end-to-end delay and higher packet delivery ratio, and are especially suitable for broadcasting safety application messages in VANETs.

4. Conclusion and Future works

Our idea to improve the performance of GPSR protocol is from a careful study and analysis of the traditional GPSR, considering the local GPS information, vehicle density, moving direction, and speed. We experimentally achieved our proposal and simulated it successfully. Our main point of improvement is on the GPSR's greedy forwarding strategy. Because it is difficult to obtain trace files in real traffic environment, and general network simulators do not have node mobility models for VANET. We used the Grid scenario constructed by MOVE and simulated our improved GPSR protocol in NS-2. The proposed protocol is compared with the traditional GPSR and AODV protocols, the performance indicates that our proposed protocol is very promising and significantly more suitable for vehicular ad hoc networks. This paper shows simulation only on the V2V (Vehicle to Vehicle), we intend to do further research on combining V2V and V2I (Vehicle to Infrastructure) as well as introducing GIS into simulation experiments. And experiment based on real urban traffic environment is also another consideration.

5. Acknowledgment

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6. References

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