A Dynamic Hop Choosing Mechanism for Routing in VANETs

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Abstract. Routing in VANETs is challenging because of the frequently changed topology. The dynamic nature is caused by the high speed mobility of vehicles as nodes in the network. Adapting the dynamic topology is the main task during routing in VANETs. Fortunately, the mobility patterns and positions of vehicles in vehicular networks are predictable. Making advantage of these characteristics, this paper presents an improved dynamic hop choosing mechanism. It not only predicts the positions and mobility patterns of vehicles, but also takes into account the vehicular traffic density. Accordingly, the next hop chosen by our mechanism is seldom out of reach even if the topology is quickly changed. Simulation results exhibit that the proposed algorithm improves the packet delivery ratio and reduces the network latency when compared with state of the art protocols.

Introduction

Vehicular Ad hoc Networks (VANETs) is a kind of mobile ad hoc networks, nodes in which are vehicles, providing inter-vehicle communication. There are kinds of ways for vehicles to communicate with each other. They can either use infrastructure or not. VANETs are self-organized networks which can run without any prior infrastructure. Especially in some extreme situation, where it’s hard to deploy any infrastructure, this infrastructure-free characteristic of VANETs is valuable.

IEEE 802 committee published a wireless communication standard for wireless access in the vehicular environment, i.e. IEEE802.11p in 2010. It will be used with dedicated short range communication system, which is suitable for VANETs and works well for vehicle-to-vehicle communication and vehicle-to-infrastructure communication. Besides these works, routing in VANETs is still a challenging task due to the high vehicular mobility and frequently changed topology.

In literature, numbers of routing protocols have been proposed, and they’re categorized into two categories: topology-based and position-based. Topology-based routing protocols perform packets forwarding on the basis of topology information of the network. However, vehicles are always moving fast. This highly dynamic nature of vehicular networks causes frequently topology changes. Which means the link states are unstable, hence the topology information used to make routing decision is with instability. This results in degraded performance of the topology-based routing protocols. Position-based routing protocols perform packets forwarding on the basis of the position information of the ultimate destination and of the direct neighbors. They are usually stateless, with no need to store the link state information which is frequently changed in vehicular networks. To this point, the forwarding strategy is not susceptible to the dynamic topology. Meanwhile, we take advantage of the real-time position information to implement the forwarding strategy. It’s common these days that the vehicles get a GPS device on board, where vehicles can get their own positions from. The position information can be broadcast to their neighbors. Under these condition, position-based routing protocols gained extensive attention. Some researchers have proved that the position-based routing algorithm are more suitable for highly dynamic vehicular networks. [1] They are more scalable and outperform topology-based routings.
The rest of the paper is organized as follows. Section 2 explains the position-based routing protocols. In section 3, we detail our design scheme of node selection mechanism based on node’s position and directional dense. Section 4 verifies the efficiency of our proposed algorithm through the simulation results. In section 5, we conclude this paper and present the future work.

Related Work

In recent years, the position-based routing protocol are widely concerned by researchers. At present, lots of position-based routing algorithms for VANETs have been proposed, such as Greedy Perimeter Stateless Routing (GPSR)[2] based on pure greedy forwarding, Geographic Source Routing (GSR)[3] base on the supporting from a map of the city, Improved greedy traffic aware routing protocol (GyTAR)[4] based on the dynamic junction selection mechanism, and Enhanced GyTAR (E-GyTAR)[5] which enhanced the junction selection mechanism. E-GyTAR is an enhanced version of GyTAR. It is designed for routing in city environment. It assume that vehicles in the discussing network have GPS devices, location services, digital maps, and IFTIS on board. Vehicles can get their own geographic positions though GPS devices, get the ultimate destination’s position though location service such as Grid Location Services (GLS)[6]. Digital maps can provide the position information of the junctions in the city. IFTIS[7] is the Infrastructure-free traffic information system used to calculate the real time vehicular density between adjacent junctions. As nodes in VANETs can always get sufficient power supply and processing capacity, these assumptions are reasonable.

In city scenario, vehicles move along streets. Hence any route can be presented by a series of junctions. And the core job of determine a route lies on the junction selection. In E-GyTAR, junctions constituting the route are selected dynamically. Each candidate junction are scored according to the directional density[7] and geographic position. Forwarding vehicles measure the distance between the candidate neighbor junction and the destination using Eq. 1.

\[
\text{score}(N_j) = \alpha \times (1 - \frac{D_n}{D_c}) + \beta \times \text{Den}_{dir} \]  

where \(D_n\) is the curvemetric distance (the distance measured following the geometric shape of the roads passing by) between the candidate junction \(N_j\) and the destination; \(D_c\) is the curvemetric distance from the current junction to the destination; \(\text{Den}_{dir}\) is the total number of vehicles between current junction and next candidate junction moving towards \(N_j\), which represents the directional density; \(\alpha\) and \(\beta\) are the weighing factor for the distance and traffic density respectively, and add up to 1.

The candidate junction with the highest score is selected as the next junction every time the packet arrived at a junction or the source starts finding the first junction. As for routing between the two involved junctions, E-GyTAR uses improved greedy approach. Before relaying packet, a forwarder consults its neighbor table to find out a best next hop at that moment.

There is still one risk, that E-GyTAR sometimes may suffer from local maximum problem (the forwarder is the closest to the next destination junction). It exploits carry and forward[6] approach as a recovery strategy. The forwarder will carry the packet until it arrived at the next destination junction or until another node closer to the next destination junction enter into its transmission range.

ITAR- Dynamic Traffic Aware Routing

The proposed hop choosing mechanism improves aforementioned junction selecting strategy, and recovery strategy used by E-GyTAR. We make a reasonable assumption that vehicles have GPS, GLS, digital maps, and IFTIS on board. ITAR selects the junction consisting a route dynamically. When a source generates a packet and each time a packet is at a junction, the neighboring junction was scored. Packets are relayed in an improved greedy forwarding manner as E-GyTAR does. When a packet encounter a local optimum, the local optimal node should score itself and its neighbor vehicles, and decide whether to carry the packet or forward it.
Next Junction Selection. When we score the neighbor junctions, the curvemetric is the core factor, but not the ratio mentioned in E-GyTAR. Considering the scenario in Fig. 1, score of junction \( J_{n2} \) is larger than the score of junction \( J_{n1} \) if we use Eq. 1. That means \( J_{n2} \) will be chosen as the next junction, which is obviously wrong. Considering \( J_c \) can directly relay the packet to \( J_{n1} \), but need 2 more hops when relay packets to \( J_{n2} \), junction \( J_{n1} \) should be chosen. We redesign the junction selection algorithm as followed:

Algorithm 1. Pseudo code for junction selection mechanism in ITAR

For (all candidate junctions \( J_n \))

1. \( D := \) the destination ;
2. \( J_c := \) the current junction ;
3. \( J_n := \) the next candidate junction ;
4. \( D_{cd} := \) the Euclidean distance between \( J_c \) and \( D \);
5. \( D_{nd} := \) the curvemetric distance from \( J_n \) to \( D \);
6. \( D_{cn} := \) the curvemetric distance from \( J_c \) to \( J_n \);
7. \( N_{avg} := \) average number of vehicles per cell;
8. \( N_{con} := \) constant which represents the ideal connectivity degree we can have within a cell;
9. between \( J_c \) and \( J_n \) moving in the direction of \( J_n \);
10. calculate score \( (J_n) \) using Eq. 2 with \( \alpha + \beta = 1 \);

\[
\text{score} (J_n) = \alpha \times \frac{D_{cd}}{D_{cn} + D_{nd}} + \beta \times \min \left( \frac{N_{avg}}{N_{con}}, 1 \right)
\]  

(2)

Figure 1. Junction selection mechanism.

The junction with the highest score is selected as the next junction. This selecting mechanism takes into account both the junction’s position and the consideration of vehicular traffic on the street.

Recovery Mode. There are still risk that packet gets stuck in local optimum. E-GyTAR and other position-based routing algorithms adopt unconditional carry and forward approach as the recovery strategy. However, considering the situation in Fig. 2, this strategy may result in unnecessary packet dropping sometimes. As in Fig. 2, node \( i \) find itself the local optimal node, and it will carry the packet rather than forward it to node \( j \). In fact, node \( j \) will be closer than node \( i \) to the destination junction a few moment later. But if note \( i \) doesn’t calculate, it won’t know this potential candidate forwarder. In ITAR, when packet gets stuck in local maximum, the node immediately score itself and its neighbors, and choose the one with the highest score to pass on the packet to. Eq. 3 presents how to score every node, including the node doing the calculation and its one hop neighbors.

\[
\text{score} (N) = m \times [\gamma \frac{(1-d/L)+ \lambda (v/v_{max})}{1}]
\]

(3)

where \( d \) is the distance between the node and the junction, \( v \) is the velocity of the node, \( L \) and \( v_{max} \) are the length and maximal velocity of the road segment which can be read from the digital map, \( \gamma \) and \( \lambda \) are used as weighting factors for the distance and vehicular speed respectively (with \( \gamma + \lambda = 1 \)), \( m \) is a directional factor with 1 for node moving towards the junction and -1 for those in the opposite direction.
Simulation

We compared the performances of ITAR with state of the art protocols. The experiments were conducted on NS-2 simulator. Medium access control (MAC) is IEEE 802.11p, with a radio range of 260m. The mobility traces were generated using VANetMobiSim with the micro-mobility controlled by IDM_IM. Table 1 illustrates the simulation setup.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation time</td>
<td>200s</td>
</tr>
<tr>
<td>Dimension</td>
<td>2500m × 2000m</td>
</tr>
<tr>
<td>Number of intersection</td>
<td>16</td>
</tr>
<tr>
<td>Number of roads</td>
<td>24</td>
</tr>
<tr>
<td>Number of vehicles</td>
<td>100-300</td>
</tr>
<tr>
<td>Average vehicle speed</td>
<td>45Km/h</td>
</tr>
<tr>
<td>Transmission Range</td>
<td>250</td>
</tr>
<tr>
<td>Packet sending rate</td>
<td>0.1-1 second</td>
</tr>
<tr>
<td>Packet size</td>
<td>128 byte</td>
</tr>
<tr>
<td>Weighting factors (α; β)</td>
<td>(0.5 ; 0.5)</td>
</tr>
<tr>
<td>Weighting factors (γ; λ)</td>
<td>(0.5 ; 0.5)</td>
</tr>
</tbody>
</table>

Effect on Packet Delivery Ratio. Fig.3 illustrates the packet delivery ratio increases as the traffic density increases. This is because the probability of connectivity will be higher in higher traffic density. It also proves that why our proposed node choosing strategy take into account the vehicular traffic density. ITAR shows better in PDR, because of the enhanced recovery mode it adopts. Wrong carrying decision of other protocols will contribute to the packet loss rate.

Effect on Average Latencies. Fig.4 shows that ITAR overcomes the other three protocols in network average latencies. This is because the junction selection mechanism of ITAR is the most reasonable. As is discussed in section 3, the next junction selection algorithm always chooses the candidate junction closest to destination, and in the meantime it’s also the closest to the current junction. This always make the route with fewer forwarding hops and consequent smaller latency.

Effect on Routing Overhead. GSR shows higher routing overhead than the other three in Fig.5. This is because it sent more control messages. The routing overhead increases as the number of vehicles increases, but ITAR is lower than the other two. This is because of ITAR used the enhanced
hop choosing algorithm which result in smaller communication traffic and higher PDR than the other two.

Summary
This work aims at improving the routing efficiency in vehicular ad-hot networks. The simulation results have proved the proposed scheme adapts itself well to VANETs in varying vehicular traffic. The proposed algorithms has improved the delivery ratio and reduced the network latencies in different node density compared with some other routing protocols. We are currently extending this work. We will try to analyze the impact of the weighting factors used for node score calculation in the future.

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References