Road-based Multipath Routing in Urban VANETs

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Abstract

In vehicular ad-hoc networks (VANETs), packet loss is a common problem because of high node mobility. Many literatures tried to solve this problem. Connectionless approach (CLA) is a road-based single path routing protocol. If a route disconnects, it has to create a new route. Ad-hoc on-demand multipath distance vector (AOMDV) and node-disjoint multipath routing (NDMR) are multipath routing protocols. They can switch to another route if ones route is disconnected. However, since AOMDV and NDMR are node-centric routing protocols, a route is easier to be disconnected than that in road-based routing protocols. In this paper, we propose a novel road-based multipath routing (RBMR) protocol. To the best of our knowledge, there is no existing road-based multipath routing protocol. We attempt to establish two fast routes from sender to receiver. We use real-time vehicular traffic information to create two road-based node-disjoint routes to reduce the impact of broken links. Once a route (the first route) is first established, it will be used to send packets immediately. The next established route (the second route) will be used if the first route is disconnected. Based on real-time vehicular traffic, the proposed RBMR selects a relatively stable node as a relay node in a road segment based on the vehicle persistence score (VPS) for data forwarding. Simulation results show that the proposed RBMR improves the packet delivery ratio by 9%, 6%, and 15%, end-to-end delay by 28%, 11%, and 7%, and control overhead by 30%, 25%, and 19% compared with AOMDV, NDMR, and CLA, respectively.

Keywords: Multipath routing, node-disjoint, road-based, urban VANETs.

1. Introduction

Without base stations and infrastructures, a vehicular ad-hoc network (VANET) is an instantly deployable wireless network [1]. It consists of mobile nodes (vehicles). Each node moves arbitrarily and communicates with others by wireless links [2]. So the topology of the VANET changes frequently.

The routing protocols can be categorized into proactive routing protocols and reactive routing protocols [3]. The traditional proactive and reactive routing protocols were designed for mobile ad hoc networks (MANETs) routing protocols that their packet delivery ratios are poor if they are applied to VANETs directly [4]. They establish node-centric view of routes (i.e., a route is established between source and destination in advance) that may break frequently because of VANETs’ high mobility. This is called the node-centric problem, as illustrated in Figure 1 [4].

(a) At time t  
(b) At time t+a

Figure 1. Node-centric problem.

In Figure 1(a), S is the source node and D is the destination node. When S wants to send packets to D at time t and N2 is a relay node. So the route from S to D is from S to N2 to D. After time a, N2 is out of the transmission range of S, so the route from S to D is broken. If S wants to send packets to D, it has to find another new route, and it will result in control overhead and transmission delays [4].

In order to resolve the above problem, greedy perimeter stateless routing (GPSR) [5] was proposed. It chooses the node which is in the transmission range of the sender and is the closest neighbor to the destination. So in Figure 1(b) S will choose N1 instead of N2. Since there are dead end roads in urban VANETs, GPSR do not always perform well in urban VANETs [4]. For instance, in Figure 2, S is the source and D is the destination. And N1 and N2 are in the transmission range of S. When S is ready to send packets to D, it will choose N2 as a relay node in GPSR. And N3 will be chosen by N2. But the road which N3 is locates is a dead end. So N3 has no node to choose as a relay node [4]. This is called the geographical routing problem.
RBVT [4] proposed a road-based routing protocol that leverages real-time vehicular traffic information to create paths. It records road segment IDs instead of node IDs. In Figure 1, S will record the road segment ID, A1, instead of the node ID, N2. If S wants to send packets to D, it will choose the node which is on A1 and in the transmission range of S. So in Figure 1(b), N1 will be chosen as a relay node instead of N2. But the RBVT creates only one path; if the only path breaks, it has to create a new path.

Multipath routing creates several routes from sender to receiver. So if one route is disconnected, the sender can choose another route for packet transmission. So multipath routing can reduce control overhead and increase packet delivery ratio [6]. In this paper, we propose a road-based multipath routing (RBMR) protocol, which focuses on establishing two routes from sender to receiver. The proposed RBMR uses real-time vehicular traffic information to create two road-based node-disjoint routes. The RBMR begins to send packets once a route is first established. The route (the second route) next established later will be used if the first route is disconnected.

The rest of this paper is organized as follows. Related work is reviewed in section 2. In section 3, we describe the background of vehicle persistence score. In section 4, we detail the proposed RBMR. Simulation results are shown in section 5. In section 6, we give concluding remarks and outline future work.

2. Related work

Multipath routing can improve the packet delivery ratio compared with single path routing, which has been proved in [6]. Multipath routing protocols can be classified into node-disjoint routing and link-disjoint routing [7]. Paths which are called node-disjoint mean they have no common node besides source and destination nodes. And paths which are called link-disjoint mean they have no common link. Figure 3 shows two node-disjoint paths. There are two paths from source S to destination D; one is S-A-B-D and the other is S-M-N-D. There are no common node except S and D. Figure 4 shows two link-disjoint paths. S-A-B-C-D and S-M-B-N-D are two paths from S to D. Because B is a common node, so the two paths are not node-disjoint. But the two paths have no common link, so they are called link-disjoint. The node-disjoint routes have been proved to have better performance than the link-disjoint routes on breaking probability of paths [8].

Ad-hoc on-demand multipath distance vector routing (AOMDV) [9], which is link-disjoint, creates several paths from source to destination, and packets are sent after paths established. So it wastes time for establishing several paths before packets can be transmitted. Node-disjoint multipath routing (NDMR) [10] is a node-disjoint multipath routing protocol. It sends packets right away after creating one path, but it is a node-centric routing protocol. Therefore, the path is easy to be disconnected in the NDMR than that in a road-based routing protocol.

3. Background of vehicle persistence score (VPS)

A reliable routing scheme based on vehicle moving similarity (RR-VMS) was proposed in [11]. This routing scheme selects a relay node by using a vehicle persistence score (VPS). A node’s neighbor which has a higher VPS means it has stayed long with the node. In order to select a stable neighbor, neighbors’ information within the transmission range has to be updated periodically. So a node sends a HELLO message to its 1-hop neighbors of the node regularly. Each node has a VPS table to record neighbors’ information. After receiving a HELLO message, a node will update its VPS table. A column, position, is added to the original HELLO message in [11]. Position is the global position system (GPS) coordinate of a node. A relay node is
chosen by the VPS value. An entry of the VPS table is <neighbor ID, position, road segment ID, direction, VPS>, which are defined as follows [12]:

Neighbor ID: the neighbor’s identifier.
Position: the GPS coordinate (x, y), which stands for the neighbor’s position.
Road segment ID: where the neighbor is located.
Direction: whether the neighbor’s moving direction towards the receiver.
VPS: the value is used to reflect the neighbor’s stability.

When a node gets a HELLO message from a neighbor, it searches the VPS table. If the neighbor’s ID does not exist in the node’s VPS table, the node adds the related information in the entry of the neighbor’s ID in the VPS table. And the VPS will be assigned to 1. If the neighbor’s ID exists in the VPS table, the VPS of this neighbor ID will be increased by 1 [12].

4. Proposed road-based multipath routing (RBMR) protocol

The main objective of the proposed RBMR protocol is to establish and maintain two node-disjoint paths and begin packet transmission once the first route (path) is established. The second route is a backup route. This protocol can be divided into two stages: route discovery stage and packet transmission stage.

4.1 Route discovery stage

A sender will first send an RREQ to neighbors when it wants to send packets to a receiver. The RREQ’s header includes sender ID, receiver ID, and a unique RREQ ID. If a neighbor node gets the RREQ with the same sender ID and RREQ ID with a previously received RREQ, it discards this RREQ. When a neighbor gets a new RREQ, it checks if it is located on the different road segment ID from the sender of the RREQ. If yes, the neighbor node adds the road segment ID to the RREQ header and broadcasts the RREQ. If no, it broadcasts this RREQ [4].

When the receiver gets the RREQ, it checks whether there is any road segment ID the same as a road segment ID except sender ID and receiver ID in a previously received RREQ. If yes, the receiver discards this RREQ. If no, the receiver sends an RREP, which includes its GPS coordinate, back to the sender through a path that follows the reverse order of road segment IDs in the header. If the sender gets an RREP, the sender proceeds to the packet transmission stage immediately instead of waiting for the second RREP. The second RREP is used to establish the second route that will be used if the first route is disconnected.

4.2 Data forwarding stage

The most important thing in the data forwarding stage is how to select relay nodes along the selected path for data forwarding. The proposed RBMR creates two road-based node-disjoint routes after the route discovery stage. The RBMR begins to send packets once a route is first established. The next route established later will be used if the first route is disconnected. When a sender wants to send packets to a receiver and one route has been established, the next stage is to choose a relay node. The procedure of choosing a relay node can be split into

Figures 5 and 6 show how to update VPS values. The VPS table belongs to node Z. The circle is the radio transmission range of Z. In Figure 5, because nodes A · B · C · D and E are in the transmission range of Z, so their node IDs and VPS values can be found in the table. However, F is not in the transmission range of Z, so it is not shown in the table. After receiving another HELLO message, in Figure 6, because A · B · D and E are still in the transmission of Z, so their VPS values are increased by 1. But C is out of the circle, so its record is deleted from the table. Now F is inside the circle for the first time, so its VPS is assigned to 1.
four steps. First, it checks each neighbor in the VPS table to see whether the next road segment ID in the header is equal to the neighbor’s road segment ID. If yes, it goes to the second step. The second step is used to check whether the direction of the neighbor is toward the receiver. If yes, the third step is to add the neighbor to the relay node list. After these three steps, the sender will sort the VPS values in the relay node list by the descending order. Finally, the relay node will follow the above four steps to select the next relay node to forward packets until the receiver is reached.

5. Simulation

In this section, we describe simulation setup and evaluate simulate results. Then, we compare the proposed RBMR with AOMDV [9], NDMR [10], and CLA [13].

5.1. Simulation setup

We use a urban VANET scenario to evaluate the proposed RBMR. Simulations were performed using NS2.34 [14]. Simulation results were acquired by the average of twenty runs. We compare the proposed RBMR with the above three protocols, in terms of packet delivery ratio, end-to-end delay, and control overhead, which are defined as follows:

Packet delivery ratio: the number of data packets received at the receiver divided by the number of data packets generated at the sender [11].

End-to-end delay: the time taken for a data packet to be transmitted (including route acquisition delay) from sender to receiver [13].

Control overhead: when transferring a data packet, how many control packets need to send [11].

Table 1. NS2 and VanetMobiSim simulation settings [6] [14] [15].

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network area</td>
<td>1000 m * 1000 m</td>
</tr>
<tr>
<td>MAC Protocol</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>Transmission range</td>
<td>376 m</td>
</tr>
<tr>
<td>Simulation time</td>
<td>600 s</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>30, 40, 50, 60, 70</td>
</tr>
<tr>
<td>Connection type</td>
<td>CBR</td>
</tr>
<tr>
<td>Packet size</td>
<td>512 bytes</td>
</tr>
<tr>
<td>Mobility model</td>
<td>VanetMobiSim</td>
</tr>
<tr>
<td>Packet sending rate</td>
<td>10 packet/sec</td>
</tr>
<tr>
<td>Max. traffic lights</td>
<td>10</td>
</tr>
<tr>
<td>Min. Speed</td>
<td>8 m/s (28 km/hr)</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>17 m/s (61 km/hr)</td>
</tr>
<tr>
<td>Max. acceleration</td>
<td>0.6 m/s</td>
</tr>
<tr>
<td>Normal deceleration</td>
<td>0.5 m/s</td>
</tr>
<tr>
<td>Sender-receiver pairs</td>
<td>10</td>
</tr>
</tbody>
</table>

VanetMobiSim [15] mobility model was used to generating vehicle mobility traces. Simulation settings are summarized in Table 1.

5.2. Simulation results

In Figures 7, 8, and 9 we compare the proposed RBMR with AOMDV, NDMR, and CLA. Simulation results show that the proposed RBMR improves packet delivery ratio by 9%, 6%, and 15%, end-to-end delay by 28%, 11%, and 7%, and control overhead by 30%, 25%, and 19% compared with AOMDV, NDMR, and CLA, respectively.

Figure 7. Packet delivery ratio under different number of nodes.

Figure 8. End-to-end delay under different numbers of nodes.

Figure 9. Control overhead under different number of nodes.
6. Concluding remarks and future work

In this paper, we have presented a novel and efficient road-based multipath routing protocol for urban VANETs. We establish and maintain two node-disjoint paths and begin data forwarding once the first route (path) is established. The second route is a backup route. The vehicle persistence score is used to select a stable neighbor as a relay node to forward packets. The proposed RBMR enhanced the packet delivery ratio by 9%, 6%, and 15%, end-to-end delay by 28%, 11%, and 7%, and control overhead by 30%, 25%, and 19% compared with AODV, NDMR, and CLA, respectively. Simulation results support that the proposed RBMR performs well in urban VANET environments than node-centric multipath routing protocols. In future work, we may combine multimedia streaming with the proposed RBMR to provide more efficient multimedia streaming for urban VANETs.

7. Acknowledgements

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