A Road and Traffic-aware Routing Protocol in Vehicular *Ad hoc* Networks

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Abstract— **The Vehicular *Ad hoc* Network (VANET), a subset of Mobile *Ad hoc* Network, is used in many applications such as assisting driver with signage, road traffic reporting, telling the way, etc. Since VANET has highly dynamic topology and various vehicle densities, developing a routing protocol that can satisfy above applications requirements is a great challenge. In this paper, we present an efficient Road and Traffic-aware Routing Protocol (RTRP), in which the best path to transmit data packets is calculated based on distance and density factor in the 1st phase. This best path includes intersection sequent numbers that data packets would be transmitted along. By using the best path information, a greedy data forwarding algorithm is deployed in the 2nd phase on each road segment, based on a Reaching Intersection Time (RIT) and a Turning Direction Probability (TDP). We develop a mobility model that includes road intersection, traffic light at intersection, various density areas, obstacles, etc. to validate proposed routing protocol. The simulation shows that our developed mobility model is realistic and can adapt well with proposed routing protocol. In future work, simulation to evaluate RTRP routing protocol will be performed to qualify its advantages in details.**

Keywords— **VANET, data forwarding scheme, routing protocol, traffic-aware, density-aware**

I. INTRODUCTION AND MOTIVATION

The Vehicular *Ad hoc* Network (VANET) is one kind of mobile *ad hoc* network that provides communications among nearby vehicles, and between vehicles and nearby fixed equipments. There are many applications, such as assisting driver with signage, warning dangerous roads, and telling the way, etc., can be implemented in VANET. However, the main problem is whether existing routing protocols can satisfy end-to-end delay and packet delivery ratio requirements of such applications. Some traditional routing protocols, such as AODV [1], DSR [2] are not suitable to VANET since VANET environment has high mobility and instability. Geographical routing protocols, e.g., greedy-face-greedy (GFG) [3], greedy other adaptive face routing (GOAFR) [4], greedy perimeter stateless routing (GPSR) [5] use any nodes that ensures progress toward the destination as forwarding node. But, sometimes they cannot find any forwarding node in case of dead-end road or constructing road.

A number of road-based routing protocols have been designed to address this issue. However, these protocols fail to factor in the vehicular traffic flow. Recently, a reactive road-based using vehicular traffic information routing protocol (RBVT-R), which bases on city-roads vehicular traffic information to create the path consisting of numbered road intersections with high probability of network connectivity among them, is proposed by work [6]. In RBVT-R, the path that data packets are transmitted along is the shortest path, so it is better than GPSR in terms of end-to-end delay and the number of forwarding hops. However, in fact, most drivers often choose the way based on two factors: distance and density. Therefore, when selecting the optimal path, density should be considered.

Since VANET topology is changed frequently, data forwarding strategies need to be adaptive. There are three classes of forwarding strategies, which can be identified: restricted directional flooding, hierarchical forwarding, and greedy forwarding. Since navigators are recently available in almost all vehicles, the greedy forwarding approach becomes more realistic and efficient approach in comparison with other approaches. In [7], some data forwarding strategies that aim to improve the conventional GPSR scheme without using any street-aware information are proposed. However, when applied in GPSR, they incur some drawbacks. First, motion vector calculation is complex and become ineffective when node reaches the intersection too soon. Second, the node selection, based on the nearest node moving towards the destination, is not effective when the path going through this node is not the optimal one. Third, a current forwarding node cannot find any next forwarding node when reaching dead-end road or constructing road.

For the above reasons, we proposed an efficient road-aware and traffic-aware routing protocol, in which the best path to transmit data packet is calculated in the 1st phase based on distance and density factor. The best path includes intersection sequent numbers that data packets should be transmitted along. Upon this best path, a greedy data forwarding algorithm can be deployed on each road segment in the 2nd phase based on the Reaching Intersection Time (RIT) and the Turning Direction Probability (TDP) [8]. As a result, in our proposal, the only thing, which needs to be solved, is the problem of data forwarding node selection in each road segment. Therefore, the end-to-end delay can be reduced significantly. Moreover, the speed of drivers are different, therefore the

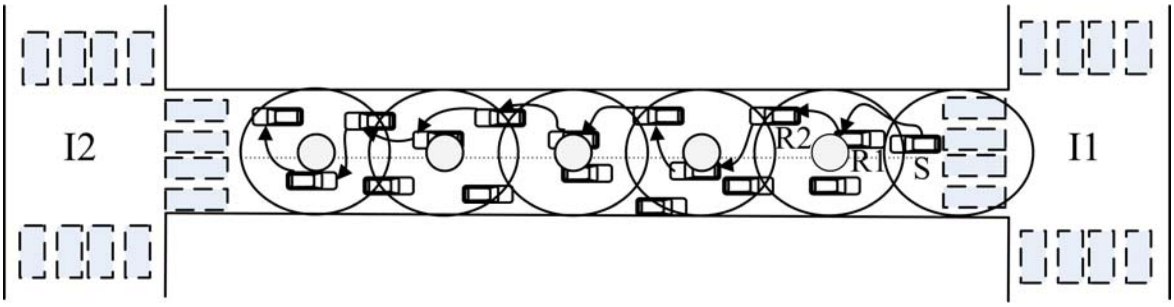

Figure 1. Vehicle density estimation

selection of forwarding node based on RIT is better than one based on distance between nodes and destination in term of forwarding-hops number. Besides, the path, which data packets are transmitted along, is the best path, so the number of hops and the end-to-end delay are also reduced significantly.

II. Road- and traffic-aware routing protocol

Before describing proposed routing protocol, we assume some conditions and factors that are used in this paper. First, we assume that all vehicles are supported by GPS, so vehicle speed, position, its neighbour position, and destination position can be determined. Second, we assume that all vehicles are equipped with street-level map by using navigation systems. We define that the neighbours of one node are the nodes located within this node's coverage range.

A. Path discovery in RTRP

Firstly, we describe the calculation of density factor which partially derived from [9]. As illustrated in Figure 1, road segment from intersection I_1 to intersection I_2 is divided into small cells. The cell size should be less than or equal to coverage range of vehicles (~ 250m in 802.11 standards). On each cell, leader node (LD node) is defined as the node that is located nearest to cell center. Therefore, LD node can determine the number of nodes in its cell by counting its neighbour nodes.

RTRP is a reactive source routing protocol. When a node wants to transmit data packet to the destination, it initiates a route discovery procedure. Source node creates a RR message that includes source address, source location, destination address, destination location, the list of intersection sequence number, total number of vehicles, total number of cells, LD bit (11: if node received RR message is cell leader, 01: the farthest node in cell, 10: the first node in other road segment), and time out.

At the initial time, source node sets LD=11, adds the ID of the moving toward intersection and forward RR message to the LD node of its cell. After that, RR message is also flooded from source node area to destination area like AODV or RBVT-R (see Figure 2). But in these routing protocols, RR flooding procedure requires many nodes to participate in discovery procedure. In RTRP, we propose a new strategy that can reduce the number of participating nodes in route discovery process. RTRP requires only the LD node, the farthest node in each cell, and the first nodes on a new road segments that receive RR message to participate in route

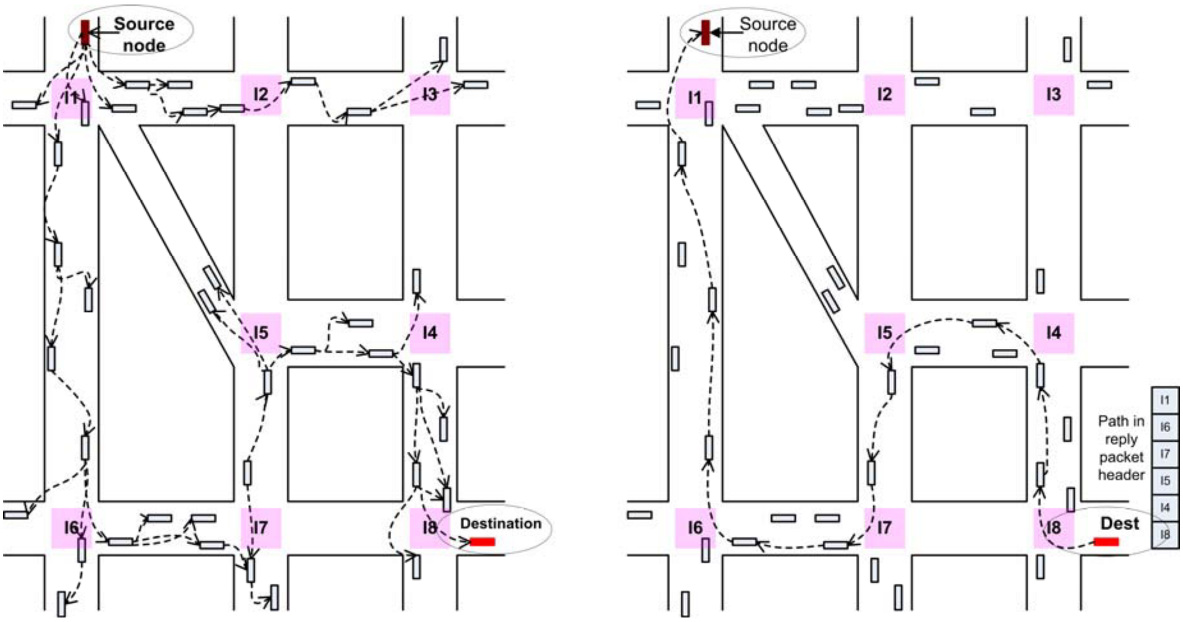

Figure 2. Route discovery in RTRP

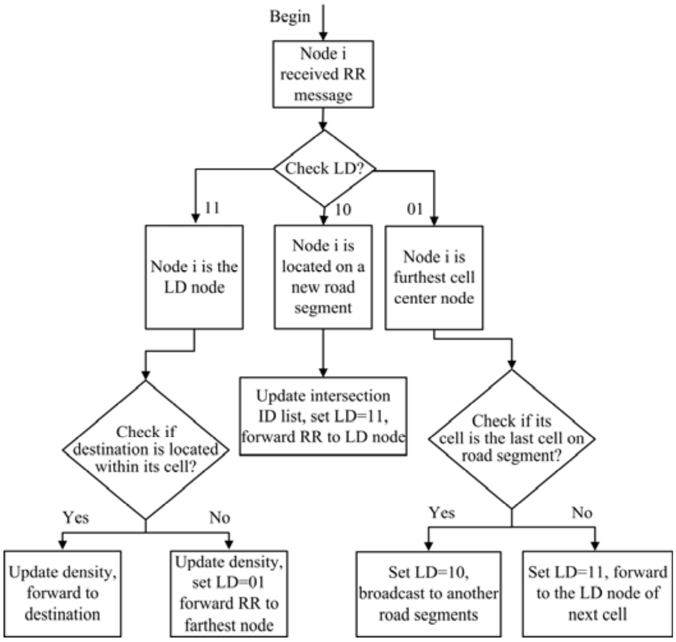

Figure 3. Flowchart of node function determination in route discovery stage

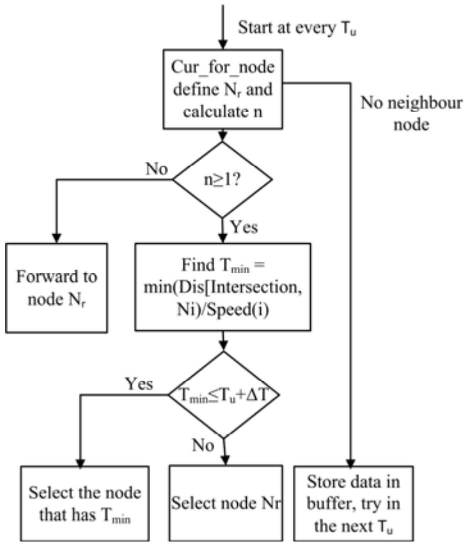

Figure 4. Flowchart of greedy road and traffic-aware data forwarding scheme

discovery.

We illustrate LD checking process in detail as shown in Figure 3. When node *i* receives RR message, LD field is checked at first.

1) If LD=01, node *i* is the farthest cell center node. In this case, the density factor does not need to be updated. Node *i* checks if its cell is the last cell in road segment. If so, it sets LD=10 and broadcast to other nodes in other road segments. If not, node *i* sets LD=11, and forwards RR to LD node in its next cell.

2) If LD=11, that means node *i* is the cell leader node. It calculates the number of node within its coverage range and updates cell density factor in RR message by adding up the total number of vehicles and the total number of cells. Then, it also checks if destination node is located within its coverage range. If so, LD node forwards RR message to the destination node. If not, it sets LD=01 and forwards RR message to the farthest node in its cell.

3) If LD=10, node *i* is the first node on the new road segment receiving RR message. It updates the list of intersection sequence numbers, sets LD=11, and forwards RR message to the LD node in its cell. When destination node receives the first RR message, it considers the path included in this RR message as the shortest path. The density factor is calculated following this formulation:

$$Cell\ density = \frac{Total\ number\ of\ vehicles}{Total\ number\ of\ cells}. \qquad (1)$$

Density factor in the first received RR message is compared with the second one, the third one, and so on, in a *T* time. *T* time is set depending on application. The destination node creates a REP message and sends back to source node through the path included in RR message. Once source node receives REP message, data packets are forwarded by using greedy forwarding strategy as described in the next section.

B. Greedy road and traffic – aware data forwarding strategy

As motivated in Section I, we propose a new data forwarding strategy to reduce the end-to-end delay, and the number of forwarding hops. Upon route discovery in 1st phase, the source node knows the list of sequential numbered intersections that the data packets are transmitted along. Each node is added with speed and TDP at every intersection. Greedy data forwarding in RTRP is illustrated by flowchart in Figure 4. At every T_u time, each node within the current forwarding node's coverage range broadcasts its current position and the next moving-to intersection. The next moving-to intersection is an intersection in the direction of highest probability. Based on this information, the current forwarding node specifies the nearest intersection node (called N_r) and calculates number of nodes (called *n*) that will turn to the next intersection belonging to the routing path.

If $n \geq 1$, the current forwarding node calculates RIT of these nodes, as the following:

$$RIT_i = Distance(intersection, N_i)/Speed(N_i), \qquad (2)$$

where *i* belongs to *n*, N_i is a node that will turn to the next intersection belonging to the routing path, and $Speed(N_i)$ is the speed of node N_i at time T_u.

If $min(RIT_i) \leq T_u + \Delta T$, where ΔT is guarantee time, this node will reach intersection soon, and it is selected as a next forwarding node.

Otherwise, if $n=0$ or $min(RIT_i) > T_u + \Delta T$, i.e., source node is far from intersection, so N_r will be selected. If there is no neighbor node, data will be stored in the buffer of current forwarding node and the current node will try to find the next forwarding node at the next time T_u.

For example, as showed in Figure 5, the red car is a current forwarding node. Upon route discovery in RBVT-R, the optimal routing path [I_2, I_5, I_4] is added in the header of data packet. At time T_{u1}, node n_1, node n_2, and node n_3 are within

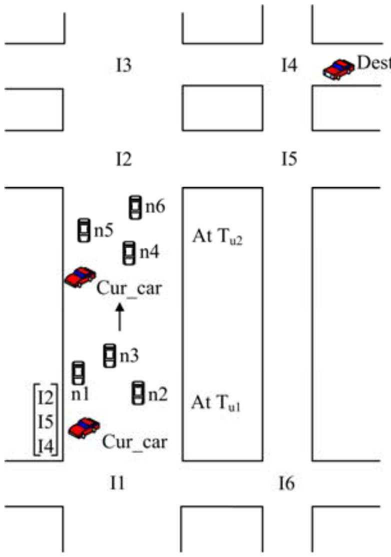

Figure 5. Example of greedy road and traffic-aware data forwarding scheme

cur_car's coverage range, they broadcast their current positions and turning directions at intersection I_2. These turning directions are based on the nodes' TDP. According to this information, the *cur_car* defines that node n_3 is the nearest intersection I_2, node n_1 and node n_2 will turn to direction leading to I_5 at intersection I_2. However, at this time, nodes n_1, n_2, and n_3 are far from intersection I_2, which means $min(RIT_1, RIT_2) > T_u+\Delta T$. Hence, node n_3 is selected as the next forwarding node. At time T_{u2}, node n_6 is the nearest intersection I_2, node n_5 and node n_4 will turn to direction leading I_5 to at intersection I_2. At that time, node n_4, node n_5 and node n_6 are near to intersection I_2, that means $min(RIT_4, RIT_5) \leq T_u+\Delta T$. Suppose that speed of n_4 is higher than that of n_5, therefore $RIT_4 < RIT_5$. That means node n_4 will reach intersection I_2 earlier than node n_5. In this case, node n_4 is selected as the next forwarding node. At the next T_u time, node n_4 will move to road segment $[I_2, I_5]$, the next forwarding node will be selected like previous process and continued until data packet reaches the destination node.

III. Developed Mobility Model for RTRP

In general, for a new proposed protocol, a new mobility model needs to be developed to adapt this routing protocol. For our proposed routing protocol, a new mobility model is developed, which includes some realistic parameters such as: various density areas, various speed, traffic lights, intersections among road segments, and trip planning to guide where vehicles to go. We develop a mobility model that can satisfy above requirements and evaluate its effect on VANET routing protocol performance. In details, we create a dimension of 2000mx2000m with three different areas: suburban, residential, and downtown. The vehicle density in downtown is highest and the vehicle density in suburban is lowest. Some other settings are shown in Table 1.

We use VanetMobisim [10], [11] and Qualnet [12] to perform simulation, in which VanetMobisim is used to develop mobility model. The VanetMobisim output trace file is used for network simulation in Qualnet network simulator. The simulation results of end-to-end delay and throughput are compared with Random Way Point (RWP) mobility model [15] to show the reality of our mobility model. The RWP model is a mobility model widely used in MANET. In RWP model, nodes move directly along straight line segments from each waypoint to the next one. The waypoints are assumed to be distributed independently and uniformly in the RWP movement domain. Table 2 shows the Qualnet simulation parameters.

TABLE 1. VANET MOBISIM PARAMETERS

Parameters	Value
Simulation area	2000mx2000m
Seed	18
Vehicle velocity	30~50km/h
Number of traffic lights	6
Number of road segments	20
Obstacle density	5/1000~20/1000
Min stay	5s
Max stay	30s
Simulation time	300s
Number of vehicles	30~200vehicles

TABLE 2. QUALNET SIMULATION PARAMETERS

Parameters	Value
Simulation area	2000mx2000m
Communication range	250m
CBR data rate	1pck/s
Packet size	512bytes
Beacon interval	30s
Mac protocol	802.11a/b
Maximum forwarding hops	60hops
Buffer time	60s
Number of vehicle	30vehicles
Number of connections	6cons

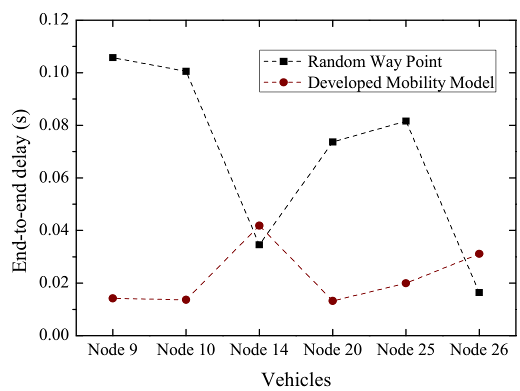

Figure 6. End-to-end delay performance

Simulation results point out mobility model effect on routing protocol performance. Figure 6 shows the end-to-end delay comparison between our developed mobility model and RWP mobility model. Since three areas are created with various vehicle densities, and traffic lights are set at intersections, the end-to-end delays of nodes are various. In detail, node 9, node 10, node 20, and node 25 are located in residential and suburban areas, where vehicle densities are not high. Hence, their end-to-end delays are better than Random Way Point. At node 14 and node 26, end-to-end delay is worse than RWP because node 14 and node 26 are located at downtown where vehicle density is highest. At intersections, vehicles suffer from long waiting time until traffic light turns green. It also causes end-to-end delay at vehicle 14 and vehicle 26 to be higher than ones located in suburban and residential.

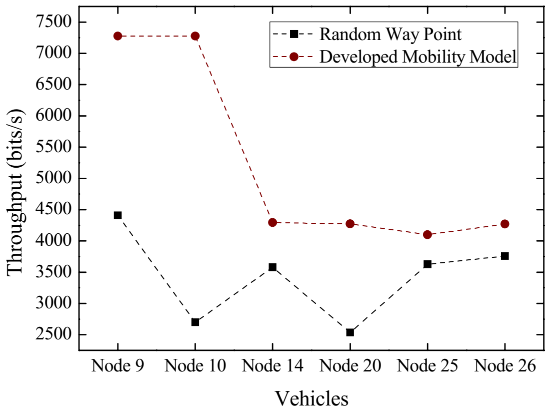

Figure 7. Throughput performance

In terms of throughput, at vehicle 14 and vehicle 26, even though end-to-end delay is worse than RWP, Figure 7 shows that throughput is greatly improved. The effects of intersections, traffic lights, and density are realistically taken into account. That means our developed mobility model is more realistic.

IV. Conclusion

In this paper, we have conceptually proposed RTRP routing protocol that includes two stages. In the 1st stage – route discovery, optimal path is determined based on density and distance. Depending on the application, destination node can prefer to choose the shortest path with higher density or the longer path with less density. In the 2nd stage – greedy data forwarding process, data forwarding node is selected based on TDP and RIT on each road segment. By using TDP on each road segment, our proposed routing protocol can reduce the time to calculate direction vector which is very complex in some previous proposals. Hence, the selection of forwarding node based on RIT is better than one based on distance between nodes and destination in terms of forwarding hops.

We have also presented a developed mobility model that is suitable to our proposed routing protocol and evaluate its effect on VANET routing protocol performance. The simulation shows that our developed mobility model is realistic and can adapt well to proposed routing protocol. In further work, we will evaluate RTRP routing protocol by simulation and quantify its advantages in detail.

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