Roadside Unit Deployment Based on Traffic Information in VANETs

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Abstract. In this paper , based on the Vehicle-Assisted Data Delivery (VADD) routing algorithm [3] we present a new approach for the deployment of roadsice units (RSU) to improve the data delivery delay in VANET. The main concept of our approach is to add RSUs in intersections that can effectively improve the packet delivery delay. We will address the problem "How to decide which intersection needs to deploy RSU as a data buffer?"

The packet will buffer in a RSU and wait for a vehicle to carry it to the next hop. The RSU increases the opportunity to use wireless communication, decreases the chance to use carry and forwarding.

We have set up a simulation scenario and various traffic conditions to evaluate the performance. The simulation results show that the packet delivery ratio of proposed method has better performance than VADD about 5-10%. The delivery delay of our approach has outperformed than VADD about 15-20% on delivery delay.

Keywords: Vehicular Networks (VANETs), Roadside Unit, Vehicle-Assisted Data Delivery (VADD), Carry-and-Forward, Wireless Sensor Networks.

1 Introduction

In vehicular ad hoc networks (VANETs), packets are delivered by wireless transmission or carry and forwarding [1-8]. The difference is the delay time, transmitted by carry and forwarding is very slowly then wireless transmission. In addition, there are different traffic flows and average vehicle velocities on each road. Some roads are suitable for wireless communication, but others are suitable to carry and forwarding. The key point is the intersection, the packets are delivered to the next road by crossed the intersection.

In this paper, there are two types of the roads (dense and sparse), one is tend to be transmitted by wireless and the other one is tend to be transmitted by carry and forwarding. Based on what types of roads are connected to the intersection. But when an intersection is connected by the two types of roads at the same time, this intersection decides the packet will transmit to which type of roads, fast or slowly. For this reason, we add roadside unit (RSU) at those intersections, based on the

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Vehicle-Assisted Data Delivery (VADD) routing algorithm [3], when the packet reaches intersection, but there are no vehicles on the best direction, RSU will store the packet for a while, and waiting for an opportunity. The RSU increases the chance to use wireless communication, decreases the chance to use carry and forwarding. In addition, based on vehicle or RSU, straight or intersection, we provide the algorithms for each conditions, the packet delivery delay is decreased. Finally, we will set up a simulation scenario and various traffic conditions to evaluate the performance.

The rest of this paper is organized as follows. The proposed approach roadside unit deployment based on traffic information is described in Section 2. Section 3 presents experimental results and evaluations. Finally, the conclusion is given in Section 4.

2 Roadside Unit Deployment Based on Traffic Information

There are two kinds of the roads, one is tend to be transmitted by wireless and the other one is tend to be transmitted by carry and forwarding. Based on what kinds of roads are connected to the intersection. But when an intersection is connected by the two kinds of roads at the same time, this intersection decides the packet will transmit to which kind of roads, fast or slowly. For this reason, we add roadside unit (RSU) at those intersections, based on the VADD [3] routing protocol, when the packet reaches intersection, but there are no vehicles on the best direction, RSU will store the packet for a while, and waiting for an opportunity. The RSU increases the chance to use wireless communication, decreases the chance to use carry and forwarding.

2.1 System Concept

(1) Packet Delivery Delay in a Straightway

VADD [3] is based on the idea of carry and forward. The main concept is to select a forwarding path with the smallest packet delivery delay. There are two cases of the packet delivery delay in a straightway. The Case 1 is wireless transmission time and the Case 2 is vehicles carry time (carry and forward).

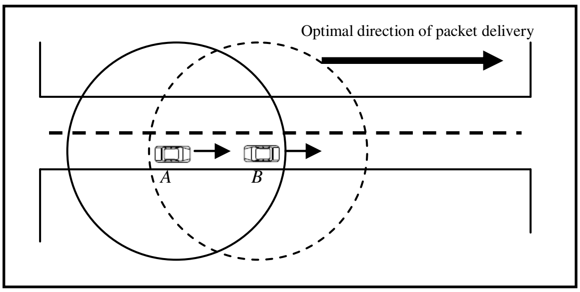


Fig. 1. Select the next vehicle to forward the packet in the straightway

In this scenario, there are two vehicles A and B in a straightway in Figure 1. The solid line and dashed line circles are the wireless transmission range of A and B, respectively. Firstly, we suppose vehicle A is the packet carrier. A will forward the packets to B that is within communication range (called *contacts*) available at the straightway. The packet delivery delay is resulted by wireless transmission (Case 1). Now vehicle B is the packet carrier. There is no *contact* available. Vehicle B will carry the packet continuously and looks for the next forwarding opportunity in the future. The packet delivery delay is resulted by vehicles carry (Case 2).

We can conclude that the main factor of packet delivery delay is carried and forward (Case 2). Our approach is to find a solution that the packet will be forwarded to the one on the road with the smaller delay. Therefore, the main objective of this paper is to reduce the occurrence of Case 2.

(2) Packet Delivery Delay in an Intersection

In above subsection, we find that the main cause of packet delivery delay in a straightway is carry and forward (Case 2). In the VADD algorithm, the packet will be forwarded to the one on the road with the smaller delay. It will try to adopt wireless transmission as soon as possible. The efficiency of VADD is limited by the traffic pattern and the road layout. Based on the existing traffic pattern, a vehicle can find the next hop to forward the packet to reduce the delay.

In VANET, the packet carrier passes the intersection with the packet, and looks for the next forwarding opportunity. The traffic pattern may be dense or sparse. On a dense road, the packets are forwarded hop by hop with wireless transmission. On a sparse road, the packets are carried by a vehicle. Therefore, the packets will be forwarded to a dense or sparse road depending on the selection of next traveling road.

As shown in Figure 2, source *S* has a packet to forward to certain destination *D*. Assume the packet has two choices on selecting the next hop to pass through intersection I_A. These two available paths are P_1: from I_A moving *south-east* to *D* (dashed line P1), and P_2: from I_A moving *east-south-west* to *D* (solid line), respectively. If there is no other contact available in the front of P_2 to carry the packet to *D*, the VADD algorithm will select shorter path P_1. However, P_1 is composed of sparse roads. It will greatly increase the packet delivery delay. In this case, we can

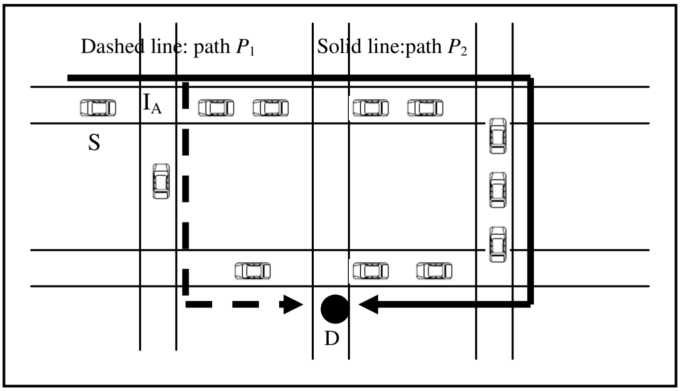


Fig. 2. Select the next vehicle to forward the packet in an intersection

add a roadside unit (RSU) at intersection I_A to play the role of data buffer. The packet will buffer in RSU and wait for a vehicle to carry it to the next hop.

2.2 Roadside Unit Deployment

(1) The Road Types

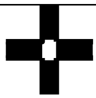
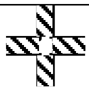
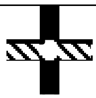
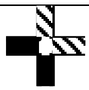
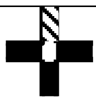
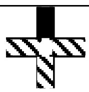
In VANET, the traffic pattern may be dense or sparse on a road. In this paper, we will define two types of roads according the density of vehicles on a section of road. The packets are forwarded hop by hop with wireless transmission on a dense road. The packets are carried by a vehicle on a sparse road.

In this paper, we will compute the average traffic flow F'_{ij} of r_{ij}. We define a *critical traffic flow* $C_{ij} = F'_{ij} * \alpha$, where α=1, 1.5, or 2. Let F_{ij} be the physical traffic flow of r_{ij}. If ($F_{ij} \geq C_{ij}$), r_{ij} is a dense road, the packets are trended to forward hop by hop with wireless transmission in most cases. Otherwise, if $F_{ij} < C_{ij}$, r_{ij} is a spare road, the packets are trended to carry and forward by a vehicle.

(2) The Intersection Types

Suppose that an intersection is connected by four sections of road. There are two types of roads dense and sparse. Therefore, the possible combinations of all traffic patterns are 24=16 kinds. Since the intersection patterns are symmetry, we can rotate and reverse the patterns. As shown in Table 1, there are totally 6 types of intersection patterns. Here, a road with solid line denotes a dense road and a road with solid line denotes a spare road.

Table 1. The Road Types

Types	Intersection Patterns	Discription
T_A		An intersection with heavy traffic load that is connected by four sections of dense road. This is a traffic bottle neck. May be in the town centre.
T_B		An intersection with light traffic load that is connected by four sections of sparse road. May be on the outskirts of town.
T_C		An intersection of a dense road (the main line) and a sparse road.
T_D		May be going into a town centre.
T_E		May be going into a town centre.
T_F		May be going into a traffic jam road.

(3) Location Selection for RSUs

The main concept of our approach is to add RSUs in intersections that can effectively improve the packet delivery delay. We will address the problem "How to decide which intersection needs to deploy RSU as a data buffer?" The packet will buffer in RSU and wait for a vehicle to carry it to the next hop. Let x denote the distance between two vehicles. If ($x \le R$) the packets are forwarded hop by hop with wireless transmission among vehicles, where R is the wireless transmission range of vehicles. Let σ denote the density of vehicle on a road. The probability of delivery packet hop by hop with wireless transmission is:

$$P(x \le R) = 1 - e^{-R\sigma} \tag{5}$$

Otherwise, if ($x \ge R$) the packets are carried and forward by a vehicle. The probability of adapting vehicle-assisted data delivery is:

$$P(x > R) = e^{-R\sigma} \tag{6}$$

Firstly, consider the type of intersection T_A of Table 1. This is an intersection with heavy traffic load that is connected by four sections of dense road, where $F_{ij} \ge C_{ij}$. The packets are almost transmitted hop by hop with wireless transmission. That is an intersection with $P(x \le R) \approx 1$ and $P(x > R) \approx 0$. If we deploy a RSU in intersection of type T_A, to buffer packets, it had to pay the penalties for packet delay. The extra packet delay time is $\frac{1}{F_{ij}}$ in average. So it is not necessary to deploy a RSU in intersection of type T_A.

Secondly, consider the type of intersection T_B of Table 1. An intersection with light traffic load is connected by four sections of sparse road, where $F_{ij} \le C_{ij}$. The packets are carried and forward by a vehicle. In this case, using RSU cannot instead of vehicle-assisted data delivery by wireless transmission. Therefore, it is also not necessary to deploy a RSU in intersection of type T_B.

As shown in Table 1, the types: T_C, T_D, T_E, and T_F are intersections of roads with $F_{ij} \ge C_{ij}$ and $F_{ij} < C_{ij}$, respectively. Let's study the type T_C as shown in Figure 3. It is an intersection of mixed kind of roads (i.e. a dense road and a sparse road).

VADD algorithm tends to rout a packet to a road with traffic flow $F_{ij} \ge C_{ij}$. Assume the optimal delivery direction is r_{ab}. However, if the packet is forwarded to r_{ac}, may be unexpected no *contact* exist. Since the traffic flow of r_{ac} is $F_{ij} < C_{ij}$, the packet must be carried and forward by a vehicle. The resulted packet delay is $P(x > R) \times (\frac{l_{ac}}{V_{ac}}) = e^{-R\sigma}(\frac{l_{ac}}{V_{ac}})$. If we deploy a RSU in intersection of type T_C, to buffer packets, the extra packet delay time is $\frac{1}{F_{ab}}$ in average. So it is better to deploy a RSU in intersection of type T_C. The intersections of types: T_C, T_D, T_E, and T_F are the same scenarios. Therefore, in this paper we will deploy RSUs in these types of intersections to reduce the packet delay.

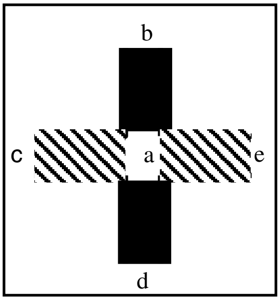


Fig. 3. An intersection of type T_C (an intersection of mixed kind of roads)

If we want to deploy the RSUs in a VANET, initially, collects the t average velocity v_{ij} and traffic load F'_{ij} for each road r_{ij}. Secondly, estimate the optimal value of α for *critical traffic flow* computation ($C_{ij} = F'_{ij} * \alpha$). Determine the type of each intersection accordingly. Finally, deploy the RSUs in intersections of mixed kind of roads according to the trade-off between cost and packet delay.

2.3 Routing Algorithm

In this paper, we use VADD routing algorithm to rout packets in a VANET. We adopt the delay model of VADD compute the optimal direction of packet delivery. For a selected direction, the packet carrier chooses the next intersection towards the selected direction as the target intersection, and applies GPRS algorithm to pass the packet. The packets are *geographical greedy forwarding* towards the target intersection. If the current packet carrier cannot find any *contact* to the target intersection, it buffers the packet in a RSU. If there is no deploying a RSU in this intersection, it chooses the direction with the next lower priority and re-starts the geographical greedy forwarding towards the new target intersection. This process continues until the selected direction has lower priority than the packet carrier's current moving direction. At this time, the packet carrier will continue carrying the packet.

3 Experimental Results

In this section, we evaluate the performance of proposed method (RUDTI). We compare the performance of the proposed approach to two existing approaches: the VADD [3] and GPSR [1].

3.1 The Simulation Environments

The experiment is based on a 600m × 300m rectangle street area, which presents a grid layout as shown in Figure 4. The street layout is derived and normalized from a snapshot of a real street map in Google Map [9].

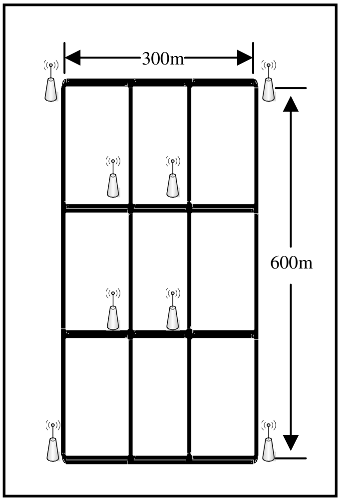


Fig. 4. A grid layout of the simulation street area

In our simulation scenario, the average speed ranges from 30 to 60 Kilo-meters per hour. Different number of vehicles is deployed to the map, and the initial distribution follows the predefined traffic density. To evaluate the performance on different data transmission density, we vary the data sending rate (CBR rate) from 1 to 10 packets per second. The simulation setup is shown in Table 2.

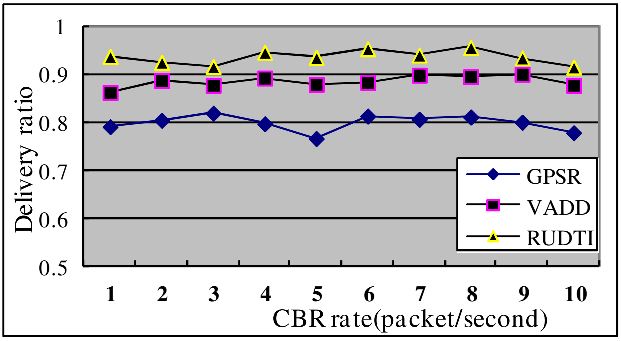
We set up a scenario to simulation and various traffic conditions using QualNet network simulator [10], SUMO [11], and MOVE [6]. The simulation results show that the packet delivery ratio and delivery delay of our approach has a better performance.

Table 2. Simulation setup

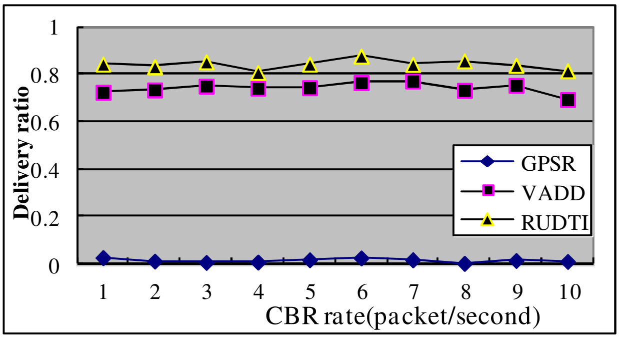
Parameter	Value
Simulation area	600m × 300m
Number of intersections	16
Number of RSUs	8
Number of vehicles	30 -60
Vehicle velocity	0 – 60 Km/hour
Data sending rate (CBR rate)	1 – 10 packets/Sec.
Data packet size	127 Byte
Vehicle beacon interval	0.5 Sec.
Time to life (TTL)	128 Sec.

3.2 Simulation Results

The performance of the approach is measured by the data delivery ratio, the data delivery delay, and the generated traffic overhead. The simulation time is 240 seconds.



(a) 60 vehicles (Dense)



(b) 30 (Sparse)

Fig. 5. Data delivery ratio for CBR

As shown in Figure 5 & 6, the proposed approach RUDTI outperformed VADD for light traffic load (sparse). Our simulation results show that the packet delivery ratio of proposed method has better performance than VADD about 5-10%.

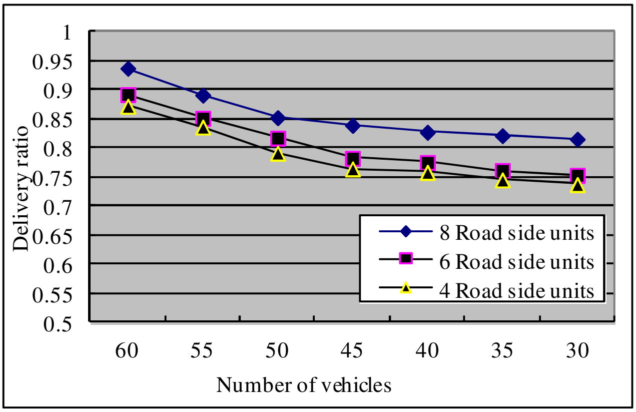


Fig. 6. Data delivery ratio for number of RSUs

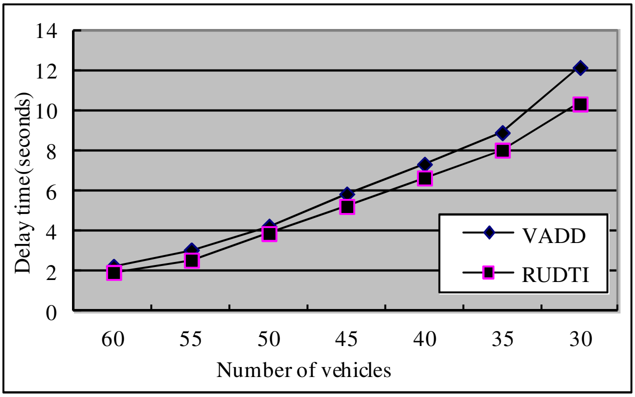


Fig. 7. Data delivery delay for number of vehicles

As shown in Figure 7, the delivery delay will increase for light traffic load. The RUDTI achieves better performance than VADD for the assistant of RSU added routing. Figure 8 show that the RSU increases the chance to use wireless communication, decreases the chance to use carry and forwarding.

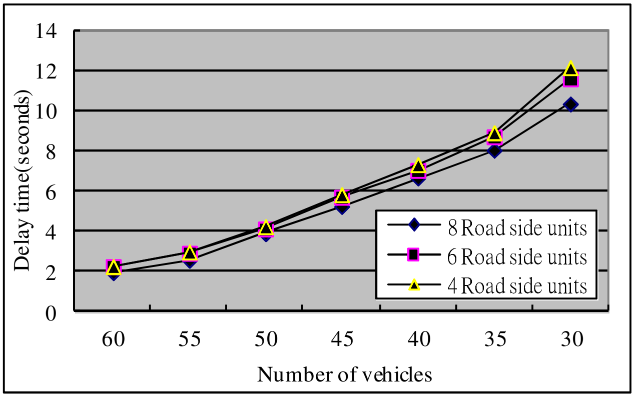


Fig. 8. Data delivery delay for number of RSUs

4 Conclusion

Based on the VADD routing algorithm, we deployed roadside unit (RSU) at intersections to add the packet delivery in VANET. When the packet reaches intersection, but there are no vehicles on the best direction, RSU will store the packet for a while, and waiting for an opportunity. The RSU increases the chance to use wireless communication, decreases the chance to use carry and forwarding.

Our simulation results show that the packet delivery ratio and delivery delay of proposed method has better performance than VADD about 5-10% on delivery ratio and 15-20% on delivery delay, respectively.

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