

# A Method for Improving Data Delivery Efficiency in Delay Tolerant VANET with Scheduled Routes of Cars

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## Abstract

*In VANET (Vehicular Ad Hoc Network), delivering messages to a specific location is difficult due to high mobility of vehicles. In this paper, we propose a method for efficient message delivery in VANET utilizing the route information in car navigation systems. In the proposed method, each car periodically exchanges the positional information and scheduled route in the car navigation system with neighboring cars in the radio range. By referring to the exchanged information, each car forwards messages to the neighboring car approaching the closest location to the destination among the neighboring cars. Through simulations, we confirmed that the proposed method achieves better delivery rate with low bandwidth usage than a Geocast-based method and the Epidemic routing.*

## 1 Introduction

Recently, considerable research efforts have been made to realize efficient communication between vehicles. A VANET (Vehicular Ad Hoc Network) is a network that uses multi-hop wireless communication among vehicles and devices on roadsides. By using a VANET, various services that do not depend on an infrastructure can be realized inexpensively. But, due to high mobilities of the vehicles, it is generally difficult to make a stable data transfer between two specific locations in a VANET. Recently, people are paying attention to a technology called a DTN (Disruption/Delay Tolerant Network) that improves delivery rate of messages in an unstable network. In a DTN, each relay-

ing node does not forward a message if no suitable relay node exists in its radio range. The node forwards the message later when such a node appears in its radio range. By this way, a DTN can efficiently deliver messages even in the case with frequent network partitions. We can expect improvement of message delivery rate by combining the unique characteristics of a DTN and a VANET, in which nodes move in high speed while carrying messages, and the moving route can be accurately predicted by referring to information in the car navigation system.

In this paper, we target a vehicular application such that each vehicle collects traffic or weather information and stores the collected data to a roadside device. In order to realize such an application, we propose a method for delivering messages on a VANET with high delivery rate and low communication bandwidth utilizing the route information in car navigation systems. In the proposed method, vehicles periodically exchange the route information, and forward messages to vehicles which will get closer to the message destination according to the route information.

To evaluate our method, we conducted simulations using a traffic simulator NETSTREAM[1] and a network simulator to check the performance of the proposed method. We conducted 10 minutes of simulations with a road system of an urban area in a 1.4km × 1.6km region. We made some vehicles send messages and compared our method to a simple flooding method, Geocast and the epidemic routing[8, 9]. The simulation results showed that our method reduced the total bandwidth to 1/4 of simple flooding under a condition with low communication traffic. When there were more communication traffic among vehicles, the delivery rate for our method was better than any of other methods.

## 2 Related Work

The main differences between a VANET and a general mobile ad-hoc network are that a VANET involves highly dynamic topology changes due to higher mobility of nodes, and the nodes move along streets. General routing protocols used in MANET like AODV[2] or DSR[3] are not utilizing these properties.

Several methods are proposed for routing or sharing information among vehicles [4, 5, 6, 7]. While these methods work well in a relatively small region with high node density, they tend to have a problem of low delivery rate of messages under a condition of low node density when delivering messages to a distant destinations.

Geocast [8] is a technique to deliver messages to the destinations identified by their geographical locations. In Geocast, each node relays messages to the neighboring node geographically closest to the destination. It works efficiently if nodes are dense enough, but if there are areas where node densities are very low, Geocast sometimes fails to deliver messages to their destinations.

We are aiming at realizing stable communication under a condition of non-uniform traffic density and no continuous network connectivity. The store-carry-and-forward is a technique for such an environment. Vahdat et al. proposed a simple routing protocol named Epidemic Routing, based on the store-carry-and-forward[9]. In Epidemic Routing, when a node gets close to another “infected” node which has a message to propagate, the infected node broadcasts the message. When the non-infected node receives the message, it will become an infected node in a predetermined probability. By repeating this probabilistic propagation, the information can be propagated efficiently without congestion. However, it is known to be difficult to determine the optimal probability of infection according to the node density, mobility, etc.

Zhao et al. proposed a method named Message Ferry for sharing data in a mobile ad-hoc network without continuous network connectivity[10]. In this method, nodes called “ferry nodes” which move along the predetermined routes are utilized. Communication between other “regular nodes” can be realized by making the ferry nodes carry messages to the nodes close to the message destination.

We proposed a method for sharing messages among vehicles where there is no continuous network connectivity[7]. In this method, we use buses on regular routes as message ferries. Since this method is for sharing messages among vehicles, the objective is different from the method proposed in this paper.

Spyropoulos proposed a technique named Spray and Wait[11] in which a message sender node sends out multiple same messages, and these messages are delivered using the store-carry-and-forward technique. By adjusting the

number of messages sent out by the originating node, the delivery rate and the communication bandwidth can be adjusted. This number is determined according to the preset information of the route to the nodes.

## 3 Proposed Method

In this section we describe our assumptions, formulate the problem, and then we explain the proposed method.

### 3.1 Application Model

We are aiming at realizing an efficient communication between devices on roadsides and remote vehicles. In this paper, we assume that a vehicle sends messages to a device on a roadside, as our application model.

### 3.2 Notations

We now give the notations used in this paper.

- Map data : graph  $G = (V, E)$  representing road system
  - $V$  : Set of all crossings. Each element is accompanied with its position.
  - $E$  : Set of all streets between crossings.
- $C$  : Set of vehicles. Each element ( $c \in C$ ) is accompanied with following information.
  - $ID$  : Vehicle ID
  - $r$  : Preset route (A list of elements  $e \in E$ )
- $B$  : Set of all destinations (devices on roadsides). Each element ( $b \in B$ ) is accompanied with following information
  - $ID$  : Device ID
  - $p$  : Position (An element  $v \in V$ )
- $D$  : Set of messages to deliver. Each message ( $d \in D$ ) is accompanied with following information
  - $ID$  : ID of the message sender vehicle
  - $q$  : The destination ( $q \in B$ ) of message
  - $TTL$  : Time to live

### 3.3 Assumptions

We assume that all vehicles are equipped with a navigation system which shows the route to a specified destination. The navigation system has the following devices.

- IEEE 802.11 wireless LAN communication device
- Data storage
- Digital map

- Route navigation function
- GPS receiver

We assume that each vehicle  $c$  strictly follows the route  $c.r$ . The vehicles use only one channel during the communication via the WiFi devices. We also assume that each message consists of only one packet.

### 3.4 Overview of the Method

In this paper, we aim at maximizing the number of messages delivered to the destination before their TTL expires. We use the store-carry-and-forward technique to route the message based on the information in the navigation system. We make each vehicle exchange route information with neighboring vehicles and forward the messages to be delivered. We make each vehicle perform these two operations in a time sharing manner. The proposed method consists of two threads : the information exchanging thread and the message forwarding thread, and these threads are executed simultaneously.

### 3.5 Information Exchanging Thread

In this thread, *hello messages* are exchanged between vehicles. A hello message sent from vehicle  $c$  consists of the ID  $c.ID$ , the current position of  $c$  and the route information  $c.r$ . Each vehicle has a table called *neighbor table* to store the received hello messages. We store the all contents in a hello message and the time to expire (described below) in a table entry.

In this thread, the following two operations are performed every second. 1) Each vehicle broadcasts a hello message every  $P$  seconds. We set  $P$  to 3, taking account of the mobility of vehicles and radio range. 2) We subtract 1 from the “time to expire” of each entry in the neighbor table, and if “time to expire” becomes 0, we delete the entry.

If a vehicle receives a hello message from a neighboring vehicle, the message is stored in the neighbor table. We set “time to expire” to  $P$  at this time. If there is an older entry from the same vehicle, the older entry is deleted.

### 3.6 Message Forwarding Thread

In the message forwarding thread, each vehicle forwards the messages according to the received hello messages. For each combination of an entry in the neighbor table and a retained message, the minimum distance between the preset route for the vehicle recorded in the entry and the destination of the message is calculated. The minimum distances between the preset route of the vehicle retaining the messages and destinations of all the retained messages are also calculated. If the minimum distance between a message

destination and the preset route for a neighboring vehicle is smaller than that for the vehicle retaining the message, the vehicle forwards the message to the vehicle with the route of the smallest minimum distance. For example, suppose that vehicle V and W are now located in the top left corner of Fig. 1, and they will follow the route shown in the figure. Since vehicle W will get closer to the message destination than vehicle V, the message will be received and carried by vehicle W.

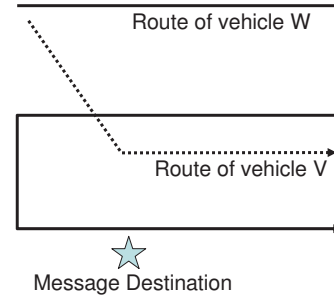


Figure 1. Example of message forwarding

## 4 Evaluation

We conducted simulations to compare the delivery rate and the total bandwidth usage of the proposed method to those of several conventional methods. To generate the traffic on the road system, we used a traffic simulator NETSTREAM[1] developed by Toyota Central R&D Labs. It has functions for reproducing behaviors of vehicles in a road system taking account of speed limits, intervals of traffic light changes, etc. To simulate the wireless network, we developed a simulator which reproduces the behavior of IEEE 802.11 wireless LAN. We used only 1 channel for the wireless communication. In order to reproduce the behavior of CSMA/CA in the MAC layer, we implemented a carrier detection and collision avoidance mechanism in the simulator. We used the Nakagami fading model [12] to determine if a reception of each packet is successful. In this model, the success rate is determined by the distance between the transmitter and the receiver as shown in Fig. 2.

### 4.1 Simulation Setting

The road system and the simulation parameters are shown in Fig. 3 and Table 1, respectively. The size of the road system is  $1.4\text{km} \times 1.6\text{km}$ . All streets in the road system have one lane for each direction. In order to reproduce the situation with non-continuous network connectivity and non-uniform traffic density, we generated 462 vehicles in 10 minutes. The maximum number of vehicles in the road

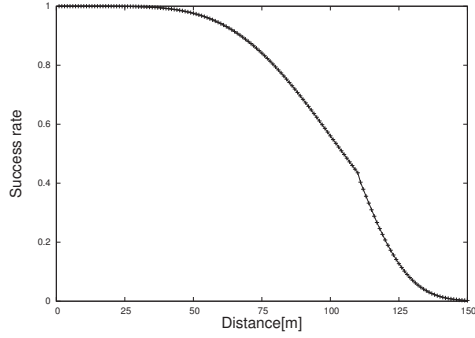


Figure 2. Nakagami fading model

system is 166, which is sparse vehicle density. We sent messages from all of the vehicles generated within 300 seconds since the start of the simulation. Each message is randomly set a destination which is either A, B, C or D in Fig. 3.

We set the parameter  $P$  to 3 (sec), because we need to make vehicles exchange messages when they pass each other. We assumed that the vehicles move in 16.67m/s and if two vehicles pass each other at this speed, they stay within 150m of radio range of each other for 4.5 sec. Thus, we set  $P$  to 3 with a 1.5 sec. of safety margin.

#### 4.1.1 Compared Methods

We compared our method with a simple flooding method, the Geocast and the epidemic routing protocols. All of these methods forward the message until the TTL of the message expires. For the epidemic routing protocols, the infection rate was set to 5% and 20%, which are relatively low. This is because the vehicles tend to form a group, and if we set the infection rate too high, all vehicles in a group will be infected.

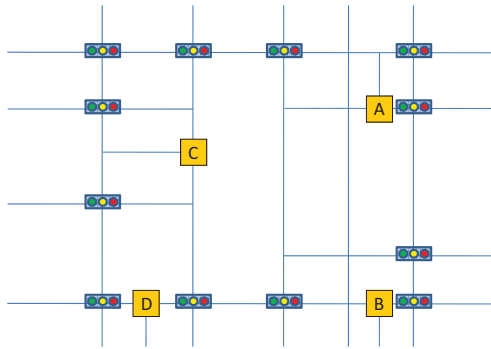


Figure 3. The road system

## 4.2 Experimental Results

We observed the message delivery rate and the total bandwidth usage while changing the number of messages

Table 1. Simulation parameters

Area size	1.4km × 1.6km
Max speed of vehicles	60km/h
Number of crossings	26
Number of vehicles	462
Number of the messages	500 - 5000
Radio range	150m
WiFi bandwidth	12Mbps
Hello message size	100byte
Message size	1.5kbyte
Simulated time	10 minutes
TTL	300 seconds

sent from vehicles. The results are described below.

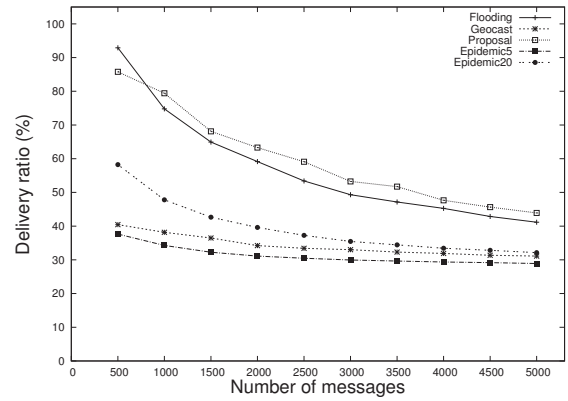


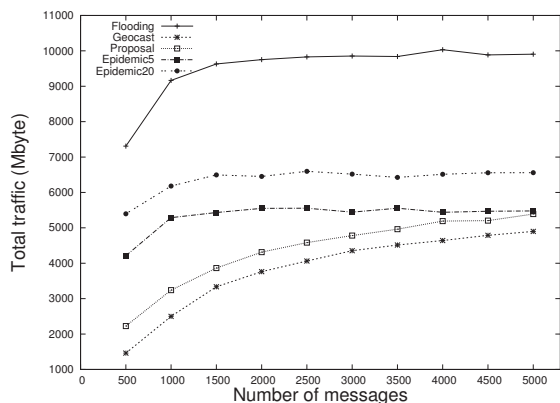
Figure 4. Num. of messages vs delivery ratio

#### 4.2.1 Message Delivery Rate

Fig. 4 shows the change of message delivery rate when the number of all messages sent is changed between 500 and 5000. When 500 messages were sent, the proposed method achieved 85.7% of delivery rate, while the delivery rate for the Geocast protocol was 40.4%. This is because the Geocast protocol tends to fail to deliver messages in a case of network partition. In all methods, delivery rate decreased as the number of all messages sent increased, but the proposed method maintains the highest delivery rate. This is because the proposed method saves the bandwidth by making vehicles carry the messages instead of relaying them via wireless communication.

#### 4.2.2 Bandwidth Usage

Fig. 5. shows the change of total amount of transmitted data from all vehicles when the number of messages sent is changed between 500 to 5000. When the number of all messages is 500, the proposed method only consumes 1/4



**Figure 5. Num. of messages vs total BW**

of bandwidth consumed by the flooding method. As the number of all messages increased, the flooding method and the epidemic protocol experienced wireless network congestion. On the other hand, the proposed method and the Geocast protocol do not have the congestion at all. In the case of 5000 messages, the proposed method only used a half of total bandwidth compared to the flooding method. The proposed method was the second best among the all compared methods in terms of the total bandwidth usage.

## 5 Conclusion

In this paper, we proposed a DTN-based method for delivering messages utilizing the route information in car navigation systems. Our simulation-based evaluation showed that our method achieves a higher delivery rate with a lower bandwidth usage compared with some existing routing protocols. As a future study, we will design and implement a protocol to deliver a message from a road side device to a specific vehicle.

## References

- [1] Teramoto, E., Baba, M., Mori, H., Kitaoka, H., Tanahashi, I. and Nishimura, Y. : "Prediction of Traffic Conditions for the Nagano Olympic Winter Games Using Traffic Simulator : NETSTREAM," *Proc. of 5th World Congress on Intelligent Transport Systems*, Vol.4, pp.1801–1806, 1998.
- [2] Perkins, C.E., and Royer, E.M.: "Ad hoc on-demand distance vector routing," *Proc. of 2nd IEEE Workshop on Mobile Computing Systems and Applications (WMACSA'99)*, pp. 90–100, 1999.
- [3] Johnson, D., and Maltz, D.: "Dynamic Source Routing in Ad Hoc Wireless Networks," *Mobile Computing*, Kluwer, pp. 153–181, 1996.
- [4] Perkins, C. E. and Bhagwat, P. : "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers," *ACM SIGCOMM Computer Communication Review*, Vol. 24, Issue 4, pp. 234-244, 1994.
- [5] Sun, W., Yamaguchi, H., Yukimasa, K. and Kusumoto, S. : "GVGrid: A QoS Routing Protocol for Vehicular Ad Hoc Networks," *Proc. of 14th IEEE International Workshop on Quality of Service*, pp. 130-139, 2006.
- [6] Shibata, N., Terauchi, T., Kitani, T., Yasumoto, K., Ito, M., and Higashino, T.: "A Method for Sharing Traffic Jam Information Using Inter-Vehicle Communication," *Proc. of Int'l Workshop on Vehicle-to-Vehicle Communications (V2VCOM) (MobiQuitous2006 Workshop)*, (CD-ROM), 2006.
- [7] Kitani, T., Shinkawa, T., Shibata, N., Yasumoto, K., Ito, M., and Higashino, T. : "Efficient VANET-based Traffic Information Sharing using Buses on Regular Routes," *Proc. of 2008 IEEE 67th Vehicular Technology Conference (VTC2008-Spring)*, pp. 3031-3036 (May 2008).
- [8] Ko, Y.B., and Vaidya, N.H. : "Geocasting in mobile ad hoc networks:location-based multicast algorithms," *Proc. of IEEE Workshop on Mobile Computing Systems and Applications (WMACSA'99)*, pp.101–110, 1999.
- [9] Vahdat, A., and Becker, D.: "Epidemic routing for partially-connected ad hoc networks," *Duke University Technical Report CS-2000-06*, 2000.
- [10] Zhao, W., and Ammar, M.H.: "Message Ferrying: Proactive Routing in Highly-partitioned Wireless Ad Hoc Networks," *Proc. of 9th IEEE Workshop on Future Trends of Distributed Computing Systems (FT-DCS 2003)*, pp.308–314, 2003.
- [11] Spyropoulos, T., Psounis, K., and Raghavendra, C.S.: "Spray and wait:An Efficient Routing Scheme for Intermittently Connected Mobile Networks," *Proc. of ACM SIGCOMM workshop on Delay-tolerant networking (WDTN-05)*, pp.252–259, 2005.
- [12] Killat, M., Schmidt-Eisenlohr, F., Hartenstein, H., Ressel, C., Vortish, P., Assenmacher, S. and Busch, F.: "Enabling Efficient and Accurate Large- Scale Simulations of VANETs for Vehicular Traffic Management," *Proc. of the 4th ACM International workshop on Vehicular ad hoc networks (VANET2007)*, pp. 29-38, 2007.