DTN Based Message Dissemination Technique Using Platoon in Urban Area

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Abstract: Message delivery is difficult due to the frequent link disconnections in VANETs. In our previous research we proposed a carry, store and forward-based method aiming at high delivery ratio and low message overhead. Each car periodically exchanges information on its current position and scheduled driving route in the car navigation system with neighbor cars. Based on the exchanged information, each car forwards its messages to the neighbor car that will approach the closest to the destination. In this paper, we enhance this previous technique by combining the idea of multi point relays (MPR) in OLSR protocol, and propose a new message delivery method.

1. Introduction

Currently, traffic jams and accidents are common problems on highways in big cities. In Japan, Intelligent Transport System (ITS) [1] has been used to alleviate these problems. This technology uses wireless communication for sharing traffic information among the roads and vehicles. Recently, usage of car navigation system is widespread, and Vehicular Ad Hoc Networks (VANETs) that use multi-hop wireless communication among vehicles and devices on roadsides for sharing information are paid attention. There have already been many research publications for VANETs, that disseminate and share messages among vehicles.

Stable data transfer between two distant locations in a VENET is inherently difficult due to the high speed and unpredictable mobility of vehicles. In some existing researches, a technique called a DTN (Disruption/Delay Tolerant Network) is employed to improve the delivery rate of messages in VANETs. In a DTN, no relaying node forwards a message if no suitable node is available for receiving the message. The node forwards the message later when such a node becomes available. In this way, a DTN can efficiently deliver messages even in a case with frequent network partitions.

In this paper, we enhance our previous work[16] that transfers messages from moving vehicles to a fixed roadside location. We propose a new method that combines multi-hop communication with our previous DTN technique. In the proposed method, we assume that every vehicle is equipped with a navigation system, and the current position and the future route of every vehicle is known. Vehicles periodically exchange route information, and forward messages to vehicles that will get closer to the message destination according to the future route information. The problem with this previous method is that each vehicle only exchanges messages between neighboring vehicles, and thus the efficiency of message delivery was not high. In this paper, we combine the idea of multi point relays (MPR) in OLSR protocol with the previous method, and make vehicles exchange messages between distant vehicles using multi-hop communication, and improve the message exchange efficiency.

We are going to implement our proposed method using the traffic simulator called SUMO [2] and evaluate the method by comparing the method with our previous method.

This paper designed as follows. In Sect. II, we provide related work, while in Section III we present our proposed method. Here we propose the notations and information exchanging and message forwarding technique. Then, section IV evaluation of experiment. Finally in section V is conclusions.

2. Related work

There are many researches in methods of routing, broadcasting, Delay Tolerant Network (DTN), and message dissemination in VANETs. Reducing the effect of broadcast storm problem in Vanets is discussed in Selective Reliable Broadcast protocol (SRB) [3]. The authors used cluster heads to efficiently rebroadcast emergency and control messages in the entire network. These techniques can detect traffic congestions, overhead and delays to destination. VADD: Vehicle-Assisted Data delivery in Vehicular ad hoc Networks protocol has been proposed [4], VADD calculate the probability for each intersection before transmitted the packet to neighbor vehicles. Another protocol called A Mobility-Centric Data Dissemination Algorithm for Vehicular Networks (MDDV) [5] is developed for vehicles running in the same direction by this technique, expected short latency and high delivery ratio in the entire network will be found. However it is known to be difficult to determine the optimal probability node mobility and wide area.

The authors in [6] proposed a new broadcast protocol in Vanets, they use geometric model to predict the maximum range of one hop broadcast message. This model can bring higher reception rates and lower message travel time in the entire network. The authors [7] proposed Broadcasting in Vanet called the Distributed Vehicular Broadcast (DV-CAST) protocol. DV-CAST protocol used local information and distributed packet in one hope neighbor vehicles. The authors in [8] proposed a new broadcast protocol in Vanets, they use geometric model to predict the maximum range of a one hop broadcast

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Delay Tolerant Network (DTN) have been proposed [9], authors introduced DTN for Vehicle2Vehicle (V2V) and Vehicle2Infrastructure (V2I) communication, an efficient network layers needed to increase a single hop communication in the entire network. They implemented DTN concept and solved limitations network communication. They implemented DTN concept and solved limitations network communication. Two algorithms, D-Greedy and DMinCost, already proposed in Delay-bounded Routing in Vehicular Ad-hoc Networks [10] the algorithms' discussed how to deliver data from a moving node to a fixed infrastructure. Here the authors focus on achieving ideal bandwidth consumption in terms of reducing the number of transmitted messages by exploiting traffic information; they used store-and-forward technique.

Berbers and Martinovic [11] proposed efficiently data dissemination in Vanets by Hybrid architecture network communication (VVID) or by combine V2V, V2I and DTN communication. Here data dissemination was done in large geographic area, authors found V2V communication and efficiently deals when mostly occurs in sparse networks. Zhao, J et al. [12] discussed data pouring (DP) and intersection buffering (IB) when data center try to distribute a data to another vehicles in the intersection. Authors utilize the vehicles at the intersection and improving data delivery ratio and reduce network traffic. Vinod Kone et al. [13] examine The Impact of Infostation Density on Vehicular Data Dissemination, by optimizing infostation density using two dissemination models the push scheme and the pull scheme. X-NETAD system [14] is traffic alerts dissemination system based on cross-network. The authors used Universal Mobile Telecommunications System (UMTS) and Wi-Fi networks for information dissemination to vehicles. UMTS is cellular networks typically in 3G.

Kitani et.al [15] proposed efficient traffic information sharing in Vanet, these methods use buses as message ferries which travel along regular routes. This method is for sharing messages between vehicles in the entire network the goal is different than method proposed.

Our previous research [16] including existing researches and did not consider with DTN in wide area, therefore traffic information lost in areas with low vehicle density.

3. Problem Definition

3.1 Overview

We assume that message delivery delay is tolerated in the applications of our method. Our method tries to minimize the propagation delay and maximize the arrival ratio. In the applications, a vehicle (a node) emits messages containing sensed data with a destination and the maximum allowed delivery delay, and these messages are delivered to the destination by our method. The basic idea of our method is that the messages are delivered with a bucket-brigade-like way utilizing vehicle-to-vehicle communication, and our method tries to make the messages get geographically close to the destination, as shown in Fig. 1.

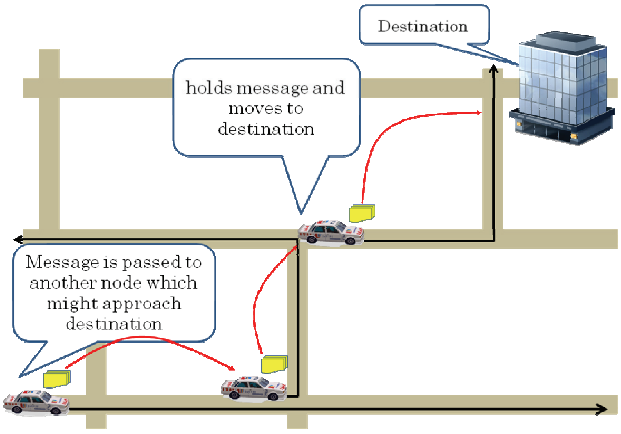

Figure 1, Assumed Application

However, the vehicle density over the region may vary according to the traffic, and thus the method switches between the multi-hop mode and DTN mode according to the vehicle density.

WiFi Multi Hop Communication Mode

The multi-hop mode is selected in regions with relatively high vehicle density. Each node collects information of every X-hop neighbor by exchanging hello messages (here, X=1 means the neighbors within the radio range.) The hello messages also contain the path to each of X-hop neighbors, and thus paths to the X-hop neighbors are also known by exchanging the hello messages. The node retaining a message transfers the message to the node that will get to the closest to the destination among the X-hop neighbors, as shown in Fig. 2. If the node that received the message knows that one of its X-hop neighbors will get even closer to the destination, it transfers the received message to that node again. This process is repeated until the node does not know an X-hop neighbor that will get closer to the destination than the node itself.

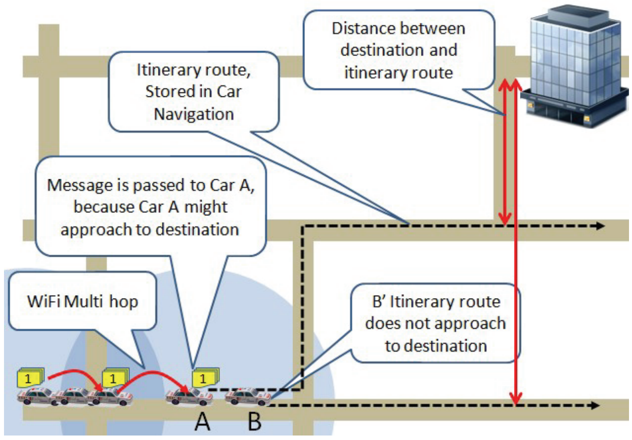

Figure 2, WiFi Multi Hop Communication Mode

DTN Communication Mode

When the node holding the message is closest to the destination among its X-hop neighbors, DTN mode is activated. We assume that this mainly happens in the area with low vehicle density, and there is only a couple of X-hop neighbors. In this mode, the node utilizes the carry, store and forward strategy to deliver the message and it carries the message until it finds an X-hop neighbor node that will get closer to the destination. Eventually, one of the following condition is met.

- The node arrives at the destination, and transfer the message to the destination
- The node finds another node that will get closer to the destination
- The message timeouts

If the node finds a node that will get closer to the destination, it sends the message to that node and remove the message from its local storage.

As we mentioned above, the proposed method switches between the multi-hop mode and the DTN mode according to the situation, and tries to make the message get closer to the destination.

3.2 Assumptions on Environment

We assume that the proposed method is used in an urban area with commonly seen patterns of streets. The map of the area is represented by graph G=(V, E), where V is the set of all crossings and E is the set of all streets connecting crossings. The vehicles runs on any points on these streets. The destination is a point on one of these streets. We consider the problem to deliver a message generated on a vehicle to this destination.

Assumptions on Vehicles

We assume that the following equipment is available on each of the vehicles.

- A communication device conforming to IEEE 802.11
- A digital map and a GPS receiver
- A device that generate messages to deliver
- A local storage device for retaining messages

Assumptions on Messages

A message contains the following information in addition to the payload.

- The ID for the vehicle that originated the message
- Coordinates for the destination
- Time to live (deadline)

When the deadline expires, the message is removed from the storage and will not be delivered.

3.3 Problem Definition

The formal definition of the problem is shown below.

INPUT

We assume that the following input is given beforehand.

- **Map**: We use Graph $G = (V, E)$ to represent the target map.
  - V is the set of all intersections. Each element is accompanied with its position (longitude and latitude).
  - E is the set of all road segment between intersections.
- **Itinerary route**: R represents the itinerary route which has been inputted into the car navigation.
- **Car**: C is the set of all vehicles equipped the proposed system. Each element c ($c \in C$) is accompanied with an unique *carID* and the itinerary route r ($r \in R$).
- **Message**: M is the set of messages to deliver. Every message m ($m \in M$) is accompanied with:
  - ***MID***: Message ID, Unique.
  - ***carID***: The message's creator.
  - ***dest***: Message destination, represented by longitude and latitude.
  - ***ttl***: Time to live, the message's delivery deadline.

OUTPUT

The set of message sending action of each node. That is, a schedule contains all nodes, all messages, and the message sending timing.

RESTRICTION

1. Every car which is equipping the proposed system moves along its itinerary route, respectively.
2. Each car can communicate with the neighbor car which is located in its radio range. We assume that all cars use same channel (Channel number is 1).

UTILITY FUNCTION

The utility function is to maximize the number of messages M that were delivered to destination within deadline (TTL).

4. Proposed Method

In the proposed method, each vehicle uses WiFi to deliver the messages to a remote destination. If the vehicle density is high, the method quickly transfers messages to a distant location by the multi-hop communication mode. It switches to the DTN mode if the vehicle density is low. In order to realize this policy, the proposed method consists of the following three stages.

- Stage 1: Information exchange : Vehicles exchange information with other vehicles in the radio range, and then they recognize platoons.
- Stage 2: Intra-platoon communication : Messages are sent using multi-hop communication, if there is another vehicle that will get closer to the destination in the same plattoon.
- Stage 3: DTN communication : If the vehicle retaining the message will get closest to the destination among the vehicles in the platoon, it continues to retain the message awaiting a opportunity to send it to another vehicle.

4.1 Information exchange stage

In the information exchange stage, each node obtains information for determining the node to communicate with in other stages. In order to realize this, each node periodically broadcasts messages called Hello Messages. The Hello Message used in the method contains entries named Car ID, Itinerary Route and Topology Info, as shown in Table 1.

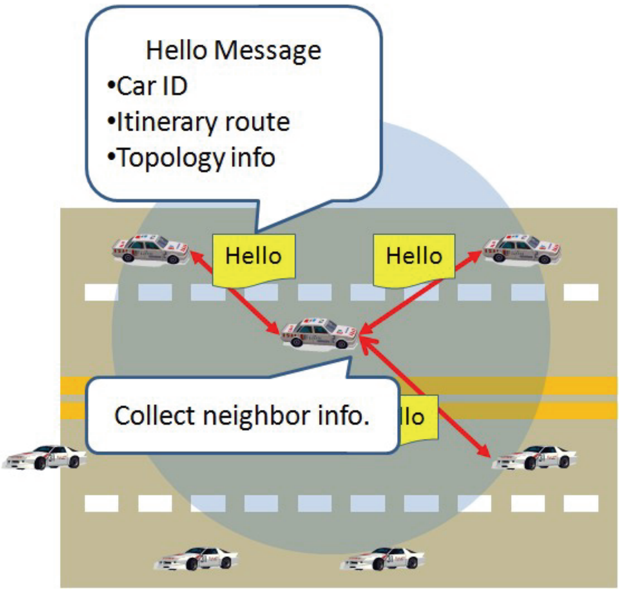

Figure 3, Hello Message Exchanging

Table 1, Content of Hello Message

Car ID	Itinerary Route	Topology Info
12	v_1,v_2,v_3,v_4	$13 \vert v_1,v_2,v_3 \vert 12>13 \vert 2$

- **Car ID**: Unique ID of a node(vehicle)
- **Itinerary Route**: The route the vehicle is going to go through. $v1, v2, v3, v4 \in V$, where every element is a crossing.
- **Topology Info**: Information for neighboring node that is known to the own vehicle. *13* in Table 1 represents the ID for the neighbor node, and the next is the itinerary route for node *13*. *12>13* means that the relaying node when a message is sent from the own node to node *13*. The last *2* means that the TTL for the neighbor node, and when this TTL expires, the information for neighbor node becomes invalid, and the entry is removed.

Each node makes a neighbor table based on the received hello messages. A neighbor table contains the information for reachable neighboring nodes located within N hops. For example, if a node receives a hello message that contains the information shown in Table 1, the resulting neighbor table will be as shown in Table 2.

Table 2, Neighbor Table

N ID	Itinerary Route	Topology Info	TTL
12	v_1,v_2,v_3,v_4	*10>12*	*10*
13	v_1,v_2,v_3	*10>12>13*	*2*
…	…	…	…

The proposed method uses the concept of platoon. A platoon is a generic term indicating the vehicles within a certain range from each node, and its size is represented by the number of hops in wireless communication. For example, if a node knows vehicle information within 1 hop, the size of the platoon is 1. In the proposed method, the size of platoon for each vehicle can be flexibly changed according to vehicle density and network traffic. Fig. 4 at the bottom indicates a case with platoon size of 3. As the size of platoon gets larger, there is more freedom of choosing relay nodes for transferring messages, and thus delivery ratio is improved. On the other hand, a larger platoon requires a large number of hello messages, and this increases network traffic. In the proposed method, the platoon size is changed dynamically according to the vehicle density estimated by counting the number of hello messages. In this paper, we use the platoon size of two as the default value.

When the vehicle density is extremely high, the proposed method searches relay nodes in on-demand style, instead of utilizing platoons. In case of congested traffic, exchanging hello messages requires too much network traffic, and the proposed method changes the structure of hello messages to alleviate the situation. We make the platoon size to 1 and remove topology information from hello messages. When a node retains a message to deliver, it sends an inquiry message containing the destination coordinates and the closest distance the node will reach, to a few hops neighbor. Every node that will reach closer to this distance will give a response to this inquiry.

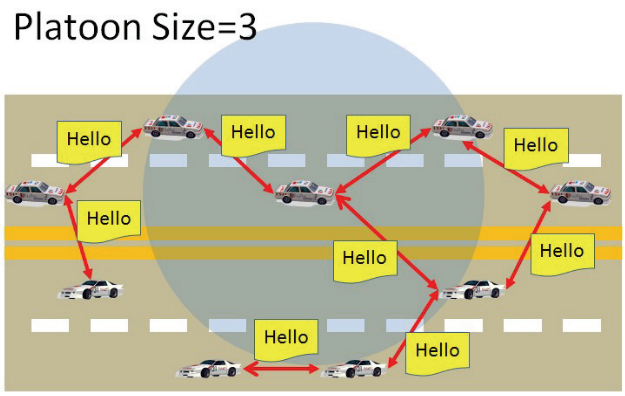

Figure 4, A Size 3 Platoon

4.2 Intra-platoon communication stage

In order to reduce the transfer delay of data, our method transfers messages using multi-hop communication when there are multiple nodes in a platoon. A node tries to find a node that will get closest to the destination in the future according to the itinerary routes, and send the message with multi-hop communication. However, if there is no node that will get closer to the destination, the node retaining the message moves while carrying the message. This stage is executed each time a new node arrives at the platoon.

We explain how this stage works by Figure 5 and Table 3. If there is a platoon with node *A* at its center, node *A* will have the neighbor table shown in Table 3. Suppose that the destination for node *A* is v_8, and *B, C* and *D* are neighboring nodes. The itinerary for node *A* is v_1, v_2 and v_9. *A* calculates the closest distance the nodes will reach, and knows *C* will get closest. Thus, it sends the message to node *C* via node *B*. After node *C* receives the message, it calculates the closest distances in the same way, and if it finds that it will get closest, it moves while carrying the message.

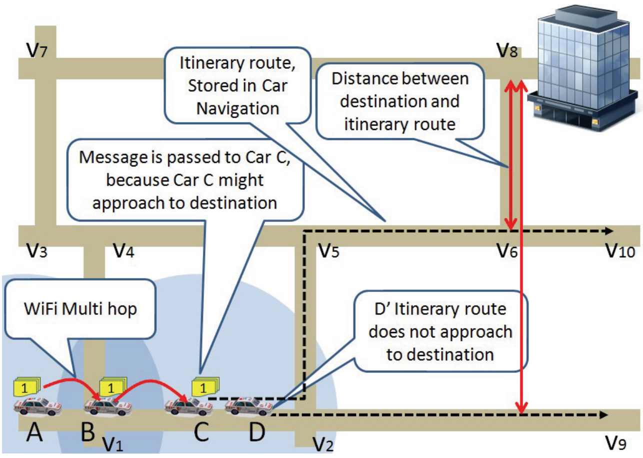

Figure 5, An Example of Intra-Platoon Communication Stage

4.3 DTN communication stage

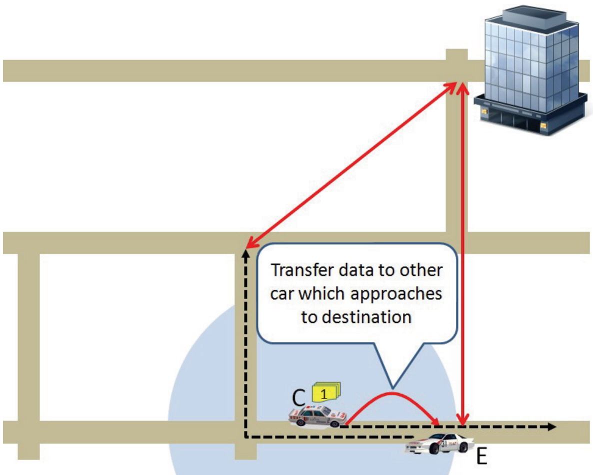

Figure 6, DTN Communication Stage

If there is no vehicle that will get closer to the destination in the platoon with the node that retains the message at its center, the node switches to the DTN mode. If it finds a node that will get closer to the destination while periodically exchanging hello messages, it transfers the message to the node. Fig. 6 shows how it works. The proposed method combines intra-platoon communication and DTN communication aiming at improving delivery ratio and delay. However, if the traffic density is low, there can be no vehicle that gets within the radio range of the destination, and the node carrying the message passes by the destination resulting in transferring the message to another node. This can repeat several times, and as a result, the message delivery deadline expires and the message can be lost. We have no good answer to this problem so far.

5. Evaluation Plan

In order to evaluate the proposed method, we are going to use SUMO vehicular traffic simulator[2], to generate the traffic patterns of vehicles, and input it to a network simulator so that the network performance can be observed.

SUMO is an Open Source traffic simulator, produced by German Aerospace Center, Institute of Transportation Systems. It is a highly portable, microscopic and continuous road traffic simulation package, suit for handling large road networks. The following Fig. 7 is a road map screenshot by SUMO.

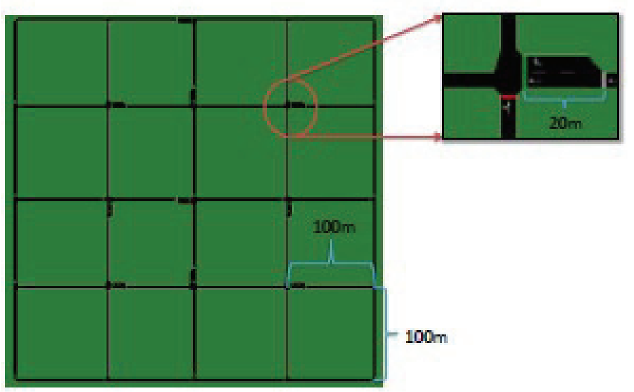

Figure 7, Screenshot of SUMO

In this paper, we are assuming a city-scale deployment, and we are going to use a map of 10km x 10km size. We are going to vary the vehicle density and analyze the performance of the method.

We assume that the all vehicles uses a same channel with 802.11g WiFi with our method. Thus, we assume that 20Mbps bandwidth is available, and the size of hello message is 1500 bytes.

We are considering the following metrics in evaluation simulation.

- Delivery ratio: The average value of all success deliveries from senders to destinations.
- Delay: The average delivery delay from senders to destinations.
- Overhead: The control message necessary in platoon, such like hello messages, or inquiry messages in extra density environment.

6. Conclusion

In this paper, we proposed a method for sending messages to a distant location utilizing vehicle-to-vehicle communication in urban environments. The proposed method switches between the multi-hop mode and the DTN mode according to the vehicle density aiming at improving the message delivery ratio and delay.

We are going to evaluate the proposed method using computer simulation.

References

[1] Road Bureau, Ministry of Land, Infrastructure, Transport and

Tourism, Japanese Government: ITS HOMEPAGE, http://www.mlit.go.jp/road/ITS/.

[2] SUMO Simulation of Urban MObility: SUMO HOMEPAGE, http://sumo.sourceforge.net/.

[3] Vegni, A.M., Stramacci, A., and Natalizio, E.: "SRB: A Selectetive Reliable Broadcast Protocol for Safety Applications in Vanets".

[4] Zhao, J., and Cao, G.: "VADD: Vehicle-Assisted Data Delivery in Vehicular AD Hoc Networks": *IEEE Transactions on vehicular Technology Vol.57 No. 3, May* 2008.

[5] Wu, H., Fujimoto, R., Guensler, R,. and Hunter, M.: "MDDV: a mobility centric data dissemination algorithm for vehicular networks": *In Proc. of the 1st ACM Workshop on Vehicular Ad Hoc Networks* (VANET 2004), pages 47–56, 2004.

[6] R.S, Raw., S, Das., N, Sing., S, Kumar., and S, Kumar.: "Feasibility Evaluation of VANET using Directional-Location Aided Routing (D-LAR) Protocol": *IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 3*, September 2012.

[7]Tonguz, O., Wisitponghan, N., Bai, F., Mudalige, P., and Sadekar, V.: "Broadcasting in VANET": *the direction of IEEE Communications Society subject matter experts for publication in the IEEE INFOCOM* 2008 proceedings.

[8] Hafeez, K.A., Zhao, L., Liao, Z., and Ma, B.N.W.: "A new Broadcast for Vehicular ad hoc Networks Safety Applications": *IEEE Communications Society subject matter experts publication in the IEEE Globecom* 2010 proceedings.

[9] Franck, L., and Gil-Castineira, F.: "Using Delay Tolerant Networks for Car2Car Communications," ENST, site of Toulouse, Berlin.

[10] Skordylis, A,. and Trigoni, N.: "Delay-Bounded Routing in Vehicular Ad- Hoc Networks": *ACM International Symposium on Mobile Ad hoc Networking and Computing*, pp.3017-3021, November 2008.

[11] Berbers, K.P.Y., and Martinovic, J.B.G.: "VVID: A Delay Tolerant Data Dissemination Architecture for VANETs Using V2V and V2I Communication".

[12] Zhao, J., Zhang, Y., and Cao, G.: "Data Pouring and Buffering on the Road": A New Data Dissemination Paradigm for Vehicular Ad Hoc Networks: *IEEE Transactions on Vehicular Technology*, Vol. 56, No. 6 November 2007.

[13] Kone, V., Zheng, H., Rowstron, A., and Zhao, B, Y.: "The Impact of Infostation Density on Vehicular Data Dissemination".

[14] Ferrari, G. and Busanelli, S., Iotti, N., and Kaplan, Y.: "Cross-Network Information Dissemination in VANETs".: *11th International Conferences on ITS Telecommunications* 2011.

[15] Kitani, T,. Shinkawa, T,. Shibata, N,. Yasumoto, K,. Ito, M,. and Higashino, T,. "Efficient VANET-based Traffic Information Sharing using buses on Regular Routes": *Proceedings of the 67th IEEE Vehicular Technology Conference, VTC Spring 2008*, 11-14 May 2008, Singapore 2008.

[16] Nakamura, M., Kitani, T,. Sun, W,. Shibata, N., Yasumoto, K., and Ito, M.: "A Method for Improving Data Delivery Efficiency in Delay Tolerant VANET with Scheduled Routes of Cars.": *CCNC'10 Proceedings of the 7th IEEE conference on Consumer communications and networking conference* Pages 1009-1013 2010.

