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Master's Thesis

A DTN/VANET Message Dissemination Technique Using Car Platoon

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Abstract

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

Keywords:

Mobile Ad-Hoc Network, Multi-Hop Wireless Communication, Routing Protocol

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Contents

List of Figures

List of Tables

1. Introduction

Currently, traffic jams and accidents are common problems on highways in big cities. In Japan, Intelligent Transport Systems (ITS) [1] has been used to alleviate these problems. In this technology, wireless communication is used for sharing traffic information among the vehicles and road-side units. Recently, usage of car navigation systems 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 been many research publications for VANETs already, and some of these researches focus on disseminating and sharing messages among vehicles.

Stable data transfer between two distant locations in a VANETs is inherently difficult due to the high speed and unpredictable mobility of vehicles. In some existing researches, a technique called DTN (Disruption/Delay Tolerant Network) is employed to improve the delivery ratio 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 thesis, we enhance our previous work [30], 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 thesis, 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 discussed some case studies in this thesis and compare with our propose method.

2. Related Works

Several methods have been proposed related to routing, broadcasting, Delay Tolerant Networks (DTN), and message dissemination in VANETs. The Selective Reliable Broadcast protocol (SRB) is aiming at reducing the effect of the broadcast storm problem in VANETs [2]. The authors used cluster heads and Zone of Relevance (ZOR) technique. This method allows nodes to efficiently rebroadcasting emergency and control messages. The authors implemented and performed a simulation-based evaluation with urban and highway scenarios. Figure 1 shows the SRB Protocol.

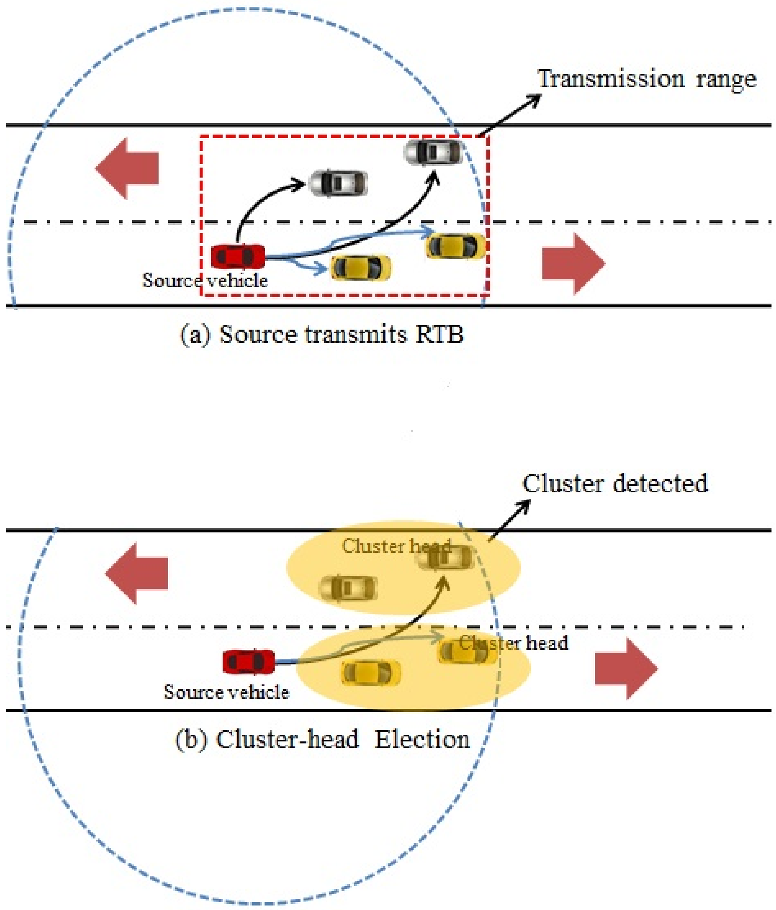


Figure 1. Selective Reliable Broadcast (SRB) Protocol

VADD: Vehicle-Assisted Data delivery in Vehicular ad hoc Networks protocol

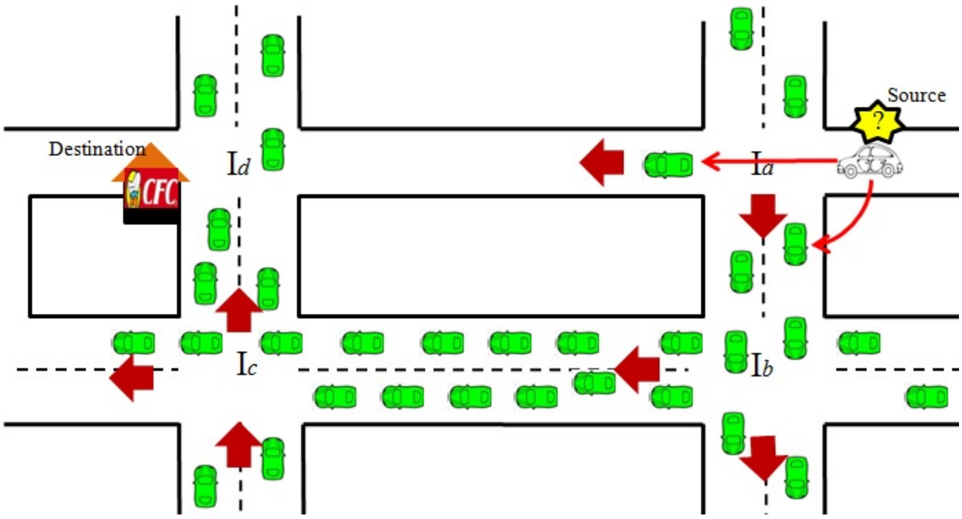


Figure 2. VADD Routing Protocol

has been proposed [3]. In this method, vehicles calculate the probability at each intersection before forwarding messages to neighbor vehicles. When the source vehicle reaches an intersection, it checks which of its neighbor vehicles is closer to the destination. Simulations were conducted in three traffic conditions. Figure 2 shows the VADD Routing Protocol.

Another protocol called Mobility-Centric Data Dissemination Algorithm for Vehicular Networks (MDDV) [4], as shown in Figure 3, was developed for vehicles running in the same direction. In this technique, the expected short latency and high delivery ratio in the entire network could be found. However, it is known to be difficult to determine the optimal node mobility in a wide area. There are two techniques to exchange data in this protocol:

- **Three-way interaction**: Node A advertises the message metadata to node B, then node B decides whether it is needed or not. If node B needs it, node B sends a request to node A and finally node A sends the message to node B.
- **One-way transmission**: Node A transmits the message directly to node B. The second condition is better, when the message metadata is much smaller than the message and authors used this second technique in their

method.

An efficient routing protocol is implemented in [5]. The authors try to reduce the bandwidth consumption and overhead by managing HELLO messages on the network by considering two main conditions: the road direction and the vehicle's velocity. When any of these factors change, vehicles broadcast HELLO messages. Otherwise, they stop broadcasting HELLO messages and wait for another change. They used fixed range of speed sup $>$ S $>$ sdwn during travelling on that road, where S, sup and sdwn are the current vehicle's speed. The techniques of the proposed method are:

- When a vehicle change its direction, it will broadcast HELLO message and confirm to other vehicles that its direction is changed.
- When any of these vehicles change its speed based on the predefined limit sup $>$ S $>$ sdwn.
- When a new vehicle joins the entire network it will broadcast a HELLO

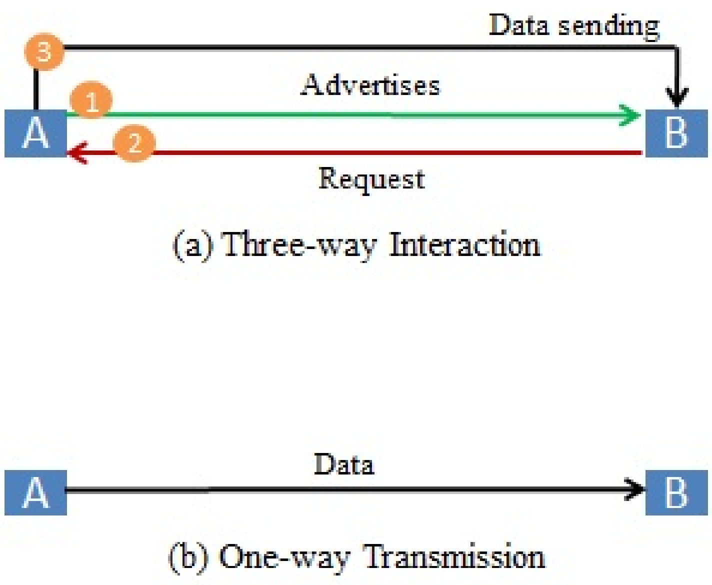


Figure 3. MDDV Data Exchange

message to confirm to its neighbor vehicles and exchange information about itself and other vehicles in the network.

By controlling broadcast of HELLO messages, they can reduce overhead and bandwidth consumptions.

Zahmerhi, M.N. et.al [6], have introduced a routing protocol called Urban Data Collector (UDC). They implemented three techniques to reduce the number of messages. The features in these protocols are:

- It is not necessary for each node to exchange messages periodically with its neighbor nodes.
- The node detects information about its neighbors using geographic information and also information about the gateway in the header of each data packet to route it using hop communication.
- Use the advantage of redundant forwarding technique to increase packet delivery ratio to the gateway.

In this routing protocol the data on the road is calculated to support sensing applications in urban location. Figure 4 shows UDC One-hop Forwarding Technique.

Ding, Y. et.al [7], introduced Static-Node Assisted Adaptive (SADV) routing protocol to restore and share traffic information when vehicles pass a static node and to prevent routing information by calculating delay time in a node. There are three techniques used for buffering:

- FIFO (First In First Out), here a packet that arrives first is eliminated first. But, this is not a good strategy because these packets may have more chance to forward.
- FILO (First In Last Out), here new packets are eliminated first. However, as these packets have just arrived, the best or even the second best path is possibly not available yet. As a result, the packets may be routed along much longer paths.

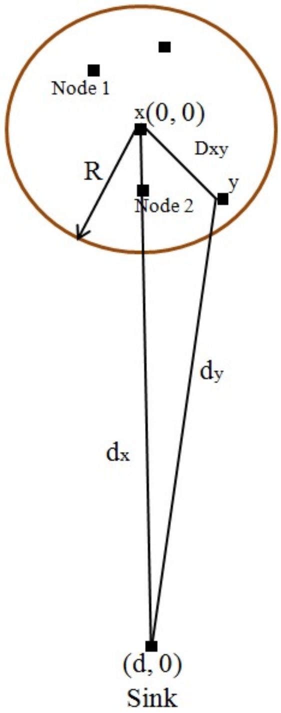


Figure 4. UDC One-hop Forwarding Technique

- The elimination strategy was used in Static Node Assisted Routing (SNAR). The main goal of SNAR is to reduce the increase in the overall packet delivery delay caused by sending packets at sub-optimal paths. Figure 5 shows the SADV Routing Protocol.

Kim, H.J. et.al [8], presented routing hole protocol to handle the gap in network communication. In the experiment, they used link expiration time (LET) and reroute the path in different directions to find another nodes to distribute messages. Figure 6 shows Routing Hole Protocol.

Wang, S.S. et.al [9], introduced PassCAR routing protocol, in which they used multi-metric election strategy when nodes get closer to destination, based on metrics such as node degree, expected transmission count and link lifetime. Ramakhrisna, M [10], introduced Distance Based Routing (DBR) protocol in VANET, as shown in Figure 7. He proposed algorithm which is based on node position, map and connectivity duration between neighboring vehicles. Experi-

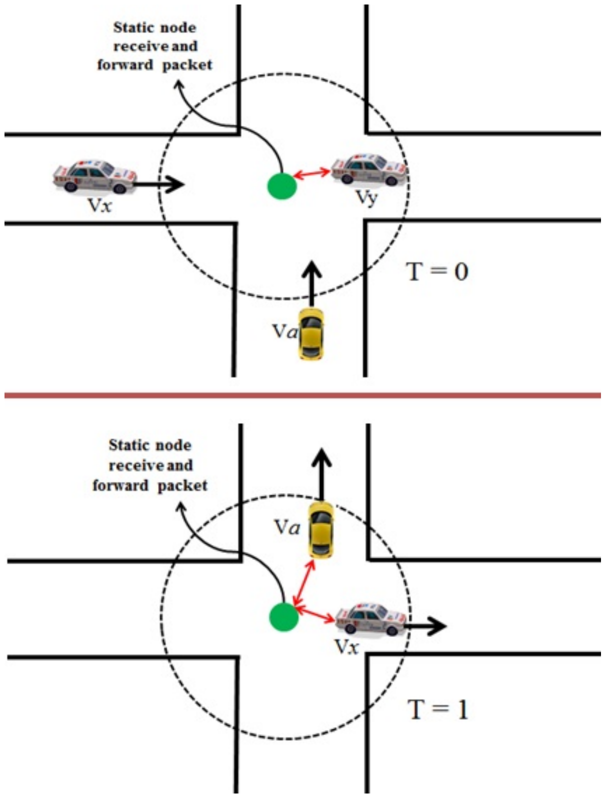


Figure 5. SADV Routing Protocol

mental results show the benefit of this protocol to keep the performance stable even when error information from GPS was detected. This protocol can be implemented in urban or rural area. Tonguz, O. et.al [11], proposed Broadcasting in Vanet called the Distributed Vehicular Broadcast (DV-CAST) protocol. DV-CAST protocol used local information and distributed packet in one hop neighbor vehicles. Figure 8 shows DV-CAST Routing Protocol.

Mustary. et.al [12] studied about the congestion detection mechanism on highway to detect areas of high traffic density and low vehicle speeds and share this information to neighbor vehicles. They implemented vehicle clustering and divide it into three stages for the algorithm:

- **Neighbor Discovery**: If the neighbor nodes are reachable, they maintain the stability and send HELLO messages simultaneously, when a node receives this messages it will increase the neighbor's stability. Otherwise if

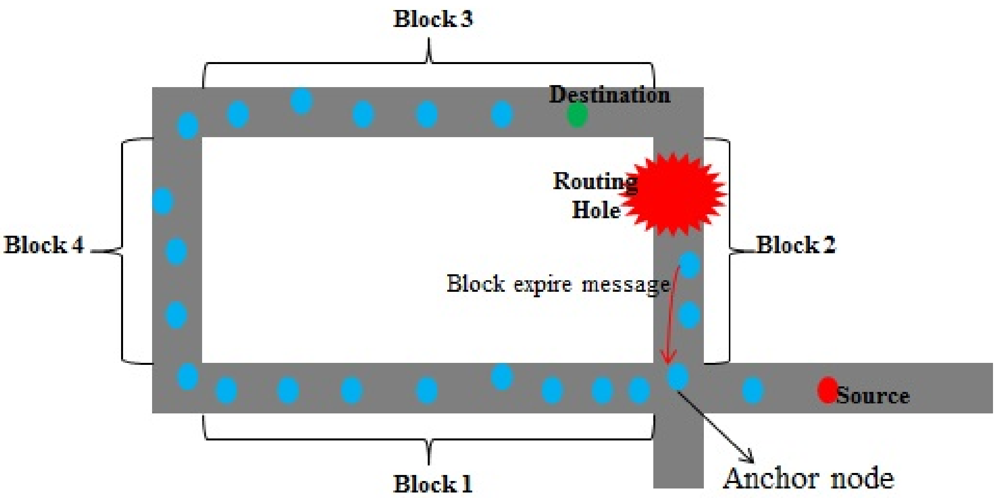


Figure 6. Routing Hole Protocol

a node did not receive this message, the neighbor's stability is decreased. In this situation when stability value of a node exceeds a certain threshold, the node is considered stable.

- **Cluster-head Election**: The election of a head of cluster is based on the connectivity to its neighbor nodes in the same cluster. Node with the maximum number of neighbors is selected as the cluster head.

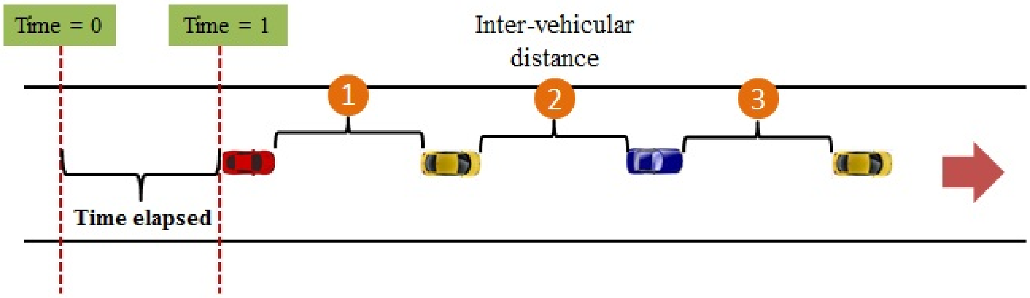


Figure 7. DBR Protocol

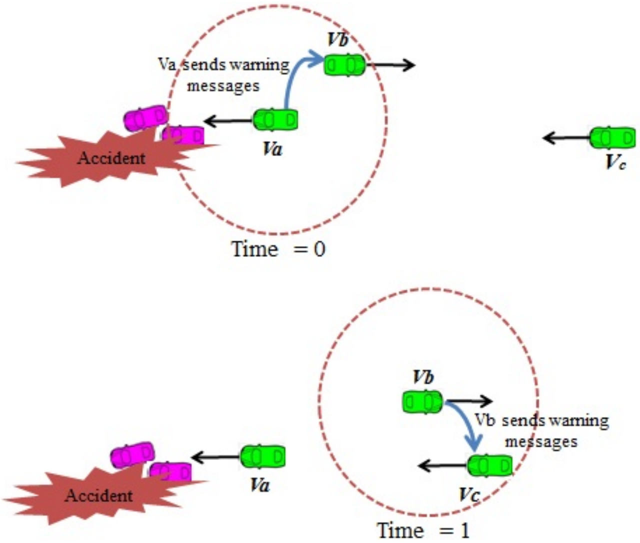


Figure 8. DV-CAST Routing Protocol

- **Maintenance Phase**: In this phase, they consider when nodes join or leave Routing Group (RG), or two RGs join into one. The cluster head responsibility is important to accept a new member into its cluster or join two RGs into one. Figure 9 shows the Procedure of Clustering Algorithm.

Villas, A.L. et.al [13], Proposed GEographical Data Dissemination for Alert Information (GEDDAI) to remove broadcast storm problem and to maximize data dissemination with small overhead and delay time. They used a zone of preference called sweet spot to remove broadcast storm. In this scenario, they divided each vehicle radio range into 4 quadrants, then a quadrant sub-area is considered as sweet spot area. A vehicle within sweet spot area received message and calculated the waiting time for priority to send message dissemination to its neighbors. Figure 10 shows the scenario of sweet spot.

Hafeez, K.A. et.al [14], proposed a new broadcast protocol in VANETs that uses geometric model to predict the maximum range of a one hop broadcast message. This model can bring higher reception rates and lower message travel time in the entire network. Authors also consider how to decrease the occurrence of broadcast storm problem. Figure 11 shows the Geometric scenario.

Busson, A. et.al [15], discussed a broadcast-based protocol. In this algorithm,

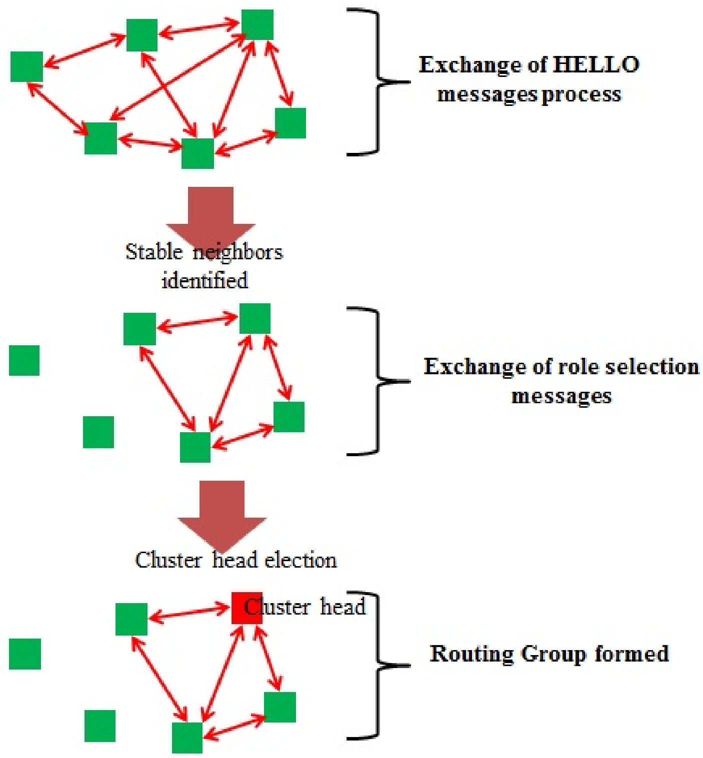


Figure 9. The Procedure of Clustering Algorithm

they choose the farthest node to distribute packets. In the simulation scenario, generic Frame Error Rate (FER) is used to show probability of loosing information. Haas, J.J. et.al [16], presented Certificate Authority (CA) to trust nodes. By using Certificate Revocation Lists (CRLs), CA distributes new information to the entire network immediately. Kerper, M. et.al [17], presented an experimental warning system for vehicles to prevent an accident on the road. In the simulation, they used two cars moving and getting closer to the intersection without a road side unit. Vehicles equipped with wireless communication will send confirmation to its neighbor on the road and get warning in ten seconds before an accident occurs.

In [18], the authors introduced a DTN-based method for Vehicle2Vehicle (V2V) and Vehicle2Infrastructure (V2I) communication, where an efficient network layer is needed to increase a single hop communication in the entire network.

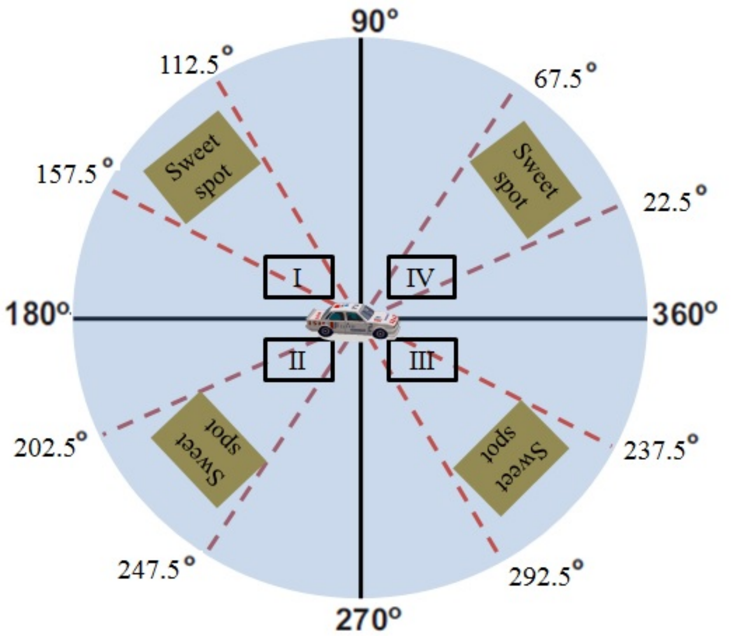


Figure 10. Sweet Spot

They implemented DTN concept and solved limitations in network communication. Figure 12 shows the DTN method for V2V and V2I Communication.

In the two algorithms, D-Greedy and DMinCost [19], how to deliver data

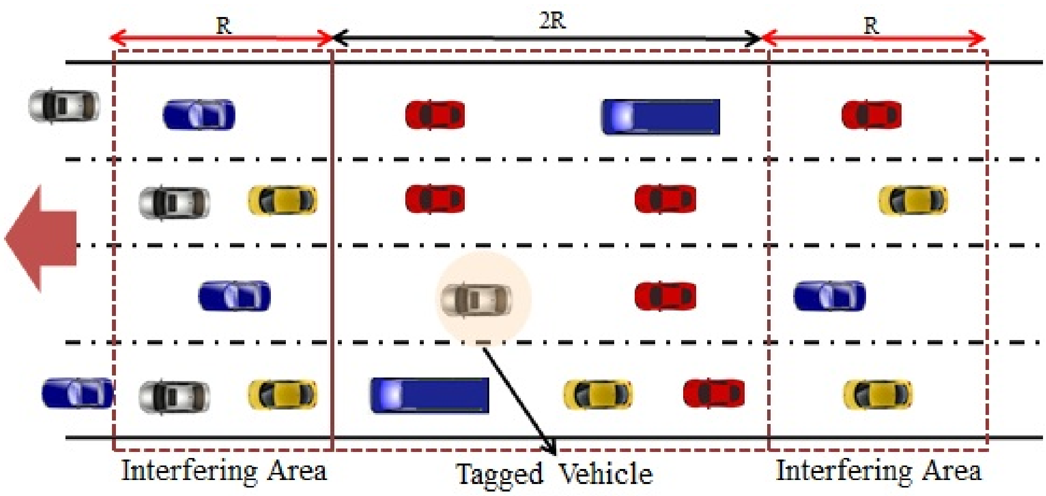


Figure 11. Geometric Scenario

from a moving node to a fixed infrastructure is focused. Here the authors discuss on achieving ideal bandwidth consumption in terms of reducing the number of transmitted messages by exploiting traffic information by using the store-and-forward technique. Figure 13 shows Delay Bounded Routing Protocol.

Al-Doori, M.M. et.al [20], proposed a new routing protocol called Vehicle Second Heading Direction (VSHD) Routing Protocol, as shown in Figure 14, for DTN with less frequent communication. The evaluation experiment used Calculus of Context-aware Ambients (CCA) to analyze the performance of the protocol. There are two scenarios in this experiment:

- Source node detects destination ID and can send packets directly to destination.
- Source node uses Second Hand Direction (SHD) or opposite vehicles as a part to disseminate packets to the destination.

Berbers and Martinovic [21], proposed efficient data dissemination in Vanets by using Hybrid architecture network communication (VVID) and combining

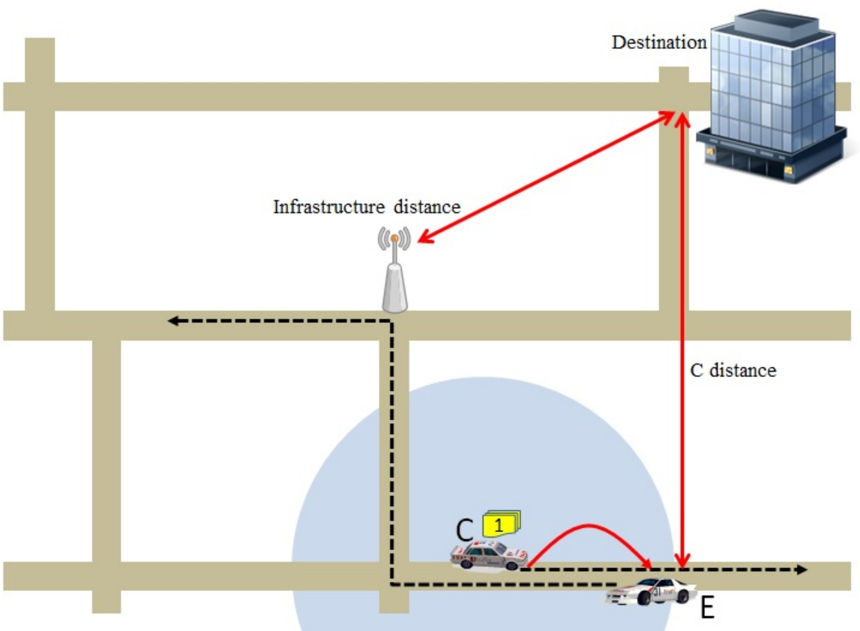


Figure 12. DTN for V2V and V2I Communication

V2V, V2I and DTN communication. Here, the data dissemination was performed in a large geographic area. Zhao, J. et al. [22], discussed data pouring (DP) and intersection buffering (IB) when a data center tries to distribute data to another vehicles at intersections. They utilize the vehicles at the intersections for improving data delivery ratio and reducing network traffic. Figure 15 shows Data Pouring Communication.

Vinod Kone et.al. [23], proposed 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 [24], is a 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 a cellular network typically in 3G. Figure 16 shown UMTS communication.

Lochert, C. et.al [25], introduced the network partition problem, that attempts on minimizing bandwidth consumption and finding aggregation location by considering data aggregation and roadside. The partition network problem is addressed using genetic algorithm to confirm and detect location of roadside unit on the street. The packet transmission in vehicle communication is discussed in [26], by implementing new mechanism called "Neighborhood WatchDog" to gen-

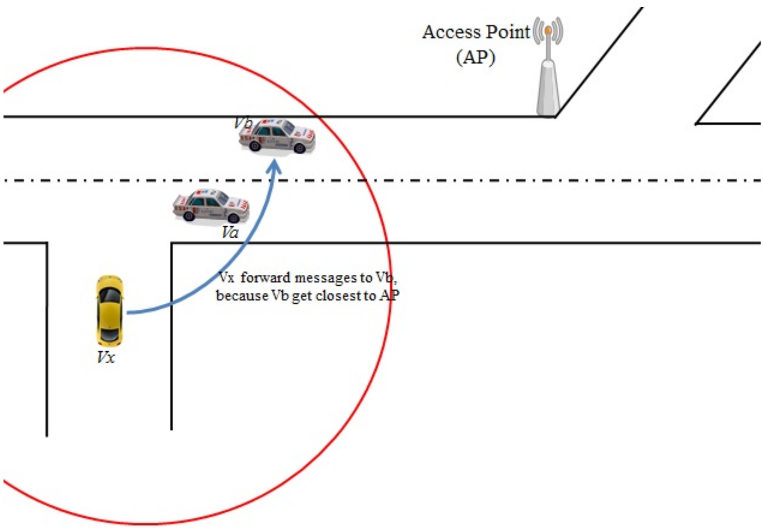


Figure 13. Delay Bounded Routing Protocol

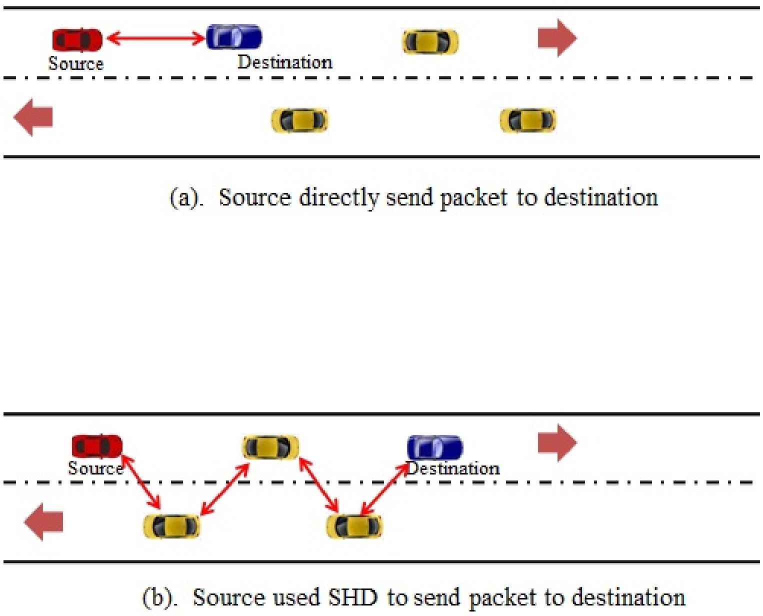


Figure 14. VSHD Routing Protocol

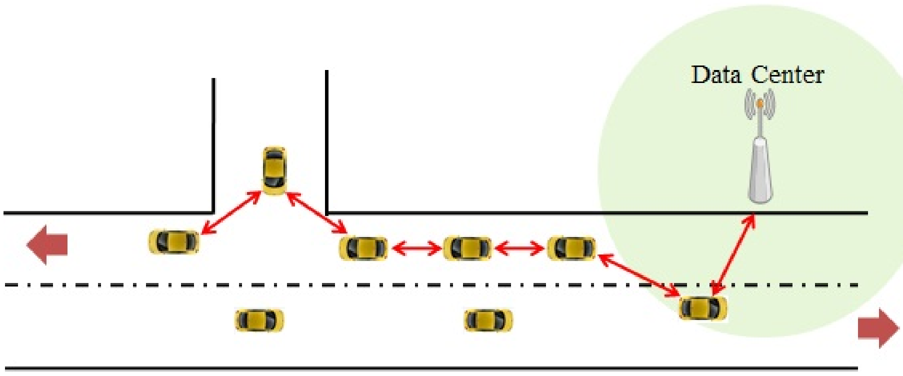


Figure 15. Data Pouring Communication

erate "Trush Token". In the method implementation, the source sends the packet to neighbor based on trust condition network communication. Song, C. et.al [27], discussed multi-hop communication in VANETs called buffer and switch (BAS), the BAS has characteristic of bidirectional communication in network path of the entire network. The experimental result shows that the performance of BAS protocol is better than flooding base in low network communication. Figure 17 shows the BAS Communication Routing Protocol.

Taherkhani et.al [28], proposed quality of service in VANETs to get an efficient communication by implementing three techniques when congestion occurs: transmission power control, packet transmission frequent control and packet duration.

Kitani et.al [29], proposed a method for efficient traffic information sharing in VANETs that utilizes buses as message ferries which travel along regular routes. This method is for sharing messages between vehicles in the entire network, and the goal is different from the methods above. Figure 18 shows the Efficient Traffic Information using BUS Route.

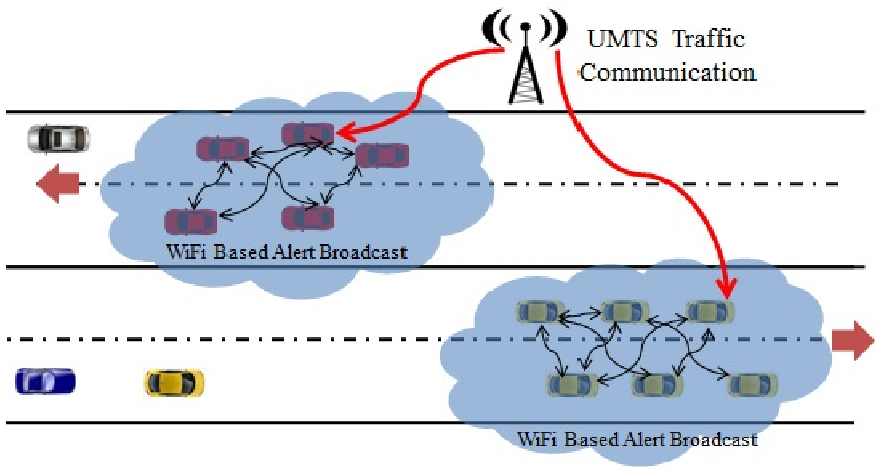
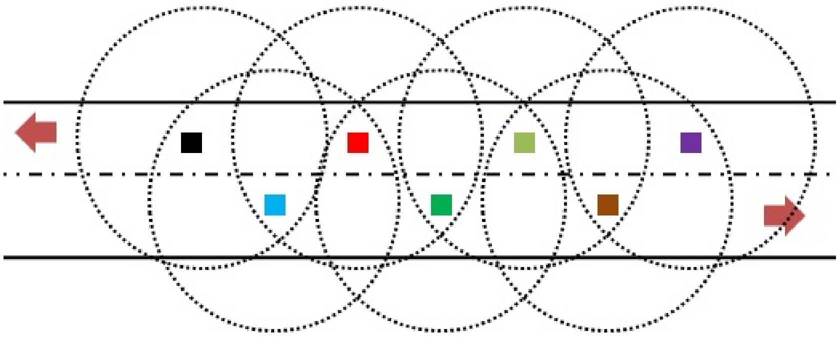
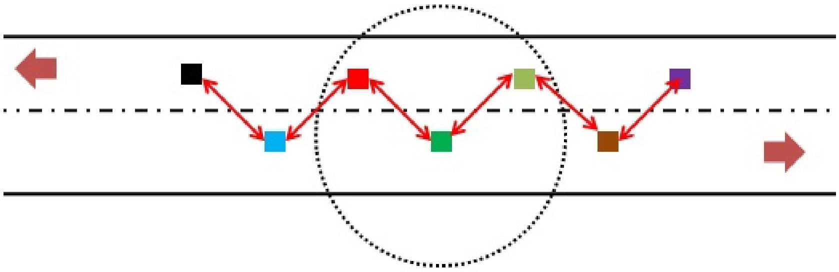


Figure 16. UMTS Communication



(a) Connection of BAS



(b) Communication of BAS

Figure 17. BAS Communication Routing Protocol

In our previous [30] research, as shown in Figure 19, we proposed a method for vehicle-to-vehicle communication to transmit packet to the destination. The basic concept of this method is the store-and-carry-forward technique. It is assumed that all the drivers input the future itinerary into their navigation systems. By using these itinerary routes, the message can be efficiently forwarded using the store-carry-and-forward technique. This consists of two parts in the simulation test:

- The first part is to exchange the full itinerary between neighboring cars, so that each car knows the itineraries of neighboring cars.
- In the second part, if there is a neighboring car that will get closer to the destination, it will hand the message to that car.

In the previous research, we did not consider the DTN in wide area. Traffic information may be lost in areas with low vehicle density.

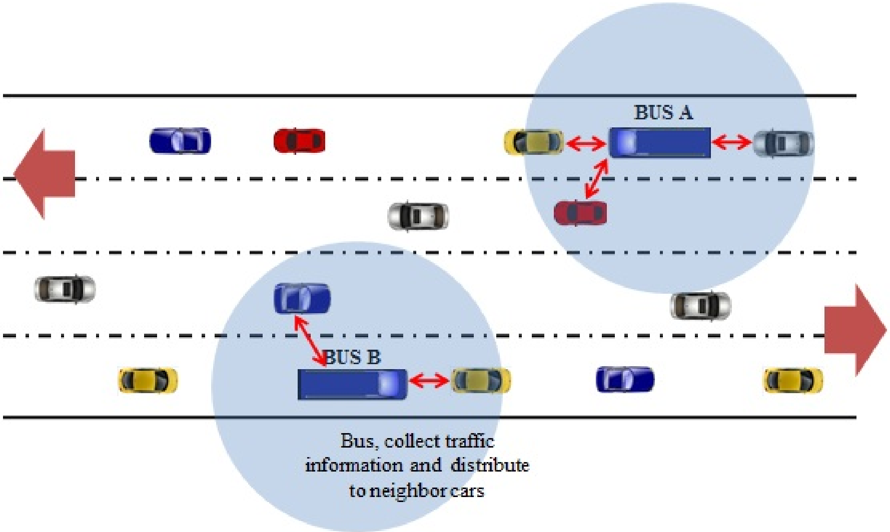


Figure 18. An Efficient Traffic Information using BUS Route

3. Problem Definition

3.1 Thesis 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

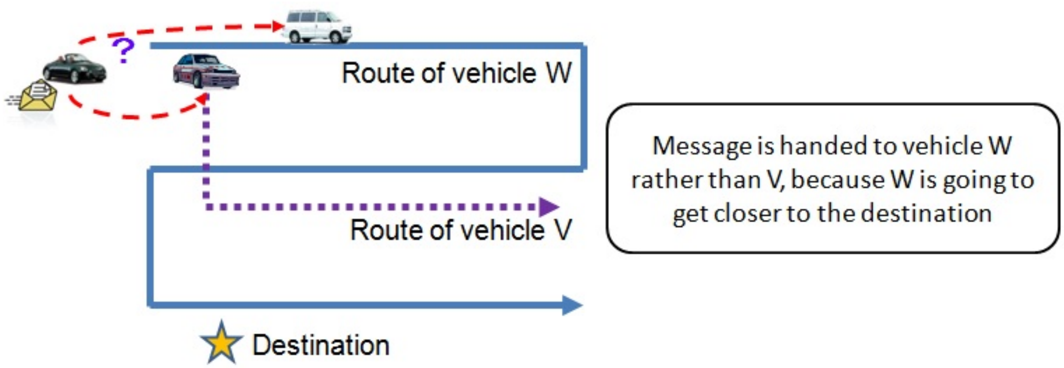


Figure 19. Previous Method

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 Figure 20.

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.

3.2 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 closest

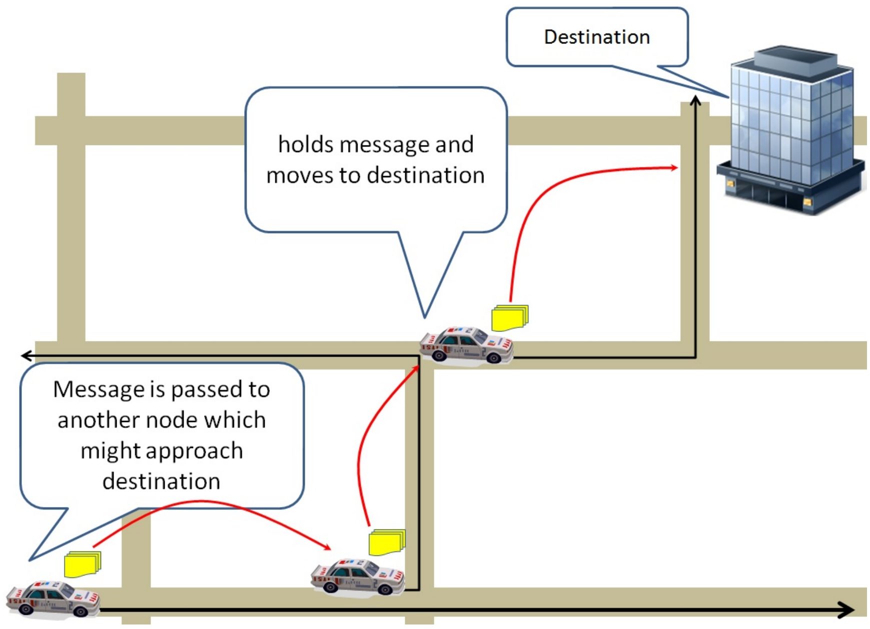


Figure 20. Assumed Application

to the destination among the X-hop neighbors, as shown in Figure 4. 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 any X-hop neighbor that will get closer to the destination than the node itself, as shown in Figure 21.

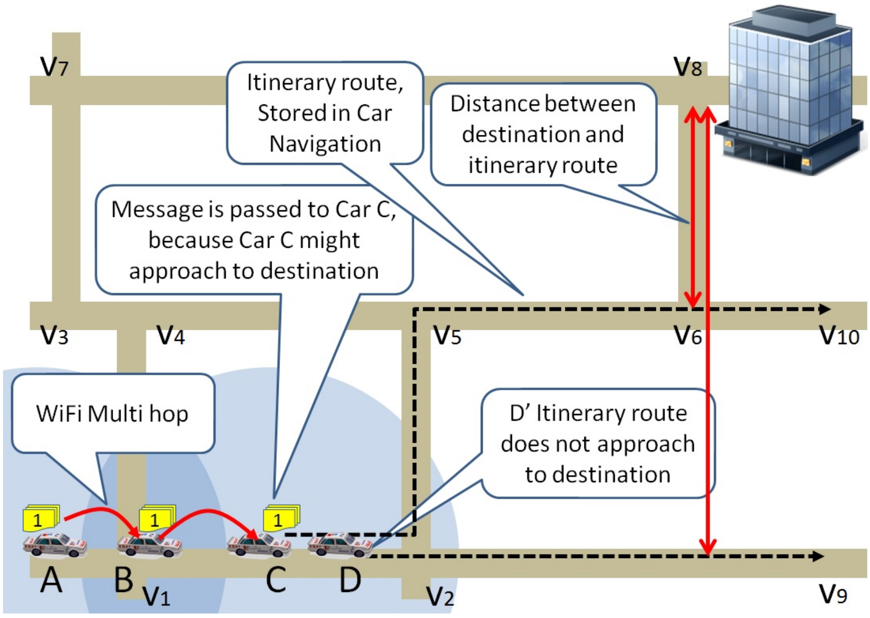


Figure 21. WiFi Multi Hop Communication Mode

3.3 DTN Communication Mode

When the node holding the message is the 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 conditions 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 times out

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. Figure 22 shows the DTN communication mode.

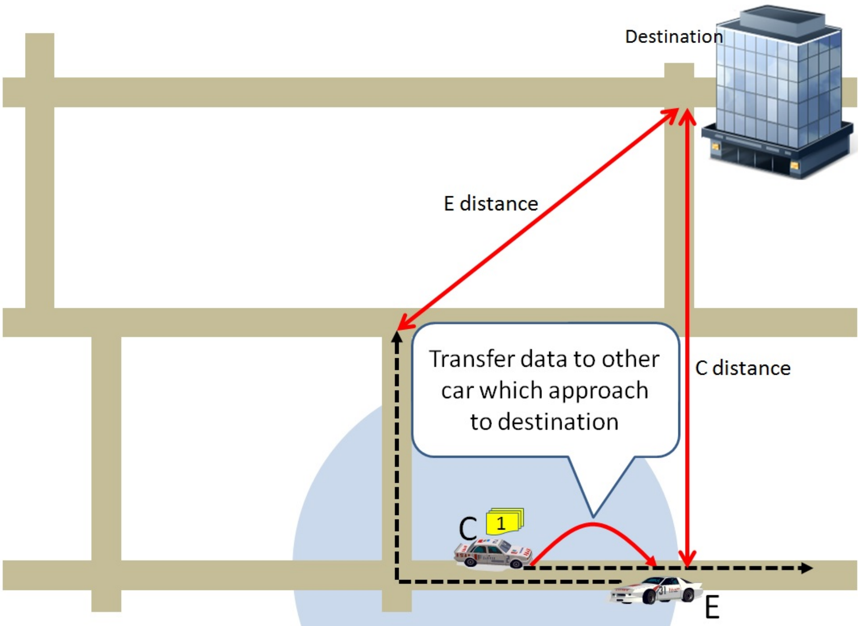


Figure 22. DTN Communication Mode

3.4 Assumption 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.

3.4.1 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

3.4.2 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.

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. Figure 23 shows the Road Map System.

  - 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 given as input for car navigation.
- **Car**: C is the set of all vehicles equipped with 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.

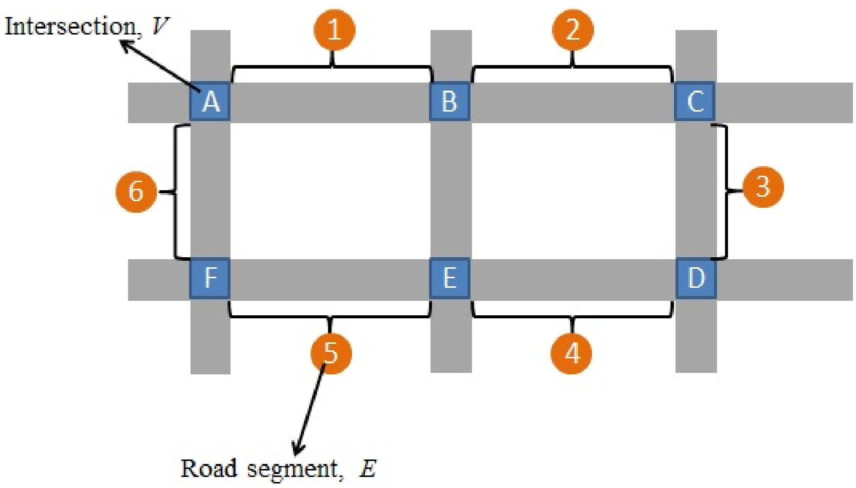


Figure 23. The Road Map System

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

- Every car which is equipped with the proposed system moves along its itinerary route, respectively.
- 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).

3.5 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 modes. The method structure is shown in Figure 24.

- **Information exchange mode**: Vehicles exchange information with other vehicles in the radio range, and then they recognize platoons.
- **Intra-platoon communication mode**: Messages are sent using multi-hop communication, if there is another vehicle that will get closer to the destination in the same platoon.
- **DTN communication mode**: 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.

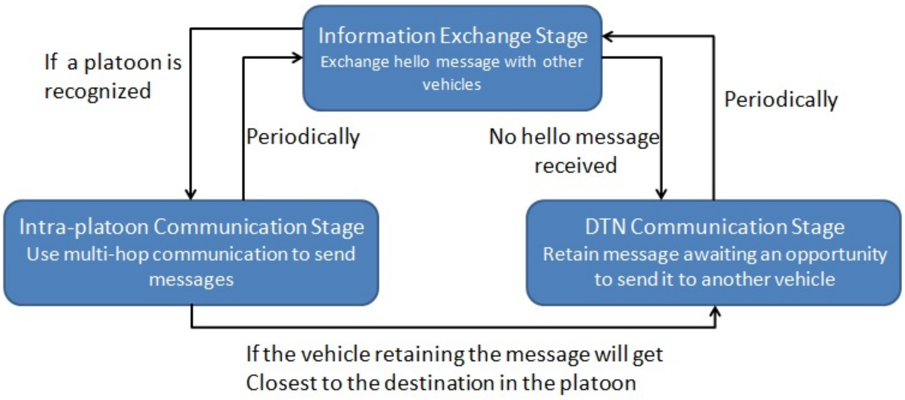


Figure 24. Method Structure

3.5.1 Information exchange mode

In the information exchange mode, each node obtains information for determining the node to communicate within other stages. In order to realize this, each node periodically broadcasts messages called Hello Messages, as shown in Figure 25. The Hello Message used in the method contains entries named Car ID, Itinerary Route and Topology Info, as shown in Table 1.

Table 1. Content of Hello Message

Car ID	Itinerary Route	Topology Info
12	V1,V2,V3,V4	13|V1,V2,V3|12>13|2

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

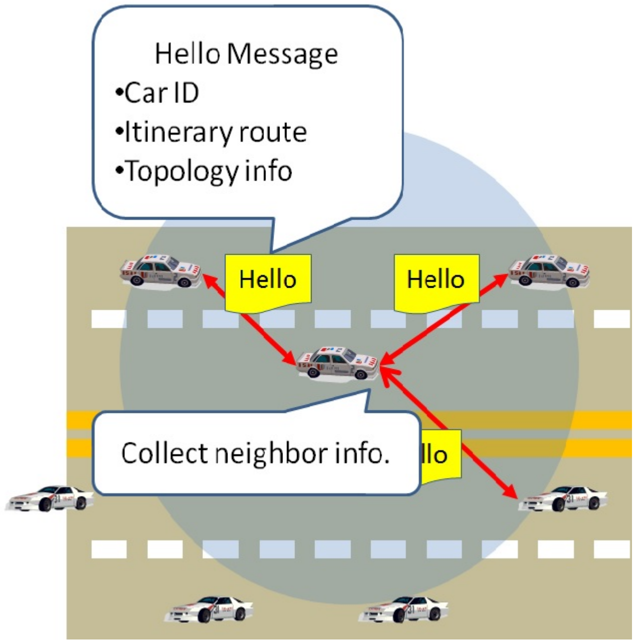


Figure 25. Hello Message Exchanging

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.

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 a hop, the size of the platoon is 1. In the proposed method, the size of platoon for each vehicle can be flexibly changed

Table 2. Neighbor Table 2

N ID	Itinerary Route	Topology Info	TTL
12	V1,V2,V3,V4	10>12	10
13	V1,V2,V3	10>12>13	2
...	...	...	...

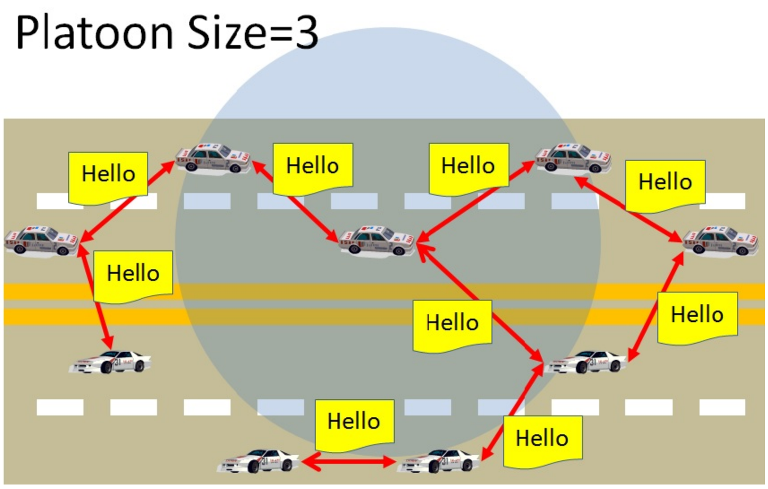


Figure 26. A Size 3 Platoon

according to vehicle density and network traffic. Figure 26 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 thesis, 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 an 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.

Table 3. Neighbor Table 3

N ID	Itinerary Route	Topology Info	TTL
B	V2,V9	A>B	4
C	V2,V5,V6,V10	A>B>C	10
D	V2,V9	A>B>C>D	2

3.5.2 Intra-platoon communication mode

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 sends 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 mode is executed each time a new node arrives at the platoon.

We explain how this mode works by Figure 21 and Neighbor 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 v8, and B, C and D are neighboring nodes. The itinerary for node A is v1, v2 and v9, node B is V2, V9, node C is V2, V5, V6, V10 and node D is V2, V9. 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.

3.5.3 DTN communication mode

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. Figure 27 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

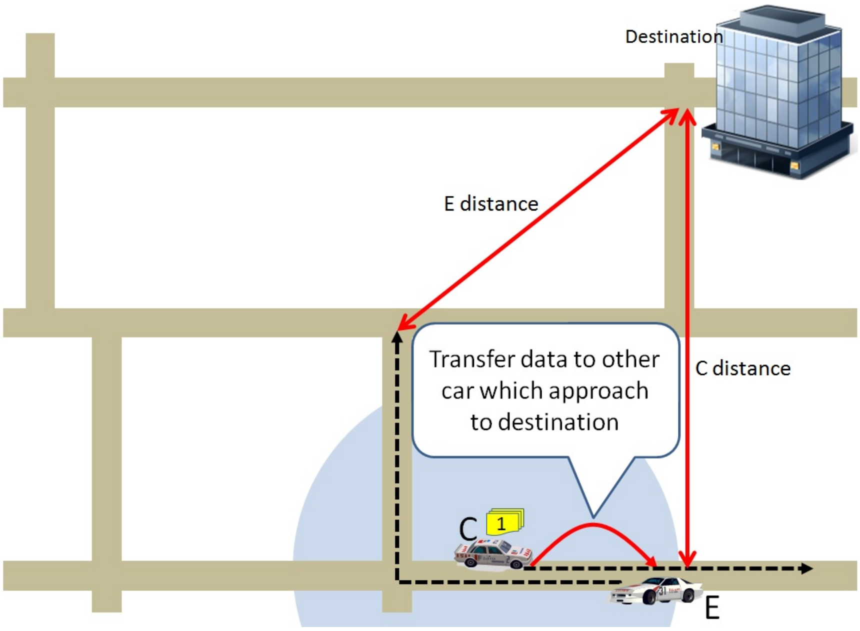


Figure 27. DTN Communication Mode

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.

4. Case Study

In this section, we explain the characteristics of the proposed method by a few cases. We compare our method with the GEOCAST and the flooding methods. We introduce how each method works in the following. We make the following assumptions :
Each vehicle equips with an IEEE 802.11-comforming wireless communication device. The communication range is 100m, and the total communication bandwidth within a radio range is 8Mbps. Data size of a message is 5MB.

- **Proposed Method**: Only the cars running in front of platoons create 3 replicas, and other cars send only one message. Size of a hello message is 100 bytes. The itinerary route takes up to 1500 bytes. The transmission rate is adjusted according to the speed of the vehicle.
- **GEOCAST**: Each vehicle makes up to 3 replicas. Each car wait for a predefined period before sending out a new replica. Hello message size is 50 bytes. Transmission rate is one per minute.
- **Flodding**: Replicas are not made. Each car floods only once after receiving a new message. Hello message size is 50 bytes. Transmission frequency is 1 per minute.

The figure 28 shows a map of 5km x 3km size. Red blocks are platoons. Other road sections do not contain a platoon. Start is the place where the message is created. DEST is the destination.

In this case, since vehicles travel at 60km/h, hello messages are exchanged every second. The proposed method transmits the message after the message is created at START. Since the destination vehicles belong to platoons, the message is forwarded to the vehicle that will get closest to DEST. The blue line in the figure shows the route of the message. The vehicle that received the message retains the message until it joins a next platoon. Then, it finds a new vehicle to forward the message. Each vehicle create up to 3 replicas, and forward them to three vehicles that will get close to DEST. In this case, messages are carried by two platoons, and since our method utilizes the DTN mode, it only creates a few tens of replicas, and it wont use up the radio bandwidth.

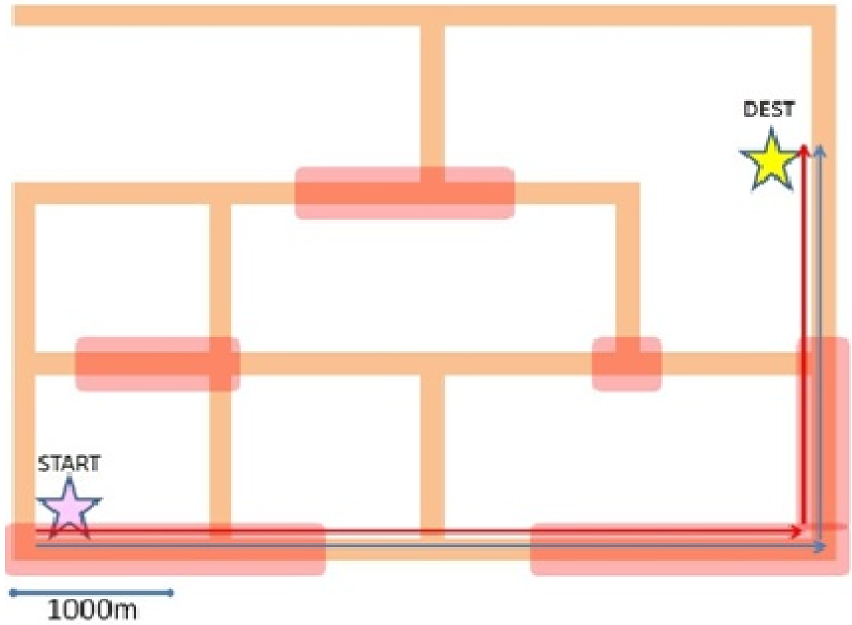


Figure 28. Case Study

GEOCAST does not utilize the itinerary information, and it only use the current positional information of the vehicles. Thus, it tends to forward the message to the cars at the front of platoons. The red line in the figure shows the message route by GEOCAST. Since all vehicles create replicas, it uses a huge amount of radio bandwidth. The message transfer speed is high if the speed of the platoon is high, however, it uses a lot of bandwidth.

Flooding does not utilize the positional information. Each car receiving a hello message broadcast the same message, and thus it uses up the radio bandwidth.

As for just sending hello messages, the all three methods do not use so much bandwidth. There is not much difference in message transfer speed either.

5. Evaluation Plan and Discussion

5.1 Evaluation Plan

In order to evaluate the proposed method, we are going to use SUMO vehicular traffic simulator [31], 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. Figure 29 is a road map screen shot by SUMO. In this thesis, 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 all the vehicles use the same channel:

- 802.11g WiFi communication
- Bandwidth size is 20 Mbps
- Hello message size is 1500 bytes

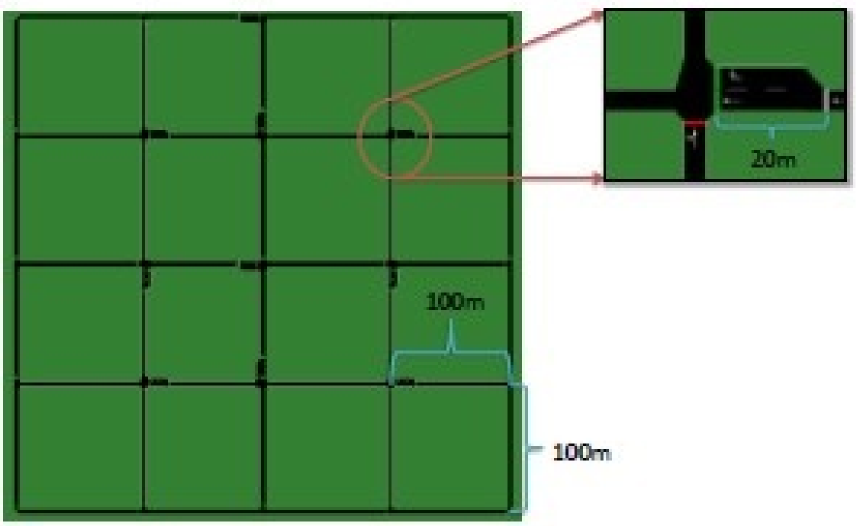


Figure 29. Screen shot of SUMO

We are considering the following metrics in evaluation simulation:

Delivery ratio: The average value of all success deliveries from sources to destinations. Improving the delivery ratio from source vehicle to destination in VANETs is difficult, as the vehicle density can be unpredictable. The problems faced with increasing the delivery ratio in VANETs are:

- **High mobility of vehicles**: Leads to rapid changes in the network topology. Vehicles traveling at high speed face difficulty to transmit or receive messages.

- **Collision**: In the situation where there are many vehicles between source and destination, sending a message using the flooding technique can lead to collision. In the flooding technique a vehicle re-transmits the received packet to all vehicles in its radio range. There are three problems in VANETs using flooding method:

  - The same packet can be rebroadcasted many times because of flooding. For example when a vehicle has n neighbors, the same packet will be sent to all neighbors.

  - There is a high probability of contention occurrence where a message will be received by many vehicles in close proximity and every vehicles will try to rebroadcast the same message.

  - Large number of collisions happening due to the lack of Request to Send/Clear to Send (RTS/CTS) mechanism and no collision detection information is available.

- **Traffic jam**: In the urban area traffic jams can frequently occur due to several reasons such as the increase in vehicles during rush hours, construction of building or roads, accidents, bad weather conditions, etc. This situation can delay the message delivery in VANETs. Figure 30 shows an example of Traffic Jam Situation.

- **Storm message**: This problem can occur when the number of HELLO messages increases in the entire network, thereby consuming excess bandwidth. Figure 31 shows an example of Storm Message.

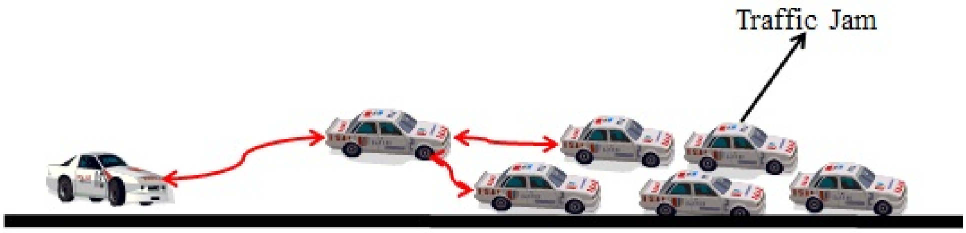


Figure 30. An Example of Traffic Jam Situation

- **Large Packet size**: A packet is said to be successfully delivered only when the destination receives the entire packet. When the packet size is large, then a packet has less probability to be successfully delivered to the destination.

Delay: The average delivery delay from source to destination can increase when there is no continuous network communication in the entire network. In general this problem occurs at night, when there are only a few vehicles available. Figure 32 shows an example of Delay Time in Vehicle Communication.

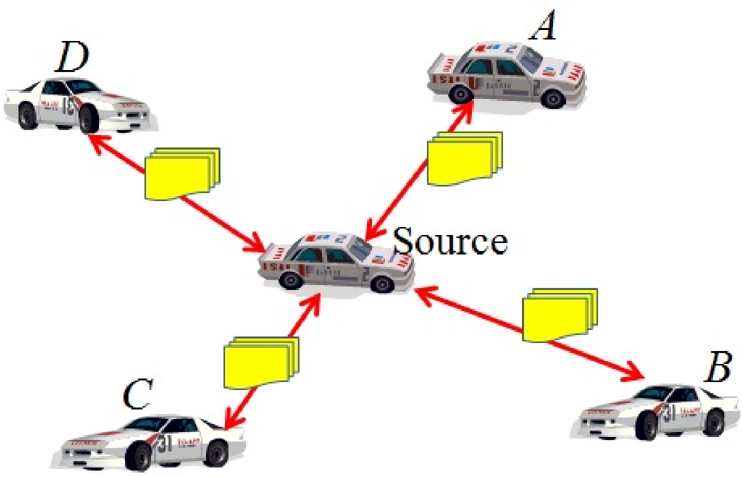


Figure 31. An Example of Storm Message

Overhead: Each vehicle broadcast HELLO messages simultaneously, the function of HELLO messages is to obtain information from its neighbor vehicles such as ID, itinerary route, topology information, etc. To decrease the overhead in VANETs we need to control the number of HELLO messages in platoon network. For example source vehicle can only choose one particular neighbor vehicle to transmit the packet which is the closest to destination.

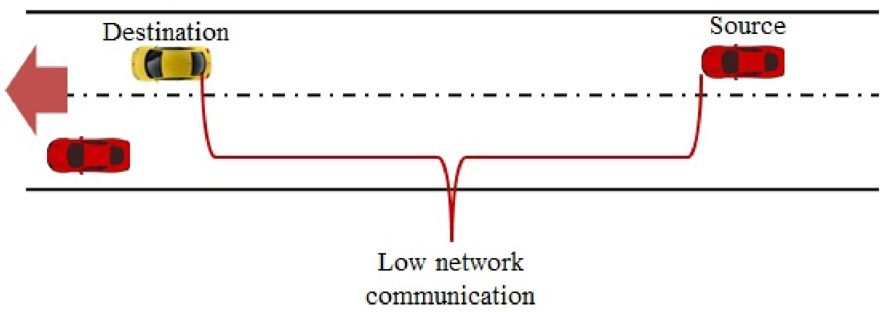


Figure 32. An Example of Delay Time in Vehicle Communication

5.2 Discussion

In this thesis we propose a new method using car platoon to do message dissemination from source to destination. Additionally we propose the controlling in number of HELLO messages transmitted to reduce the HELLO message overhead and increasing the delivery ratio using multi-hop communication in the car platoon. There are some questions in this thesis:

- Question: How to calculate vehicle density?
- Answer: We set a threshold for the number of received hello message within past x second, if a node received more than the threshold, then the node considers it is a high density. On the other hand there is another threshold if hello message less than this threshold then it is a low density.

- Question: How big is hello message and how do you represent if it decide fix number it can suppressed the size of hello message?
- Answer: Maximum size for hello message is 1.500 byte in general it is less than 100 byte. Hello message format information such as itinerary route, this information is not so big, because we use simple ID for each intersection in the map. For example using SUMO simulator map size is 10 km x 10 km present 50 intersections and the size is only 193 byte.

- Question: What is the frequent of hello message?
- Answer: The frequent is set based on the node speed:
  - 60 km/h its can broadcast one hello message/1 second.
  - 50 km/h its can broadcast one hello message/1.2 second.
  - 30 km/h its can broadcast one hello message/2 second.
  - 1 km/h its can broadcast one hello message/1 minute.

In order when traffic congestion occurs, there can be a few tens of vehicles in a one-hop region. We use congestion mode to improve the protocol performance in this case. In the congestion mode, we set the platoon size to minimal so that it does not need to contain the topology information in hello messages. Then, we make each node to find the relay node on demand. The inquiry message contains the destination coordinates, and the node that will reach closer to the destination will respond to the inquiry.

- Question: Platoon topology will change so how to update TTL?
- Answer: TTL will be updated based on hello message. Maybe topology change before hello message received, our system does not care it.

- Question: Please consider the mechanism to duplicate important messages.
- Answer: We consider some replicas are necessary so now we let the maximum platoon number are 3.

6. Conclusions

In Vehicular Ad-hoc Networks (VANETs), increase in the packet delivery to the destination is difficult because of the high vehicle mobility, this may cause delay in delivery of packets to destination. By combining multi-hop communication and DTN based method we expected to increase the delivery ratio and reduce the delay time. In this thesis we proposed a method for sending messages to a destination utilizing vehicle-to-vehicle communication in urban environments. Our proposed method consists of the following three modes:

- **Information exchange mode**: Vehicle broadcast and exchange of HELLO messages in the entire network. The messages contains vehicles ID, full itinerary route information, etc.
- **Intra-platoon communication mode**: Messages are sent using multi-hop communication if there is another vehicle that will get closer to the destination in the same platoon. If none of its neighbors are closer to the destination than the source, then even in the presence of neighboring vehicles it switches to the DTN mode.
- **DTN communication mode**: 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 an opportunity to send it to another vehicle.

Additionally we also consider the performance of our method in the situation of traffic congestion by setting the platoon size to minimal so that it does not need to contain the topology information in messages. Then we make each node find the relay node on demand.

The inquiry message contains the destination coordinates, and the node that will reach closer to the destination will respond to the inquiry. We expect that the network traffic will be reduced by switching to this stage. In the future we plan to evaluate the proposed method using simulations.

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Domestic Conference

1. Budi Rahmadya, Weihua Sun, Naoki Shibata, Minoru Ito, "DTN Based Message Dissemination Technique Using Platoon in Urban Area," *Proc. Information Processing Society of Japan, IPSJ*, ITS-53 No.5, June 14, 2013.