A Vehicle Clustering Algorithm for Information Propagation by Inter-Vehicle Communications

Naohiro Washio*, Satoshi Matsuura†‡, Masatoshi Kakiuchi*, Atsuo Inomata*, Kazutoshi Fujikawa*
*Nara Institute of Science and Technology, Japan †Tokyo Institute of Technology, Japan
‡National Institute of Information and Communications Technology, Japan
Email: washio.naohiro.wh4@is.naist.jp, matsuura@gsic.titech.ac.jp, {masato, atsuo, fujikawa}@itc.naist.jp

***Abstract*—There are some cases regarding information propagation over a wide area, such as Vehicle-to-Vehicle (V2V) communications, in which an end-to-end path does not exist, due to the non-uniform density of vehicles. In order to solve this problem, Delay Tolerant Network (DTN) architectures have been studied to facilitate message delivery in V2V communications. However, existing message delivery methods for the purpose of information sharing do not consider the efficiency of message passing communications. As a result, information can be lost, due to a decrease in the efficiency of information propagation. In order to increase the efficiency of information propagation, we propose a vehicle clustering algorithm, based on the similarity of geographic locations and trajectories. This contributes to efficient message passing communication. In order to evaluate our proposal, we carry out a simulation. The simulation results confirm that our proposed method provides higher message reachability, and utilizes bandwidth more efficiency than existing methods.**

I. INTRODUCTION

Recently, in order to achieve high levels of safety and efficiency for the drivers, the demands for Intelligent Transportation Systems (ITS) have increased. As an ITS application, a system that aggregates the information generated from vehicle sensors or a road side unit and delivers traffic information relating to, for example, traffic congestion and traffic accidents, has been proposed. Some systems of this type have already been deployed, e.g., the Vehicle Information and Communication System (VICS) in Japan [1]. However, information systems such as VICS, which are used in a nationwide-scale highway, require costs for maintenance and infrastructure. In addition, it is not possible to receive services if a vehicle is not traveling on a main road. On the other hand, applications that aggregate information with a roadside device or mobile telephone network [2][3] are not able to obtain real-time information, due to delays in information propagation. These problems can be resolved by sensing surrounding traffic conditions using vehicle sensors, and sharing this traffic information through vehicle-to-vehicle (V2V) communications.

Concerning the propagation of information over a wide area, such as in V2V communications, there are cases where an end-to-end path does not exist, due to the non-uniform density of vehicles. In order to solve this problem, Delay Tolerant Network (DTN) architectures [4] have been studied with regards to message delivery in V2V communications. A proposed example of an application of the information propagation of V2V communications is the exchange of information by communicating with passing vehicles. In general, by exchanging communications with an oncoming vehicle, it is possible to propagate information from one vehicle to the vehicle behind it. As shown in Fig.1, a vehicle can obtain information from one that is in front of it, though not within the communication area, as a result of information propagation through oncoming vehicles. Therefore, it is possible for that vehicle to travel while avoiding road traffic congestion and traffic accidents based on the information that can be obtained from an oncoming vehicle. In applications involving the exchange of information with oncoming vehicles, the limited opportunities for passing message from vehicle to vehicle are efficiently utilized. If a system does not consider the efficiency of message passing communications, this causes loss of information, due to a decreased efficiency of information propagation. For the purpose of propagating information efficiently, we propose a vehicle clustering algorithm based on the similarity of geographic locations and trajectories. This algorithm contributes to efficient message transfers in passing communications. The rest of this paper is organized as follows. Section II describes work related to our research. Section III explains the design of our proposed method. Section IV evaluates the performance of our implementation. Section V summarizes this paper.

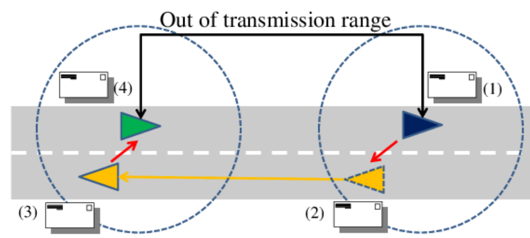

Fig. 1. Message passing communication

II. RELATED WORK

In this section, we will introduce the existing routing methods in the DTN environment, and discuss the DTN applicability of inter-vehicle communications. Moreover, existing studies aiming towards cooperation with other vehicles in V2V communications are described.

A. Delay Tolerant Network (DTN)

Many routing techniques have been proposed for message delivery in a DTN environment. Message delivery in a DTN environment is performed using the store-and-forward method. In this method, relay node stores all or part of the received message in its own storage device, and then forwards this when a link to the next node is available (this is defined as a contact). In other words, the architecture of the DTN constructs a bundle layer that communicates using the store-and-forward method. By providing a layer that communicates using the store-and-forward method bundle layers, each layer below the transport layer can be used as a communication system in accordance with the characteristics of the network.

B. Classification of DTN routing methods

DTN routing can be classified into six types (Oracle, Model-based, Epidemic, Estimation, Coding, and Node Movement), based on the information used for the routing and approach, and the request to the node [5]. The Oracle type is a routing technique in which a route calculated by considering delays or available contacts almost certainly, due to some knowledge. The Model-Based type is a routing technique that assumes a specific environment is modeled, such as social life or crowd behavior. The Epidemic type is a routing technique in which it is assumed that the status of the network is not clear, such as in a disaster, or network mobile sensor networks. The use of Epidemic is considered for applications to the inter-vehicle communications in a wide area DTN environment. The Estimation type is a routing technique used to control the status of the network by exchanging information with neighboring nodes. ProPHET [6] is typical example of this type of technique. The Coding type is a routing technique that performs the transmission of messages using the encoding scheme, such as network coding [7]. The Node Movement type is a routing technique that performs message delivery based on the movement of active nodes, such as an unmanned exploration robot.

C. Application in DTN environment

In the following, DTN routing techniques that can be applied to V2V communications are considered. In the environment of V2V communications, the Model-Based, Oracle, and Estimation types cannot be applied, because the prediction of traffic and contacts is very difficult. The Coding type also cannot be applied, because the environment will not always contain a large number of nodes within the communication range. In addition, since the control of a node based on the requirements of the network is also difficult, it is not possible to apply methods of the Node Movement type. Therefore, when considering the application of DTN routing techniques to inter-vehicle communications, the Epidemic type is the most suitable.

We will discuss the application of the Epidemic type to inter-vehicle communications. Epidemic is a simple routing technique of Epidemic type, proposed by Vahdat et al. [8]. Nodes transfer a message to be stored to all possible contact nodes. In Epidemic routing, the copies of messages are diffused in the network, and messages are delivered to the destination by replicating all messages between nodes that have had contact. Therefore, the propagation efficiency is high, but compresses the communication bandwidth. In order to prevent the compression of the communication band, a routing technique called Spray and Wait is proposed by Spyropoulos et al. [9]. In Spray and Wait, an upper limit of the replication number is imposed on the source node, in order to reduce the total number of messages. Messages are forwarded through two stages in Spray and Wait routing. Messages generated by the source node are assign an integer L, and when generating messages, messages are limited be copied up to L times to each node. As an improvement, MaxProp has been proposed by Burgess et al. [10]. MaxProp is a technique that selects the transfer message to reduce the number of message copies, and improve the message reachability. In MaxProp, messages are replicated in the order of priority. Message priority in MaxProp is calculated using the node contact list, and the number of hops of the messages. In MaxProp, each message records the number of previous copies. If the replication number is below a certain threshold, the message is given a high priority, in the order of ascending numbers of replicas. The threshold value is calculated using the current amount of storage, and the average bandwidth of contacts in the past.

D. Cooperation with neighbors

When the DTN routing technique is applied to inter-vehicle communications, there is a possibility that the limited communication bandwidth cannot be efficiently used, as a result of the constraints of the wireless communication range and high mobility. In any wireless communication technology, wireless communications do not always retain enough connectivity and a stable communication speed. The exchange of high-capacity packets, or frequent communication as in existing DTN routing approaches, are also likely to cause channel congestion or the occupancy of the bandwidth. Since urgent and not-urgent information will be treated in different channels in inter-vehicle communications, there is no possibility that non-emergency communications will interfere with emergency communications. However, when the application of non-emergency communications has multiple operations, the available bandwidth is reduced. Therefore, the total communication is required to be sufficiently small.

Consequently, methods are studied for increasing the utilization of communication bandwidth and reachability for efficient propagation in the inter-vehicle communications, by classification or by cooperating with neighboring vehicles. In a study by Han et al. [11], a clustering on the map using the trajectories of vehicles, and visualizing their tendencies, has been proposed. This approach aims to classify vehicles using their trajectories, but cannot be applied directly to inter-vehicle communications, because of the use of map data in off-line situations. In a study by Li et al. [12], a method of clustering vehicles using their trajectories and geographic

TABLE I
EXAMPLE OF A CLUSTER MANAGEMENT TABLE (CMT)

Vehicle ID	Trajectory	Cluster ID
Vehicle1	0000 - 0001 - 0002 - 0003	ClusterA
Vehicle2	0000 - 0001 - 0002 - 0003	ClusterA
Vehicle3	0006 - 0005 - 0004 - 0003	ClusterB

locations is considered. This approach can be applied to inter-vehicle communications, but it is known to be limited to vehicles with special characteristics, such as buses and taxis. In a study by Kanemaru et al. [13], by using vehicle trajectories and geographic locations, a clustering algorithm for vehicles involved in the same traffic congestion has been proposed. This approach makes it possible to perform the identification of traffic congestion, and its head vehicle, with information about traffic congestion. This approach has also achieved high reachability of messages for vehicles within the same traffic congestion, but it has a problem, in that information cannot be propagated out of the cluster. In a study by Ramon et al. [14], an available bandwidth is allocated fairly across the neighboring vehicles. In this method, by increasing the efficiency of the utilization of the communication bandwidth, the transfer efficiency of the message is improved. However, this approach is limited by the fact that it does not consider the message priority, and does not consider the efficiency of the message passing communications.

III. PROPOSED METHOD

With the aim of propagating information efficiently, we propose a vehicle clustering algorithm based on the similarity of geographic locations and trajectories. In this section, details of our clustering algorithm are described.

A. Cluster management

As shown in TableI, each vehicle is managed autonomously "Cluster Management Table" (CMT). The CMT is used to manage the cluster ID derived from the trajectories relating to the ID of each neighboring vehicle. Note that each vehicle is provided with mechanisms to identify the cluster that vehicle trajectories match to above a certain threshold.

In this way, the cluster ID is given based on the common trajectory of each vehicle. The trajectory is a sequence of pairs of latitude and longitude, to be recorded at each time. However, the problems in comparing the trajectories are caused by GPS. Consider that each vehicle calculates and records its own location using the GPS receiver at regular time intervals. At this time, even though two vehicles may be traveling the same road, the possibility that their trajectories match is very low. This is positioning errors, due to differences between antenna installation positions, and differences of positioning timing for each vehicle. Therefore, matching cannot be determined by a simple comparison of the latitude and longitude on the trajectory. In order to solve this problem, Quadkey[15] is used by abstracting the latitude and longitude to compare the trajectory. Our main idea is to use an abstracted trajectory as

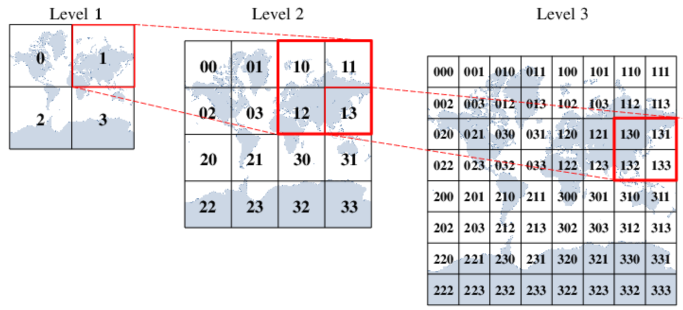

Fig. 2. Hierarchical structure and inclusion-relation of Quadkey

a clustering metric, instead of an actual trajectory, i.e., using latitude and longitude directly.

1) Geographical and hierarchical separation by Quadkey: Quadkey is one of Geocoding method that allows two-dimensional coordinates (latitude and longitude) can be expressed as a one-dimensional unique string. Geocoding divides the map using some law, assigns a unique ID that is called "mesh ID" to each mesh, and expresses a latitude and longitude that is included in the area of each mesh as an abstract mesh ID. In Quadkey, the map is divided with mesh close to a square, and they are treated hierarchically. The mesh ID is designed to be a prefix to the lower abstract mesh ID, describing the area within a mesh. It becomes possible to give a unique abstract expression for any point on the earth, to any level of geographical division as shown in Fig2.

2) Abstraction of trajectory by Quadkey: As mentioned above, Quadkey abstracts any degree of latitude and longitude, and outputs it as a unique string. By utilizing this, we can compare the trajectory of each vehicle on an abstraction at the same level, in order to identify similar trajectories. Our method is based on the following two assumptions. First, each vehicle is equipped with a GPS, or any other positioning system. Therefore, it can obtain its own current location, including its latitude and longitude, with high accuracy. Second, each vehicle stores its own trajectory information in its own internal storage. We call this internal storage the trajectory table, which contains n samples of passed location with, time stamps. The passed locations are stored in a Quadkey form, for the abstraction of trajectory. In Quadkey, we can choose the abstraction scale by adjusting the "Level of Detail" (LoD). Quadkey can perform calculations as follows. First, it calculates $tileX$ and $tileY$ using (1) and (2).

$$S_{lat} = \sin(lat)$$

$$tileX = \left\lfloor \frac{lng + 180}{360} \times 2^l \right\rfloor \quad (1)$$

$$tileY = \left\lfloor 0.5 - \log\left(\frac{(1 + S_{lat})/(1 - S_{lat})}{4\pi}\right) \times 2^l \right\rfloor \quad (2)$$

where lat is the latitude, lng is the longitude, and l denotes the LoD. A higher value of l forms a finer grained sub-area.

TABLE II
EDGE LENGTH OF QUADKEY

Level of Detail	the lengths of the edge [m] $\pm 0°$	$\pm 35°$	$\pm 70°$
1	20037508.34	16413765.92	6853231.47
2	10018754.17	8206882.96	3426615.74
⋮	⋮	⋮	⋮
19	76.44	62.61	26.14
20	38.22	31.31	13.07
21	19.11	15.65	6.54
22	9.55	7.83	3.27
23	4.78	3.91	1.63

Then, the values of Quadkey are given as follows:

$$Quadkey = \text{BASE4}((Y_{l-1}X_{l-1}Y_{l-2}X_{l-2}...Y_0X_0)_2) \quad (3)$$

where each X_n and Y_n denote the nth bit of $tileX$ and $tileY$ respectively, and BASE4() is a conversion function to 4 decimal places. When it is assumed that LoD is l in lat, the length of the edge l_e is given as follows:

$$l_e = \frac{\cos(lat) \times C_e}{2^l} = \frac{\cos(lat) \times 2\pi \times 6378137}{2^l}[m] \quad (4)$$

where C_e is the length of the outer circumference of the Earth. We use LoD denoted as $LaneLevel$, and assign the level to an actual LoD as 22. This level indicates that the length of the edge is 7.8 m at latitudes near to ±35.0° (shown in TableII). This assignment is determined based on actual lane width. The 7.8 m is sufficient to span a general road width.

A summary of the clustering by Quadkey is shown in Fig.3. Vehicles V1, V2, V3, and V4 are traveling in each lane. Each mesh corresponds to the $LaneLevel$. The vehicles record for the samples of trajectory above a certain level. In the case of the Fig.3, each vehicle holds the last three mesh IDs. In this situation, the trajectories of V1, V2, V3, and V4 are "0003-0012-0013", "0002-0003-0012", "0012-0003-0002", and "0013-0012-0003" respectively. Then, if the mesh IDs of the trajectory are consistent within a certain threshold, it is considered that two vehicles are in the same cluster. If the discontinuous mesh IDs are obtained, the trajectory is interpolated as the continuous mesh IDs. In this way, V1 and V2 are identified as in cluster A, and V3 and V4 are identified as in cluster B. That is, even when some vehicles are geographically proximate, it is possible that they are identified in different clusters depending on their traveling history.

B. Cluster formation

Each vehicle one-hop broadcasts a beacon that defines a HELLO message at regular intervals, of the order of several seconds. Note that it is assumed that own CMT is in the HELLO message. When a vehicle receives a HELLO message from new neighbor vehicles, the vehicle sends back HELLO messages, and adds new vehicles to its own CMT. Then, the vehicle removes a registered vehicle from its own CMT, when

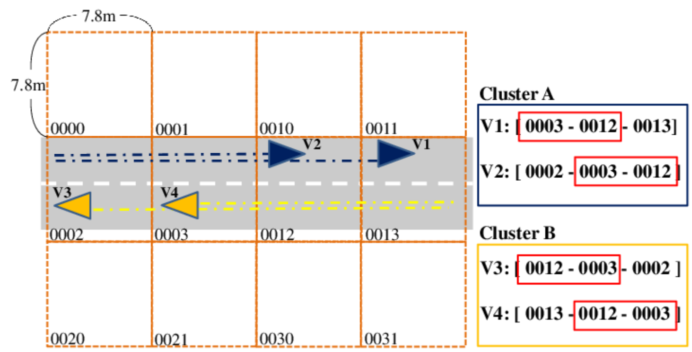

Fig. 3. Identifying similar trajectories by Quadkey

there is no response to the HELLO message within a fixed period. Through such mechanisms, each vehicle is able to identify a vehicle traveling on the same route in the past, and to improve the transfer efficiency in message delivery.

C. Message delivery by the Vehicle Cluster

The CMT is designed to enumerate a list of communicable vehicles. The vehicle does not send any message about the road information to vehicles that are identified in the same cluster. By sending road information to other clusters, it is possible to improve the propagation efficiency of the information. Furthermore, by reducing the message transfer activity within the cluster, it is possible to solve the problem of compressing the communication bandwidth. Vehicles having the same cluster ID are capable of maintaining a connection for relatively long time. Therefore, a vehicle sends a request for the necessary information, and a vehicle in the cluster returns responses.

IV. EVALUATION

In order to verify the usefulness of the proposed method, we performed a simulation, and compared with existing methods, using a DTN simulator "The ONE Simulator" [16]. In this section, we describe the simulation environment and the results of our experiments. The communication system is assumed as ITS FORUM RC-006 [17], the transmission range is 100m, and the speed is 10Mbps, assuming a frequency band of 700MHz.

A. Basic Simulation for Evaluation of Message Passing Communication

In order to evaluate the efficiency of message passing communication, we simulated communication between vehicles to platoon the straight road. Message generating vehicles, message relay vehicles, and a trailing vehicle are defined (Fig.4). The message generation frequency is assumed to generate 40 messages before communication. The trailing vehicle is assumed to be a traveling vehicle that cannot communicate directly with the message generating vehicles. Therefore, messages generated by the message generating vehicles are delivered through the relay vehicles traveling in

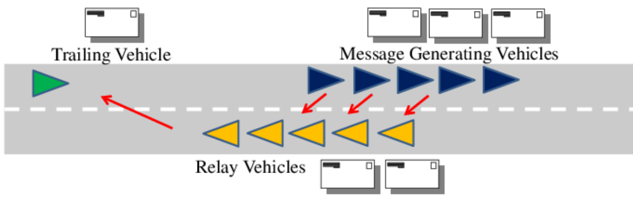

Fig. 4. Overview of message passing communication in the experiments

the opposite lane. Note, it is assumed that there is sufficient buffer capacity for each vehicle to avoid dropping messages.

Message generating vehicles are not able to communicate with the trailing vehicle. Therefore, they send messages to the trailing vehicle via relay vehicles. The percentage of messages received by the trailing vehicle, from those generated by generating vehicles, is defined as the message delivery ratio. A high message delivery ratio shows that the trailing vehicle is likely to acquire traffic information, relating to the forthcoming roads. In addition, the number of times that vehicles attempt to transfer messages is defined as the quantity of message transfer. If the quantity of message transfer is large, channel congestion occurs, and vehicles cannot receive the safety message. Therefore, controls over the message delivery ratio and the quantity of message transfer are required.

Subsequently, we compared the existing methods (Epidemic, MaxProp) with the proposed method, using experiments of following two types (ex1, 2). Here, we define the number of the combined relay vehicles and message generating vehicles as the number of passing vehicles. In ex1, the message delivery ratio has been verified in a scenario where the message size generated by the vehicles is incremented from 1MB to 10MB. (The number of passing vehicles is fixed to 10.) In ex2, the quantity of message transfer has been verified in a scenario where the number of passing vehicles is increased from 10 to 25. (The message size is 3MB.) In these experiments, we assumed that the number of relay vehicles and message generating vehicles were same, and that relay vehicles do not generate any massage, but only try to relay messages.

The Result of ex1 is shown in Fig.5. The routing techniques of Epidemic, MaxProp, and proposed method show the same trend. The message delivery ratio decreased with an increase in message size. It may be considered that by the constraints of the communication speed, the number of messages that can be transferred within the communication time is reduced. Epidemic routing displays a higher message delivery ratio. This is because, without considering the communication bandwidth utilization, the node forwards all of the contacts to all messages. Our proposed method also achieves a message delivery ratio comparable to the Epidemic method. Finally, the result of ex2 is shown in Fig.6. Epidemic routing displays a high reachability in Fig.5, but the quantity of message transfer increases with an increase in the number of passing vehicles.

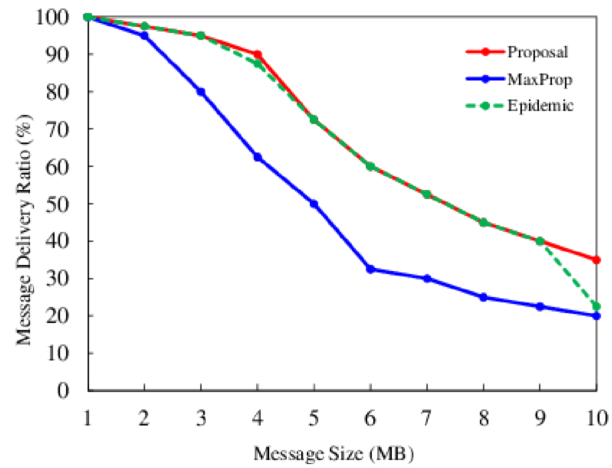

Fig. 5. ex1: The message delivery ratio has been verified in each case, when the message size generated by the vehicles is incremented from 1MB to 10MB.

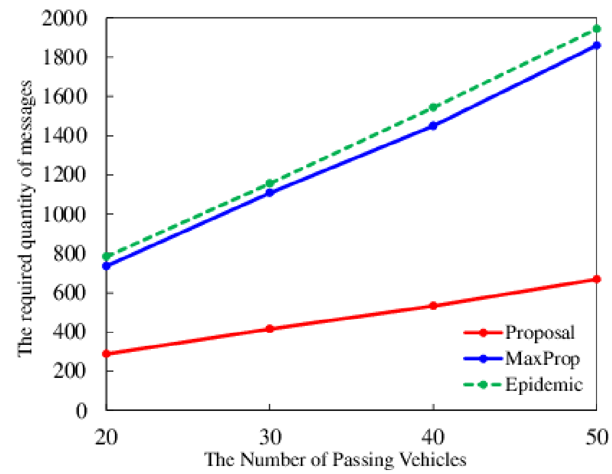

Fig. 6. ex2: The total number of messages has been verified when the number of passing vehicles is increased from 10 to 25.

MaxProp routing required a smaller quantity of message transfer than Epidemic routing, but the quantity of message transfer increased. On the other hand, the proposed method is shown to have greatly reduce message traffic, by reducing intra-cluster transfers.

If bandwidth utilization is not considered at all, then each vehicle tries to use the maximum channel capacity. As a result, channel congestion occurs, and the message delivery ratio decreases. Moreover, if some kind of message is occupying the channel, then the messages for other applications cannot be transferred. The Epidemic method achieved a higher delivery ratio, but this is not utilizable. Our proposed method is utilizable, due to higher message delivery ratio as well as bandwidth utilization.

B. Simulation for Evaluation of Clustering

By using the proposed method, we have verified the reachability of the information generated at some distance. This is

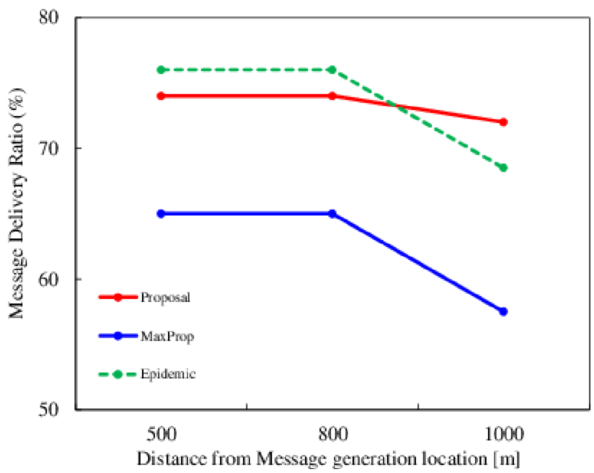

Fig. 7. The message delivery ratio has been verified in each distance from message generation location.

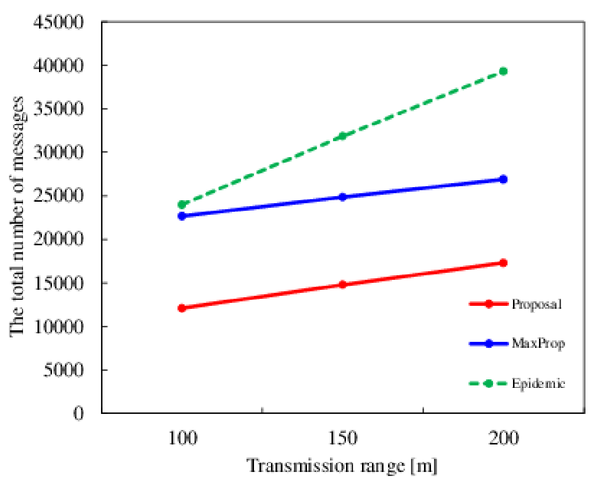

Fig. 8. The total number of messages has been verified in each transmission range.

simulated in grid road of 2 km × 2 km, and messages that were acquired by a target vehicle are evaluated. Subsequently, the target vehicle travels 2 km towards the destination. The number of vehicles in the area is 300, and the speed at which each vehicle moves is 50 km/h. The percentages of messages acquired by the target vehicle, when they are generated at distance of 500 m, 800 m, and 1000 m, are shown in Fig.7. According to simulation results, in all methods, the message delivery ratio reduces with increasing distance from the generation point. The proposed method displays the same degree of reachability as the Epidemic methods. If the message delivery ratio is 70 % or more, it is possible to fully understand the situation of the surrounding area. In addition, the total number of messages that all of the vehicles generated and transferred during the simulation is shown in Fig.8. Our method limits the number of duplicate messages, by identifying clusters. Therefore, in our method, it is possible to propagate messages without having to compress the communication bandwidth.

V. Conclusion

For the purpose of efficient information propagation in V2V communications, we proposed a vehicle clustering algorithm, based on the similarity of geographic locations and trajectories. This contributes to efficient message passing communications. In order to evaluate our proposed method, we executed some simulations. The simulation results show that our proposed method provides a higher message delivery ratio and better bandwidth utilization efficiency than existing methods. According to our results of our simulation, we have shown that our proposed method is utilizable, as it displays a high message delivery ratio, and incorporates bandwidth utilization. However, to consider its use in a real environment, the cluster formation and its stability must be evaluated and simulated in an actual road environment. Furthermore, in a scenario in which traffic congestion information is propagated using the proposed method, verification by simulation regarding the efficiency of information propagation in an environment that includes traffic congestion will be demanded. This is an area for future work.

References

[1] Vehicle Information and Communication System Center, "Vehicle Information and Communication System (VICS)." [Online]. Available: http://www.vics.or.jp/english/vics/index.html

[2] Google, "Google Maps." [Online]. Available: https://maps.google.com/

[3] "Waze." [Online]. Available: http://www.waze.com/

[4] V. Cerf, "Delay-Tolerant Networking Architecture." RFC 4838, Internet Engineering Task Force, April 2007. [Online]. Available: http://www.ietf.org/rfc/rfc4838.txt

[5] Z. Zhang, "Routing in intermittently connected mobile ad hoc networks and delay tolerant networks: overview and challenges," IEEE Communications Surveys and Tutorials, vol. 8(1), pp. 24–37, 2006.

[6] A. Lindgren, A. Doria, and O. Schelen, "Probabilistic routing in intermittently connected networks," Lecture Notes in Computer Science, pp. 239–254, 2004.

[7] R. Ahlswede, "Network Information Flow," IEEE Transactions on Information Theory, Vol. 46, No. 4, pp. 1204–1216, Jul. 2000.

[8] A. Vahdat, D. Becker, "Epidemic Routing for Partially-Connected Ad Hoc Networks," Duke Tech Report CS-2000-06, Jun. 2000.

[9] T. Spyropoulos, K. Psounis, and C.S. Raghavendra, "Spray and wait: an efficient routing scheme for intermittently connected mobile networks," In Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking, 2005.

[10] J. Burgess, B. Gallagher, D. Jensen, and B. N. Levine, "MaxProp: Routing for vehicle-based disruption tolerant networks," In B. Gallagher, editor, Proc. 25th IEEE INFOCOM 2006.

[11] B. Han, L. Liu, E. Omiecinski, "NEAT: Road Network Aware Trajectory Clustering," 2012 IEEE 32nd International Conference on Distributed Computing Systems, 2012.

[12] Y. Li, M. Zhao, and W. Wang, "Internode Mobility Correlation for Group Detection and Analysis in VANETs," IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, NOVEMBER 2013.

[13] Y. Kanemaru, S. Matsuura, M. Kakiuchi, S. Noguchi, A. Inomata and K. Fujikawa, "Vehicle Clustering Algorithm for Sharing Information on Traffic Congestion," IEEE 13th Intelligent Transportation System Telecommunications (ITST) 2013.

[14] R. S. Schwartz, A. E. Ohazulikey, C. Sommerz, "Fair and Adaptive Data Dissemination," 2012 IEEE Vehicular Networking Conference (VNC), 2012.

[15] Microsoft corp, "Quadkey: Bing Maps Tile System," [Online]. Available: http://msdn.microsoft.com/en-us/library/bb259689.aspx

[16] A. Keranen, J. Ott, and T. Karkkainen, "The ONE simulator for DTN protocol evaluation," Simutools 2009 Proceedings of the 2nd International Conference on Simulation Tools and Techniques, 2009.

[17] The ITS Info-communications Forum, "ITS FORUM RC-006 version 1.0," 2009.