MESSAGE DISSEMINATION BASED ON PRIORITY/INTEREST IN VEHICULAR NETWORKS

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ABSTRACT

Vehicle-to-Vehicle (V2V) communication attracts attention as an important wireless communication technology for realizing Intelligent Transport Systems (ITS). This technology supports safe driving for car drivers and distribute contents for comfortable driving. On the other hand, severe restrictions are imposed on time and range in such communication between mobile nodes in general. Based on these characteristics, we regard V2V communication as an assumed example of Delay/Disruption/Disconnection Tolerant Networks (DTNs), which is famous as an architecture using store-carry-forward (SCF). In this paper, we focus on the fact that messages diffused over such networks have levels of priority and interest depending on their contents, and they differ for each message. In our method, we use such message contexts and control the speed of information propagation throughout the network. As a result, we use lesser amounts of network resources efficiently and provide information according to user's requirements even in restricted environment.

KEYWORDS

Vehicle-to-Vehicle Communication, Delay Tolerant Networks, Context Awareness

1. INTRODUCTION

Vehicle-to-Vehicle (V2V) communication [ITS America; Ertico ITS Europe; ITS Japan] is indispensable for Intelligent Transport Systems (ITS) which will support next generation driving support. In this system, vehicles traveling at high speeds exchange directly with each other. And further, exchanging with unspecified number of vehicles, it is possible to share information in V2V network. Vehicles can recognize surrounding traffic conditions from sensors mounted on themselves or Roadside Units (RSUs). Concurrently, V2V communication is used to diffuse traffic information observed by each vehicle to surrounding vehicles that do not have that information. The advantages of V2V are as follows: expansion of service available range, real-time information acquisition, reduced system operation cost, improve service fault tolerance.

However, communication between vehicles is not always stable. This is caused by V2V communication and network characteristics: the high vehicle movement, communication range restriction, imbalance in vehicle density, highly dynamic topology. Delay/Disruption/Disconnection Tolerant Networks (DTNs) [Benamar, 2014] is an architecture that realizes highly reliable data transfer in harsh environment. DTNs originates from interplanetary Internet, but now it is expected to be applied to various environments (vehicular networks, military networks, disaster networks, and so on) on the ground. In the architecture of DTNs, when a sender cannot communicate directly with a receiver, store messages in its own storage and waits until communication becomes possible. Furthermore, a multi-hop relay is used for communication with a spatially distant receiver.

In a DTNs where nodes move randomly like the V2V network, there is still a problem with message delivery using a simple multi-hop relay. Perhaps there is a serious delay in receiving the message, or the message cannot be delivered. As an approach to solve this problem, a scheme in which each node multicasts a copy message has been proposed. Additionally, the node that received the copy message becomes a relay node and multicasts the message again. The sender expects that the message will be delivered to the receiver by repeating this cycle. However, this approach is not perfect yet, it is necessary to consider the number of relay nodes that send copies of messages. For example, if nodes generate many copies of messages, ideal message delivery (high probability and no delay) may be possible, but wasting lots of network resources.

In our research, we aim to solve such problems, namely, to deliver messages with low latency and high probability while efficiently using network resources. We assume V2V network as the most typical example of DTNs. We note that messages diffused there have priority of sender and interest of receiver according to their content. These are messages contexts we consider and we propose a method of dynamically controlling the diffusion speed of each message using probability based on this. The structure of this paper is as follows: Section 2 introduces some existing dissemination techniques. Section 3 shows our proposal. Section 4 shows the results of simulation and related considerations. Finally, Section 5 presents conclusions and future tasks.

2. RELATED WORKS

In DTNs, a lot of methods have already been proposed for transferring copies of messages to multiple nodes. Epidemic Routing [Vahdat, 2000] is the simplest and widely known routing technology. In this approach, each node stores all copies of the received message in its own storage and copies all messages to an encountered node. As a result, senders can spread messages to many nodes like infections, but diffusing messages bluntly increases the possibility of wasting network resources. So, there are various methods to adaptively propagate messages according to the contexts such as the content of the message and surrounding situations.

[Taguchi, 2014] proposed a method using parameters to change the degree of diffusion according to the message contexts. This research focuses on the V2V network, and the authors assumed that any message has parameters *Priority* and *Urgency*. *Priority* is the degree of profit to be brought to the vehicle getting a message. *Urgency* is the degree to which that profit decreases with the passage of time since the message was created. The authors realized that the diffusion range and spreading speed of messages can be controlled based on such message contexts.

In [Abdou, 2015], in addition to the priority according to the content of the message, the authors proposed a method considering the network density as well. In this research, appropriate parameters such as transfer probability, number of repetitions, TTL, transfer interval corresponding to the context are set by a preceding experiment. Each node can autonomously determine a broadcast strategy using this parameter. Author's experiments confirmed the scalability of the diffusion of messages classified into several priority classes in networks with different node densities.

[Yan, 2013] proposed a method to successfully deliver a message to vehicles that are interested in the message in the network of the vehicle. First, each vehicle periodically exchanges a beacon message expressing own interests with neighboring vehicles. Next, the source vehicle which emits a message estimates the position of the vehicle that is interested in the message. Finally, the message is routed to the area where the interested vehicle exists with high probability, and broadcast there. This method is an attempt to deliver a message to as few vehicles as possible using position estimation of the interested vehicle and reduces wasteful overhead than repeating the broadcast.

[Paridel, 2014] introduced a context-based grouping mechanism in addition to interest-based message delivery of each vehicle. This mechanism is based on the premise that neighboring vehicles have a similar interest in the V2V network, vehicles are grouped according to position and direction of travel, and vehicles with special roles such as head and tail are selected. These special vehicles have knowledge of the interests of the vehicles in the group and can decide whether to diffuse into the group when receiving the message. In this way, messages in which the group does not have interest do not arrive therein, and it is possible to improve the efficiency of communication.

In the former two methods, the source node that found the message or the relay node autonomously determines the broadcast strategy. On the other hand, in the latter two methods, the recipient notifies the own interests in advance, and the message is delivered based on it. In other words, there are both sender-driven and recipient-driven types of context-based research.

3. PROPOSED METHOD

We target information sharing on V2V network which consists only of terminals without infrastructure and is an application example of DTNs. In this situation, there is no need to consider end-to-end communication with a specific destination, and messages are delivered for public interest to an unspecified majority. We control the spreading speed for each message from the viewpoint of sender and recipient using message contexts (*Priority* and *Interest*) determined from the its contents and aim to efficiently utilize network resources.

3.1 Context Representation

According to investigation of related work (mentioned in Section 2), there are some methods for context-aware information distribution based on the viewpoint of the sender and recipient, and we thought that it is necessary to consider both viewpoints. We named the former viewpoint as *Priority* and the latter viewpoint as *Interest*.

3.1.1 Priority

This parameter is determined based on the degree of value that the message gives to the vehicle that received it. For example, a value is set to high for information concerning the driver's life and access information of the emergency vehicle. In the case of congestion information or accident information, a value considering its seriousness is set. Based on *Priority* for each message, the parameter *Communication-Rate* used for controlling the diffusion speed is set.

3.1.2 Interest

This parameter is determined based on the degree of a driver's necessity. For example, the driver wants information about the surroundings of the destination and route, but it does not need the information on the roads that passed already. Also, the information requested by the driver differs according to road attributes such as highway, urban area, countryside etc. Therefore, *Priority* is set for each message, *Interest* is set for each driver (vehicle).

3.1.3 Metadata

This is the data given to each message, briefly representing the contents of the message itself. This data is set by the vehicle application, for example, information such as congestion, traffic accident, sightseeing, restaurants, etc. is classified in advance and an identifier unique to each classification is given. Since *Metadata* is much smaller than the message itself, it is possible to prevent wasting extra network resources by exchanging this data before forwarding the message.

3.2 Communication Techniques

In our proposed method, communication using the message contexts (*Priority* and *Interest*) defined in the previous section is performed as follows:

1. The source vehicle gets the message context (*Priority*).
2. Assign parameter used for spreading according to the message contexts (*Priority* and *Interest*).
3. Send message depending on the parameter.

The item 1 above means setting the *Priority* of the message when the vehicle acquires message from sensor mounted on itself or RSUs. Originally, this needs to be automatically decided from the content of the message, but this time we assume that there is a system to judge it. Then, based on this context, parameter to be used for message diffusion is set. In our method, we change the context (*Priority*) for determining this parameter dynamically by the surrounding recipient *Interest*. That is, even for the same message, the parameter used for spreading can be set different values according to the surrounding environment.

In the V2V network, the vehicle moves and communication occurs when another vehicle is encountered. In this method, all communications between these two vehicles follow the phase shown in Figure 1. This communication method extends the way of Epidemic Routing, and its details are as follows:

3.2.1 Send Summary-Vector Phase

At this phase, the sender first transmits the Summary-Vector to the recipient. The Summary-Vector is a list of messages possessed by the sender, and includes a message ID and its *Metadata* that can uniquely identify the message. In this way, it is possible to prevent the recipient's already possessing message from being transferred again.

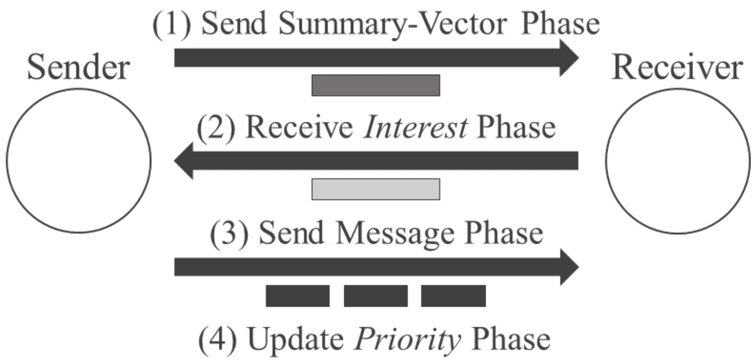

Figure 1. Communication of the Proposed Method

In addition, our method probabilistically determines messages included in the Summary-Vector for each recipient (Figure 2). In other words, the Summary-Vector is a list of possessed messages of the sender, but not all messages. We define this probability as the *Communication-Rate* and use it to control the diffusion speed per message. The *Communication-Rate* is determined based on the context (*Priority*) of the message. Specifically, messages with high *Priority* are included in the Summary-Vector with high probability, while messages with low *Priority* are included less frequently. As a result, the waste of network resources is reduced because the number of messages spread with one communication is reduced rather than copying all messages. Also, as encounters between vehicles occur randomly, even messages that could not be stochastically received may be received later by another communication. In this way, messages with low *Priority* slowly diffused, that is, the diffusion speed for each message is controlled.

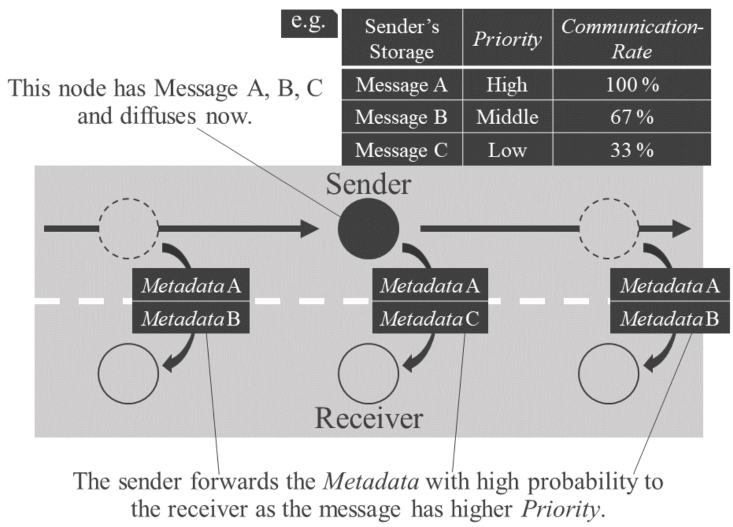

Figure 2. Example of Send Summary-Vector Phase

Regarding how to determine the *Communication-Rate*, the basic policy is to give a higher *Communication-Rate* for messages with higher *Priority*, but we need to think about how to allocate them appropriately. The easiest way is to set the maximum *Communication-Rate*, define *Priority* to be in the range 0 to 1, and then multiply them. That is, it can be expressed by the following expression, we use this:

Communication-Rate = Maximum *Communication-Rate* × *Priority*

3.2.2 Receive *Interest* Phase

At this phase, the recipient returns *Interest* to the message in the received Summary-Vector to the sender. The sender stores *Interest* collected from the recipient in its own storage for each message.

3.2.3 Send Message Phase

At this phase, the sender forwards the message itself to the recipient. Taking two phases before forwarding the message body, the sender can check whether the recipient possesses the message it wants to send, so it's possible to reduce the number of messages to be copied rather than scattering messages in a blatant way.

3.2.4 Update *Priority* Phase

This step occurs when the sender collects a specific number of recipients' *Interest* for any message. As mentioned in Section 3.2.1, our method selects the message to be transferred stochastically when communicating between vehicles. This probability is determined by the message context (*Priority*), but it is conceivable that this *Priority* changes due to factors such as passage of time, area, vehicle type to be received, etc. Therefore, we propose a method to periodically update *Priority* using *Interest* to each message of surrounding vehicles (Figure 3).

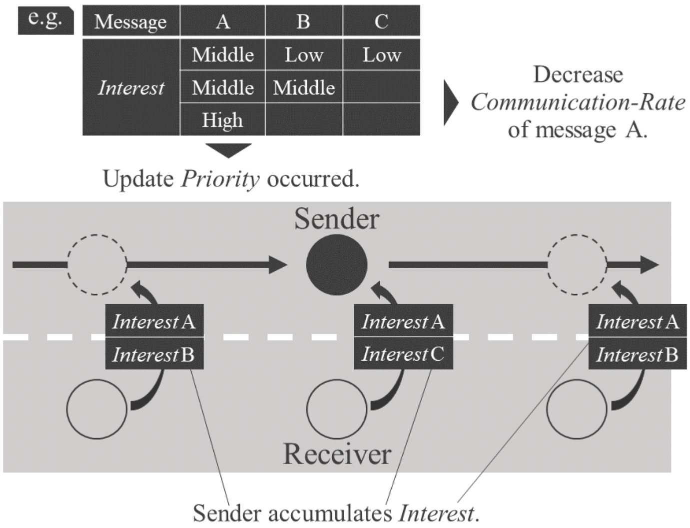

Figure 3. Example of Storing *Interest* and Updating *Priority*

Updating of *Priority* is performed when a certain number of *Interests* are accumulated in a specific message, and the next *Priority* is calculated using the following expression:

$$P_{n+1}(s) = \alpha * P_n(s) + \beta * \overline{I(r)} \quad (\alpha + \beta = 1)$$

$P_n(s)$ represents the *Priority* before updating, $\overline{I(r)}$ represents the average value of the degree of *Interest* collected from surrounding vehicles. α and β are controllable weights as to how much the *Interest* is reflected in the updated *Priority*. Naturally, since the *Communication-Rate* is set based on *Priority*, it also dynamically changes. Using this method, as shown in Figure 4, it is possible to prevent unnecessary spreading of messages with low *Interest* of the surrounding vehicles, and waste of network resources can be reduced.

4. SIMULATION

In order to observe the state of message spreading using the proposed method and evaluate it, we created a simulator on one computer and simulated it. This simulator is a self-made using the Java language, and is a DTNs simulator that communication occurs when a node moves and encounters another node. We assume that the node is a vehicle and the node performs message diffusion for information sharing based on the context of various traffic message.

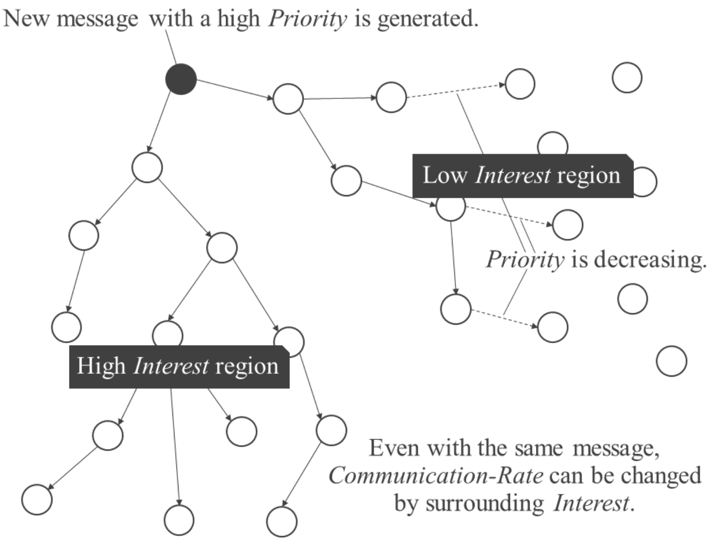

Figure 4. Usage of the Proposed Method

4.1 Simulator Design

The unit of time on our simulator is defined as a cycle, and the following processing is performed in one cycle:

1. Each node moves within the simulation field.
2. Each node searches other nodes in communication range.
3. Each node communicates with the discovered node.

All nodes move by 1 in one cycle and this is defined as a unit of distance on the simulator. The number of nodes is 50, the communicable distance of all nodes is set to 10, and the field is set to 1000 × 1000. Also, in order to observe how to spread messages to DTNs, we designed the behavior of the nodes on the simulator as follows:

- Each node moves freely and randomly: all nodes proceeding straight ahead and changing direction at random because of simplicity of simulator design.
- Each node moves at a constant speed: the diffusion speed does not change according to the speed of the node having the specific message.
- Each node moves only within field: in order to observe the speed at which messages spread to all nodes, the node does not go outside the field and the number of nodes does not increase or decrease.

In addition, the *Communication-Rate*, which is the propagation parameter of the proposed method, is determined by the message contexts, and the contexts (*Priority* and *Interest*) is assumed to be statically set in the message at the start of the simulation.

4.2 Results and Considerations

First, we observed the diffusion of messages given a fixed *Communication-Rate*. Figure 5 shows the spreading rate and the number of transfers of 10 kinds of messages giving different *Communication-Rates*. The spreading rate is the probability of expressing how much messages have spread to the nodes in the field, and when all the nodes receive the message, it becomes 100%. It is also possible to observe the diffusion speed of messages on the network by continuously measuring the increase in spreading rate. In the V2V network, there are messages that need to be spread quickly such as information related to human life and messages not having urgency such as tourist information and advertisement, so it is important to observe the diffusion rate. From Figure 5 (left), the higher the message *Communication-Rate*, the shorter the time spent on spreading. As the *Communication-Rate* increases, the probability that messages are transferred by one exchange between nodes increases, so this is natural. Also, although there is a difference in diffusion completion time, all messages complete diffusion at some point. This is because the proposed method uses stochastic method, unlike a method of sending out from a message with a high priority, so there is no problem that a message with low priority is not sent out forever (starving problem). On the other hand, Figure 5 (right) shows the total number of messages transferred by all nodes in each cycle. Due to limited space, we chose 5 kinds out of 10 kinds of messages given different *Communication-Rates*. As the *Communication-Rate* increases, the amounts of messages transferred to one cycle in the early time explosively increases. In this case, forwarding many messages in a brief time leads to waste of network resources and communication conflict. Controlling the spreading speed and efficient use of network resources, which is the object of this research, means to avoid spreading enormous amounts of messages at the same time utilizing the difference in diffusion speed according to the message contexts, for example, slowly spread messages with low *Priority*.

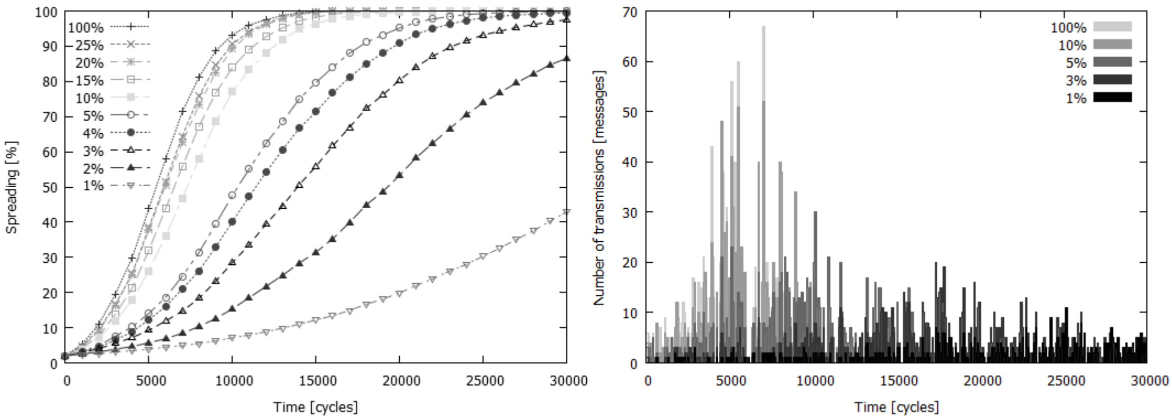

Figure 5. Scattering of Various Messages - Spreading Rate (Left) and Number of Transmissions (Right)

Next, we simulated how each node collect *Interest* and use it to update *Priority* of message. A more realistic simulation using different *Priority* messages and vehicles with different *Interest* is required, but this simulator sets these contexts statically, so the experimental results depend on that setting. Therefore, in this experiment, we observe how the message given a certain *Priority* changes the diffusion rate by collecting several constant *Interests*. Figure 6 shows the transition of the spreading rate which is the result of the experiment. Figure 6 (left) represents the spreading rate change that occurs when a message given the high *Priority* collects 10 kinds of constant *Interest* less than that, and Figure 6 (right) represents the opposite situation. The slope of each graph represents the diffusion speed, and it can be seen that a change according to the value of the surrounding *Interest* occurs as time passes. As the features of the two graphs, the beginning of the change in Figure 6 (left) is faster and the change in Figure 6 (right) is larger. A message with a high initial *Communication-Rate* will be exchanged between many nodes sooner so that the node can collect a lot of *Interest* and spread a lot of that message early.

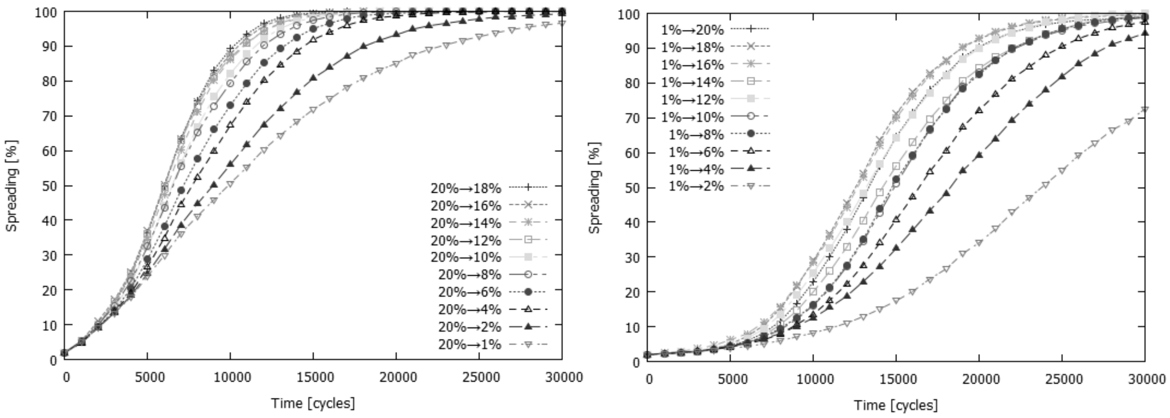

Figure 6. Transition of Spreading Rate - High *Priority* and Low *Interest* (Left), Low *Priority* and High *Interest* (Right)

These experiments showed that the *Communication-Rate* is related to the diffusion rate, that the diffusion rate can be changed using *Priority* and *Interest*. Thus, for example, it is possible to spread important messages quickly and to slowly spread messages that the source node or surrounding nodes judged not important. As a result, the proposed method realizes adaptive message spreading that efficiently utilizes network resources.

5. CONCLUSION

In this paper, we assumed message spreading for information sharing on DTNs assuming V2V networks. In such networks, there were issues such as exhaustion of network resources and limitation of communication time and range between vehicles. Therefore, we focused on the message contexts, and aimed to use network resources efficiently changing the diffusion speed of messages according to the importance of the events represented by the message and the driver's request. In order to realize the purpose, we proposed a method of dynamically changing the transfer probability for each message using contexts (*Priority* and *Interest*). The experimental results showed that we can control the diffusion speed of the message from the viewpoint of both the sender and the receiver. If our method is applied to a real V2V network or a realistic simulator, it will be expected to spread the useful messages preferentially while efficiently using the network resources.

The future tasks of this research are as follows:

- Creation of a system for automatically determining contexts from message contents: As mentioned in the section 3.2, in this paper, the message context (*Priority*) is given in advance. In practical terms, however, it is necessary to automatically determine the content of the message and assign an appropriate *Priority*. In addition, the system that performs such processing needs to have versatility that can be used in various networks for information sharing.
- More realistic simulation: In our simulator, the node moved randomly within the field. In the future, it is necessary to simulate the application of a movement model that imitates the behavior of the vehicle, and to simulate the message diffusion on the road considering intersections, traffic lights, and the like.
- Utilization of surrounding node density: In our method, *Communication-Rate* is used as an approach to efficiently utilize network resources. We treated this probability as static in this paper, but in an actual network we should change according to node density. In a network with low density, there is no problem even if a lot of messages are dispersed, while in high density network it is necessary to further suppress message spreading.

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