An Enhanced Message Dissemination Protocol Using Multichannel with Clustering

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Abstract

As autonomous vehicles are going to be deployed on public streets in near future, vehicular communications, which is one of the core technologies, will work to connect vehicles and exchange traffic information. The WAVE standards have been established to provide safety and transportation services through vehicular communications. In this paper, we analysis the communications method in the WAVE standard and propose a method for fast and stable message transmission. The proposed scheme improves the performance by using duplicate messages and suspension of beacon messages. The simulation results show that the proposed method reduces collisions and provides fast communications.

Keywords: Cluster, Protocol, VANET, WAVE

I. INTRODUCTION

Recently, domestic and foreign automobile and IT companies are making efforts to develop autonomous vehicles. As a result, a lot of interest in vehicular communications (V2X) which one of the key technologies of autonomous driving is growing. It not only sends and receives information for safety, but also is used for services such as traffic convenience and infotainment. Although it is a technology that is used in automobiles, it is combined with IT technology and is also developed by information technology companies. A standard called WAVE (Wireless Ad hoc Vehicular Environments) has been established to utilize the vehicle communication and it describes one-hop communication. For safety and transportation services, messages must be transmitted in multi-hop. However, if vehicles transmit messages in high vehicle density, a network traffic increases rapidly. This causes a broadcast storm problem. In this regard, several studies have been conducted on an efficient message transmission in VANET.

Villas et al. proposed the DRIVE (Data dissemination pRotocol In VEhicular networks) protocol [1]. This protocol defines a "sweet spot" within an AOI (Area of Interest). Only the vehicles in the sweet spot position are retransmitted and different transmission delay time is specified according to the area to reduce message collision. However, the overall number of message transmissions is kept high. Chaqfeh et al. proposed the G-SAB (Grid Speed Adaptive Broadcast) protocol [2]. This protocol calculates the time slot and delay time for transmission using the speed and distance of the vehicle. And it sets the delay time differently according to the lane to reduce the message collision. Wisitpongphan et al. proposed the weighted *p*-Persistence technique, which is a dynamic gossip by utilizing the location information [3, 4]. The gossip retransmits to neighbor nodes with fixed probability *p* when a node receives a first message. It reduces message retransmissions. But, the weighted *p*-Persistence scheme sets a probability dynamically based on the location of nodes. Since these protocols transmit messages only on a single channel, researches have been conducted to improve performance using multi-channel.

Felice et al. proposed a method to transmit a message over the SCH interval [5]. This method switches SCH frequency to transmit messages to all vehicles to avoid collisions. However, this method has an overhead since each vehicle should manage connections of its 1-hop and 2-hop neighbors. Wu et al. also proposed a method to transmit a message on the SCH interval as well as the CCH interval to reduce a transmission delay [6]. But this method cannot deliver a message if neighbors are not in the same SCH interval. This case does not reduce a delay time efficiently.

In this paper, we propose a multi-channel message transmission method. The proposed scheme is based on the cluster structure in the previous study [7]. In addition, it uses redundant messages and beacon suspensions to reduce message latency and improve reception.

The rest of the paper is organized as follows. At section 3, a message transmission of the WAVE system is presented. Section 4 proposes an enhanced multi-hop message dissemination algorithm. Section 5 describes some simulation results of the proposed method. Section 6 concludes the paper and discusses some directions of the future research.

II. ANALYSIS OF WAVE COMMUNICATION

WAVE is a vehicle communication standard composed of 802.11p and 1609 series. It uses a multi-channel which uses a CCH (Control channel) and SCH (Service channel) alternately. An emergency messages such as accidents and general messages such as traffic information and convenience services are transmitted through the CCH and SCH, respectively [8-10]. Fig. 1 shows channel switching of the WAVE communication.

As shown in Fig. 1, WAVE communicates by exchanging two time-slots with a period of 100*ms*. Time slot 0 can be assigned to CCH and time slot 1 to SCH, and CCHI (CCH interval) and SCHI (SCH interval) the time of each slot is 50*ms*. A 4*ms*

GI (Guard Interval) is included to stabilize the frequency change when switching the channel. For wireless channel access, it uses a random back-off method and EDCA to provide QoS (Quality of Service) [8, 11]. Therefore, the message is transmitted after the back-off time ($T_{Backoff}$) according to the EDCA parameter value.
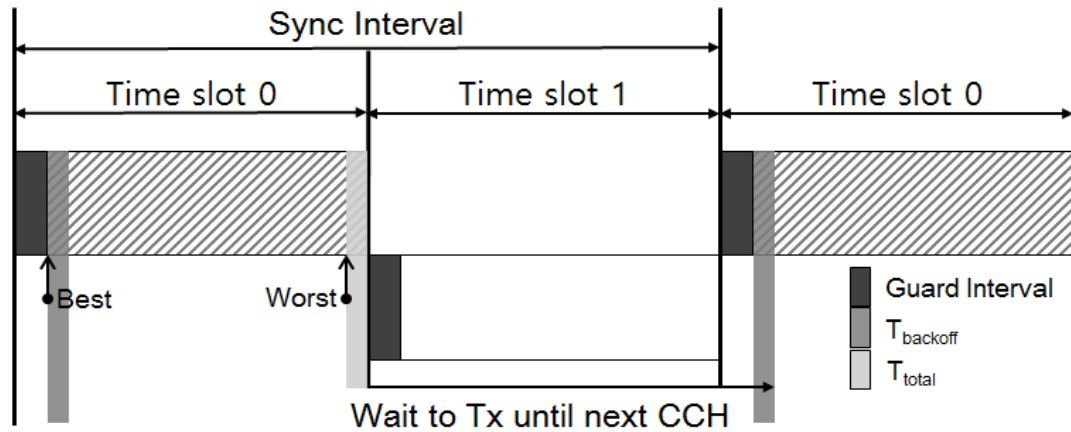
Figure 1. WAVE channel switching

A message is broadcasted every 100*ms* in WAVE communication. When the alternate method is used, the urgent message is delivered only through the common channel CCH. Since forwarding is performed only on the CCH, if the message is to be forwarded at the time of switching to the SCH, it is necessary to wait until the next CCHI according to the policy. As shown in Fig. 1, the best way to transmit a message is to start transmission immediately after the GI of the CCH. However, in the worst case, it is time to transmit at the end of the CCHI interval.

The following equation (1) shows the time taken for a message transmission.

$$T_{Total} = T_{Backoff} + \frac{PL}{DR} + T_{Delay} \tag{1}$$

PL is a packet length, and DR is a data rate. T_{Delay} is the delay time according to multi-hop policy. When a message is delivered immediately upon receipt, it occurs a collision with messages from nearby vehicles. Therefore, different transmission delay time is added to each vehicle according to the multi-hop policy according to the distance, probability, and etc. When a message is transmitted between the end of CCHI and, the channel switching starts during message transmission. It should wait until the next CCHI. In other words, the message transmission becomes possible after ($T_{Backoff} + T_{Delay}$) time has elapsed in the next CCHI.

Therefore, the multi-channel scheme using a SCH can be an alternative for the faster transmission of urgent messages [5, 6]. It is necessary to know the SCH of

neighboring vehicles to use multi-channel. In this paper, we propose a method to increase message reception rate and reduce delay time by applying cluster structure to VANET.

III. PROPOSED PROTOCOL

In this section, we propose an emergency message transmission method in VANET environment based on WAVE standard. The proposed method improves the transmission method in the previous study [7] and the key concept is to utilize a WAVE multi-channel. The warning message is transmitted not only in the CCH interval but also in the SCH interval. This reduces the message transmission delay in the alternative mode.

A SCH is a channel that is selectively used according to a service, not a public purpose channel. Neighboring vehicles must have the same SCH to deliver the urgent message through the SCH interval. If the neighboring vehicles use different SCHs, it is like delivering urgent messages using only the CCH.

We use the cluster method to construct a group of vehicles traveling in the same direction on the same road to synchronize the SCH for multi-channel transmission. When duplicate messages and urgent messages are transmitted, beacon transmissions are suspended temporarily. This method reduces message collisions and increases reception ratio. To utilize the proposed method, the basic configuration of the cluster is described.

III.I CLUSTER CONFIGURATION

In the case of an intersection in a city center, hundreds of vehicles must simultaneously construct a network when signals are waiting in a VANET environment. In this case, one vehicle cannot communicate with all the vehicles. Therefore, the number of vehicles in a cluster should be limited and managed [7].

When constructing a cluster, we compare the speed, distance, and signal strength with neighboring vehicles and select a vehicle with the smallest movement as the head [12-14]. This paper also considers speed when calculating vehicle is in motion. Although the vehicle changes in a short period of time, the movement is limited by the shape of the road in the VANET. Frequent cluster merge and split of vehicles in opposite lanes can be prevented and the cluster can be maintained stably.

When constructing a cluster, a common method is to select a head by comparing movements. However, all of them start with a head when configuring a cluster in the proposed method. At initial stage of clustering, all vehicles start with a cluster of zero members. Therefore, the overhead for initial configuration can be reduced by omitting the head selection process. Since all vehicles start with clusters which do not have any members, vehicles start the merge process if there is a cluster head in the vicinity. First, we compare the moving direction, the number of members, and the speed of the cluster. If the condition is satisfied, the merge proceeds. After merging, the head and

cluster information are updated. Fig. 2 shows the cluster merging process.

CH_i : header of cluster i

CH_j : header of cluster j

1: **if** (($CH\_NUM_i + CH\_NUM_j > MAX\_NUM$)

2: or ($|CH\_DIR_i - CH\_DIR_j| < THR\_DIR$)) **then**

3: return;

4: **end**

5: **if** ($|CH\_VEL_i - CH\_VEL_j| < THR\_VEL$) **then**

6: **if** ($CH\_NUM_i > CH\_NUM_j$) **then**

7: $CH_{New} = CH_i$;

8: **else**

9: $CH_{New} = CH_j$;

10: **end**

11: CMs update CH_{Old} to CH_{New}

12: Update cluster velocity

13: **end**

Figure 2. Cluster Merge

1: **if** (($CH\_DIR + CM\_DIR > THR\_DIR$)

2: or ($|CH\_VEL - CH\_VEL| < THR\_VEL$)) **then**

3: **if** (CH) **then**

4: $CH\_NUM = CH\_NUM - 1$;

5: Update cluster velocity

6: **end**

7: **if** (CM) **then**

8: Change state from CM to CH

9: $CH\_NUM = 0$;

10: **end**

11: **end**

Figure 3. Cluster Split

In Fig. 2, *CH_NUM* is the number of vehicles in a cluster. *MAX_NUM* is the maximum number of vehicles in a cluster. Also, *CH_DIR*, *CH_VEL* and *THR_VEL*, are represented as the cluster's direction, cluster's speed, the maximum speed difference for the merged cluster, respectively. CH_{New} is a new cluster after merged and CH_{Old} is an old cluster before merged.

The split process starts when the movement of the vehicle changes in the proposed cluster configuration. That is when the speed of a vehicle in a cluster is different from the speed of its cluster or the moving direction is changed. A member that is different from the movement of the cluster converts its state into a new cluster head. Existing cluster head reduces the number of members and updates the cluster speed. Fig. 3 shows the cluster partitioning process. *CM_DIR* and *CM_VEL* are the moving direction and speed of the split vehicle, respectively

III.II PROPOSED MESSAGE DISSEMINATION ALGORITHM

The proposed message transmission method utilizes a multi-channel of WAVE communication in case of emergency message transmission. The forwarding strategy basically uses the distance-based transmission and reduces the delay time by transmitting the message through the SCH interval as well as the CCH interval. We use the clusters described above to use a multi-channel. Since the members in the cluster use the same SCH, the message delay time can be reduced as much as they are transmitted through the SCH.

The WAVE communication transmits and receives various messages such as urgent message and beacon message through the common channel a CCH. This method increases the probability of message collision such as hidden terminal problem. Therefore, the beacon message transmission channel of the CM is changed from the CCH to the SCH to increase the reception ratio of the urgent message. The beacon transmissions stop temporarily for T_{wait} and then transmit again to increase the reception ratio of the emergency message. This can temporarily reduce network traffic and reduce message collisions with nearby vehicles. By reducing the probability of collision, the message reception rate can be increased and the delay time can be reduced. The beacon contains the location information of the vehicle, and the cluster consists of vehicles with similar movements. Therefore, even if the beacon transmission is temporarily interrupted, the position change of the vehicles is within a predictable range. The Fig. 4 shows the role of the cluster head.

The basic role of CH is to manage members and communicate with other clusters. The collision probability increases, when a beacon message is transmitted to each other at an arbitrary time. Therefore, CH specifies the slot of the members and CM transmits the beacon at the allocated slot time. At this time, since the members transmit the beacons through the SCH at their respective slot times, the probability of message collision is reduced. The CH also checks for redundancy and retransmits if an emergency message is received. Then, it checks the ACK signal to confirm if the CMs have received the message. After the CH checks the ACK signal from CMs, it

retransmits to CMs which have not been received, to increase the reception ratio. The emergency message is reused as an ACK signal. And it can be delivered to CMs that have not been received in the vicinity. Therefore, it is possible to reduce the time taken from the CH after a certain period of time.

1:	Slot allocation of CMs
2:	Tx beacon to CMs and other CHs on CCH
3:	Rx beacon from CMs and other CHs
4:	**if** (Rx new emergency message) **then**
5:	forward to CMs and other CHs
6:	Save message information
7:	Suspend beacon Tx for T_{wait}
8:	**end**
9:	Rx ACK from CMs
10:	**if** (no ACK) **then**
11:	Tx emergency message again
12:	**end**

Figure 4. Cluster head process

1:	Tx beacon on CCH or SCH
2:	**if** (Rx new emergency message) **then**
3:	Suspend beacon Tx for T_{wait}
4:	Tx duplicate message as ACK
5:	**if** (SCH interval and edge member) **then**
6:	**if** (switching time is enough) **then**
7:	Switch to neighbor cluster's SCH
8:	**end**
9:	**end**
10:	Forward the message
11:	Save message information
12:	**end**

Figure 5. Cluster member process

Fig. 5 shows the role of the CMs. CMs is divided into a general member and a boundary member. The boundary member transmits and receives beacons through the CCH interval and can communicate with members of other clusters using the SCH information contained in the beacon. That is when it can be switched to the SCH of the neighboring cluster to transmit the message. When there is a message to be forwarded in the SCH interval, it calculates the time of the remaining SCH interval. If there is an enough time to switch the channel and transmit a message, it forwards the message after channel change to the SCH of the neighbor cluster.

IV. SIMULATION AND RESULTS

The simulation has been performed using NS3. It is assumed that each vehicle has a communication module and a GPS device. The number of vehicles are allocated 200 per kilometer distance and the communication radius of a vehicle is 350m, the data rate is 6Mbps, and it is used an alternative mode for multi-channel operation. The beacon and emergency message are set to AC_BE and AC_VO, respectively. And the other parameters are set according to the standard of IEEE 802.11p. Table 1 shows the parameter settings used in the simulation.

Table 1. Simulation parameters

Parameters	Value
Packet generation rate	10 *Hz*
Data rate	6 *Mbps*
Propagation model	Nakagami
Packet size	100 *bytes*
Number of lanes	4
Communication range	350 *m*

The message delay time and message reception ratio were measured for packets sent and received by the application layer to compare the proposed scheme with the following four schemes.

1) SINGLE - All vehicles transmit beacons and emergency messages only on the CCH interval. If the channel is switched to SCH interval, messages cannot be transmitted and vehicles waits until the next CCH interval.

2) DRIVE - Messages are delivered only in the CCH interval like SINGLE scheme. When a message is transmitted, the message is transmitted earlier in the forward, backward, left, and right directions according to the driving direction of the vehicle [1].

3) RANDOM - To transmit the message using the multi-channel, the SCHs of the vehicles are randomly allocated and the messages are also transmitted through the SCH.

4) CLUSTER - Messages are transmitted using multi-channel through the SCH synchronization among cluster members [7].

IV. I END-TO-END DELAY

The messages are queued for back-off time before being transmitted in the WAVE communication. If a message collision occurs internally after waiting, the message with the highest priority is transmitted first. Even if it is a high-priority message, it must wait in a queue if any message is being transmitted. For this reason, the delay time increases. Therefore, the single-channel scheme should wait for $(50+T_{Backoff})$ms time if a message transmission does not end before channel switching. However, multi-channel method can be transmitted after $(4+T_{Backoff})$ms time even if the channel is switched. Since it is transmitted through the SCH, the message collision is reduced and the delay time due to the retransmission is also reduced. Therefore, as shown in Fig. 6, the difference in delay time between single channel and multi-channel transmission can be confirmed.
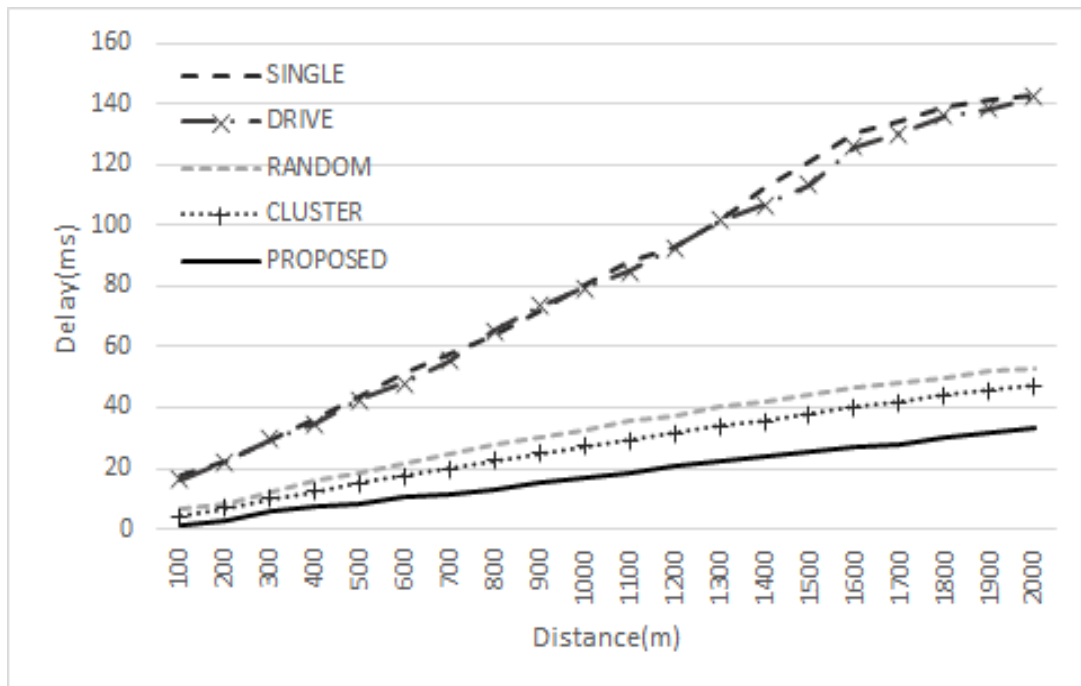
Figure 6. Packet Delay Time

At *2km*, the delay time of the multi-channel method was 24 ~ 37% of the single

channel method. The proposed scheme reduces the number of retransmissions by stopping the beacon transmission, which reduces the time by about 10ms compared to the CLUSTER method.

IV. II PACKET RECEPTION RATIO

Fig. 7 shows the message reception ratio according to the transmission methods. The reception ratio of all methods reduced slightly as the communication distance is increased. The reception ratio of single-channel scheme is lower than that of multi-channel scheme. Since the message is transmitted only through the CCH, the probability of collision between the beacon and the emergency message is increased. On the other hand, since the multi-channel scheme can be transmitted through the SCH, the probability of message collision is lower than that of the single-channel scheme. Therefore, it enables and maintains a reliable message delivery. Comparing with the reception ratio at 2 *km*, the multi-channel scheme is 6~20% higher than the single-channel. And the proposed method using duplicate message and beacon transmission suspension is 7% higher than the cluster method.
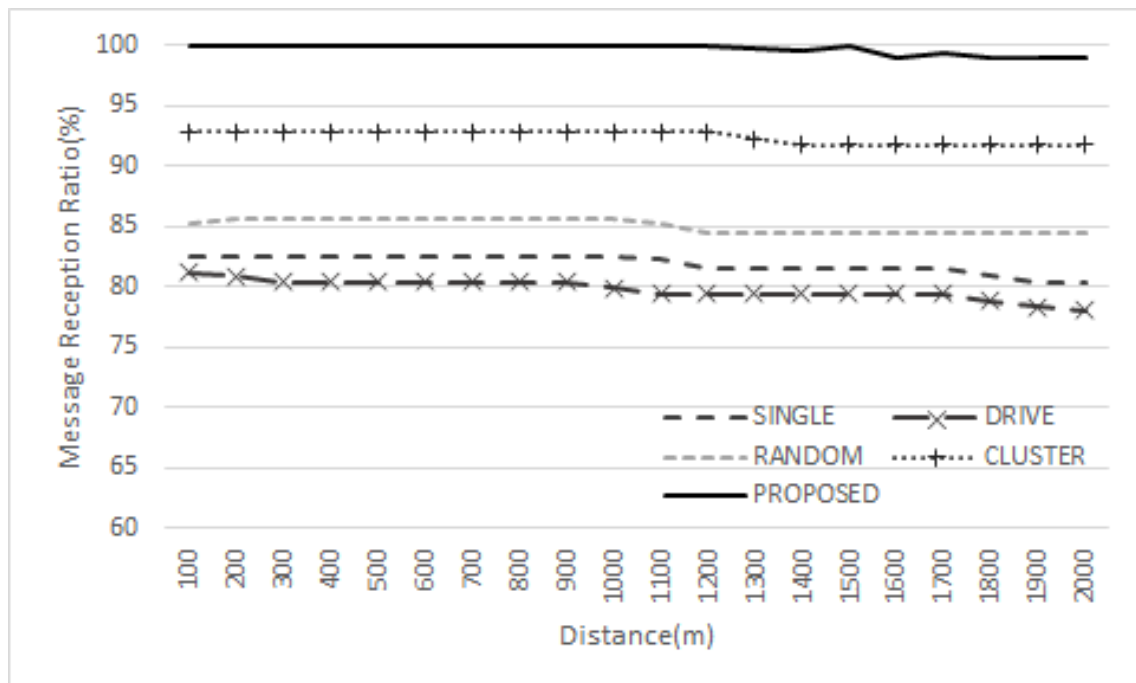

Figure 7. Message Reception Ratio

V. CONCLUSION

This paper proposes a message transmission method to improve communication efficiency using WAVE communication standards. By configuring clusters, its performance has been improved by using redundant messages and beacon

transmission interruption. Using the received urgent message as an ACK message, the vehicle which is not received in the vicinity can be received more quickly. Also, when the emergency message is sent or received, the beacon transmission is interrupted for a while to reduce the message collision. As a result, the delay is reduced by 10*ms* and the reception ratio is increased by 7% compared to the clustering method by Lee [7].

In the future, we will discuss an adaptive message transmission method according to vehicle density and an efficient message transmission through communication with the infrastructures.

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