A Study on the Selection of Candidate Leaders for flexible Platooning in Urban Road

Sumin Choi
Department of Software Convergence
Soongsil University
Seoul, Korea
suumn1538@soongsil.ac.kr

Jaehee Back
Department of Software Convergence
Soongsil University
Seoul, Korea
jh223@soongsil.ac.kr

Yongtae Shin
Department of Computer Science
Soongsil University
Seoul, Korea
shin@ssu.ac.kr

Abstract**—** Recently, technology development of self-driving cars has gradually expanded, and interest in Platooning has also increased, and system development has been taking part in the development of several automobile manufacturers. The existing method of Platooning falls short of the original goal of Platooning, which is to reduce the amount of road traffic and time due to delays in the process of reorganizing the cluster or joining another group. Thus, in this paper, the existing SAE J2735 Message Protocol has been improved to newly design the cluster-running algorithm, and the flexible cluster-running, which can be applied even in urban road, has been put forward.

Keywords—V2X(Vehicle to Everything); Platooning; Candidate Leader; Multicast; IoT(Internet of Things);

I. Introduction

There are many areas that need to be supplemented in order to expand platooning, which are currently limited only to highways, to urban roads with many intersections. In the existing platooning mode, if the cluster is disbanded, the leader vehicle can be re-elected to re-form the cluster or join another group. This process results in delays that fall short of the original cluster run goal of maximizing road throughput. Therefore, this paper added the candidate leader so as to increase efficiency in road throughput and time reduction in the disintegration of the cluster and to respond quickly to the problem situation. In addition, the leader vehicle prioritized the candidate leader vehicle so that it could flexibly separate and reshape clusters not only on highways but also in urban road with many intersections. To this end, the SAE J2735 Message Protocol was improved to redesign the platooning algorithm and proposed a plan for platooning, which can be applied to urban road.

II. Ease of Use

A. Platooning

Platooning is a technology that constructs and operates a road train with two or more vehicles connected as one, and a combination of self-driving technology and connected technologies is a driving method. During a cluster run, each vehicle is connected in a single set and moved in a train-like procession, keeping a close distance from each other. Vehicles located at the head of a platooning serve as leaders, followed by vehicles that follow along the path of the leader vehicle. In addition, the more vehicles you drive in cluster mode than in normal mode, the more effectively you can use the road. It can shorten transportation or arrival time of destination, and it is based on self-driving technology, so drivers can carry out other tasks such as phone calls, leisure life and so on. As a result, it will be possible to reduce energy, increase the convenience of the vehicle users, reduce traffic accidents, and help streamline road traffic logistics and transportation.

B. SAE J2735 Message Protocol Structure

WAVE (Wireless Access in Vehicle Environments) is the standard for a set of messages consisting of data elements and data frames used in communication-based applications. Fig. 1 is the structure of the existing BSM (Basic Safety Message) [1]. It is defined as the basis for WAVE communication, but it is also available for use by other radio communication technologies. The message distinguishes the range of provision that is transmitted between vehicles according to the user's needs.

On the V2V side, vehicle path and acceleration data are provided by vehicle access with vehicle intersection safety data. Includes data intersection identification, vehicle location and movement, expected lanes and movements at intersections, notifications of potential violations, or notification of detected hazard situations. In terms of vehicle safety data, it includes vehicle safety data such as vehicle position, vehicle movement (e.g. speed, heading, acceleration), vehicle control (e.g. brake, steering, throttle, exterior lighting), and basic vehicle dimensions (e.g., length, width). Examples include crash prevention, situation-specific warnings, emergency vehicle warnings, emergency response to vehicle emergencies, and a day-time request.

From the V2I (Vehicle to Infrastructure) perspective, the environmental probe data refer to the measured temperature, exterior lighting conditions, wiper conditions, light sensor status, brake status, and other system status and sensor information. Examples include vehicle data for highway management and design, vehicle data for determining road failure situations, and vehicle data for weather forecasting.

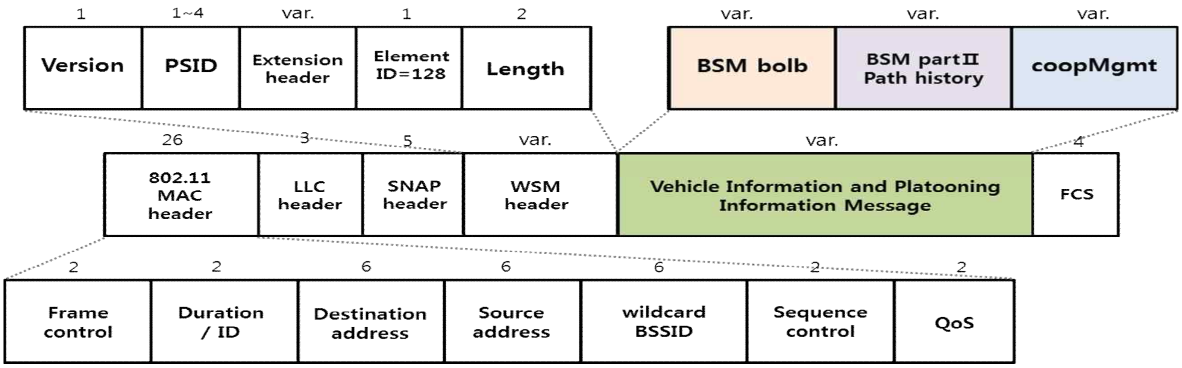

Fig. 1. Existing Message protocol structure

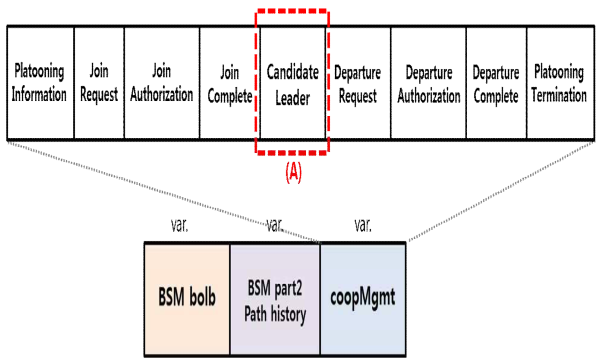

Fig. 2-a. Candidate Leader Status

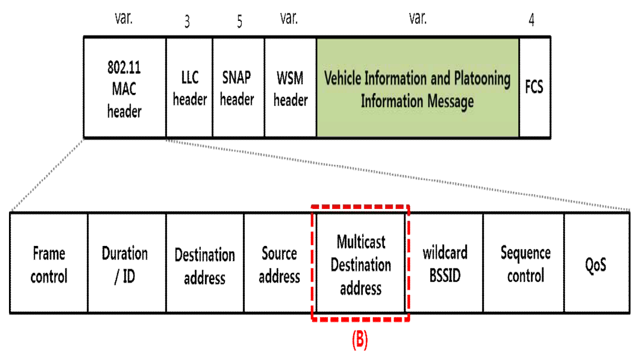

Fig. 2-b. Multicast address for sending candidate leader priority information to the vehicle

III. Suggestion Technique

To solve the problem of existing cluster runs, the candidate leader vehicle is added within the cluster and packet messages are transmitted multicasting based on this.

A. Platooning Candidate Leader Possible Vehicle Priorities.

- Set the status of whether candidate leaders in the cluster are possible by adding a data element called " Candidate Leader" in the existing message structure. This is sent in the message, with the information necessary for the leader vehicle to prioritize.
- When the driver tries to join the existing cluster, driver requests the cluster leader to join. When the leader approves the joining, the cluster joining is completed. The driver then sets the status as to whether the candidate leader. This status setting can be changed directly from the vehicle's center fascia to the screen, not only when joining the cluster but also when the driver wants to. This status information is stored in the data element (A) of Fig. 2-a in the form of 0 or 1, which means that 0 is not a candidate leader, and 1 is a candidate leader.
- Several of the trailing vehicles in a cluster may be candidates. In this case, the leader vehicle identifies the candidate leader data elements of messages sent to the trailing vehicle and priority the candidate leader vehicles based on the vehicle status information for those vehicles.
- If the priority of the candidate leader's vehicle is set, platooning will be possible even in urban road where there are many intersections. When the leader vehicle needs to be changed due to various variables, such as traffic signals, the leader is automatically re-elected through priority information to maintain the cluster.

B. Multicast Based on Candidate Leader Vehicle Address

Data elements are added as shown in Fig. 2-b to transmit priority information for candidate leader vehicles defined by leader vehicles. The process of joining or leaving the vehicle when driving in a cluster often occurs. As the priority information of the group candidate leader changes in real time, the number of packets sent to the vehicles also increases. Broadcasting a message to all vehicles whenever there is a change in priority results in a tremendous traffic load.

Thus, Fig. 2-b stores the addresses of the candidate-leaderable vehicles in the Data Element (B) so that they are multicast only to the candidate-leaderable vehicles, except for those vehicles that do not need to receive priority information.

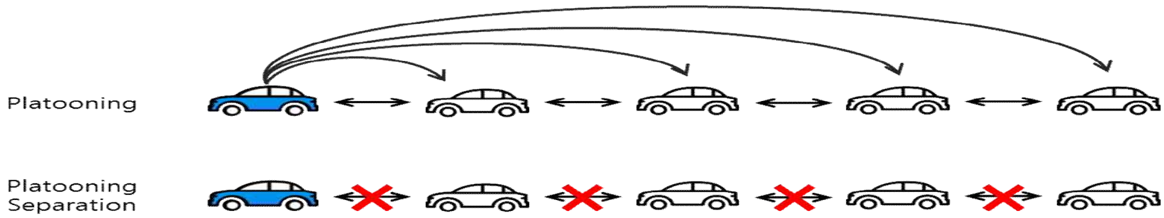

Fig. 3-a. Decommissioning process in an existing platooning

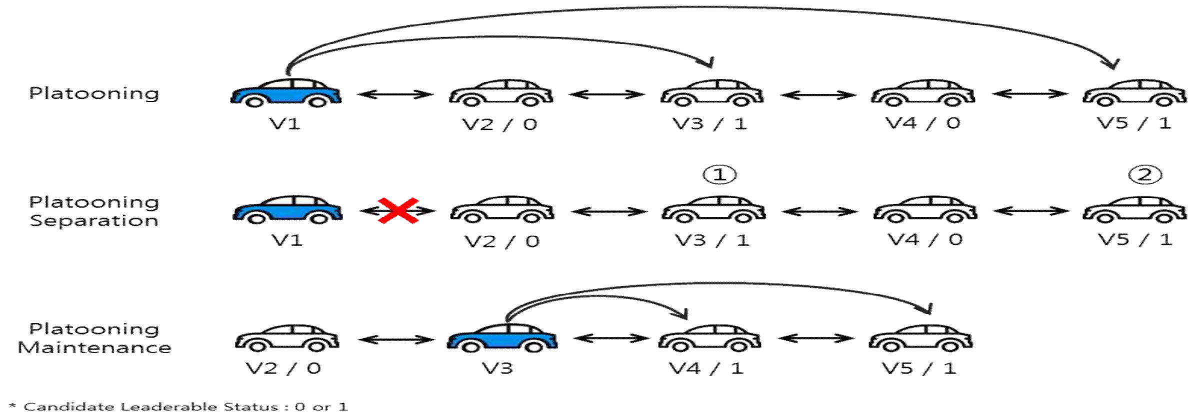

Fig. 3-b. The process of disbanding a group from the proposed method

C. *Proposed Platooning Algorithm*

- Fig. 3-a shows the process of disassembling a cluster due to various variables while driving in a conventional platooning fashion. If the leader vehicle changes from Cluster to Normal mode, all of the trailing vehicles in the cluster are also changed to Normal mode, which causes the cluster to be dismantled. Even if a vehicle wants to continue to maintain its cluster, it will be dismantled as soon as the leader vehicle leaves.
- To form a cluster again, one of the trailing vehicles must be set up as the cluster leader. Other trailing vehicles will also complete their registration after sending a request to the leader vehicle to join and obtaining approval from the leader vehicle. This process is repeated whenever a vehicle wants to join a cluster.
- Fig. 3-b shows the process of keeping a cluster by adding candidate leader vehicles. Initially, when the vehicle joins a cluster, the candidate leader status is set and sent to the leader vehicle in the form of 0 or 1. If there are a number of candidate leaderable vehicles in the cluster, the priority of the candidate leader is determined based on the status information of the vehicle that each vehicle sent to the leader vehicle.
- When a group is about to be disbanded during a cluster run, candidate-leader vehicles decide on a new leader vehicle based on the priority received from the leader vehicle. The new leader changes the leader vehicle ID of the cluster to its own vehicle ID. Send a message containing the changed leader vehicle ID to the rest of the candidate leaderable vehicles.
- If the priority of the candidate leader's vehicle is set, it will be possible to apply platooning even in urban road where there are many intersections. Even if the middle of the cluster is separated due to various variables, such as traffic signals, the leader is replaced without delay based on priority information.

IV. PERFORMANCE EVALUTION

A. *Traffic Load*

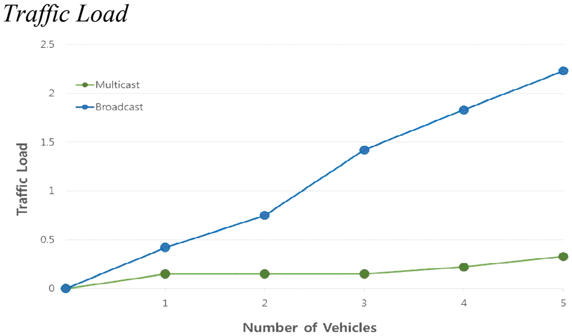

Fig. 4. Broadcast and Multicast traffic load comparison

In a conventional platooning method, packets are transmitted between vehicles in a broadcast manner. Each time a vehicle is in a cluster, the leader vehicle sends a packet of changed information to all trailing vehicles that follow. In this case, the larger the number of trailing vehicles, the greater the number of packets that one trailing vehicle receives from the leader vehicle. This results in traffic overload and unstable communication between vehicles.

In this paper, packets are transmitted between vehicles using multicast method to reduce traffic load and increase reliability. Thus, even if the number of vehicles joining the cluster increases, it can improve the traffic problem of the existing platooning broadcast system by only sending packets selectively to the candidate leaderable vehicles.

B. *Latency*

TABLE I. CLUSTER REFORMING PROCESS IN THE EXISTING PLATOONING WAY

Existing Platooning (mesc)	
Re-election of a cluster leader	0.4
Follow-up vehicle approval request	0.2
Leader Vehicle Approval Request	0.2
Complete cluster registration	0.2
	1.0

TABLE II. CLUSTER REFORMING PROCESS IN PRIORITY PLATOONING WAY

Priority Platooning (mesc)	
Cluster Leader Change Request	0.2
Reader Vehicle ID change	0.2
	0.4

The delay in the re-forming of the cluster was compared when the leader vehicle of the cluster was changed while driving. In the existing cluster run, if the leader vehicle of the cluster is changed, the cluster is not maintained but separated. Thus, in order to recreate the cluster, one of the first separated vehicles must change his vehicle to the cluster's leader state. Other vehicles are then requested to join, approved, and signed up in turn from the first stage.

However, the proposed cluster run continues to maintain the group even if the leader vehicle is changed based on the priority of the pre-determined candidate leader vehicle. When a request for a leader change has been received, the ID of the highest priority vehicle is changed to the leader vehicle ID to form a cluster.

This proposal simplifies the process of joining existing clusters, reducing the latency that can occur when changing leaders.

V. CONCLUSION

In the paper, the priority of cluster candidate leader vehicle was added to improve the problem of traffic overload, time delay arising from the existing cluster-run method. Based on this, proposed a plan to apply cluster driving to urban road with many crossroads. In the event that the leader has to be changed due to traffic conditions or vehicle variables, the leader can be quickly changed without separating the cluster, enabling a flexible platooning.

This allowed platooning, which could only be applied in highway, to traffic lights and intersections in urban road.

Between the vehicle and the vehicle, the packet includes the identity of the vehicle and the various information required to drive it, which is used to transfer data. Therefore, research is required to develop a vehicle information hacking prevention or detection algorithm that can enhance security to protect the safety of vehicle drivers or clustered vehicles.

ACKOWLEDGMENT

This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIT) (No. 2017-0-00724, Development of Beyond 5G Mobile Communication Technologies (Ultra-Reliable, Low-Latency, and Massive Connectivity) and Combined Access Technologies for Cellular-based Industrial Automation Systems).

REFERENCES

[1] TTAS, “Communication Protocol for Group Driving ,” “TTAK.KO-06.0439 "

[2] Inès Ben Jemaa, “Multicast communications for cooperative vehicular systems ,” “Robotics [cs.RO]” Ecole Nationale Supérieure des Mines de Paris, 2014