A Study on the Election of Suitable Leader Vehicle in Vehicle Platooning Using the Raft Algorithm

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Abstract—Existing vehicle platooning creates platooning of vehicles with the same destination, and the leader vehicle manages the platooning. Since there is no way to elect a leader vehicle for platooning management, and the leader vehicle has not changed since its initial election, it is difficult to cope with the traffic situation in real time. To complement this, it is proposed that the Raft algorithm is applied to automatically elect the appropriate leader vehicle. To verify this, the proposed platooning was analyzed by comparing them according to the platooning scenarios to confirm that flexible platooning is possible.

Keywords—Platooning; Leader Election; Raft Algorithm; V2X(Vehicle to Everything); IoT(Internet of Things)

I. INTRODUCTION

With the development of autonomous vehicle driving technology for vehicles, commercialization of the technology has come to a near future. As a result, it is expected that this will be the first start of commercialization of autonomous cars. Platooning means the technology of driving by grouping several vehicles with the same destination into platoon and classifying them as leader vehicles and member vehicles. Using this technology, the leader vehicle collectively controls several vehicles at the same destination, providing a more comfortable driving environment for the driver of the member vehicle. In addition, vehicles in platoon drive at minimum intervals, thereby reducing the vehicle's air resistance, which increases fuel efficiency. In addition, driving at minimum intervals between vehicles reduces the vehicle's road use, thereby increasing road use and thereby easing traffic congestion.

However, conventional vehicle platooning with a simple structure in which members' vehicles use the information of the vehicles immediately ahead to control the spacing has limitations to the various situational responses on the roads where they cannot predict when the event will occur.

To address this, studies have been conducted in which leader vehicles manage overall cluster driving, but no studies have been conducted on how to select leader vehicles to best perform them. It was therefore impossible to determine whether the leader vehicle was suitable for the leader role [1][2][3].

To overcome this problem, we propose a method to identify the leader 's status in real-time and re-select appropriate leader according to the situation. To this end, the overall process of selecting a leader vehicle considering the emergency situation was designed and the Raft algorithm was applied to elect an appropriate leader vehicle.

To validate this proposal, I compared the existing vehicle platooning method and the proposed vehicle platooning according to the scenarios in which the leader election that can occur in the vehicle cluster driving is required.

II. RELATED WORK

A. Vehicle Platooning

1) Vehicle Platooning: Multiple vehicles with the same destination form a platooning of vehicles, while vehicles within the platooning at minimum intervals. Vehicles within the cluster range are divided into leader vehicles and member vehicles, which communicate between vehicles using the Cooperative Adaptive Cruise Control (CACC). It shares information such as the position of the vehicle, vehicle speed, etc. to control the clearance between the vehicles and to maintain platooning. CACC is a technology that improves performance of ACC (Adaptive Cruise Control), a technology that controls distance from other vehicles by using Ladar and Lidar sensors. Using the V2X (Vehicle to Everything) communication technology using the WAVE (Wireless Access in Vehicle Environment) system via the DSRC (Dedicated Short Range Communication) method, it transmits its information to vehicles not adjacent toddd each other. Vehicles within the cluster range are driven using CACC to maintain a minimum distance from the preceding vehicle. The member's vehicle follows the leader's vehicle and the driver of the member's vehicle only needs to make sure that the leader's vehicle is in the right direction. With clustered vehicles, vehicles within the cluster range drive with minimal space, thereby smoothing the flow of vehicles without expanding existing roads, making use of the road capacity to a much higher level than it is today. In addition, the trailing vehicle can be driven along the preceding vehicle, providing the driver with a pleasant and safe ride. In addition, because the preceding vehicle acts as a barrier to the trailing vehicle, the energy required to drive the trailing vehicle is reduced, thereby increasing fuel efficiency. The leader vehicle in platooning is responsible for identifying forward traffic conditions at the head of the platooning queue and transmitting information obtained through communication with the infrastructure to the member vehicle. The leader vehicle becomes the leader vehicle, the first vehicle to create the colony or the front vehicle of the platooning[4][5].

2) Suitable Leader Vehicle Necessity: In order to form a platooning in an existing vehicle platooning, a vehicle which is desired to be a leader sets a ' platooning leader mode', and the corresponding vehicle becomes a leader vehicle. After that, the vehicles that want to become a member vehicle can participate in the community by setting 'platooning member mode' after confirming the cluster formed by the leader vehicle. In this form of platooning, the leader vehicle was maintained if the platooning was not released, and in the event of an emergency, the whole platooning was released in the event of a platooning separation [6]. Existing leader vehicles serve as the leader in the platooning and communicate representedly with the outside of the platooning, such as infrastructure, to the member vehicles within the platooning. However, this is suitable for driving a vehicle such as a freight car which mainly runs on a road having a special characteristic of a highway in which an unexpected situation is hardly existed, but there is a limitation in that it causes an inefficient crowd driving. For example, there is no way to maintain platooning in the case of existing platooning, even if platooning that have been temporarily separated by traffic lights are allowed to rejoin the traffic lights. Although a new leader vehicle may appear to form a platooning voluntarily, there is also no guarantee that there is an unnecessary process to repeat the formation of the platooning from the beginning and that the same platooning will be formed again even if it is formed. In order to solve the limitation of the unexpected situation during the platooning, it is necessary to expand the role of the leader vehicle. In order to efficiently run the platooning, the leader vehicle that can respond appropriately according to the sudden environment is automatically elected according to the environment to facilitate the management of the platooning of the leader vehicle. For this purpose, it is necessary to select the appropriate vehicle to perform the role of the leader among the vehicles in the platooning, subject to various conditions, including the presence in the most efficient position to select the vehicle that can best serve as the leader.

B. Raft Algorithm

The Raft algorithm is a kind of consensus algorithm that is easy to understand the Paxos algorithm. A leader is elected by voting between nodes.

The nodes in the Raft algorithm have three states: Follower, Candidate, and Leader. The follower node is the initial state of all nodes. The follower node has an Election timeout to become a leader for each node, and when this time becomes 0, it starts the Election period to become a leader after changing state to the candidate node. The selection timeout is set at random and the decreasing speed is proportional to the performance of each node. The candidate node votes to itself and sends a message to the other follower node requesting the vote. Upon receiving the request to vote, the follower node first votes the candidate node that delivered the message. After the vote of all nodes, the election period ends, and the node with the most votes becomes the leader node. In other words, the best performing node is selected as the leader node.

The leader node periodically sends an Append Entries message to another follower node according to the preset Heartbeat period. The selection timeout of the node receiving this message is initialized and the response to the message is sent to the leader node. If a message is not received from the leader node during the heartbeat period, the leader node is judged to be abnormal and the leader node is re-elected. Therefore, little change will occur once the leader node is selected [7].

III. A Study of the Election of Proper Leader Vehicle in Vehicle Platooning Using the Raft Algorithm

To complement the limitations of platooning of existing vehicles that are difficult to respond quickly in the event of an emergency, it is proposed that the existing fixed leader vehicles be transformed into a fluid and the suitable leader vehicles be elected for them. The main functions of this proposal are largely classified into four categories and describe the whole process.

A. Overall Process

The overall process of this proposal is shown in the flow chart in Fig 1. If a vehicle that wants to drive a platooning chooses Platooning mode, another vehicle that wants to platooning at the same destination will join the platooning and start platooning.

During the election of the appropriate leader, a temporary leader to act as the leader should be selected. In order to select the appropriate vehicle to serve as the leader and to distinguish between vehicles with performance below a certain level, the vehicles in the platooning calculate the numerical value of each vehicle's performance.

Based on this value, the leader is elected through a process using the Raft algorithm. Most of the components and methods of the Raft algorithm are followed, but the criteria of voting are changed to suit the leader vehicle of platooning. Based on the digitized values of the vehicle's performance calculated earlier, the selection timeout is calculated and the first 0 vehicle is converted to the candidate vehicle first, giving the opportunity to become the leader vehicle.

After selecting a leader vehicle, check the status of the leader's vehicle in real time to enable rapid response to an emergency. Paragraphs section 3.B to section 3.E, the procedure described earlier.

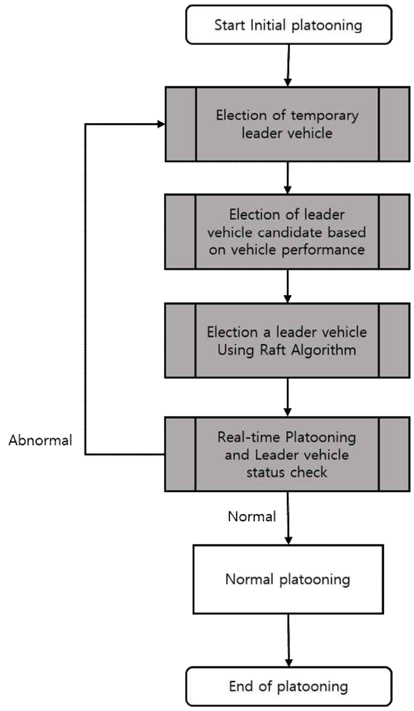

Fig. 1. Overall Process

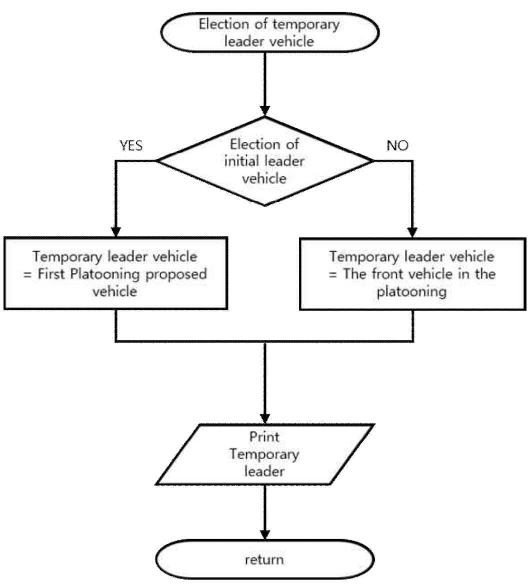

Fig. 2. Election of Temporary leader vehicle

B. *Election of Temporary leader vehicle*

In the first case of platooning and when an unexpected situation occurs and a leader vehicle must be elected, it is necessary to select a vehicle to perform the role of the leader while electing the appropriate leader vehicle. This uses the leader vehicle method of conventional platooning.

During the first platooning, the first proposed platooning vehicle is elected as a temporary leader vehicle without any process. In the event of an unexpected situation and the leader needs to be re-elected, the front vehicle in the platooning is selected as the temporary leader and driven.

The temporary leader vehicle performs the role of the leader, but is also included in the candidate for the appropriate leader election and is evaluated for the suitability of the leader. The previous descriptions are shown in Figure 2.

C. *Election of leader vehicle candidates based on vehicle performance*

It is a process to elect the right leader in earnest. In order to determine whether there is a qualification for the role of leader, each vehicle collects basic vehicle performance information such as the communication speed of the vehicle for efficient V2X, and then quantifies the value. The higher the relative value, the more suitable the leader role is, because the higher the likelihood that the higher the performance vehicle will perform the role of the leader. If this value is not equal to or greater than the reference value, the vehicle is judged to be a vehicle that does not meet the minimum qualification of the leader vehicle and can’t be even a candidate vehicle, thereby reducing unnecessary leader election process. This process is shown in Figure 3.

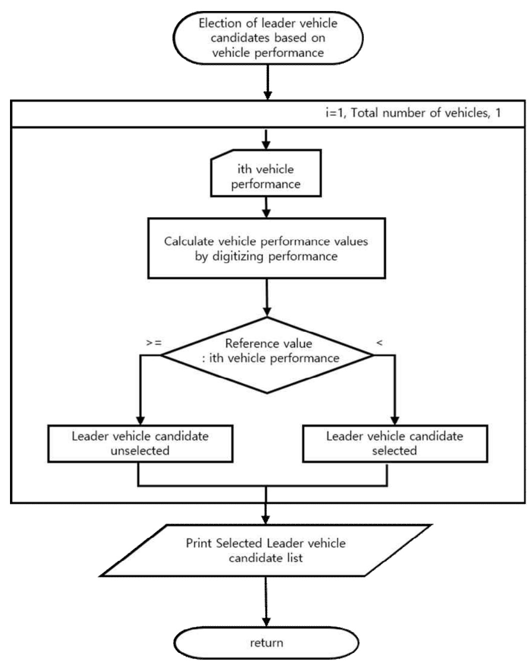

Fig. 3. Election of leader vehicle candidates based on vehicle performance

D. Election a leader vehicle Using Raft Algorithm

In the new leader election process using the Raft algorithm, the leader is elected by applying the numerical value in section 3.C. In the Raft algorithm, all vehicles in the platooning have three states: Followers, Candidates and Leaders, and early vehicles are Follower. Each vehicle has an election timeout set to random, which is reduced by speed with a performance value digitized at section 3.B. This means that the election timeout of vehicles with good performance is reduced faster. When the Election timeout is 0, the vehicle is changed to a candidate vehicle and the election period begins. Candidate vehicles send messages requesting votes to other vehicles after voting on themselves. Other vehicles vote for the first vehicle to receive a request to vote. The vehicle with the most votes is elected leader when a majority of the vehicles vote for the same vehicle or at the end of the Election period.

Eventually, the vehicle with good performance will be the first to change status to the candidate vehicle and the first to receive a request for a vote will be elected leader.

The elected leader vehicle follows and sends messages to the vehicle every set heartbeat period. Upon receiving this message, the Follower vehicle initializes the Election timeout and sends a response to the Leader vehicle. If a message is not received from the leader vehicle during the heartbeat period, the leader vehicle is determined to be unable to run, so that the election timeout is initialized and the leader election process is repeated. This process is shown in Figure 4.

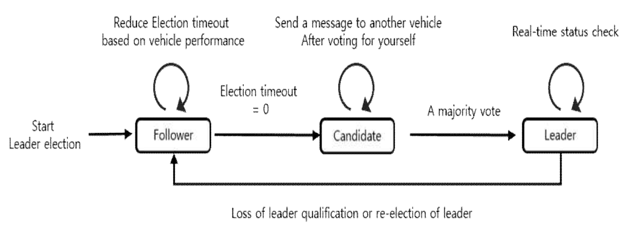

Fig. 4. Election a leader vehicle Using Raft Algorithm

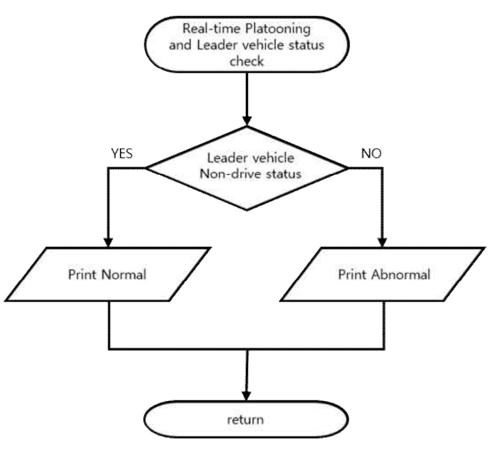

Fig. 5. Real-time Platooning and Leader vehicle status check

E. Real-time Platooning and Leader vehicle status check

Check the status of the leader in real time to prevent any gaps in the leader in platooning. Using the section 3.D Raft algorithm, a leader election can be used to check the life and death of the leader's vehicle during each heartbeat period, but no sudden situation can be identified in real time. Therefore, it is possible to check the status of the leader's vehicle in real time so that a quick response can be made. If the leader vehicle is judged by various circumstances to be unable to serve as the leader vehicle, another vehicle is elected as the temporary leader vehicle by section 3.B and the appropriate leader is re-elected. This is illustrated in Figure 5.

IV. Performance Analysis

Performance evaluation is carried out based on a leader vehicle election method using the Raft algorithm proposed in Chapter 3 to compensate for the limitations of fixed leader vehicles in existing vehicle platooning. For this purpose, the scenarios that could occur in a platoon run were summarized in section 4.1 and section 4.2 describes how the functions proposed in section 3 are utilized and what their advantages are, according to the scenario in section 4.1, and summarizes them as shown in Table 1.

A. Platooning Leader Election Scenario

Most of the existing platooning studies were conducted mainly by using leader vehicles to manage the entire platooning. Although there is no direct research on how to elect a leader vehicle, we have defined scenarios that require the election of leader vehicles based on existing scenarios of platooning[1] [2] [3].

1) Initial Platooning formation: In the case of forming a platooning for the first time, a vehicle which wants to travel in a platooning selects a platooning mode. A platooning is formed when there is a vehicle that wants to travel with the same destination. It is necessary to elect and elect which vehicle in the community is able to perform the role of leader.

2) Leaving the Leader vehicle of Platooning: If the leader vehicle becomes inoperable, e.g. due to a failure, the vehicle cannot continue to act as the leader, thus abandoning the leader's role. In this case, the existing platooning is released, but it is unnecessary to release the platooning due to the problem of one leader vehicle. Therefore, it is effective to re-elect leaders to maintain the community.

3) Seperation of Platooning: It is defined as the separation of the platooning if the platooning is detached or several member vehicles are displaced by vehicles outside the platooning by transient traffic conditions such as traffic lights. At this point, there will be platooning that do not include leaders. In this case, the platooning has been released in the previous vehicle platooning, but for momentary platooning disconnections such as traffic lights, unnecessary platooning release and unnecessary re-platooning generation occurs.

To prevent this, re-eelect the leader vehicle in real time depending on the situation and maintain the platooning.

4) Merger of Platooning: If several platooning of the same destination are driven nearby, they may be driven by merging into one platooning. When re-electing and driving one of the most suitable leader vehicles of several leader vehicles, efficient platooning is possible, including increased driver convenience.

5) Add Member Vehicle: If a new member vehicle has been added to a normally driven platooning, the possibility exists that the member vehicle is suitable for the leader. Therefore, it is necessary to elect the appropriate leader vehicle between the leader vehicle and the new member vehicle.

B. Analysis by Scenario

1) Initial Platooning formation: Temporary leader election is required before the initial platooning is formed and appropriate leader vehicles are elected. This will be elected as the temporary leader vehicle by the vehicle that first requested a colony according to section 3.B. All vehicles, including temporary leader vehicles, participate in the election of leaders to start section 3.C. In the existing platooning, the first vehicle to ask for a colony automatically became the leader vehicle. The proposed measures have the advantage of being the leader vehicle, with the most appropriate vehicle for communication to all internal vehicles within the platooning, for efficient platooning.

2) Leaving the Leader vehicle of Platooning: If the elected leader vehicle wishes to depart from the platooning, the leader vehicle immediately follows a message for re-election of the leader vehicle. In the case of an emergency, this can be seen when checking the status of the real-time leader vehicle, a function of section 3.E, and when checking the status of the leader vehicle during the Raft algorithm heartbeat period of section 3.D. Follower vehicles receiving the message will elect the vehicle that can be the candidate vehicle based on the value calculated in section 3.C. Then, proceed to section 3.D based on this value. As a result, the group is maintained even after the leader vehicle is reelected and the leader vehicle is removed. If a leader deviates from the existing platooning due to external or internal effects, the platooning is released and the platooning is terminated. In this case, the member vehicles are released even if they do not want to end the platooning. If a member vehicle wants to maintain that platooning, there is an unnecessary process that requires that one vehicle, after the end of the platooning, becomes the leader vehicle and form a new platooning. Applying the proposed measures would allow the leader vehicles to be changed only without de-collecting to omit these unnecessary processes and keep the existing platooning intact.

3) Seperation of Platooning: If the platooning is separated, the leader vehicle will not be present in the platooning. The first vehicle in front is elected as the temporary leader vehicle, using section 3.2, after judging that it is an emergency situation by section 3.E. Follower vehicles then calculate the numerical values of each vehicle's performance at section 3.C to elect the vehicles that can be candidate vehicle. Based on this value, the leader vehicle is re-elected through section 3.D to be elected as the leader vehicle of a group that did not have a leader vehicle in a separate platoon. It was not given special consideration in cases where platoons are separated during previous platooning. Only the defect of the leader or member vehicle exists. If several member vehicle leave the platooning, all of their member vehicles termiate their platooning. If the effects of temporary external environments, such as traffic lights, result in the separation of platooning from which several member vehicles leave the platooning, there is an unnecessary process that requires the initial platooning formation process to be re-enacted in order for these multiple member vehicles to re-enter the platooning.The proposed measure allows several vehicles leaving the platooning to remain platooning by electing a new leader vehicle within the vehicle without having to terminate the platooning without any of these unnecessary process.

4) Merger of Platooning: In the event of multiple platooning being combined, the leader vehicle shall also be re-elected, judging by section 3-E as an emergency situation. The combined leaders of the platooning choose a new leader because they are the ones who are elected leaders in recognition of the performance of each vehicle's performance. Before selecting a new leader, use section 3.B to select the front vehicle of the platooning as the temporary leader vehicle. Calculate the value of section 3.C of the vehicles that were the existing leader and proceed to section 3.D. This makes the elected leader the leader of the combined platooning. For existing platooning, the situation where two platoons of the same destination drive on two leader vehicles was not specifically considered. In the proposed approach, multiple platoons with the same destination can be managed as a single leader vehicle by re-electing the leader vehicle. In traditional platooning, two leader vehicles can be driven with only one leader vehicle, making it more efficient to drive in platooning

5) Add Member Vehicle: If a new member vehicle is added to the existing normally platooning, check it through section 3.E. However, since it is not possible to re-elect a leader every time, it utilizes a certain cycle of Raft algorithm, which is a heartbeat period of Raft Algorithm. If the status of the leader vehicle is normal and the new member vehicle is introduced by exploring whether or not a new member vehicle has emerged during the heartbeat period of the leader vehicle, the leader vehicle is re-elected to determine which of the existing leader vehicles or the new member vehicles is more suitable for the leader vehicle. During re-election of the leader vehicle, the first vehicle in the platooning is elected as the temporary leader vehicle in accordance with 3.B. Existing leader vehicles and new member vehicles are to be calculated and applied to section 3.D, respectively, to quantify the vehicle's performance in accordance with section 3.C. This allows a more appropriate vehicle to be selected as the leader and the colony to be managed. In the old case, members have been added only and have not considered the possibility that this vehicle may be a suitable vehicle for the leader vehicle. The proposed method allows the re-election of a leader vehicle considering the possibility that the new member vehicle is the appropriate leader, thereby selecting a more efficient and suitable leader.

TABLE I. COMPARISON OF THE APPLICATION OF PROPOSAL WITH EXISTING SCENARIOS

Scenario	Existing Leader Vehicle	After application of suggestion	
		Leader Vehicle	**Advantage**
Initial Platooning formation	Platooning First Forming Request Vehicle	Electing the appropriate leader vehicle through suggestion	Enable efficient platooning and management through appropriate leader election
Leaving the Leader vehicle of Platooning	Release of platooning	Electing the appropriate leader vehicle through suggestion from member vehicle	Enable maintain platooning
Seperation of Platooning	Maintaing platooning with leader vehicle and Release without leader vehicle	Electing the appropriate leader vehicle from a platooning without leader vehicle	Enable maintain platooning
Merger of Platooning	Not specifically considered	Electing the appropriate leader vehicle among the leader vehicle fo the platooning being merged	Enable efficient platooning and management through appropriate leader election
Add Member Vehicle	Maintaing existing leader vehicle	Electing the appropriate leader vehicle for the added member vehicle or the existing leaer vehicle	Enable efficient platooning and management through appropriate leader election

V. CONCLUSION

In order to solve the problem that the leader vehicle which was elected first in case of existing platooning is unchanged and the platoon is released when an unexpected situation occurs, there is a limit to cope with various traffic situations. For this purpose, we propose a method to automatically re - elect the leader vehicle according to the situation in order to convert the existing leader vehicle which had a fixed leader into a flexible leader vehicle. We used the Raft algorithm to elect suitable leader vehicles with numerical values of the vehicle performance by grasping the status of the leader vehicle in real time and responding to various situations.

To verify this, the scenario for selecting a leader during platooning was defined to compare and analyze platooning using the existing method of platooning and the proposed method. Because the existing platooning runs did not take into account the circumstances of an outbreak, most of the platooning end up in the event of an emergency. However, the proposed method confirmed that flexible platooning is possible because it can eliminate unnecessary procedures by selecting the leader properly and maintaining the platoon in the event of an emergency.

It is expected that this will contribute to the application of platooning, which has been applied only on highways where most of the existing contingencies are low, to general roads where various external environments exist.

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