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A SURVEY OF V2X COMMUNICATION TECHNIQUE FOR SUPPORTING PLATOONING

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Abstract. *Recently, autonomous vehicles using artificial intelligence have been attracting attention. Beyond the autonomous driving, research about platooning is being carried out to achieve driver convenience and increase vehicle capacity on the road and fuel reduction. To carry out the platooning, various data such as vehicle driving, sensing, and control data between vehicles must be exchanged. Due to the dynamic nature of inter-vehicle communication, bandwidth is limited, and it is difficult to transfer safety data successfully. This paper studies the existing inter-vehicle communication techniques and analyzes how these techniques overcome the unstable communication environment. In the result, we present important factors to efficiently utilize the bandwidth and considerations to support platooning.*

Keywords: Vehicle platooning, Platoon supporting system, V2X communication

1. **Introduction.** An autonomous vehicle is a vehicle that can run on its own without driver's manipulation [1]. Recently, according to the improvement of artificial intelligence technology, autonomous vehicle is getting a lot of attention. Therefore, not only manufacturers, but also IT companies are participating in the autonomous vehicle industry.

Lots of autonomous techniques are on research. Adaptive Cruise Control (ACC) is one of that, which autonomously maintains the distance from the preceding vehicle. There is a radar mounted on the vehicle, and it helps to calculate the distance. This technique could give convenience a lot to the driver, but it cannot adapt to a sudden change in speed because it uses the sensor to collect the data.

In contrast, Cooperative Adaptive Cruise Control (C-ACC) can adapt to the sudden speed change. Instead of using sensing data, it can collect the data through the wireless communication channel which is much faster. Such data include position, velocity and acceleration of the vehicle. ACC and C-ACC assist only the longitudinal control only, so the driver needs to steer the wheel for the latitudinal control.

Recently, the platooning technology has attracted much attention in addition to ACC and C-ACC. The platooning technology operates with multiple vehicles connected together and combines autonomous driving technology and the technology that connects vehicles by network. The platooning connects each vehicle into a cluster and makes them drive like a train with a close distance from the preceding and following vehicles. The preceding vehicle of the cluster performs as a leader, and the following vehicles move along the path

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of the preceding vehicle. Therefore, the driver does not need any operation during the platooning and will only drive on its own when leaving the cluster or independent driving is required.

For platooning, each vehicle should sense the environment information through the sensors and inform nearby vehicles. For example, each vehicle should periodically inform nearby vehicle about their vehicle speed, location and hazardous situations, and nearby vehicles also need to transmit their data. If the number of vehicles increases, the number of messages transmitted over the network increases, which can induce the packet collision or latency problem.

If the communication problem occurs in platooning, the platoon can be broken down and lead to the safety problem. Therefore, it is necessary to have enough bandwidth or to use efficient communication method to deal with the insufficient bandwidth. To do that, we analyze which techniques are supporting inter vehicle communication and which factor is crucial for supporting platooning.

The rest of the article is as follows. Chapter 2 introduces platooning technique and inter vehicle communication environment. Chapter 3 analyzes communication techniques to support platooning and Chapter 4 concludes this paper.

2. **Background.**

2.1. **Platooning.** Platooning means a set of vehicles dynamically aligned and traveling together with techniques for managing them [2]. In the platooning, vehicle in the lead position is called platoon leader, and the remaining vehicles in the platoon are called platoon member, which follows the platoon leader. The platoon leader performs platoon operation via Dedicated Short Range Communication (DSRC), and all the vehicles including platoon leader transmit and receive driving data or platooning control data via vehicle-to-vehicle communication such as DSRC, and automatically adjust the distance with the preceding vehicle based on sensors such as Radio Detection and Ranging (RADAR) or Light Detection and Ranging (LIDAR). Platooning has various advantages, including increased vehicle capacity on the road, increased traffic stability, increased driver convenience and reduced fuel consumption [3]. However, it should be considered that there is a trade-off like between safety and road throughput [4]. Since platooning requires simultaneous communication of multiple vehicles in the cluster, it is required to reduce network load and consider the communication technique.

2.2. **Vehicle to Everything (V2X) communication.** V2X communication refers to a communication paradigm that exchanges data between vehicles and road infrastructure over a dedicated network, and it includes Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure (V2I) communication. Figure 1 shows the V2X communication scheme. V2X communication technology allows information such as the location, speed and the route of the vehicle to be shared with the nearby vehicle and road infrastructure to reduce the risk of accidents and traffic congestion to provide optimal traffic conditions. In V2X communication, as vehicles increase, simultaneous network access may result in increased delays or packet collision rate caused by communication channel congestion. Therefore, reliable communication methods and methods to minimize packet collision should be considered in the environment in which multiple vehicles communicate. However, it is difficult to design communication techniques in V2X communication due to the high speed of the vehicles and frequent changes in topologies.

Dedicated Short Range Communication (DSRC) is a communication technology to provide Intelligent Transportation System (ITS) service. It provides short distance communication for Road Side Unit (RSU) and vehicles. DSRC's maximum bit rate is 54Mbps and it can allocate a total of seven channels of 1 Control Channel (CCH) and 6 Service Channels (SCH) [5]. Figure 2 shows the frequency for each channel. DSRC's maximum

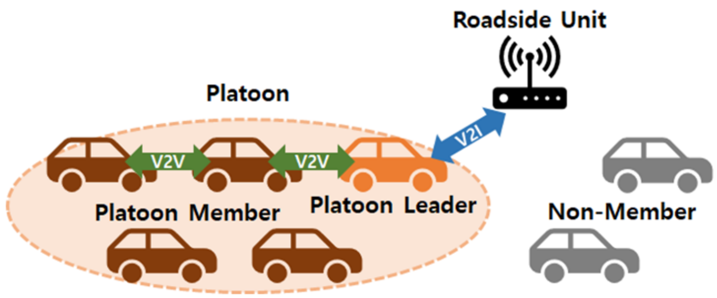

FIGURE 1. V2X communication scheme

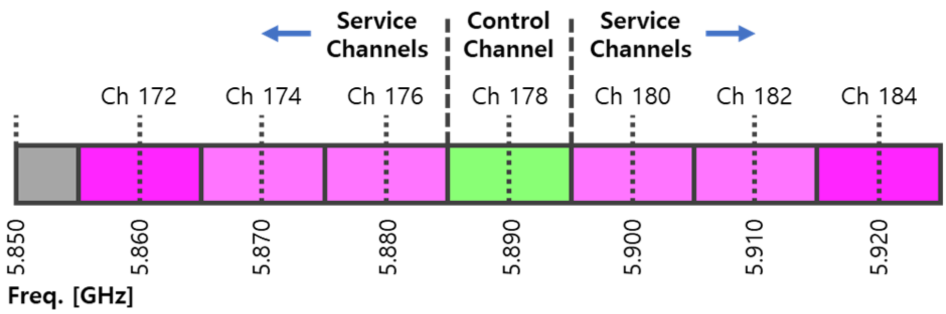

FIGURE 2. DSRC frequency range

transmission radius is 1km, but the Packet Delivery Ratio (PDR) is the highest when the transmission radius is 500m [6]. For safe driving between vehicles, bounded transmission delay of lower than 100ms is recommended [7], and low latency of DSRC is mainly used. However, due to the low bandwidth of DSRC, not only Basic Safety Message (BSM) which contains vehicles driving information, but also messages for platooning are transmitted to the network, which leads to high load on wireless channel. Since vehicles use a shared wireless transmission channel, a Medium Access Control (MAC) technique for efficient use of shared wireless transmission channel has been studied.

MAC techniques are divided into contention-based and contention-free technique and for contention-based, increasing packets in real-time network increase the delay due to the loss or transmission caused by signal collisions. For contention-free, since data is transmitted in pre-allocated frequency or time slot, it offers bounded delay. However, it needs synchronization operation to allocate frequency or time slot.

Current communication between vehicles uses IEEE 802.11p standard and Carrier Sense Multiple Access – Collision Avoidance (CSMA/CA) as contention-based. However, since it cannot guarantee bounded communication delay, it is not suitable for traffic safety message delivery in a road environment where a number of vehicles exist.

Frequency Division Multiple Access (FDMA) method as contention-free divides frequency bands and allocates them to a pair of transceivers, which is complex in synchronization and high overhead for frequency allocation. Code Division Multiple Access (CDMA) method as contention-free receives different codes from the same frequency band and communicates with these codes which result in code synchronization overhead being delayed because the transceiver needs to know about the code in advance. Figure 3 shows the difference between FDMA and TDMA. Time Division Multiple Access (TDMA) method as contention-free divides time into time slots within the same frequency, allowing one node to transmit data from a single slot. In this case, it is necessary to transmit control messages periodically for the time slot allocation and synchronize the nodes. Since contention-based and contention-free have their advantages and disadvantages, it is necessary to carefully analyze the communication environment and design communication

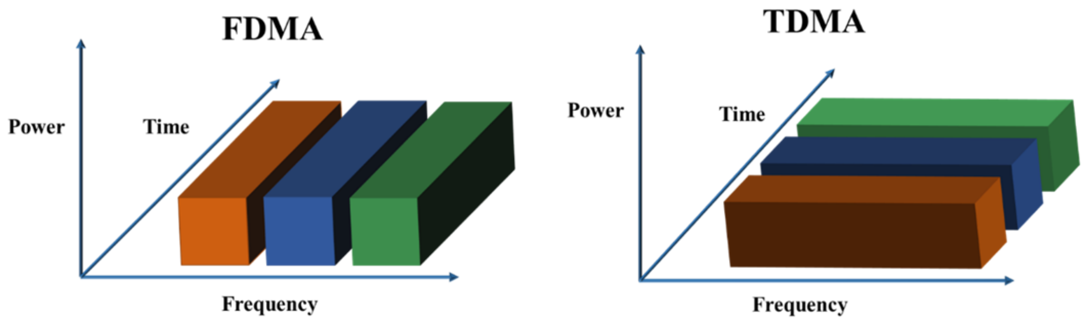

Figure 3. Comparison of FDMA and TDMA

techniques to meet requirements such as latency or network packet transmission. Recently, lots of studies have been carried out to deliver more data at lower latency in the V2X communications environment.

3. **An Analysis of Communication Techniques for Supporting Platooning.** In a road environment assuming platooning, it is important to provide packets in a bounded delay as vehicles are moving in a denser form. Therefore, various techniques have been studied to enable the efficient transmission of safety messages from multiple vehicles in intervehicle communications without collisions or delays.

In a study that combines the advantages of CSMA/CA and TDMA to provide delay bounded transmission in V2V communications without packet collisions [8], 100ms of channel access time is evenly divided into CCH interval and SCH interval. CCH interval consists of TDMA-based communication techniques to send safety messages or vehicle control messages without collisions. In this communication technique, the vehicle captures and analyzes messages from other vehicles that it can use, and when it finds a time slot, it informs that it has occupied the time slot. CCH interval also reserves the time slot for use in SCH interval as contention based.

Although TDMA scheme can provide bounded delay once a time slot is allocated, a time slot is required for a network node to transmit data, resulting in overheads and time delay. Therefore, methods have been studied to reduce the number of messages by configuring a cluster while CSMA/CA techniques can be used to quickly send safety messages without separate settings, and ways to increase network bandwidth with multiple channel TDMA techniques.

In study which designed the multi-channel MAC protocol to send real-time safety messages without delay [9], the use of TDMA and clustering techniques increased packet collision prevention and improved data transmission bandwidth. Vehicles are divided into a cluster header and a cluster member, and it assumes that communication devices are capable of using two channels at the same time. One of communication devices sends and receives control messages and safety messages within the cluster, while the other communicates between the cluster headers. In addition, the cluster header also assigns time slots to the cluster members in a TDMA manner and provides the cluster members with contention-free communication. Figure 4 illustrates the communication scheme using clustering.

A study that proposed multi-channel MAC communication considering the characteristics of the platooning environment [10], a platoon leader announces cluster size, spacing, and algorithm in CCH interval and allocates time slots to its platoon members. Using platoon leader information from CCH interval, platoon members can change channels from SCH interval to SCH in use by platoon. This technique could prevent communication conflicts between cluster when sending and receiving data, but the SCH allocation method

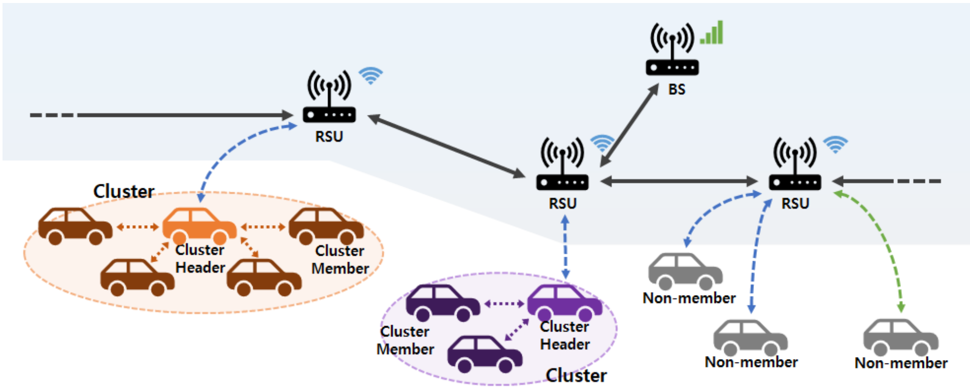

Figure 4. Communication scheme using clustering

between clusters was not presented and the overlapping channels were not considered due to movement between clusters.

In [11], authors proposed new communication strategy to avoid channel contention. DSRC uses CCH for safety or control messages and SCH for other application messages. Therefore, if the vehicle wants to transmit safety message in SCH channel, it needs to wait until the CCH channel starts. It leads to the situation that when the CCH channel starts, lots of vehicles try to transmit the messages at once. This situation yields the channel contention which leads to the waste of bandwidth and packet loss. Therefore, the new strategy gives the random delay to each packet to avoid the channel contention. Because of the random delay, the packets are spread out all over the channel.

In [12], authors proposed communication strategy which combined transmit power adaptation technique and synchronized communication slot. The transmit power adaptation technique makes each member have difference transmission power depending on the role. Only the leader uses 20dBm transmit power and the follower uses 0dBm transmit power because leader sends the message all over the platoon, but the follower communicates with only immediately behind in this scheme. This technique is simple but can reduce the channel interference. The other technique, synchronized communication slot, looks similar to TDMA technique but difference. In this technique, the leader first sends the beacon message, and followers can decide their timeslots by leader's beacon message by cascading way after receiving the leader's message. This technique can reduce the channel contention and the synchronization overhead is lower than TDMA scheme.

As we mentioned, lots of communication techniques are on research to support platooning. One of the most important factors to support platooning is to efficiently utilize the bandwidth. When the number of vehicles increases, the channel contention occurs, and it leads to the packet loss. Therefore, there were lots of research to avoid channel contention and efficiently synchronize the timeslots. Another important factor is to consider the platooning characteristic. Because the platoon leader and platoon member have other roles, they would have difference transmit power and communication method. In [13], considering physical mobility characteristics of platooning vehicles, it presents the feasible region of communications delays and bound on the probability of safe braking.

4. **Conclusions.** In this paper, communication techniques for supporting platooning are introduced and analyzed. Platooning is the attracting field beyond autonomous driving which has lots of benefits. However, because of dynamic environment of vehicles and characteristics of platooning, it needs high bandwidth to ensure high packet delivery rate for safe driving.

Therefore, some researches tried to avoid the channel contention in contention-based MAC protocol. Another research could reduce the overhead for the synchronization in contention-free MAC protocol. Another technique to efficiently utilize the bandwidth was clustering. With clustering, the number of packets can be reduced as well as packet collision. One of the most important factors to support platooning is to consider the characteristic of the platooning. Because platoon leader and platoon members have different roles, they can have different transmission power or communication method.

According to the many researches, we found that there were several ways to design efficient communication techniques for supporting platooning. However, because the vehicle environment is very dynamic, it needs to find the optimal technique to adapt to the specific situation.

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