2018 IEEE Intelligent Vehicles Symposium (IV)
Changshu, Suzhou, China, June 26-30, 2018

# Enhancing the Performance of Vehicle-to-Vehicle Realtime Video Streaming for Platoons*

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*Abstract*— **Platooning is nowadays one of the most promising applications for vehicle-to-vehicle communications. Platooning makes multiple vehicles travel as closely as possible to get the maximum driving efficiency. The problem here is that the view of the rear vehicle driver may be blocked by the front vehicle. In order to improve rear driver's safety and psychological stability, video streaming among vehicles aims to provide the front view of the platoon leader to rear vehicle drivers. In this paper, we first focus on measurement of realtime video streaming performance using IEEE 802.11p broadcast in the platoon. As a result, packet delivery ratio dropped to 48 % in the worst case that the collision and hidden terminal problem coexist. To mitigate the frame loss, we use pseudo-broadcast that can recover frames by retransmission instead of broadcast. In addition, we employ Request-To-Send/Clear-To-Send whose transmission power increased by 5 dB to solve the hidden terminal problem. Consequently, we can prevent the frame loss and increase the packet delivery ratio up to 96.8 %. Our proposal enables vehicle-to-vehicle communications to exploit a new method integrating characteristics of unicast and broadcast to solve this problem. Besides, our proposal can easily apply to existing devices by updating a device driver without any hardware chip level modification.**

## I. INTRODUCTION

Vehicle-to-vehicle (V2V) communications enable vehicles to share crucial information such as vehicle and driving status with other vehicles to improve driving safety and convenience. The vehicle uses the V2V communication to transmit driving information such as its own position, speed, and direction to surrounding vehicles so as to grasp the situation around the vehicles and to quickly cope with the dangerous situation. In the past decade, research on the improvement of driving safety using V2V communications has been carried out, and the U.S. Department of Transportation (DoT) issued a notice of proposed rulemaking (NPRM) to legislate the deployment of V2V communication capability on all new light-duty vehicles recently [1].

Platooning is one of the promising applications using V2V communications. Platooning makes multiple vehicles travel as closely as possible, reducing air resistance and increasing fuel efficiency. Especially, for transportation vehicles, platooning is an important method which can reduce the annual fuel consumption by more than 10 % [2]. The U.S. Federal Highway Administration (FHWA) has already conducted a platooning demonstration using three trucks in Virginia [3] to look into the feasibility in real world environment. One of platooning projects in Japan has reduced the distance between the platooning vehicles by 4 meters [4].

In case that the platooning vehicles reduce the inter-vehicle distance minimally, blocking the vision of the drivers that follow the leader vehicle of the platoon is a problem that cannot be ignored. Although the vehicles prevent for accidents such as collisions with other vehicles through Advanced Driver Assistance System (ADAS) and V2V communications, the blockage of the driver's vision can cause anxiety of the driver. In order to solve this problem, various studies have been conducted on how to use the video taken by the front and rear view camera. Bouchaala *et al*. [5] implement an application which detects vehicles, obstacles, and pedestrians using video streaming via V2V communications to complement Light Detection and Ranging (LiDAR) in platooning or reverse parking scenarios. The application provides extended front/rear vision to the driver to elevate the driver's safety. Vinel *et al*. [6] propose an overtaking assistance system that transmits front view video and beacons to rear vehicles of platoons when a platoon encounters the other platoon on the opposite lane. Also, a few surveillance applications exploiting video streaming on Vehicle-to-Everything (V2X) communications are explored [7], [8]. Taken together, video streaming among vehicles has been utilized to increase driving safety and comfortableness by providing additional visual information from the front or/and rear view cameras to drivers whose vision is restricted by the surrounding vehicles and obstacles.

In this paper, when platoons use realtime video streaming, we closely examine the situations and solve the problems. The situations are depicted as follows. First, the leader vehicle of a platoon broadcasts the front view video to its platoon members. Due to the limited bandwidth, the leader vehicle should transmit the video stream by broadcast/multicast provided by Medium Access Control (MAC) layer transmission method in IEEE 802.11 [9]. The member vehicles of the platoon receive and play the streamed video on the screen in front of the driver. At this time, the performance of one-hop broadcasting can be affected by distance between vehicles, surrounding environments, vehicles, channel utilization, and etc. Therefore, we evaluate the communication performance under these circumstance and propose methods to improve these difficulties.

In the previous work, Park *et al*. [10] propose a new method named *pseudo-broadcast* based on IEEE 802.11 unicast and broadcast/multicast to improve efficiency and reliability of multi-room IPTV transmission. An access point

*This research was supported by a grant (18CTAP-C133064-02) from Technology Advancement Research Program (TARP) funded by Ministry of Land, Infrastructure and Transport of Korean government

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(AP) using pseudo-broadcast transmits frames to a IEEE 802.11 station (STA) which has the worst link quality, and the other STAs receive the unicast frames in promiscuous mode [1]. In case that the destination STA loses a frame, the AP retransmits the lost frame to recover, and each STA has a chance to recover that frame until the destination STA receives the retransmitted frame successfully. We first substitute pseudo-broadcast for broadcast that is a basic transmission method in V2V communications. The leader of platoon designates one vehicle that has the worst frame error rate (FER) as the unicast receiver and transmits the front view video. The other vehicles receive the video in promiscuous mode as if each vehicle is the target of the unicast frames. As a result, we improve packet delivery ratio (PDR) of the video transmission by up to 30 % when collision and hidden terminal problem coexist, which is the worst environment. Pseudo-broadcast has two strong points. First, pseudo-broadcast enables V2V communications to exploit methods such as retransmission only used in unicast. Second, it is easy to apply to existing devices by updating a device driver without any hardware chip level modification. However, pseudo-broadcast cannot completely reduce the frame loss by hidden terminal problem. Therefore, we consider Request-To-Send (RTS)/Clear-To-Send (CTS) [9] which is another method in unicast mode to reduce the effect of hidden terminal problem. In this paper, we use 5 dB stronger RTS/CTS to prevent frame loss by increasing transmission range. Consequently, when the video streaming application uses pseudo-broadcast with RTS/CTS, the PDR can be increased by up to 36 %.

Contributions of our work are summarized as follows:

- We evaluate the performance of IEEE 802.11 broadcast when the platoon leader transmits the front view video
- We enhance the packet delivery ratio (PDR) by using pseudo-broadcast without hardware modification
- We prevent hidden terminal problem among platoons by integrating transmission range extended RTS/CTS with pseudo-broadcast

This paper is organized as follows. Section 2 describes a procedure of V2V communications for realtime video streaming in the platoon, and provides predicted problems and solutions of them. Simulation environments and results are presented in Section 3. Finally, we conclude this paper.

## II. V2V Communications for Video Broadcasting of Platoons

To increase driving efficiency while platooning, each member vehicle should minimize the distance from its front vehicle. It causes the limited frontal view of rear-vehicle drivers, and it can reduce the concentration of the driver and make it difficult to cope with unexpected situations, even though platooning is operated safely. One way to solve this problem is that the leader vehicle shares the front view video with the rear vehicles to enable the rear-vehicle drivers to grasp the surrounding environments and situations.

For broadcasting realtime video stream of the front view of the platoon, the leader vehicle can use V2V communications. Fig. 1 depicts the procedure of video streaming application using V2V communications. In the application, as the leader vehicle serves as a video streaming server, the member vehicles receive and display the streamed video. By using Wave Service Advertisement (WSA) in IEEE 1609.3 [11] on V2V communications, this application let the leader vehicle and the member vehicles play a role of `Provider` and `User`, respectively. In more detail, `User` registers the streaming application in `UserServiceRequestTable` by sending a service request including a predefined Provider Service IDentifier (PSID). The streaming application on the leader vehicle transmits a WSA that contains the PSID, the IPv6 address of the leader, and the port number of the application on control channel (CCH) periodically. The member vehicles receive the WSAs during the CCH interval (CCHI), and access to the service channel (SCH) announced in the WSA during the SCH interval (SCHI). Finally, the applications of the member vehicles start to stream the front view video of the leader. In case of vehicles that are not platoon members, they may not move to the broadcasted SCH in the WSAs despite receiving WSAs of the leader in CCH. This is because the PSID in WSA has not been reigistered in their own `UserServiceRequestTable`.

MAC layer of V2V communications using IEEE 802.11p can use unicast, broadcast, and multicast for video streaming. Due to limited bandwidth of V2V channels, however, unicast is inefficient to transmit the front view video to all member vehicles. Consequently, the application should use broadcast or multicast. The methods, however, cannot prevent video quality degradation because they do not exploit retransmission or RTS/CTS to reduce frame loss caused by high speed mobility and hidden terminal problem. Therefore, it is required that a new solution integrating the strong points of unicast and broadcast to solve this problem.

When using V2V for platooning, as shown in Fig. 2, there

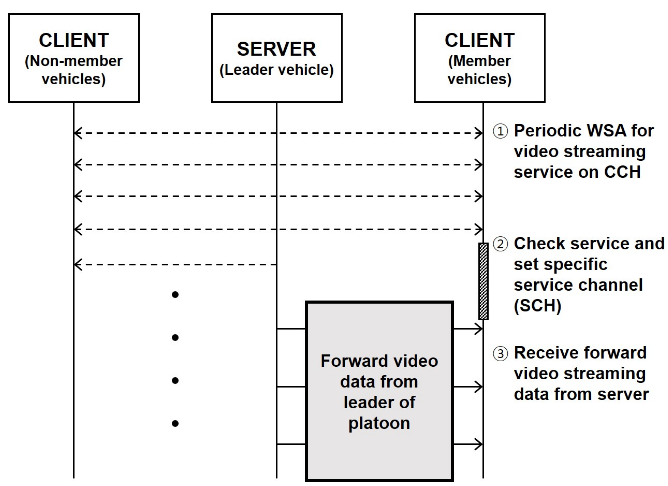



Fig. 1: Message exchange of video streaming application

[1]Promiscuous mode enables a STA to receive all frames regardless of the destination address of the frames

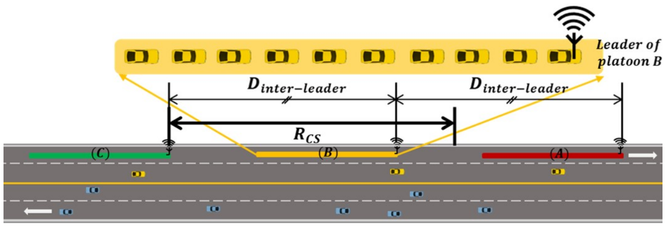



Fig. 2: Contention and hidden terminal problem among platoons on a dedicated platooning lane

may be contention for transmitting video when several platoons line up in a lane and move along the lane. In addition, as in platoon A and C, the hidden terminal problem can occur when the leaders do not recognize each other's transmission (*e.g.* the carrier sense (CS) range $R_{CS} < 2 \times D_{inter-leader}$). In this case, intermediate vehicles between leader A and C may experience lower frame reception rate and deterioration of video quality because of the collision between frames transmitted simultaneously from two leaders. For example, in Fig. 2, if $R_{CS}$ is 300 m in V2V communication environment and $D_{inter-leader}$ exceeds 150 m, hidden terminal problem may occur.

In this paper, to overcome the frame loss due to contention and hidden terminal problem, we propose (1) pseudo-broadcast transmission [10] with (2) RTS/CTS exchange [9] when the leader vehicle transmits a realtime video stream of its front view.

### A. Pseudo-broadcasting

Pseudo-broadcast [10] is a transmission method integrating frame retransmission of unicast with broadcast/multicast in promiscuous mode. An AP that uses pseudo-broadcast should designate a target node of unicast transmission to utilize frame retransmission. In order to decide the target node, pseudo-broadcast exploits an exchange mechanism based on Measurement Request and Measurement Report frames in IEEE 802.11k [12]. As the AP sends a FER request frame to STAs, each STA reports FER of it to the AP. For example, the AP selects a target STA **A** that has the worst FER based on the reports from the STAs. Finally, the AP transmits data frames to **A**, and retransmits the frames when the AP does not receive acknowledgements from **A**. If the other STAs except **A** fail to receive a data frame, the STAs have a chance to recover when the AP retransmits the data frame to **A**. On the contrary, if the AP receives an acknowledgment of a data frame from the **A** while some STAs fail to receive the frame, the STAs have no chance to recover, which is similar to broadcast/multicast.

Fig. 3 depicts an example of pseudo-broadcast utilized in a platoon. First, the leader vehicle of the platoon and the other members exchange a PDR (instead of FER) request/report frames to choose a target vehicle receiving frames in unicast mode. When transmitting video frames, the leader designates the target vehicle as a destination of video frames while the other vehicles receive the frames in promiscuous mode

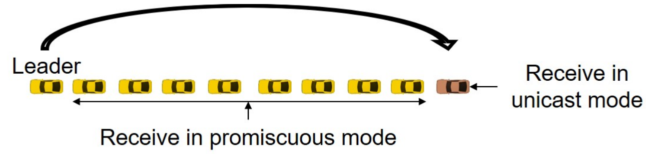



Fig. 3: Example of pseudo-broadcast

regardless of the destination of frame. Therefore, even if the vehicles cannot receive the first attempted frame from the leader, they can play the video without any problems if they receive following retransmitted frames successfully. Besides, existing devices can easily apply pseudo-broadcast by updating only device drivers without hardware chip-level modification [10].

### B. Exchanging range-extended RTS/CTS

RTS/CTS is short control frames exchanged between source and destination STAs of unicast to explicitly occupy the channel before transmitting data. When succeeding to receive a RTS containing frame duration, the destination STA returns a CTS to the source to acknowledge RTS reception. After receiving CTS, the source starts to transmit the data frames to the destination. At the same time, surrounding STAs can recognize the frame duration from the RTS and the channel occupancy (*i.e.* `BUSY` state) from the CTS, and wait for the end of transmission. The CTS is also delivered to the nodes outside the transmission range of the sender, thereby avoiding the hidden terminal problem by waiting for the transmission time of the sender as well. Since using unicast transmission instead of conventional broadcast/multicast method, pseudo-broadcast can use performance enhancement methods which are available only in unicast. Therefore, pseudo-broadcast with RTS/CTS can prevent hidden terminal problem so that channel access can be stably.

Fig. 4 is an example of when the distance between the A's leader and the B's leader following the platoon A is greater than the carrier sensing range when the two platoons travel along the platoon lane. If two platoons accidentally make video streaming on the same SCH, both vehicles may continue to attempt video transmission, and the member

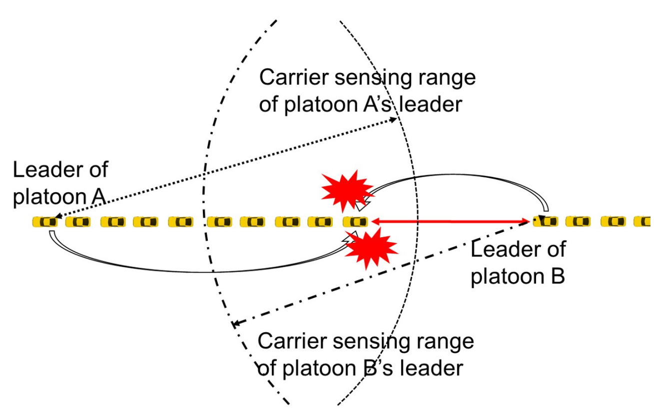



Fig. 4: Example of hidden terminal problem

vehicles in platoon A may fail to receive frames due to collision of video frames transmitted by both A and B. In this case, if pseudo-broadcast and RTS/CTS are used together, the target vehicle sends CTS to defer the transmission of the leader vehicle of the platoon B, which can prevent the hidden terminal problem. However, if RTS/CTS is transmitted with the same transmission power as the data frame, the following problems may occur. If the target vehicle of the pseudo-broadcast receives the video transmitted by the hidden terminal preemptivley, the leader vehicle continuously transmits the RTS without knowing this situation. As a result, RTS retransmission timeout occurs, and the data frame cannot even be transmitted and is eventually dropped. In this paper, we increase the transmission power of RTS/CTS for farther transmission range to prevent hidden terminal problems by transmitting RTS/CTS properly.

## III. Simulation

### A. Experimental Setup

In order to estimate the performance and solve the problems when multiple platoons conduct video streaming service in a single lane, we perform simulations.

We assume when 5 platoons move at 90 km/h (= 25 m/s) in a circle lane with a radius of 1 km, which is depicted in Fig. 5. Each platoon consists of 10 vehicles, and the foremost vehicle serves as a leader. Inter-vehicle distance between adjacent vehicles in the platoon is 0.5 seconds (12.5 m) [13]. Each leader (except very front leader) follows a foregoing platoon group with safety distance of 2 seconds (50 m) [14], and we assume that it forwards a front video captured by camera to its platoon members.

For our simulation, we use QualNet 5.1 network simulator [15] and IEEE 802.11p to transmit video data at a data rate of 6 Mbps, a transmission power of 20 dBm, and a receiver sensitivity of -85 dBm. The wireless channel is modelled using free space channel model (pathloss exponent = 2.0) and Rician fading model (K-factor = 3). The video application transmits data of 1460-byte by User Datagram Protocol (UDP) in every 22.278 ms, and the target video rate

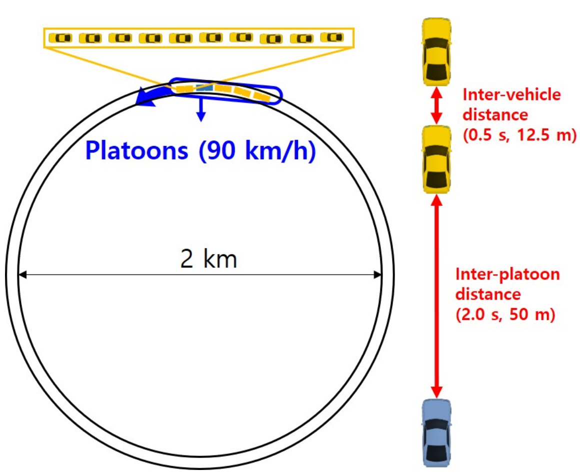



Fig. 5: Simulation topology

is 0.5 Mbps. In this paper, we investigate the performance improvement when the pseudo-broadcast and RTS/CTS that we propose are used in the above environment. Depending on the target rate of video transmission, the video quality of the transmitted video may change, and the impact on the proposed method may vary, but this remains to be studied in the future.

By exploring the platoon in the middle among 5 platoons, we observe how the video streaming performs when the platoon experiences in the harshest environment in platoon lane, and the performance improvement as leaders of platoons use pseudo-broadcast and range-extended RTS/CTS. For range-extended RTS/CTS, the transmission range is approximately doubled by increasing the transmission power of RTS/CTS by 5 dB. In order to mitigate the hidden terminal problem caused by leader vehicles of the middle and the endmost platoons, the latter vehicle of the endmost platoon sends CTS reliably to the middle platoon vehicles by using range-extended RTS/CTS. When using the pseudo-broadcast, the methods to classify frames and to report a PDR at MAC layer refers to Park et al. [10]. For the former method, it uses reserved 2-bit ($11_2$) of a `type` of a frame control in a IEEE 802.11 MAC header to pick out frames, and for the latter one, a Measurement Request and Report frames of IEEE 802.11k are employed to report the PDR of platoon members to the leader vehicle.

The experiment is conducted during 40 seconds, and metrics in below are observed in the simulation.

- Packet Delivery Ratio (PDR): The ratio of packets that are successfully delivered to a receiver compared to the number of packets trying to send by the sender.
- Inter Packet Gap (IPG): The time gap between consecutive received frames. In case of the video transmission, there is a frame rate for playback, so a certain number of frames arrive within this period to enable smooth video playback.

Depending on causes of frame losses, the performance change of the V2V communication for the video streaming is completely different. Thus, we first arrange the causes, and proceed simulations that are suitable for the cases. When broadcasting, there are three causes of frame losses, which are *channel loss*, *collision*, *hidden terminal problem* [16]. Firstly, the *channel loss* is occurred when the signal is attenuated by the effects of interference or attenuation due to wireless channel condition. Secondly, the *collision* is caused when two nodes that exist in a same carrier sensing range try to send frames at the same contention slot (*ie.* 13 us of 1 contention slot time in 10 MHz channel [9]) by accident. Finally, the *hidden terminal problem* is a situation that two or more signals are overlapped at sandwiched nodes when channel is already occupied by one sender, and other nodes that cannot be aware of the sending node try to send frames.

Thus, we adjust initial transmission timing at application layer to generate each frame loss cases for simulation. In case of *channel loss*, the transmission timing of each platoon leader is longer than the minimum contention window $CW_{min}$ to generate a situation where no competition occurs. To generate *collision case*, we make transmission timing of adjacent platoons in carrier sensing range to be less than $CW_{min}$ so that competition can occur at each transmission. Lastly, we make *hidden terminal problem* happen continuously by lessening the difference of the transmission timing between the leaders that are outside mutual carrier sensing range than the frame transmission duration. Furthermore, we also create a scenario where *collision* and *hidden terminal problem* occur together for performance evaluation in the worst condition.

### B. Packet Delivery Ratio

Table I shows PDR by distance from the leader vehicle to the receiving vehicles, members of platoon, when the leader vehicle of the middle platoon of 5 platoons performs video streaming. In the table, PBcast is the pseudo-broadcast, D is the distance (meter), HTP is the hidden terminal problem, and C+HTP is the combination of collision and hidden terminal problem.

When a video stream is transmitted using IEEE 802.11p broadcast, it can be seen that PDR reduction is different according to the type of loss mentioned above. Firstly, in the Channel loss case, the PDR of the last vehicle in platoon that is in 170 m far is about 92.2 %. In the Collision case, the PDR of the nearest vehicle is 86.5 %, and the PDR of the farthest vehicle is 78.7 % because two vehicles compete with each other for every frame transmission. In the event of a frame loss due to a collision, all the vehicles in the platoon are affected, so we can observe the overall PDR reduction in all platoon members. In case of the HTP case, the leader vehicle of the endmost platoon serves as the hidden terminal. The PDR is reduced faster than the Channel loss case, and the PDR of the furthest vehicle is about 55 %. This is because the signal transmitted by the hidden terminal overlaps the signal of the leader vehicle and causes loss. Especially, as the distance from the leader vehicle increases, the signal of the hidden terminal is strongly received so that the PDR sharply decreases. The C+HTP case is the worst case, and the PDR of the last vehicle is reduced by 48 %.

TABLE I: PDR (%) of each platoon member

| | D (m) | 17.5 | 35.0 | 52.5 | 70.0 | 87.5 | 105.0 | 122.5 | 140.0 | 157.5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Broadcast | Channel loss | 100.0 | 99.8 | 99.4 | 99.3 | 98.9 | 97.5 | 96.2 | 94.4 | 92.2 |
| | Collision | 86.5 | 85.7 | 85.7 | 85.1 | 84.2 | 82.9 | 81.1 | 79.8 | 78.7 |
| | HTP | 99.8 | 99.4 | 98.3 | 96.8 | 92.8 | 87.6 | 77.3 | 68.2 | 55.0 |
| | C+HTP | 84.8 | 79.9 | 77.8 | 73.9 | 69.5 | 64.5 | 59.6 | 54.0 | 48.0 |
| PBcast | Channel loss | 98.4 | 99.0 | 98.8 | 98.6 | 97.9 | 96.9 | 95.9 | 94.0 | 100.0 |
| | Collision | 99.3 | 99.3 | 98.7 | 98.8 | 97.3 | 95.9 | 94.8 | 92.3 | 100.0 |
| | HTP | 99.7 | 99.6 | 99.2 | 98.5 | 96.7 | 93.4 | 88.6 | 84.0 | 99.0 |
| | C+HTP | 96.7 | 96.2 | 95.8 | 94.0 | 92.2 | 89.1 | 87.2 | 84.0 | 100.0 |
| PBcast w/ RTS/CTS | Channel loss | 99.3 | 98.8 | 98.8 | 98.3 | 97.8 | 96.5 | 95.4 | 93.5 | 99.3 |
| | Collision | 97.8 | 97.5 | 97.3 | 96.8 | 96.4 | 95.7 | 94.5 | 93.0 | 97.9 |
| | HTP | 99.3 | 99.2 | 98.7 | 98.4 | 98.1 | 96.5 | 95.7 | 94.0 | 98.4 |
| | C+HTP | 96.8 | 96.3 | 96.2 | 95.8 | 95.0 | 94.3 | 92.9 | 90.9 | 96.8 |

In this paper, we try to improve the reliability of video transmission by using pseudo-broadcast to achieve the same effect as unicast retransmission in broadcast/multicast transmission. PBcast in Table I is the result of applying pseudo-broadcast in video transmission to cope with channel loss, collision, and hidden terminal problem. In contrast to broadcast, by using retransmission, the PDR of the last vehicle designated as a pseudo-broadcast destination in all cases is improved up to 99 %, and the C+HTP situation is improved by 52 %. In the case of other vehicles that are not subject to pseudo-broadcast destination, the frame loss is different from that of the last vehicle when the last vehicle succeeds in receiving or successfully recovering by retransmission. If another member vehicle still can not recover the frame at that time, the retransmission no longer occurs, and the opportunity to recover the loss is lost. Nevertheless, in most cases, frame loss is recovered by retransmission, and the PDR is improved by up to 30 % improvement of the PDR. On the other hand, in the Channel loss case, it can be seen that a maximum frame loss of 6.0 % occurs in all vehicles except the last vehicle. This is because the competition among platoons caused by the increased transmission time including retransmission occurs.

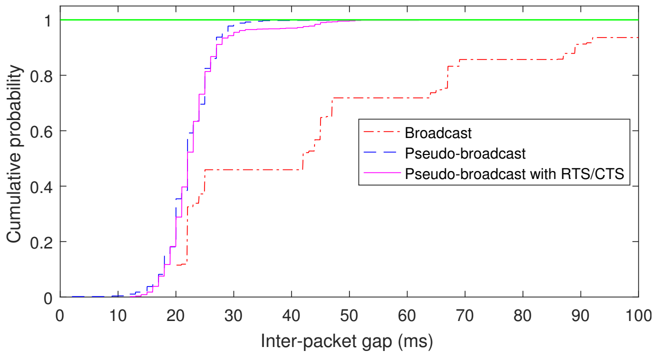
We use RTS/CTS to reduce the hidden terminal occurrence situation because the frame loss due to the hidden terminal problem still occurs when viewing PBcast of Table I. If the leader vehicle transmits a RTS before frame transmission, and a target vehicle transmits a CTS, the other leader vehicle in the vicinity of the attempted transmission may enter the reception state to prevent the hidden terminal problem. As a result, we can maximally obtain PDR improvement by 10.0 % in case of the HTP case and by 6.9 % in case of the C+HTP case by using RTS/CTS. This is because the use of RTS/CTS with increased transmission power prevents the hidden terminal problem and increases the transmission success rate.

From the above results, we can improve the PDR by loss recovery through frame retransmission of pseudo-broadcast, and by prevention of hidden terminal problem by using channel preemption of RTS/CTS with increased transmission power.

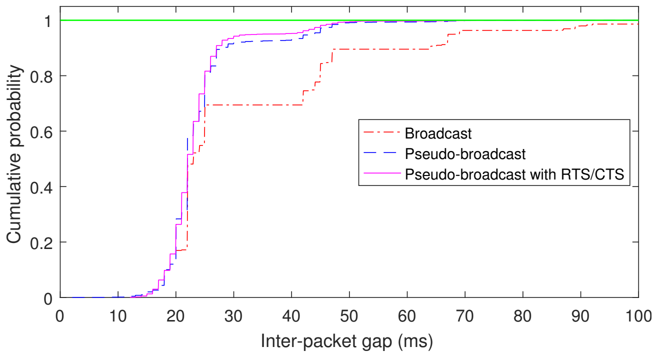
### C. Inter-packet gap

Finally, we measure IPG when using pseudo-broadcast and RTS/CTS to check whether the reception of the frame is stable. Especially, because of the constrained paper space, we focus on the the IPG of the C+HTP case that is the most severe frame loss environment in Fig. 6.

The cumulative distribution function (CDF) of each IPG observed when all vehicles receive a video transmitted by the leader vehicle. The ideal frame-to-frame IPG for video transmission in our video streaming application is 22.278 ms. A jitter may occur due to channel contention and retransmission of pseudo-broadcast. In case of IPG that is more than twice of 22.278 ms, frame loss may occur. In the case of the last vehicle of Fig. 6 (a), 54.0 % of frames are received after loss when using legacy broadcast. Due to




(a) IPG of last vehicle




(b) IPG of all platoon members

Fig. 6: IPG of platoon members when collision and hidden terminal problem are occurred

the frame loss from collision and hidden terminal problem, the transmission interval of frames is not uniform, and more than 8 % of cases exceeding 100 ms are observed. In case of using pseudo-broadcast, a jitter by retransmission is added, but IPG is almost constant because 100 % of all frames are received. In addition, when RTS/CTS is used, since the RTS is transmitted instead of the data when retransmitting, the transmission time is reduced, and the jitter is decreased. Nonetheless, it can be seen that the RTS retransmission timeout occurs, and the 3 % of the frame reception takes more than twice of ideal IPG. Fig. 6 (b) shows the IPG results for all vehicles in the platoon. There is a total frame reception delay of 30.6 % when using broadcast. This is because the middle members are closer to the leader vehicle than the last vehicle so that the frame loss is reduced. In addition, the ratio is reduced to 7.21 % when using pseudo-broadcast and 4.78 % when using RTS/CTS.

Consequently, through the use of pseudo-broadcast and RTS/CTS in a platooning situation where collision and hidden terminal problem exist, it is possible to smooth video transmission by increasing frame transmission success rate and decreasing frame reception delay.

## IV. Conclusion

In this paper, when using platooning, we measure the performance of front view video streaming using V2X communication of leader vehicles in platoons to solve the drivers' blockage of sight problem that may occur. We also simulate the improvement of transmission performance using pseudo-broadcast and RTS/CTS. As a result, it is possible to provide an environment in which all platoon members can smoothly receive video by improving the PDR and stabilizing the IPG.

In the future, we will go beyond the simulation-specific experiment and check the performance using real video in real-world environment. In this experiment, the simulation is confirmed assuming that the channel is not saturated. In the future, we will examine the effect of pseudo-broadcast and RTS/CTS on channel saturation that can occur when two or more platoon lanes are used or higher quality video is used.

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