5G Overall System Trial

— *An application of 5G Ultra-Low-Latency Communication to Truck Platooning* —

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1. Introduction

Research and development is underway toward the commercialization of 5th generation mobile communication systems (5G) in 2020. In addition to extending the capabilities of 4G networks with enhanced Mobile Broadband (eMBB), 5G will provide capabilities in the new domains of Ultra Reliable and Low Latency Communication (URLLC) and massive Machine Type Communication (m-MTC), and is highly anticipated as social infrastructure for our advanced information society. URLLC and m-MTC in particular have potential for developing new markets, and establishing concrete 5G applications for these is an urgent matter.

The Ministry of Internal Affairs and Communications (MIC) began 5G system trials in Japan in FY2017[1]. These trials request evaluation of 5G wireless system technologies for commercial use, as well as trials of 5G in collaboration with other vertical sectors, meaning use of 5G in sectors other than mobile communications.

The trials discussed here belong to the 5G URLLC test group (Group V, or GV) led by SoftBank, and deal with a use case applying 5G to truck platooning. This article reports on these activities in GV.

2. Application of 5G to truck platooning

Truck platooning involves multiple trucks driving together in a convoy. The truck platoon is controlled as a unit by using inter-vehicle communication. Development to implement truck platooning is currently underway in several countries around the world.

Several social issues can be resolved through use of truck platooning. Platooning can enable trucks to drive closer together to reduce wind resistance, which can reduce fuel consumption and reduce CO2 emissions. It has been shown that a platoon of three trucks travelling 4 m apart at 80 km/h consume 15% less fuel[2]. If the distance between trucks is reduced to 2 m, the fuel consumption would be reduced by 25%. Reducing the distance between vehicles can also increase the traffic capacity of roads, mitigating congestion. This could further reduce CO2 emissions. In Japan, an aging driver population and driver overwork are also social issues, so truck platooning can reduce the burden on drivers and increase safety.

Adaptive Cruise Control (ACC) measures the distance between a lead vehicle and following vehicle using radar or other technology and maintains a safe separation between vehicles according to their cruising speed. ACC has been implemented and many vehicles are already equipped with it. However, when controlling based only on the measured distance between vehicles, there is a significant delay between when the lead truck begins to slow down and when the following distance changes. There is further delay until the following truck begins to slow down. For this reason, if only ACC is used, a longer following distance must be maintained to prevent collisions.

On the other hand, Cooperative ACC (CACC) controls speed based on speed and acceleration information sent from the lead truck to the following truck by inter-vehicle communication, which can greatly improve control of the following distance when the lead truck needs to brake suddenly. This also enables stable operation with less fluctuation in following distance (hunting oscillation) due to control delay. Fuel consumption can be further reduced and traffic capacity of roads increased while maintaining safety by further reducing the following distance and increasing the number of platooned trucks, so using 5G URLLC, which realizes low latency and high reliability, in this field is very promising.

3. Trial description

In the GV trials, the ultra-low latency radio capabilities of 5G were used in the transport field for two use cases: (1) Communication between vehicles involved in platooning, and (2) Remote monitoring and operation of the entire truck platoon. These use cases are shown in Figures 1 and 2.

There are two main communication requirements for these use cases. The first is low-volume, low-latency communication needed for the vehicle control systems (speed, acceleration, vehicle positions, etc.). The other is high-volume, low latency communication needed for the video monitoring system, to monitor the whole platoon (monitoring the truck surroundings, etc.). The former must also be highly reliable.

Figure 3 shows the forms of communication for platooning, including (1) Vehicle-to-Network-to-Vehicle communication (V2N2V), (2) direct vehicle-to-vehicle communication (V2V Direct, Sidelink), and (3) vehicle-to-network communication (V2N). Communication with (1) above is between vehicles through a base station, and can provide relatively stable and low-latency communication with the help of the base station. With

Figure 1: Use case 1: Inter-vehicle communication for truck platooning (Vehicle control and video monitoring around following truck)

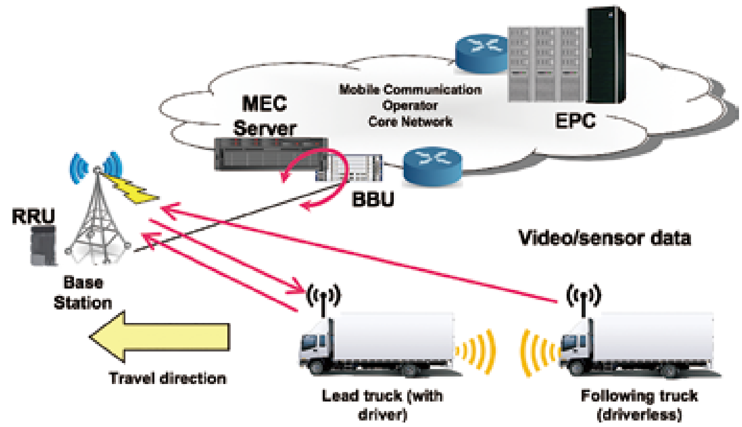
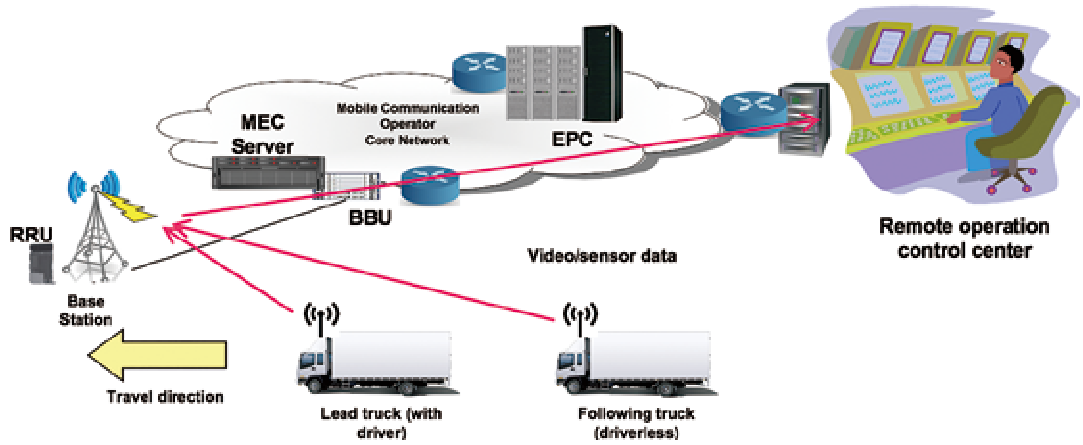


Figure 2: Use case 2: Remote monitoring, remote operation(Communication between platooned trucks and remote operation control center)



(2), there is a possibility that signals become blocked by other vehicles coming between the platooned trucks, so it could become less reliable than (1), but it can achieve lower latency than (1). With (3), delays within the network dominate vehicle-to-network communication, but it is needed for remote monitoring and operation of the vehicles.

In FY2017, application of 5G communication to self-driving of following trucks in a platoon is being studied, so the basic performance of communication necessary for vehicle control and video monitoring of the surroundings of following truck was evaluated. Specifically, the communication types (1) and (2) above were tested. The specifications of test equipment are shown in Table 1.

4. Trial results

A truck platoon driving environment using large trucks was set up on the Tsukuba City test course to evaluate 5G communications equipment (Figure 4).

(1) Latency characteristics

The latency characteristics of 5G communication equipment were measured in tests, with consideration for use in vehicle control for platoon driving. The 4.7 GHz band was used in the tests, and the evaluation was done in a test environment with vehicle-to-vehicle communication via base station. The tests were done assuming truck speeds up to 90 km/h. An example of over-the-air latency measurement is shown in Figure 5. It shows that at a speed of 87 km/h, the transmission delay on the air was 0.58 ms.

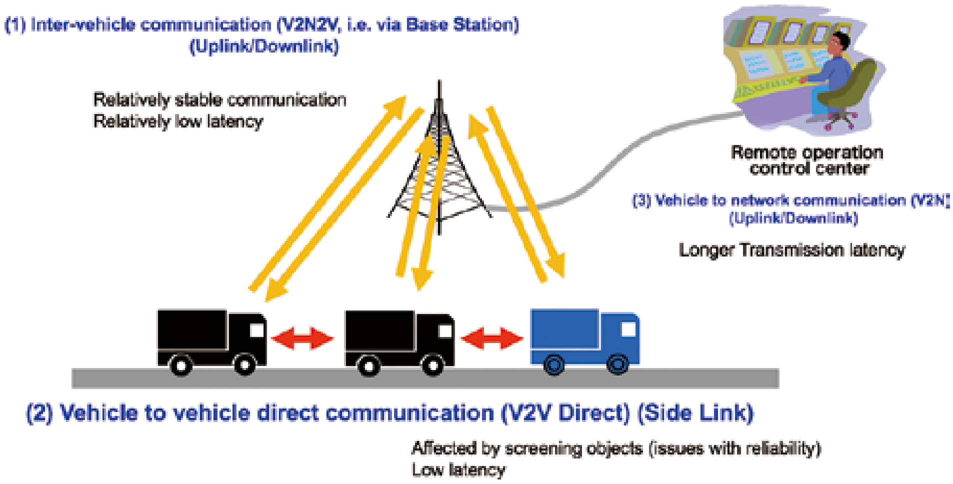
(2) Throughput characteristics

While platoon driving, the surroundings of the following vehicles must be monitored at the lead truck for safety. The feasibility of low-latency, high-volume communication for video monitor-

Table 1: Test equipment specifications

No.	Item	4.7 GHz band equipment	28 GHz band equipment
1.	Center frequency	4.74 GHz	27.9 GHz
2.	Bandwidth	100 MHz	700 MHz
3.	Duplex scheme	TDD	
4.	Radio access scheme	Downlink: OFDMA, Uplink: OFDMA	
5.	Subcarrier interval	60 kHz	120 kHz
6.	Radio subframe length	0.125 ms	
7.	Data modulation schemes	Downlink: QPSK, 16QAM, 64QAM, 256QAM Uplink: QPSK, 16QAM, 64QAM	
8.	Transceiver antenna configuration	Base station: 64Tx/64Rx Mobile terminal: 4Tx/8Rx	Base station: 4Tx/4Rx Mobile terminal: 2Tx/4Rx

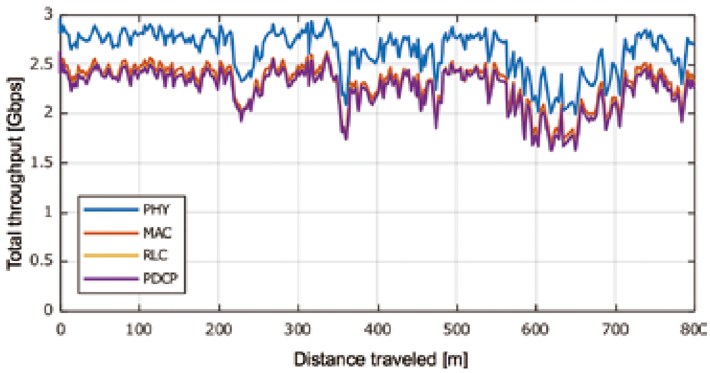
■ Figure 3: Forms of communication for platooning



■ Figure 4: Real truck platooning test

■ Figure 5: V2N low latency communication performance assuming vehicle remote monitoring and control (4.7 GHz band)

■ Figure 6: Throughput characteristics (28 GHz band)



ing was tested. The test environment involved vehicle-to-vehicle direct communication with vehicles separated by approximately 10 m. The 28 GHz band was used to ensure wide bandwidth. Figure 6 shows the relationship between distance traveled and throughput. The figure shows that throughput of approximately 2 Gbps was achieved. This shows that video transmission is possible without increasing the delay due to video encoding, thanks to such high throughput.

5. Conclusion

We conducted basic performance evaluations applying 5G to truck platooning on a real test course. We studied two cases of communication: low-volume, low-latency communication needed for platooning (for truck control), and high-volume, low-latency communication (for monitoring the following vehicles). The test results confirmed that the communication requirements for advanced truck platooning were met.

In the future, we will conduct integration testing for a platooning control system as well as testing to ensure reliability.

References
[1] Ministry of Internal Affairs and Communications, "5G System Trial Begin," Press Release, http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000297.html, May 2017.
[2] K. Aoki, "Current Activities of Development on the Automated Truck Platoon," pp.303-309, IPSJ Journal, Vol.54 No.4, Apr. 2013.