5G Trial Overview (FY2017)
Connected cars, Construction Equipment Remote Operation, Transmission of High Resolution Video from Drones

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1 Introduction

In preparation for implementation of 5th Generation mobile communication systems (5G), the Ministry of Internal Affairs and Communications (MIC) began 5G Trials in FY2017. The authors, together with other collaborating organizations, participated in a group conducting trials of applications using 5G low-latency communication, measuring radio propagation characteristics and evaluating performance of 5G, generally and in applications, using the 4.5 GHz and 28 GHz bands in urban and suburban areas. This article reports on the results of these activities.

2 Sample applications, locations, and frequencies used in trials

Trials with three applications: Connected car, ICT Construction, and Drone aerial photography; were conducted as shown in Table 1.

Table 1: Sample applications

Sample applications	Environment	Demonstration location	Frequency
Connected car	Urban Suburban	Tokyo Aichi Prefecture	4.5 GHz 28 GHz
ICT Construction	Suburban	Saitama Prefecture	28 GHz
Drone aerial photography	Urban	Tokyo Kanagawa Prefecture	28 GHz

3 Assumed use cases and test details

The assumed use cases and test details are described below.

3.1 Connected car (Figure 1)

In the use case studied, a server application receiving instructions from an operator instructs the on-board camera in a vehicle travelling below 60 km/h to record images of a moving object. This application requires a low-latency transmission channel to minimize the time between when the operator issues the instruction and when video capture begins, to minimize changes in relative positions of the camera and subject during that time. Tests of transmission from the vehicle were conducted during FY2017.

3.2 ICT Construction (Figure 2)

Due to the demand for rapid recovery after severe natural or other disasters and the need to rebuild social infrastructure, and considering the social issue of declining numbers of skilled laborers, there is increasing anticipation placed on construction robots and remote operation of equipment. In this application, video captured by 4K 3D cameras installed on construction equipment and multiple overhead HD cameras is transmitted using 5G to a remote control room, where operators watch the video and operate the equipment remotely. Current remote control systems use Wi-Fi, but the high capacity and low latency of 5G makes use of high-resolution video possible and is expected to increase efficiency of remote operation. In FY2017, field tests

Figure 1: Connected car application

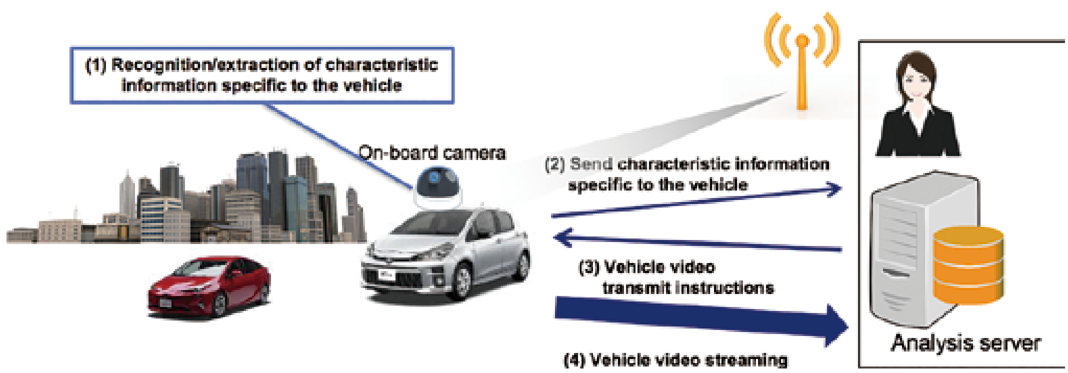
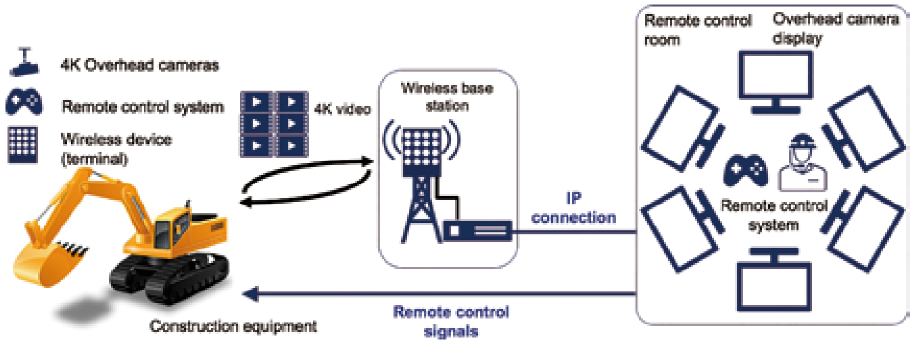


Figure 2: ICT construction application



conducted in a simulated construction environment quantitatively demonstrated the effectiveness of 5G by comparing remote control through both Wi-Fi and 5G.

3.3 Drone photography (Figure 3)

The objective of this use case is to use 5G to transmit 4K video from a drone during an event or disaster. Preliminary studies, evaluations, and selection of issues when using 4G were done in FY2017.

4 Trial results

4.1 Connected car

Trials were conducted in Shinjuku Ward, Tokyo, and Ichinomiya City, Aichi Prefecture (Figures 4, 5).

The results of 4.5 GHz transmission tests conducted in Ichinomiya City are shown in Figure 6. The downlink throughput using a bandwidth of 100 MHz and a 1:1 ratio for up and downlink time intervals was almost 300 Mbps. In the environmental conditions for these tests, the median value for one-way delay on the radio segment was 0.935 ms, which is less that the 1 ms target value.

The results of 28 GHz measurements are shown in Figure 7. The median delay value was 0.915 ms, confirming low latency communication similar to the 4.5 GHz case. A comparison of the 4.5 GHz and 28 GHz cases is shown in Figure 8. In the driving routes shown in Figure 9, the Section 2 driving area is the same for both bands. The sections indicated in red in Figure 8 show that 4.5 GHz is more resistant to degradation of throughput due to the environment.

4.2 ICT Construction

To compare working efficiency when using Wi-Fi and 5G, the time required to stack three blocks was measured using various systems. (See Figures 10, 11, and 12)

Figure 3: Drone aerial photography application

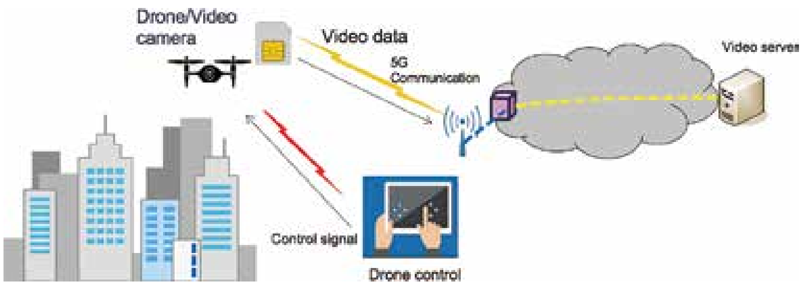
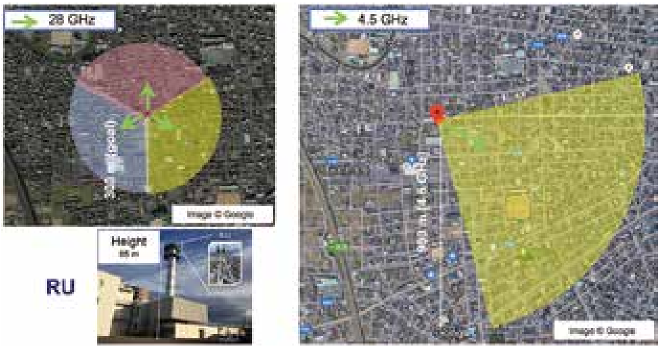


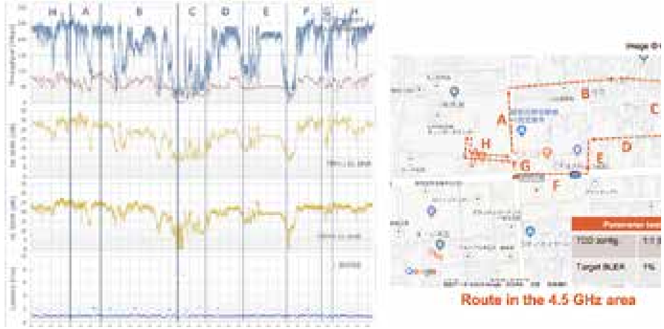
Figure 4: Test area in Shinjuku Ward, Tokyo

Notations	Height (from ground)
TP1	10m
TP2	25m
TP3	90m

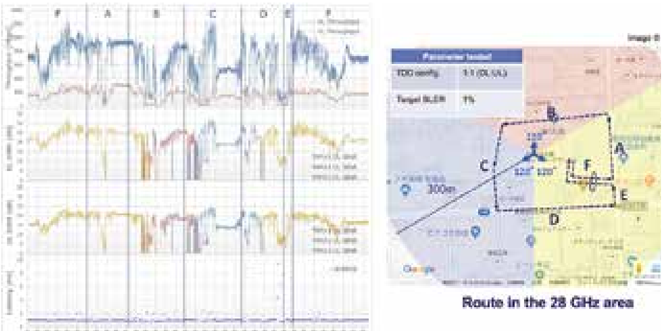
■ **Figure 5: Test area in Ichinomiya City, Aichi Prefecture**



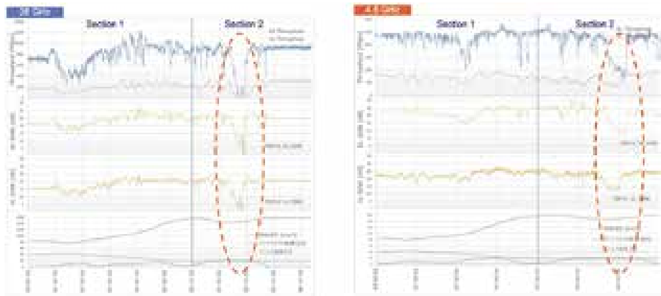
■ **Figure 6: 4.5 GHz transmission test results (Ichinomiya area)**



■ **Figure 7: 28 GHz transmission test results (Ichinomiya area)**

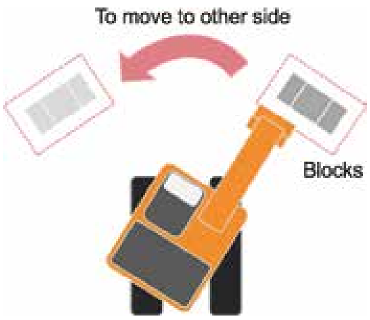


■ **Figure 8: Comparison of 4.5 GHz and 28 GHz (Shinjuku area)**



■ **Figure 9: Driving routes**

■ **Figure 10: Block stacking test overview**



■ **Figure 11: Block stacking test photograph**

■ **Figure 12: Machinery configurations**

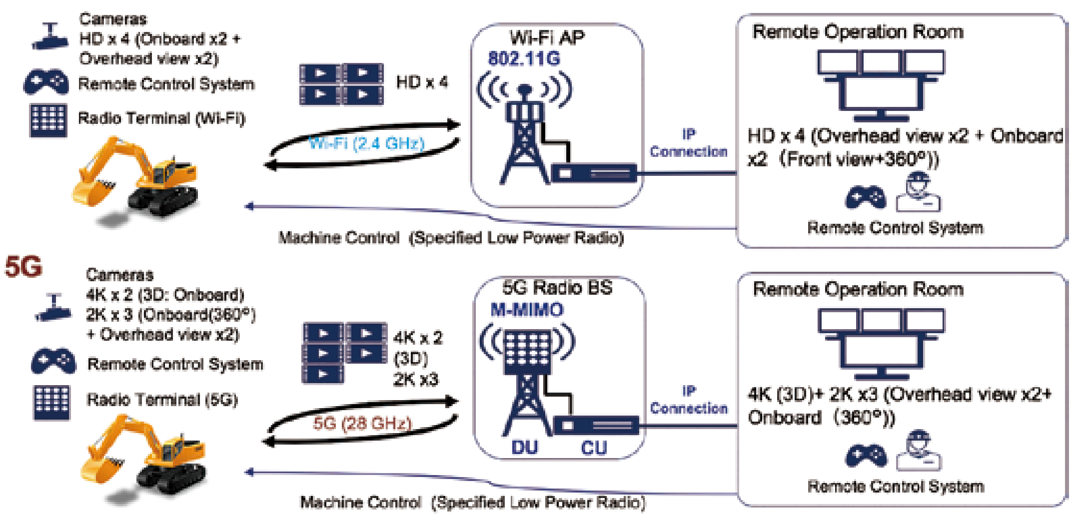


Figure 13: Block stacking test results

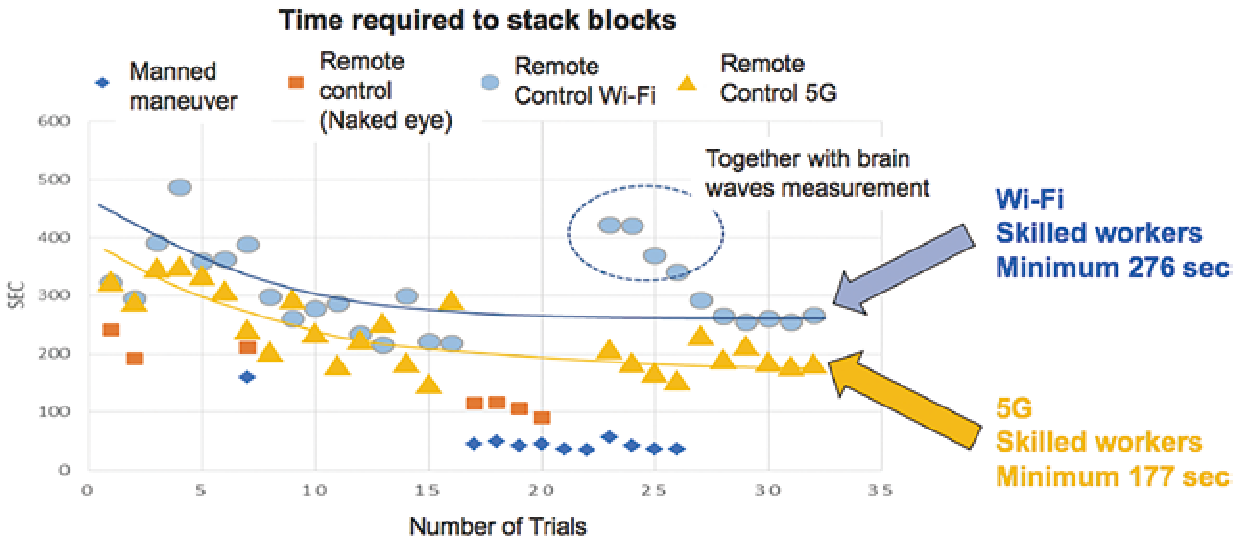
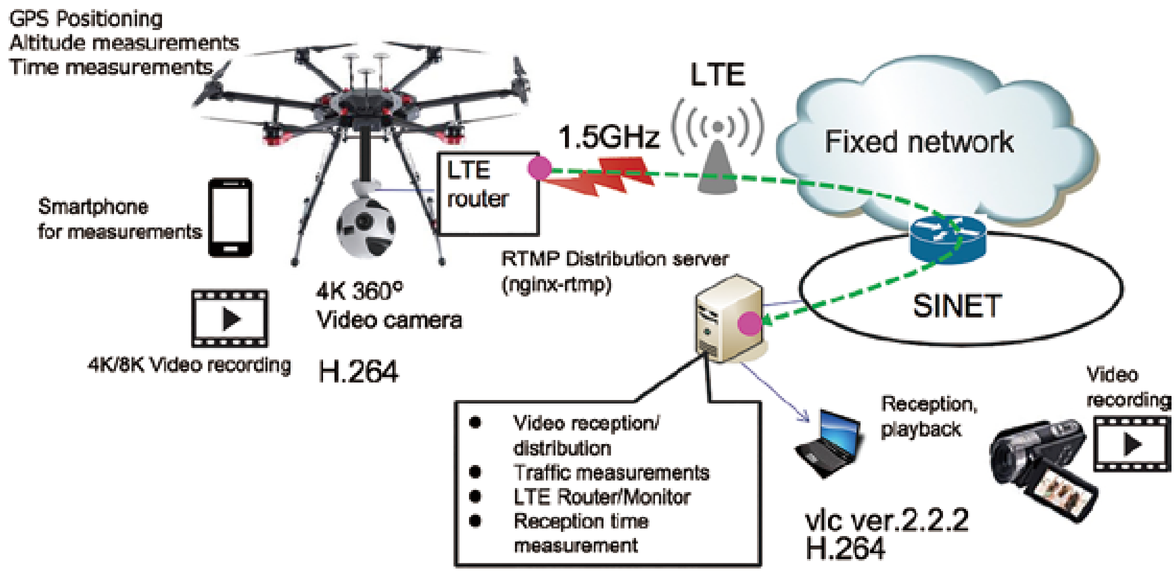


Figure 14: Drone aerial photography test configuration



Configurations using the conventional method (Wi-Fi) and 5G are shown in Figure 12. To reduce differences between the environments, the number of cameras and distance to the remote control room was the same. The conventional system used 2K video, while the 5G system used naked-eye 3D 4K video, comparing based on image quality. The remote control system used Specified Low-power Radio.

In the experiments, the same operator alternated between the two test environments and compared them with consideration for how work time decreased as they gained practice. Assuming an exponential approximation, the expected time for an experienced user would be 276 s on the Wi-Fi system, and 177 s on the 5G system, reducing work time by a third (Figure 13).

4.3 Drone aerial photography

As shown in Figure 14, video captured with 4K and 720p cameras mounted on a drone was transmitted to a server using a 4G terminal mounted on the drone, and the transmission delay and throughput were measured. 4K video resulted in delay of approximately 30 s, confirming that transmission would be difficult using 4G.

5 Conclusion

This article has described 5G performance evaluations for application use cases in 5G trials conducted by the MIC.