2019 Field Trial Results: Part 3

Field Trial Group 5

Use Case Field Trial of 5G Low Latency Reliable Communication in a High-speed Mobile Environment

Field Trial Group 6

Use Case Field Trial of 5G Massive Machine-type Communication in Indoor and Rural Outdoor Environments

Hitoshi Yoshino
SoftBank Corporation

Hideto Funayoshi
Wireless City Planning Inc.

Part I: Field Trial to Realize Connected and Automated Vehicles using 5G Ultra Reliable and Low-latency Communication

Field Trial Group 5 SoftBank Corporation:
Hitoshi Yoshino, Manabu Mikami

1. Introduction

5th Generation Mobile Communication Systems (5G) encompasses not only enhanced Mobile Broadband (eMBB), which is a further enhancement of conventional Mobile Broadband capabilities, but also the new features of Ultra Reliable and Low Latency Communication (URLLC) and massive Machine Type Communication (m-MTC). These new features are anticipated as infrastructure for our advanced information society. Commercial deployment of eMBB has already begun. The new 5G features, URLLC and m-MTC, have potential to open up new markets in industrial applications. It is important to establish concrete 5G use cases in these new areas as early as possible.

From FY2017 to FY2019, the Ministry of Internal Affairs and Communications (MIC) of Japan conducted 5G Comprehensive Demonstration Tests[1] (hereinafter referred to as "5G Field Trials"). These field trials needed not only to assess technical aspects of 5G radio systems for commercial deployment, but also to conduct the 5G field trials in cooperation with potential industrial 5G users (Vertical sectors).

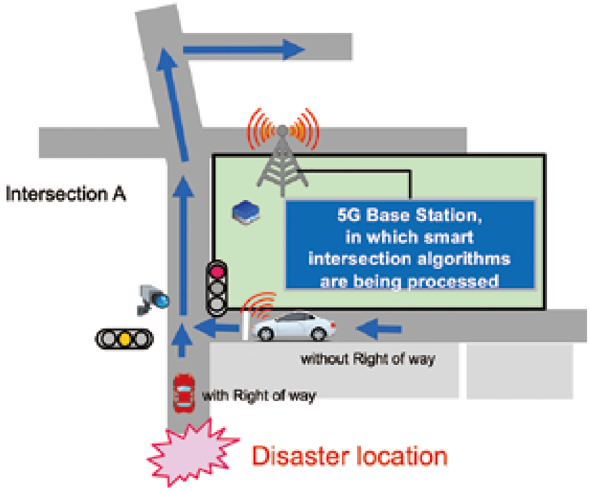
For this field trial, SoftBank Co. Ltd. and Wireless City Planning Co. Ltd. were members of Field Trial Group V (GV), which handles the 5G URLLC domain. The 5G URLLC field trials handled mission-critical use cases, studying applications of 5G to remote operation of passenger vehicles and truck platooning. This article reports on the activities of GV.

2. Evacuation Guidance during Disaster (Smart intersections)

In the use case category of connected vehicles, a field trial was conducted using the low-latency feature of 5G to provide guidance for safe and rapid evacuation during a disaster. The trial was carried out in March 2020, in collaboration with the City of Kitakyushu and the Kitakyushu Foundation for the Advancement of Industry, Science and Technology (FAIS) and in partnership with Nippon Signal Co. Ltd., at the Kitakyushu Science and Research Park (KSRP) in Kitakyushu City, Fukuoka Prefecture. Car collisions and traffic congestion are issues during evacuation when disaster occurs. The trial verified that smart intersections utilizing 5G can help avoid collisions and ensure that evacuations proceed smoothly. The demo scenario examined (i) controlling traffic to merge smoothly at intersections during an evacuation, and (ii) how to avoid collisions between vehicles and protect pedestrians at intersections during evacuation. For use of 5G to provide evacuation guidance during a disaster, the trial focused on three issues: (i) when implementing smart intersections, whether it is possible to significantly reduce the cost at an intersection by utilizing the high capacity and low-latency communication of 5G, (ii) whether advanced intersection control such as collision prevention can be done for vehicles entering an intersection using 5G low-latency, and (iii) whether a low-cost smart intersection with advanced functionality can be built without installing special equipment for traffic control on the roadside, using the high capacity and low latency of the wide-area 5G network.

The evacuation guidance field trial scenario using 5G is shown in Figure 1. In the figure, a 4K surveillance camera is installed at intersection A, and the video from the camera is sent to a Mobile Edge Computing (MEC) server at the 5G base station by a 5G user terminal device installed on the traffic-light pole. The MEC server uses AI image processing to detect the positions of vehicles entering the intersection (in the figure, the red car with the right-of-way, and the white car without right-of-way), and if they get close within a predetermined zone, it sends warnings that they are getting too close, to terminals in the cars via 5G. If they get too close, it also sends a stop command through the 5G connection to the vehicle entering the intersection that does not have right-of-way (the white vehicle in the figure), forcing it to stop and

Figure 1: Field trial scenario for evacuation guidance PoC



preventing a collision. If a pedestrian crosses the intersection, they are also detected in the surveillance camera video using AI image processing, and if the pedestrian and a vehicle get close within a prescribed area, The MEC server at the base station sends a stop command to the 5G terminal in the vehicle, giving it a warning, and even forcing it to stop.

The course used for the field trial at KSRP is shown in Figure 2.

Photographs of the traffic signal, surveillance camera, and 5G terminals installed for the field trial are shown in Figure 3, the 5G base station used is in Figure 4, and the remote-controllable vehicle with 5G terminal installed is in Figure 5.

Figure 2: PoC field trial course

Kitakyushu Science and Research Park

Figure 3: Smart intersection

Figure 4: Experimental 5G base station

Figure 5: Remote-controlled car with onboard 5G user terminal

The results of the field trial showed that a low-cost smart intersection able to protect pedestrians and prevent vehicle collisions can be implemented, without installing expensive sensors at intersections, using just a 5G terminal and a surveillance camera (with 4K resolution) at the smart intersection. The cost of the smart intersection system at each intersection for installation and maintenance can be reduced significantly, because AI and other advanced image analysis of video from the intersection can be performed centrally by a MEC server at the 5G base station.

3. 5G Application to remote operation of abandoned vehicle

In the use case category of connected vehicles, a field trial of remote vehicle operation using the low-latency feature of 5G was conducted. The trial was demonstrated in March 2020, in collaboration with the City of Kitakyushu and the Kitakyushu Foundation for the Advancement of Industry, Science and Technology (FAIS) and in partnership with FEV Japan, Co. Inc., which develops remote control vehicles, at the Kitakyushu Science and Research Park (KSRP) in Kitakyushu City, Fukuoka Prefecture. The scenario for this field trial was the removal of abandoned vehicles by remote operation, to open up roadways for disaster relief, to help with rapid rescue and recovery during disaster. For disaster rescue, any obstacles on roadways must be removed quickly, so that rescue vehicles can get through. In contrast with wireless control systems using dedicated frequency bands, or local remote control using wireless LAN, using a 5G wide-area cellular communications network for remote operation enables abandoned vehicles to be moved to a vacant area from

Figure 6: Field trial scenario for remote operation of abandoned car

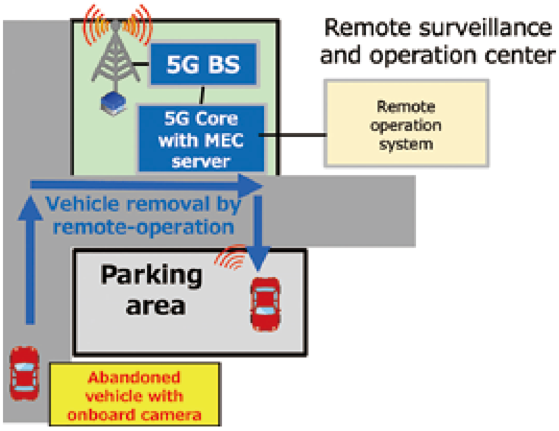


Figure 7: Remote operation of abandoned car from a remote surveillance and operation center

distances of hundreds of km or more away. In other words, using 5G enables disaster rescue and recovery activities to be done in real time from outside of the disaster area.

In the field trial, vehicles were controlled remotely from the remote-vehicle control center through 5G, while looking through a forward-facing onboard camera in the vehicle, and abandoned vehicles were moved from the roadway to a vacant area (Figure 6). In fact, to get a feel for 5G radio control in the trial, the remote vehicle control center was set up under the 5G base station used for the trial and not at a distant location, for demonstration purposes. Figure 7 shows a photograph of performing remote vehicle operation at the remote vehicle operation center.

Conventionally, remote operation has been done with systems using dedicated frequency bands or wireless LAN systems, within the operator's field of view and the radio signal range (tens to hundreds of m). The trial showed that, using the high capacity and low-latency of 5G communication, an operator can operate a vehicle by looking through a high-resolution onboard camera with low-latency communication rather than having the vehicle in their field of view. 5G networks have low latency in the tens of milliseconds, even including network delay, so remote operation will be possible even from locations hundreds of kilometers away in the future. This field trial showed that when a disaster occurs, damage recovery with remote operation from outside the disaster area will be possible using the low latency and high-capacity of wide-area 5G networks.

4. 5G Application to truck platooning

In the use case category of automated vehicles, a field trial of truck platooning (self-driving following vehicles) using the high reliability and low latency of 5G was conducted. With truck platooning, several trucks form a platoon and drive together. Communication between trucks is used to control the platoon as one unit.

Truck platooning can be used to solve various societal issues. The distance between trucks can be reduced through platooning, reducing air resistance, and improving fuel economy. It has been shown that a three truck platoon travelling at 80 km/h with 4 m between trucks would reduce fuel consumption by 15%[2]. By further reducing the separation to 2 m, fuel consumption would be reduced by 25%. Reducing the distance between vehicles also increases capacity of the roadway, mitigating congestion. This can also reduce CO2 emissions. There are also other societal issues in Japan, such as an aging driver population and driver overwork. Platoon driving can be expected to reduce driver workload and improve safety.

Use of 5G for communication between vehicles can improve stability and reduce a phenomenon called hunting (fluctuation of distances between vehicles), which is caused by delay in the control process. To further reduce fuel consumption and increase capacity of roadways, the distance between vehicles must be reduced still more, and the number of vehicles in a platoon increased, while still maintaining safety, so application of 5G URLLC, with its low latency and high reliability, is anticipated for application in this field.

In FY2019 (Feb. 2020), a field trial was conducted on the Shin-Tomei expressway using 5G URLLC for platooning, with an inter-vehicle distance of 10 m (trials in FY2018 used 35 m), and with later trucks following the lead truck (steering control). The trial was done in partnership with Advanced Smart Mobility Co. Ltd. (ASM) and received technical and operational support from the Platooning Project of the Ministry of Economy, Trade and Industry (METI) and the Ministry of Land, Infrastructure and Transport (MLIT). Several 5G bases stations were also installed along the Shin-Tomei Expressway and trials were conducted on dynamic switching with two modes of radio resource management: (1) base station control mode and (2) autonomous

Figure 8: Field trial of 5G Truck platooning on Shin-Tomei expressway —CACC—

■ **Figure 9: Field trial of automated following of a leading vehicle using 5G —automated steering—**

control mode; for 5G New Radio (NR) Sidelink (vehicle-to-vehicle direct communication).

Trial conditions on the Shin-Tomei Expressway are shown in Figure 8 and Figure 9.

5. Conclusion

Field trials of 5G ultra-reliable low latency communication (URLLC) in the use case category of connected cars and automated vehicles were conducted. For connected vehicles, field trials of smart intersections and vehicle remote control were done in the city of Kitakyushu. The actual use cases for the trials were of giving fast and safe evacuation guidance and of clearing roadways during a disaster. Results showed that smart intersections can be created at low cost per intersection using 5G, and that vehicles can be cleared from roadways using remote control from outside of the disaster area, even hundreds of kilometers distant.

In the field of automated vehicles, 5G was applied to truck platooning (automatic driving of following trucks), and driving trials were conducted on the Shin-Tomei Expressway. Results verified that 5G was effective in two cases: for low-volume, low-latency communication needed for truck platooning (for vehicle control), and for high-volume, low-latency communication (for monitoring the following trucks).

References
[1] MIC, “5G Comprehensive Demonstration Tests Begin,” Press Release, http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000297.html, May 2017.
[2] K. Aoki, “Implementing autonomous driving and platooning —State of autonomous driving development—,” pp.303-309, IPSJ Journal, Vol. 54, No. 4, Apr. 2013.

Part II: Field Trial for Early Introduction of 5G Massive Machine-type Connectivity

Field Trial Group 6 Wireless City Planning Inc.:
Hideto Funayoshi, Yusuke Tajima

1. Introduction

Products are currently being developed and implemented for commercialization of 5th Generation Mobile Communication systems (5G) in 2020. 5G is anticipated as next generation social infrastructure featuring ultra-high-speed communication, but it also features ultra-reliable low-latency communication (URLLC) and massive Machine-Type Communication (mMTC). Establishing concrete uses cases for these features is an urgent matter.

This article introduces field trials of two such use cases, conducted as 5G commercial services were starting in 2020. The first was i-Construction, which was proposed at a 5G utilization ideas contest for solutions to regional issues, with the theme, “Safe, secure, labor-saving, and usable anywhere.” The second use case was smart logistics, to deal with a serious labor shortage in the logistics industry.

2. 5G for i-Construction

Because the population of working-aged people in Japan is decreasing, various industries need to increase labor productivity by upgrading information and communications (ICT) and other equipment, reducing travel and labor by utilizing data, and other measures. Japan is also very mountainous, with many tunnels as part of the social infrastructure. Serious accidents can occur on tunnel construction work sites, such as cave-ins, landslides, suffocation, and fires, so safe and secure work environments must be implemented.

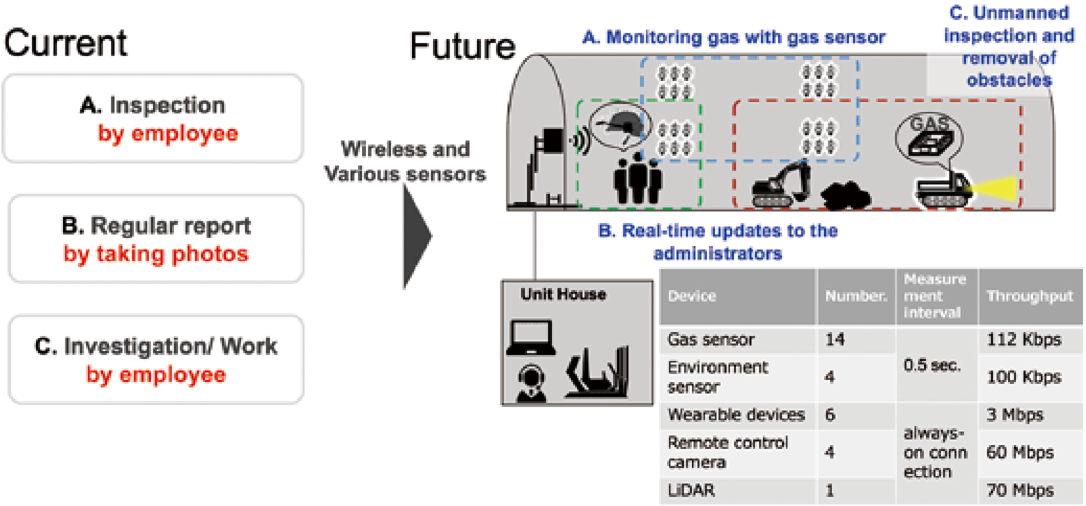
In this field trial, sensors for dangerous toxic or flammable gases, and other indexes of work environment conditions such as temperature and carbon dioxide were installed to detect hazards within a tunnel, and data was collected through 5G, making it easier to detect these dangers. If an accident occurred, unmanned construction equipment was also remotely operated to perform an initial safety check inside the tunnel.

2.1 Tunnel construction site safety monitoring with gas sensors, environment sensors and wearable sensors, and remote operation of construction machinery for initial safety confirmation during disaster

This trial involved a system to monitor safety in tunnel worksites, using gas and other environmental sensors and wearable sensors to gather data on poisonous or flammable dangerous gases that can occur in tunnel worksites, to monitor work environment indices such as temperature and carbon dioxide levels in real time, and to send alerts to workers if dangerous levels were detected.

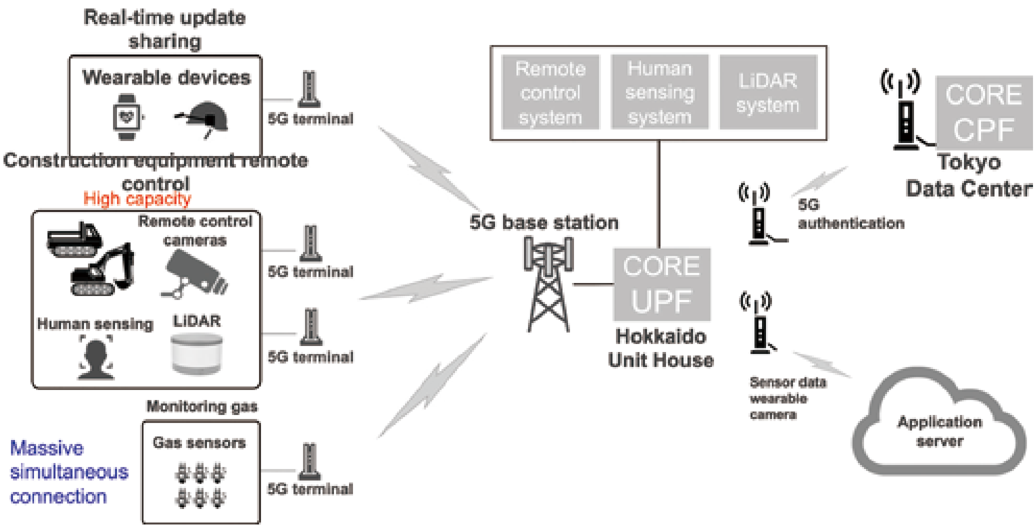
Then, 5G terminals were installed with remote control equipment on a hydraulic shovel and crawler carrier at the tunnel work site, to build an environment remotely operating construction equipment from an operator room outside of the tunnel. By using 5G high capacity communication and a MEC server, the trial verified that construction equipment could be operated remotely from the operating room, approximately 1,400

■ Figure 1: Issues with tunnel work and trial details

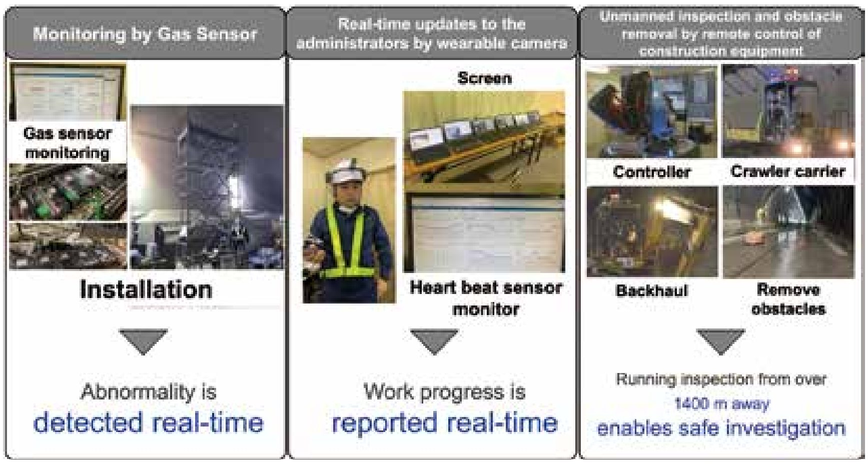


Device	Number.	Measurement interval	Throughput
Gas sensor	14	0.5 sec.	112 Kbps
Environment sensor	4		100 Kbps
Wearable devices	6	always-on connection	3 Mbps
Remote control camera	4		60 Mbps
LiDAR	1		70 Mbps

■ Figure 2: System architecture



■ Figure 3: Trial results



m from the 5G equipment, and that video from four, full-HD cameras mounted on the equipment could be transmitted to the control room, with no problems due to data loss or delay. Gas sensors were also installed on the construction equipment, and the trial verified the ability to check the environment in the tunnel.

2.2 Verifying slicing functions integrating various communication requirements

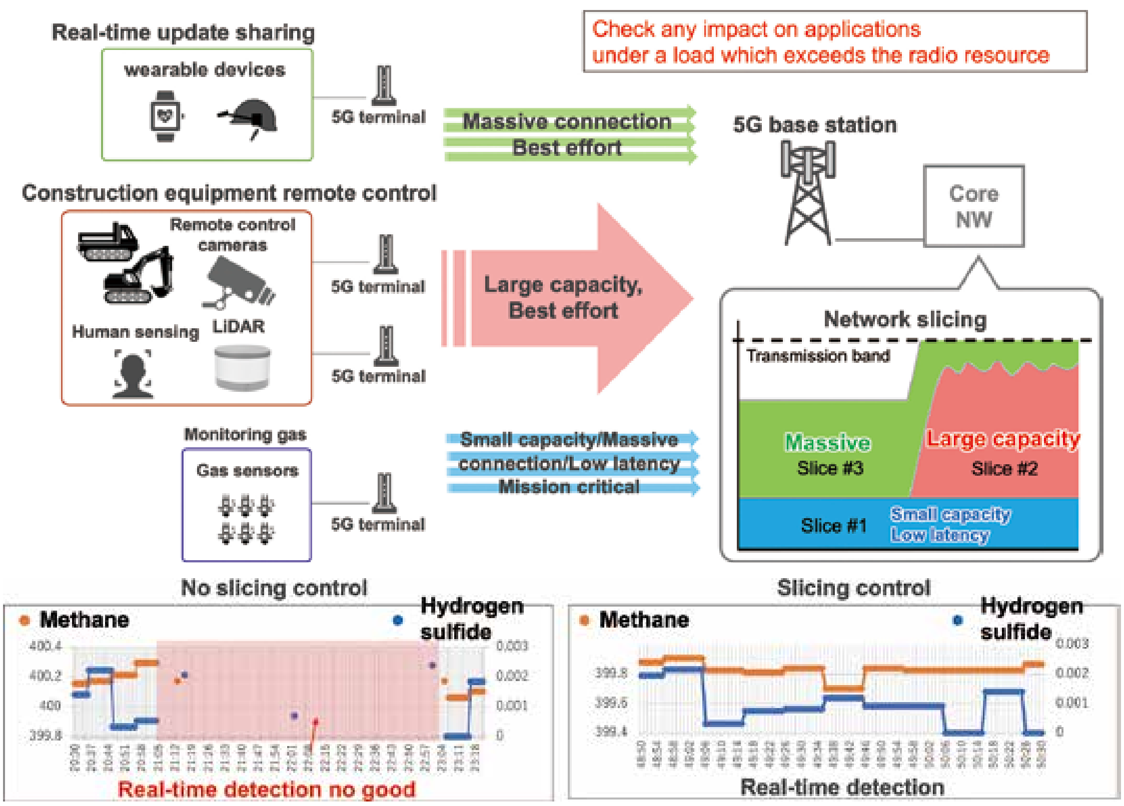
It was anticipated that wireless communication capacity could be strained when remotely controlling construction equipment to check site safety when a disaster has occurred. This would require high-capacity communication in a tunnel construction site with many IoT devices such as gas and other environmental sensors. Accordingly, the trial also verified the performance of per-application priority control using the network slicing function. The slicing function allows the required bandwidth to be guaranteed for the priority application, according to a pre-determined priority profile, even if the capacity is strained. In this trial, gas sensor data, which is life-critical, was given the highest priority and communication for remote operation of equipment was given the next highest priority. In this way, the ability to transmit gas sensor data without loss, and to transmit the video data required to control equipment remotely, with acceptable delay, was verified.

3. Smart logistics

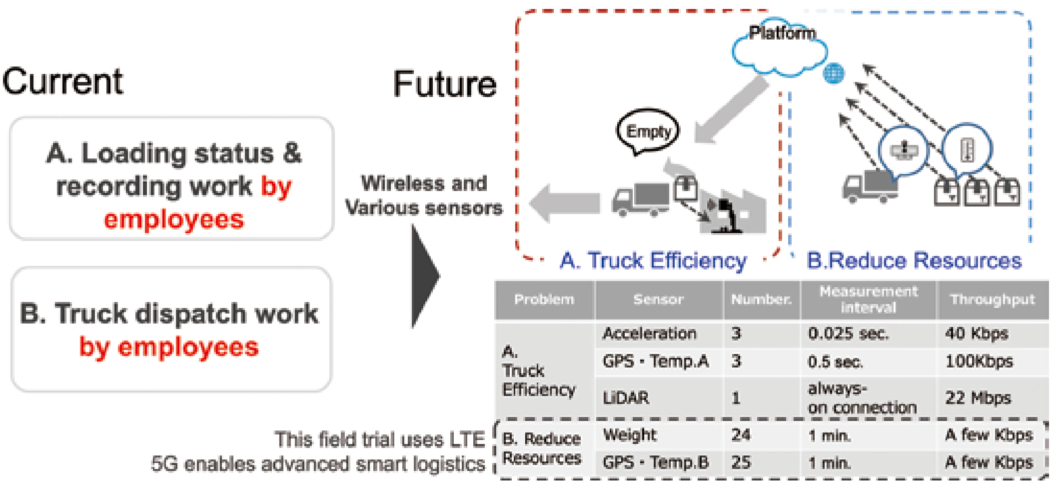
A promising way to address significant issues in the logistics industry, such as the shortage of truck drivers and reforming work practices, would be to build an efficient cargo loading system. As Mobility as a Service (MaaS) has developed, various measures have also been proposed, such as mixing loads of passengers and goods or sharing transport, and there is increasing need to visualize load data in order to implement such measures.

To deal with such needs and issues, Wireless City Planning and Nippon Express are conducting a field trial using 5G networks with LiDAR (laser scanners) to visualize the state of the load on a truck, and acceleration and other sensors to make decisions about loading the storage compartment. A field trial

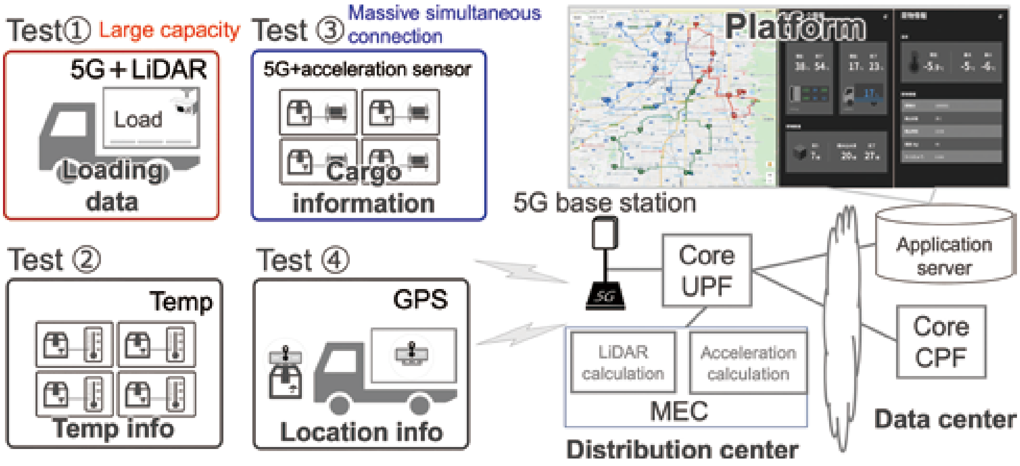
■ Figure 4: Use of network slicing



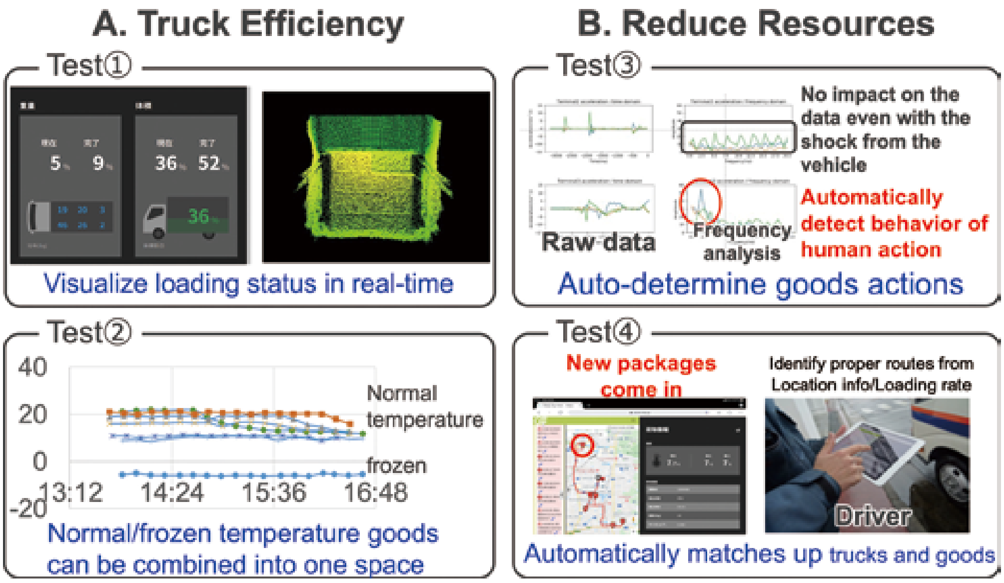
■ Figure 5: Issues with cargo loading work and trial details



■ Figure 6: System architecture



■ Figure 7: Trial results



was also conducted using Cat. M1 to check load temperature and weight.

3.1 Truck load state visualization and loading decisions using 5G and a MEC server

To visualize the space available in the cargo area of a truck, a 5G terminal was used to send a point set of the space, obtained using LiDAR, to a manager in a location distant from the truck. Using high-capacity 5G communication and a MEC server, the point set data from the cargo area can be transmitted and analysed in real time, and the load state can be visualized on the manager's screen. By attaching sensors to the freight that send data frequently, the trial verified that whether the freight has been packed in the cargo area can be detected based on the acceleration and location data from the sensors.

4. Conclusion

This article has described two usage scenarios envisioned for 5G mass connectivity, working toward implementations of 5G in society that provide solutions to regional issues.

In tunnel recovery work after a disaster as envisioned for i-Construction, workers would conventionally have to check the environment with absolutely no idea what the conditions were. However, by using remote operation of equipment and gas sensors to get information, it was demonstrated that a higher level of safety can be expected. With smart logistics, it was shown that the system could be used to save labor by reducing the amount of work in loading cargo, and also by increasing loading efficiency. Both of these use cases required an amount of traffic exceeding that specified by ITU-R, but the implementation operated without difficulty using 5G. The two use cases also required the 5G network to satisfy both ultra-fast communication and massive connectivity requirements at the same time, and this was shown to be possible with a single base station.

These trials also revealed further issues with implementation of 5G in society, including packaging, reducing the size, power consumption and price of 5G terminals, and selecting sensor devices with consideration of measurement accuracy. Further study of these issues will need to continue in the future.