2019 Field Trial Results: Part 2

Field Trial Group 3

Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Urban and Suburban Settings

Field Trial Group 4

Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Indoor Environments

Akira Matsunaga
Mobile Network Technical Development Division
KDDI

Hiroyuki Yokoyama
Advanced Telecommunications
Research Institute International

1. Introduction

The FY2019 5G Comprehensive Demonstration Tests[1] (hereinafter referred to as "5G Field Trials") initiated by the Ministry of Internal Affairs and Communications (MIC) included field trials of use cases leveraging the features of the 5th generation mobile communications system (hereinafter referred to as "5G"). These field trials were part of a "contract for investigating technical criteria of a 5th generation mobile communications system capable of ultra-high-speed communications exceeding a bit rate of 300 Mbps on average in the uplink from a terminal in an urban or suburban environment consisting of multiple base stations and multiple terminals" (hereinafter referred to as "field trials of use cases exploiting 5G ultra-high-speed communications in urban and suburban settings") and of "achieving ultra-high-speed communications exceeding a bit rate of 300 Mbps on average in the uplink from a terminal in indoor environments" (hereinafter referred to as "field trials of use cases exploiting 5G ultra-high-speed communications in indoor environments"). This article provides an overview of these field trials. Videos of these field trials have been placed on the Web.[2]

2. Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Urban and Suburban Settings

Field Trial Group 3 KDDI:
Akira Matsunaga, Satoshi Nakano,
Masahiko Nakao, Yuki Shida,
Seiichiro Sakai

Envisioning four use cases exploiting 5G, we conducted field trials in collaboration with partners (Table 1). The technical objective of these field trials was to achieve ultra-high-speed communications in uplink communications from user terminals in an environment consisting of multiple base stations and multiple terminals.

2.1 Invigorating the new sporting event of "slacklining"

The promotion of new sporting events suffers from a number of problems due, for example, to the inability of spectators to understand the rules of the game or the difficulty of the skills required. As a result, the appeal of new sports has not been adequately conveyed and a sense of unity has not been created among spectators as well as between spectators and athletes. The purpose of this field trial was to revitalize regional communities by giving a boost to sporting events rooted in regional areas. Specifically, we conducted a field trial of a new viewing experience for the new sporting event of "slacklining" exploiting the ultra-high-speed and low-latency features of 5G at the 2019 Slackline

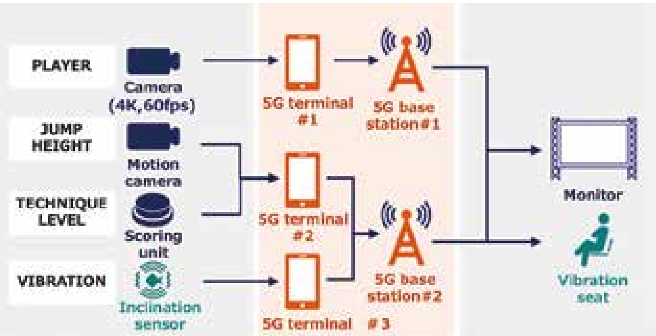
■ Table 1: List of use cases

Use case	Frequency band	Implementers/partners
Invigorating the new sporting event of "slacklining" *	28 GHz	KDDI, Goolight, Asobism, Japan Slackline Promotion Organization, Obuse Town
Discovering potential distress and sharing information in a mountain climber observation system *	28 GHz	KDDI, Shinshu University, Chuo Alps Kanko Co., Ltd., Komagane City
Promotion of tourism using high-definition omnidirectional VR video *	28 GHz	KDDI, Tokai University, Air Camera, Agrid, Minamiaso Village
Integrated management system of construction work	28 GHz 3.7 GHz	KDDI, Obayashi Corporation, NEC Corporation

Note: Use cases marked with an asterisk (*) were top winners in the 5G Utilization Idea Contest held by the Ministry of Internal Affairs and Communications in FY2018[3].

■ Figure 1: Slacklining competition

■ Figure 2: Configuration of field trial for promotion of slacklining



■ Figure 3: Monitor video and vibration seat at venue

World Cup Japan FULL COMBO held at Obuse Park in Nagano prefecture in September 2019.

Slacklining is a sport that lets players compete in acrobatic skills while jumping on a 5 cm wide line and that involves competition in terms of trick difficulty, proficiency of movements, etc. (Figure 1).

In this field trial, we installed two 5G base stations at a height of 5 m above the ground and set up three 5G terminals to conduct two separate field trials as use cases (Figure 2).

In the first field trial, we transmitted 4K high-definition video of the competition by 5G together with information such as the height of a jump automatically determined from the video of a motion camera and trick level, number of consecutive jumps, etc. determined by a judge. We then combined all of this information in the video and relayed it in real time to a large monitor at the venue so that spectators could better understand trick level and other aspects of the sport. Next, in the second field trial, we used inclination sensors installed on the slackline to detect the instantaneous vibration that occurs when a player makes contact with the slackline and transmitted that sense of vibration to vibration seats installed in the spectator seating area via 5G. We were able to transmit this vibration information with a delay of 41 – 50 ms by exploiting the low-latency characteristics of 5G. This enabled spectators to feel the impact of a jump synchronized with what they were seeing with their own eyes and to feel a sense of unity with the player. Spectators that experienced this sensation offered comments such as “I felt as if I was jumping in the air! I’d like to try slacklining” (Figure 3).

This field trial demonstrated that a transmission system leveraging the ultra-high-speed and low-latency features of 5G could promote understanding of important game rules and the challenge of certain skills while contributing to new and exciting experiences for spectators.

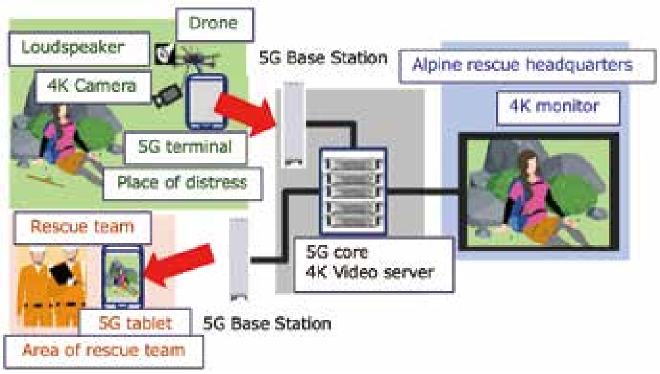
2.2 Discovering potential distress and sharing information in a mountain climber observation system

In recent years, the number of disasters and accidents involving mountain climbers has been on an upward trend thereby increasing the workload of rescue operations. To solve this problem, we have developed a mountain climber observation system that can detect the location of a mountain climber by having mountain climbers carry a Low Power Wide Area (LPWA) terminal with a built-in GPS function and transmitting that GPS location information to alpine rescue headquarters by LPWA at the time of an accident.

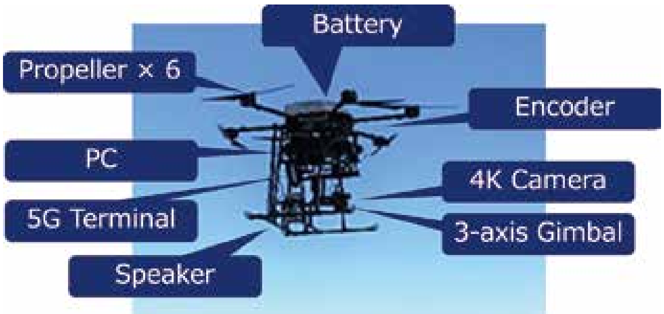
The purpose of this field trial was to help improve rescue operations by first obtaining accurate information on the location of the victim through the mountain climber observation system and to then transmit high-definition video of the accident scene from a drone having a compact airframe and excellent mobility using the 5G feature of ultra-high-speed communications in the uplink. The first step in this trial was to capture the reaction of the victim when hailed from the drone equipped with a 4K camera, loudspeaker, and 5G terminal. The next step was to relay that 4K high-definition video to a monitor at the alpine rescue headquarters and a tablet-type 5G terminal held by the rescue team (Figure 4). To test the feasibility of these operations, we conducted this field trial in the vicinity of Hotel Senjojiki at Mt. Komagatake in Nagano prefecture in October 2019.

Prior to testing this use case, we evaluated the 5G radio performance by equipping the drone with a 5G terminal and measuring uplink throughput at 15 points (Figures 5 and 6). Based

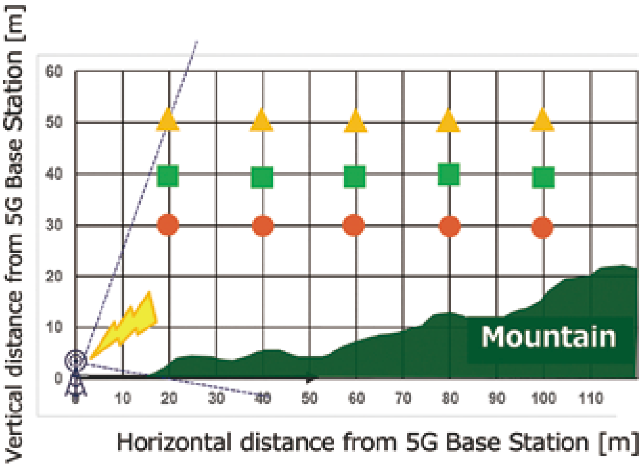
■ Figure 4: Configuration of field trial of mountain climber observation system



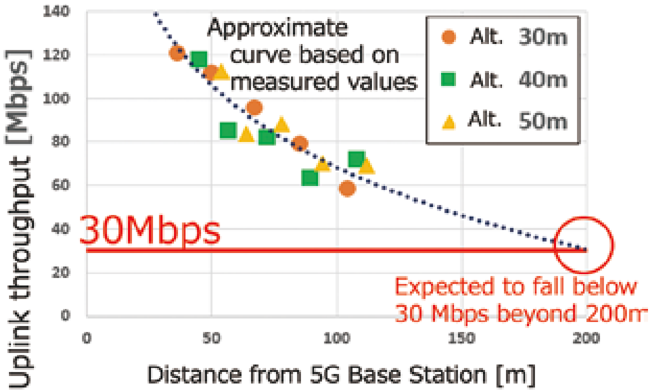
■ **Figure 5: External view of drone**



■ **Figure 6: Measurement points**



■ **Figure 7: Measurement results**



■ **Figure 8: Scene of field trial of mountain climber observation system**

on the results of these measurements, we inferred, for this field trial configuration, that the maximum range for achieving 30 Mbps in the uplink as required for this use case involving 4K video transmission was approximately 200 m from the 5G base station (Figure 7).

Next, we successfully transmitted 4K high-definition video from the drone to both the alpine rescue headquarters and rescue team by 5G and showed that the accident scene could be grasped in greater detail in this way (Figure 8). The rescue team that participated in this demonstration commented that they looked forward to actual implementation of the system because, in their words, "We could obtain a better understanding of the victim's situation."

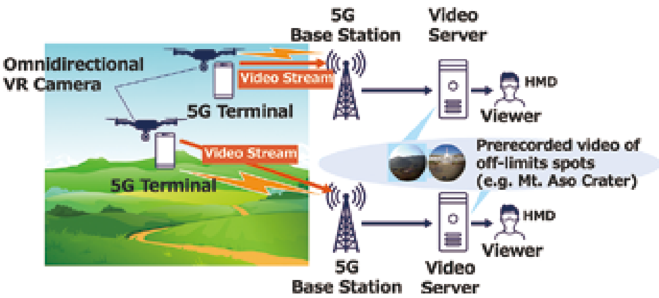
2.3 Promotion of tourism using high-definition omnidirectional VR video

Since the Kumamoto earthquake in 2016, the revitalization of tourism to ignite a recovery in tourist numbers has been a major issue for Minamiaso village. However, many tourist sites in the Minamiaso area such as the Mt. Aso crater and colonies of rare plants have become off limits or severely limited from the viewpoints of safety or environmental protection. As a result, traditional approaches to tourism have not been sufficiently conveying the charm of this region. In this field trial, we flew two drones each equipped with a high-definition omnidirectional virtual reality (VR) camera over such tourist sites and presented the video to individual tourists visiting the area in real time through a head-mounted display (HMD). In this way, we envisioned a use case that could provide a means of tourism that was safe and not environmentally destructive and that could convey the beauty and charm of the Minamiaso area (Figure 9).

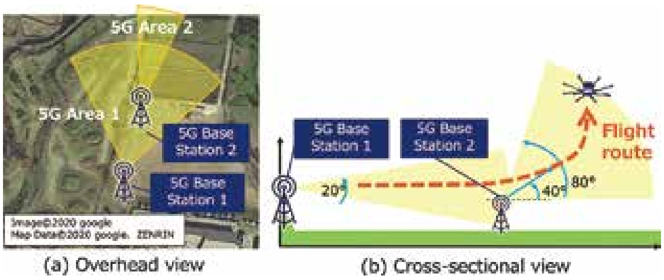
In this field trial, we installed two 5G base stations at roadside station "Asobou no Sato Kugino" in Minamiaso village and conducted the field trial in December 2019 (Figure 10).

We flew the two drones each equipped with a 5G terminal over two overlapping areas each covered by one of the base stations in an airspace ranging as far as 67 m from the base station. We captured high-definition omnidirectional VR video on the two drones and transmitted the video in real time to two HMDs, respectively (Figure 11). We also supplemented this live video transmitted from the drones with prerecorded video of structural remains from the earthquake that are now off limits as well as regional images and seasonal images and enabled tourists to switch between the video and images via a HMD as desired.

■ **Figure 9: Overview of field trial for promoting tourism using VR video**



■ **Figure 10: 5G evaluation environment**



■ **Figure 11: Scenes of field trial**

The president of "Asobou no Sato Minami-Aso," a company involved in local tourism and a collaborator in this field trial, said "Aerial sightseeing by helicopter, which was popular in the past, is now on hold due to noise issues associated with flights, but I feel that this demonstration that included scenes from below and behind may even be better. Image quality is good and I expect further improvements to be made." This comment underscores the possibility of creating attractive sightseeing services using 5G.

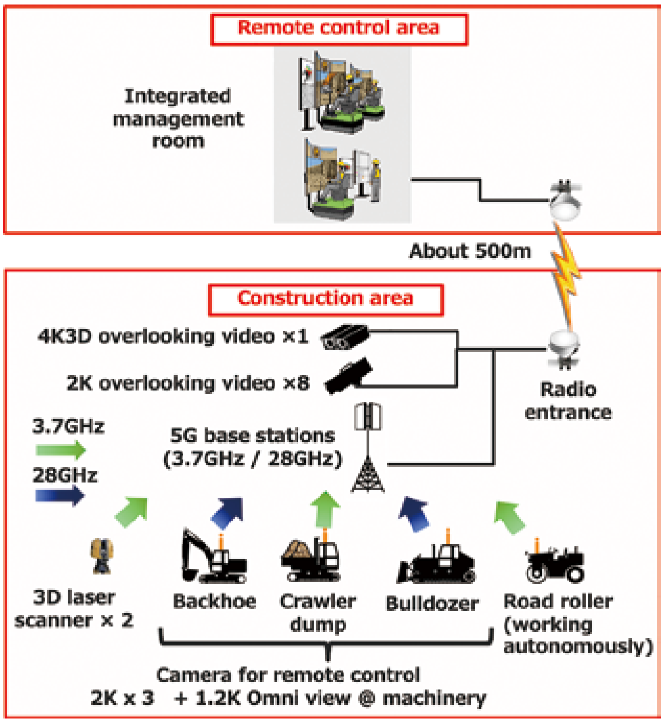
2.4 Integrated management system of construction work

The purpose of this field trial was to deal with the shortage of on-site workers in construction work and to achieve real-time management of massive amounts of on-site work data to make the entire process more efficient. We conducted this field trial simulating road construction at a dam construction site exploiting the 5G features of ultra-high-speed and low-latency communications.

As part of the 5G Field Trials, trials examining the remote control of construction machinery using 5G began in FY2017 and the successful remote control of a single machine was demonstrated in the same year. Then, in FY2018, a field trial envisioning the work of recovering from a landslide disaster was conducted. This trial involved the rapid deployment of a 5G network in the disaster-hit area, the remote control of two machines that work together, and the removal of landslide debris.

Next, in FY2019, with an eye to applying remote control to general construction work based on construction drawings, an "integrated construction management system" was created that combined the remote control system with a machine guidance system for determining machine working status and 3D laser scanners for measuring work results. Using this system, a field trial simulating road construction was conducted at Kawakami Dam in Mie prefecture in February 2020. In the trial, road construction was performed by three pieces of machinery (backhoe, crawler dump, and bulldozer) remotely controlled via 5G and by an

■ **Figure 12: Configuration of field trial of integrated management system of construction work**

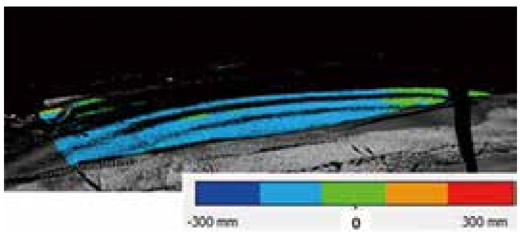


autonomously operated machine (road roller). This was combined with high-precision management of completed work important in general construction work and with real-time remote quality management of compactness, which is the most important factor in road construction (Figure 12). The results of this field trial revealed video transmission latency of 140 ms – 220 ms. The standard target for transmission latency for achieving remote operation without discomfort or confusion is no more than 200 ms, so from an operator's viewpoint, these results showed that work could be sufficiently performed.

This field trial also showed that the state of earth leveling by the bulldozer, the number of surface compaction runs by the road roller, etc. could be displayed on machine guidance system screens in color-coded schemes and that the results of measuring unevenness of the constructed road by the 3D laser scanners could also be displayed. In short, it was possible to present the state of construction work to construction supervisors in real time (Figure 13).

In this field trial of road construction, we measured work time in relation to transport and construction and compared measured values with labor productivity standards of the Ministry of Land,

■ **Figure 13: Deviation from targeted height after road construction**



Infrastructure, Transport and Tourism (MLIT). Construction work by remote control is generally considered to require 1.5 – 2.0 times the corresponding labor productivity standards, but in this field trial, we obtained work times of approximately 1.4 times those standard values, which was a favorable outcome. The reasons for this were (1) the transmission of high-definition video could be integrated with supplementary information such as that from 3D laser scanners and (2) operators working together could control their machines sitting side-by-side in the management room within the remote control area and could therefore communicate smoothly with each other, which would not normally be possible at a noisy construction site. Operators involved in this remote operation were impressed with "a sense of operation without any discomfort or confusion" and evaluated the trial positively with comments like "I could perform construction in a comfortable environment through remote operations."

At this construction site, the work surface was prone to unevenness due to the cohesive and soft soil of the foundation, and we found that leveling the soil by bulldozer via video-assisted remote control was quite difficult since this type of work requires sensitive operations. We therefore determined that there was room for system improvements with respect to work that requires a finished form. In the machine guidance system used in this trial, the operator controlled the bulldozer's blade for soil leveling and the direction taken by the bulldozer. However, if a recently automated system were to be introduced, the operator could concentrate on only bulldozer direction and entrust this automated system with blade operations that are highly difficult in remote manual control. In this way, we can expect the required level of precision to be achieved even in remote operations.

This field trial demonstrated the feasibility of road construction by remove control of construction machinery using 5G and the possibility of applying 5G to general construction work. At present, the construction industry assumes that all construction work must be carried out on-site since it is not possible to concentrate operations in the manner of a manufacturing hub in the manufacturing industry. However, remote control as demonstrated by this field trial opens up the possibility of consolidating at least part of the construction process in a permanent hub and revolutionizing construction work including worker roles and production management.

3. Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Indoor Environments

Field Trial Group 4 Advanced Telecommunications Research Institute International:
Hiroyuki Yokoyama

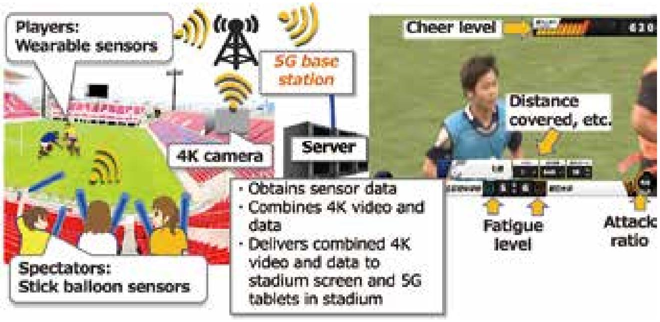
Envisioning four use cases exploiting 5G, we conducted field trials in collaboration with partners (Table 2). The technical objective of these field trials was to achieve ultra-high-speed communications in uplink communications from a user terminal in indoor environments.

3.1 Sports viewing to enhance sense of unity between players and spectators

With the aim of revitalizing regional sports stadiums, we conducted a field trial of a new sports-viewing system at the Hanazono Rugby Stadium in Higashiosaka, Osaka in October 2019. This system exploits the 5G feature of ultra-high-speed communications to share players' vital data and the level of spectator cheering and bring about a sense of unity between the players and spectators. It enables degree of player fatigue, level of cheering, etc. obtained from sensor data to be visualized and delivered to 5G terminals and the main stadium screen after being synthesized with the live video (Figures 14 and 15). In the trial, spectators were encouraged to cheer on the players when they got tired, and at halftime, the spectators themselves participated in a cheering competition that included game-like elements.

These new sports viewing technologies powered by 5G can enhance the sense of unity between players and spectators, and increase the number of people attending regional stadiums.

■ Figure 14: Concept of sports-viewing field trial



■ Table 2: List of use cases

Use case	Frequency band	Implementers/partners
Sports viewing to enhance sense of unity between players and spectators *	28 GHz	ATR, KDDI, Jupiter Telecommunications, Data Stadium, Knows, TECHTUITE
Streamlining of diary/livestock industry *	28 GHz	ATR, KDDI, Waseda University, University of Miyazaki, Kamishihoro Town, Tokachi Murakami Farm
Support of racehorse breeding *	28 GHz	ATR, KDDI, The University of Tokyo, Sharp Corporation, Niikappu Town, Hidaka Racehorse Cooperative Upbringing Center

Note: Use cases marked with an asterisk (*) were top winners in the 5G Utilization Idea Contest held by the Ministry of Internal Affairs and Communications in FY2018[3].

■ **Figure 15: Video delivered in sports-viewing field trial**

(a) Video delivered to a 5G terminal

(b) Video delivered to stadium screen

3.2 Streamlining of diary/livestock industry

With the purpose of raising the efficiency of the dairy/livestock industry, we conducted a field trials for two use cases in November 2019 at Tokachi Murakami Farm in Kamishihoro town, Hokkaido (Figure 16). The first trial aimed to detect the location of cows within a cowshed from 4K video transmitted by 5G such as when a veterinarian wants to check for signs of a breeding period or diagnose the health of a cow. In this trial, we installed multiple 4K cameras within the cowshed, shot the cows while fixed to a stanchion during feeding, and transmitted the video to servers by 5G. The ID numbers on the ear tags of the cows were identified using a video analysis program running on these servers and were then used to display the positions of these cows on a tablet (Figure 17 (a)).

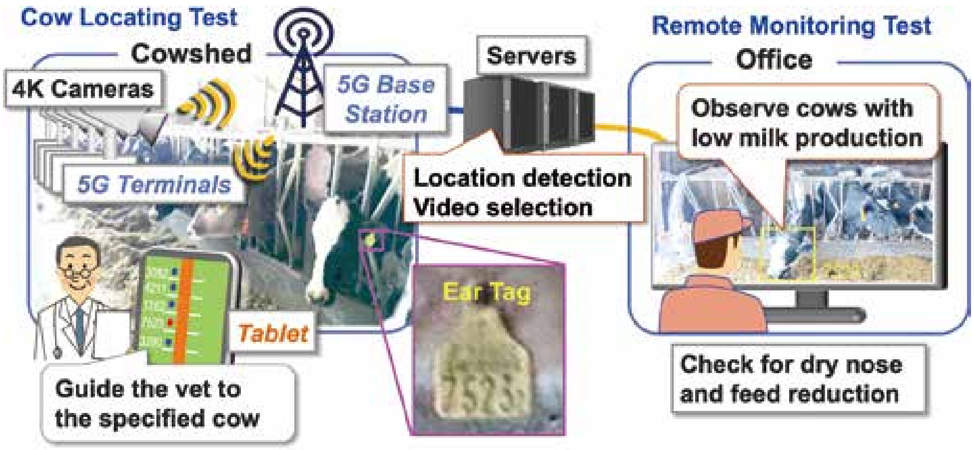
The second field trial aimed to remotely monitor cows from an office via 4K video to observe, for example, cows with low milk production. We confirmed that real-time or stored 4K video of the cows specified by ID numbers could be shown on the screen in the office (Figure 17 (b)).

These results showed that the time required to search for a cow's location, which takes more than 15 minutes per head by visual means, could be greatly reduced and that a specific cow could be remotely monitored, all of which should increase work efficiency in this industry.

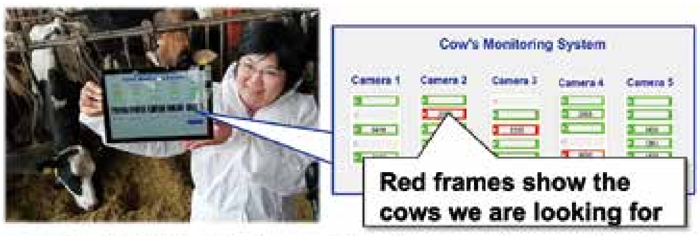
3.3 Support of racehorse breeding

To support the racehorse breeding industry, we envisioned the use of 5G to enable horse owners and production ranch owners to observe the raising of entrusted horses from afar. To judge the

■ **Figure 16: Overview of field trials for dairy/livestock industry**



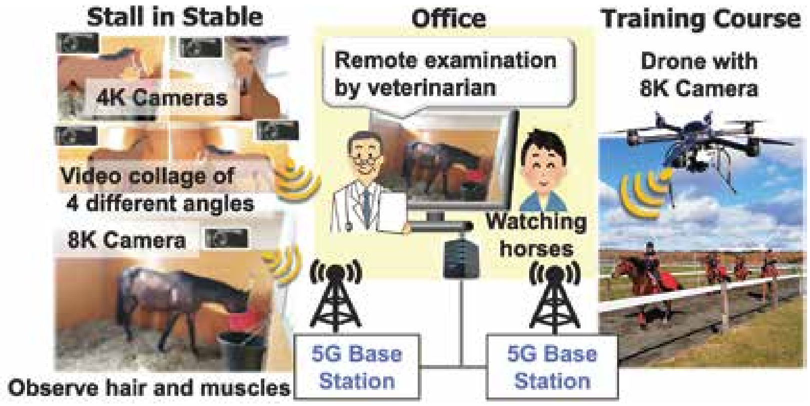
■ **Figure 17: Field trials for dairy/livestock industry**



(a) Field trial of searching for cows in cowshed

(b) Field trial of monitoring cows from an office

■ Figure 18: Overview of field trials in support of racehorse breeding industry



■ Figure 19: Field trials in support of racehorse

merits of this premise, we conducted a field trial of using 5G ultra-high-speed communications to transmit 8K video of racehorses at the Hidaka Racehorse Cooperative Upbringing Center in Niikappu town, Hokkaido in November 2019 (Figure 18). In this trial, we installed 5G base stations at two locations inside a stable and beside the training course. We also installed four 4K cameras within a stall in the stable for monitoring by staff and remote diagnostics by veterinarians. These four 4K video streams were combined into one 8K video stream and transmitted by 5G to an office. In addition to the above, we installed an 8K camera in the stable passageway to capture a horse's gait and transmitted this video by 5G to the office in the same way. At the training course, we captured the running of horses by a drone equipped with an 8K camera and succeeded in transmitting 8K video streams with uplink throughput over 120 Mbps (Figure 19). In this way, the condition of a horse's muscles built up through training, its hair gloss, and other characteristics could be checked through remote monitoring, which shows that 5G and 8K video can be useful tools in racehorse breeding.

These technologies will improve service and access for horse owners and increase ranch-related tourism through video distribution.

4. Conclusion

This article introduced the results of conducting "field trials of use cases exploiting 5G ultra-high-speed communications in urban and suburban settings" and "field trials of use cases exploiting 5G ultra-high-speed communications in indoor environments."

Acknowledgments

We would like to express our deep gratitude to the Ministry of Internal Affairs and Communications and related institutions for their cooperation in holding these field trials.

References

[1] Ministry of Internal Affairs and Communications: "Start of FY2019 5G Comprehensive Demonstration Tests."
https://www.soumu.go.jp/menu_news/s-news/01kiban14_02000390.html, Aug. 2019.
https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/pressrelease/2019/8/16_1.html (in English)

[2] URLs to reference videos on KDDI's official YouTube channel for each section of this article:
Section 2.1: https://youtu.be/S_mOloyQk6s
Section 2.2: https://youtu.be/Zr3u0xCFBuE
Section 2.3: https://youtu.be/JcrlzK7nLac
Section 2.4: https://youtu.be/fZ_vm5U8LTI
Section 3.1: https://youtu.be/clhCCTTi-7U
Section 3.2: https://youtu.be/DyQqvYx0mhY
Section 3.3: https://youtu.be/WtvhSTebvLw

[3] Ministry of Internal Affairs and Communications: "5G Utilization Idea Contest,"
https://5g-contest.jp/, Jan. 2019.