Innovation Projects Utilizing 5G Technology

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Abstract

We planned and implemented a project utilizing "5G" (5th generation mobile communication system), one of the most promising technologies of the future. "5G" has the features of "high speed, large capacity", and "low latency" compared to conventional systems, and we utilized these features to develop three measures to realize "a new style of spectating". Unfortunately, there were no spectators at the venues, but the experience was well-received, especially by those involved in the Games. This new style of spectating, including its application to other competitions, is expected to take off in the future.

Keywords : Innovation, 5G, High-speed, Large capacity, Low latency, Highly realistic, New style of spectating

1. Introduction

The Tokyo Organising Committee of the Olympic and Paralympic Games has made several efforts to make the Olympic and Paralympic Games Tokyo 2020 (hereinafter referred to as "Tokyo 2020 Games") "the most innovative Games in history". To provide an "innovative new spectator experience", we have been working to develop and realize measures that utilize one of the latest technologies, "5G".

"5G" is an abbreviation for the 5th generation mobile communication system, a next-generation communication standard used for cell phones and other communications. Compared to "4G", which is currently in widespread use, it has features such as "high speed and large capacity" and "low latency". For example, the maximum transmission speed is expected to be10 Gbit/s with a delay of about 1 ms[1]. The combination of "5G" with other technologies, such as AI (Artificial Intelligence) and IoT (Internet of Things), is expected to bring about new changes in industrial structures, and its introduction is progressing worldwide. The introduction of these technologies is progressing around the world. In Japan, commercial services were launched in 2020.

The measures utilizing "5G", the focus of worldwide attention, were made possible by the generous support and cooperation of associated partners. Although the project's goal was to "provide a new spectator experience", and unfortunately, there were no spectators ; the project was able to appeal to Games stakeholders and the media.

This article describes three measures planned and implemented by the "TOKYO 2020 5G PROJECT" (Figure 1), a project that provides a new sports spectator experience utilizing "5G".

Although there were many challenges in realizing the service, each challenge was cleared through coordination with the Games stakeholders, and the measures were implemented mainly at three venues. Among the features of "5G", the "high speed and large capacity" measures for "Sailing" and "Golf" and "low latency" measures for "Swimming competitions" were designed to make the most of these features. The measures for "Sailing" and "Golf" were designed to take maximum advantage of "high speed and large capacity" and "low latency" for "Swimming competitions". The project was implemented under the following structure.

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Figure 1 "Tokyo 2020 5G PROJECT" Logo (©2021-International Olympic Committee-All Rights Reserved)

Organizer : Tokyo Organising Committee of the Olympic and Paralympic Games
Cooperation : Japan Broadcasting Corporation (NHK), The Japan Commercial Broadcasters Association (JBA)
Technical cooperation : Intel Corporation, Nippon Telegraph and Telephone Corporation, NTT DOCOMO, INC.

2. Description of the Measures

2.1 5G×Sailing×Ultra-Realistic Communication Technology Kirari!

2.1.1 Overview of our Initiatives at the Sailing Regatta

In sailing races, spectators usually have to use binoculars to watch the races (from breakwaters, etc.) because the races are held quite far from land. At the sailing regatta, we took up the challenge of solving this problem by using communication technology to create an innovative style of spectating that goes beyond the real world ; namely, the spectators feel as if they were watching the races from a special seat on a cruise ship. Ultra-wide video images of the races (with a horizontal resolution of 12K) were transmitted live to a 55-m-wide "offshore wide-vision" display near the spectators' seats (Figure 2) by using the 5G and our ultra-realistic communication technology Kirari!.

Initiatives at the sailing regatta for the TOKYO 2020 5G PROJECT are summarized below :

- Period : July 25, 2021 to August 4, 2021
- Venue : Enoshima Yacht Harbour, Kanagawa Prefecture
- Total number of participants : about 4,000 (only athletes and related people were allowed to watch the event)

Figure 2 Example of Live Video Transmission Via Offshore Wide-vision Display (©2021-International Olympic Committee-All Rights Reserved)

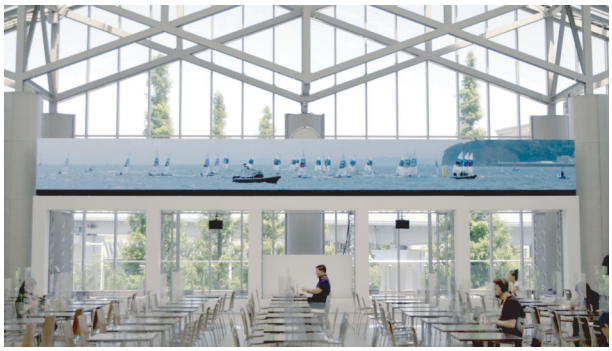

Figure 3 Example of Video Transmission to Main Press Centre (©2021-International Olympic Committee-All Rights Reserved)

The ultra-wide video images were also transmitted live to Tokyo Big Sight, where the Main Press Centre (MPC) was located, to convey the realism of the event to media personnel whose movements were restricted within Japan because of coronavirus disease 2019 (COVID-19) pandemic (Figure 3).

Although the sailing regatta was held without spectators, we implemented a measure called a "virtual stand" for sending support to the athletes from their far-away families and friends (Figure 4).

2.1.2 Configuration of the Video Transmission System

The configuration of the video transmission system for the sailing regatta is shown in Figure 5. First, the sailing action is captured from boats or a drone equipped with multiple 4K cameras. The captured video images are synthesized as ultra-wide video images with 12K resolution and transmitted in real time by using Kirari! and 5G, which enables highspeed, large-capacity

Figure 4 Remote Cheering from the Virtual Stands (©2021-International Olympic Committee-All Rights Reserved)

transmission. The transmitted images were displayed in real time on a 55-m-wide offshore wide-vision display floating in front of the viewing area at the regatta venue.

2.1.3 Technology

(1) Ultra-realistic Communication Technology Kirari![2]

In this project, we implemented two technological elements of Kirari!, video transmission using ultra-wide video-synthesis technology and ultra-realistic media-synchronization technology.

① Ultra-wide Video Synthesis Technology

First, the optical axes of each of four cameras are aligned as much as possible, and the cameras are set up so that their shooting ranges overlap adjacent captured images by 20-40%. Before the actual synthesis process, as a pre-processing step to correct the disparity between each camera, a projection-transformation matrix is calculated from feature points extracted from a reference still image. Next, during the synthesis process, video frames were combined using a projection-transformation matrix calculated for each video frame to correct disparities and find appropriate seam lines in the video images (i.e., a process called "seam search").

② Ultra-realistic Media-synchronization Technology (Advanced MMT)[3]

The video images generated using the ultra-wide video-synthesis technology are divided into multiple 4K images for transmission so that they can be handled by general display devices, encoders, and decoders. In this case, the image on the display was 12K wide and 1K high, so it was divided into three 4K images.

(2) Wireless Communication Technology

The races of the sailing regatta at the Olympic and Paralympic Games Tokyo 2020 were held on six race courses (Figure 6). Ultra-wide video images were captured from three camera boats for the Enoshima course, and ultra-wide images were captured using a drone camera in addition to three camera boats for the Zushi course.

The configuration of the network used in this project is shown in Figure 7. For uplinking video from the boats to shore and downlinking from the video-editing base to the barge-mounted offshore wide-vision LED display, NTT DOCOMO's 5G line was used as the core in conjunction with multiple wireless communications with different characteristics such as bandwidth, distance, and directionality. NTT DOCOMO's 4G line was used for

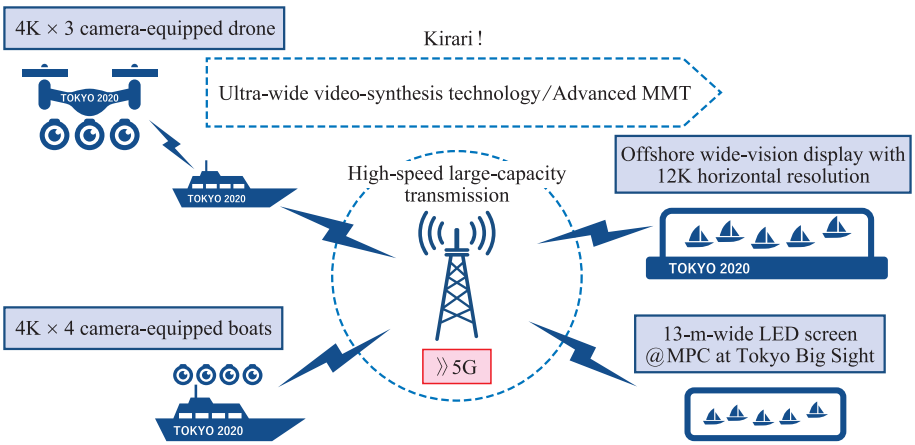

Figure 5 Overview of the Video Transmission System (©2021-All rights reserved NTT)

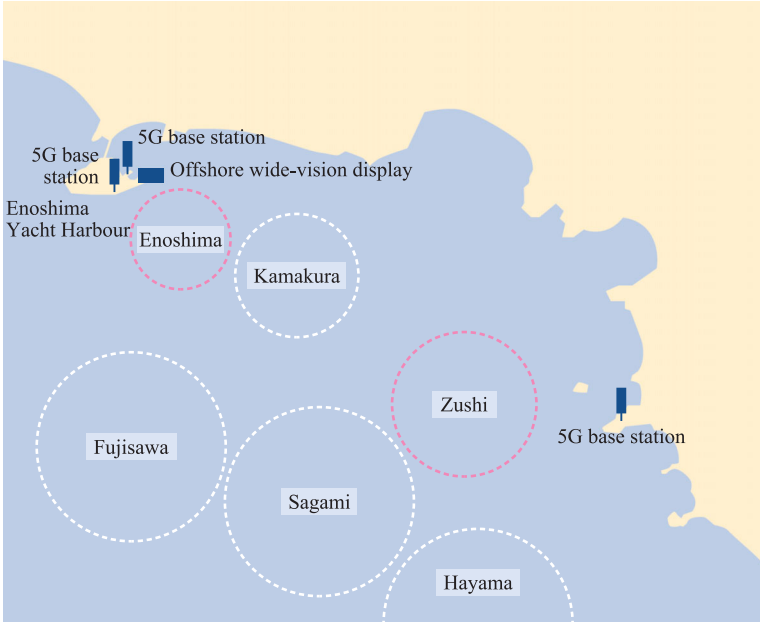

Figure 6 Map of the Race Courses for the Sailing Regatta (©2021-All rights reserved NTT)

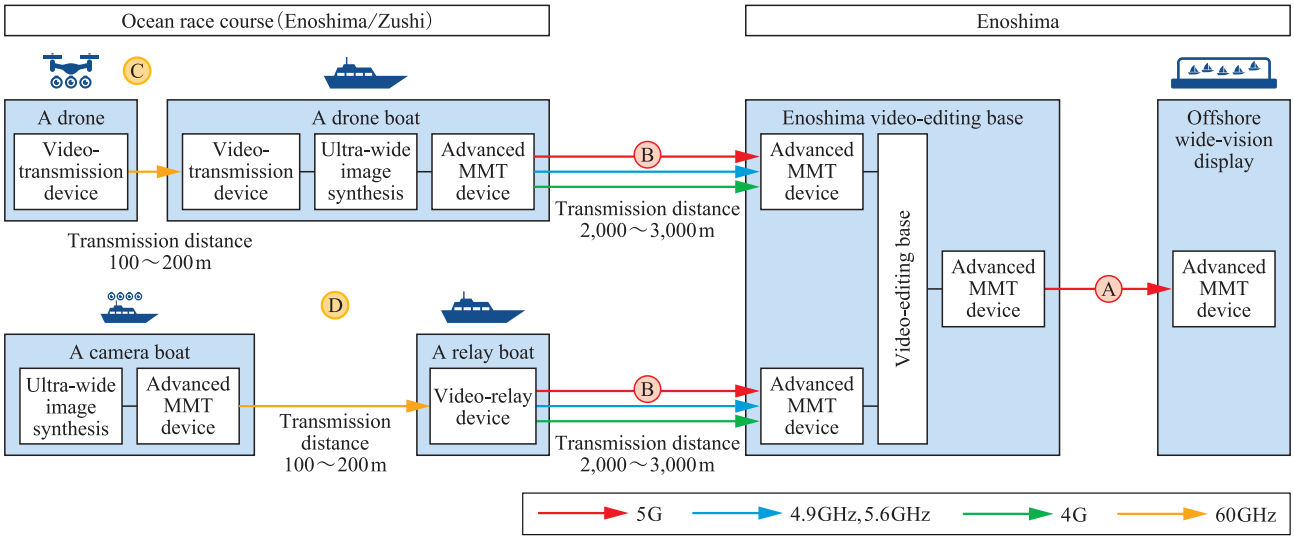

Figure 7 Network-configuration Diagram (©2021-All rights reserved NTT)

flight control of the drone, backup video, and control of the server located on the camera boats.

For the wireless equipment, it is necessary to keep the antenna surface facing the drone all the time. To ensure more-stable wireless communication, we developed a technology that automatically controls the direction of the antenna by using real time kinematic (RTK) GPS (Global Positioning System) information so that the antenna always points in the direction of the drone.

2.1.4 Results

Although the regatta was not attended by spectators, hundreds of people, mainly athletes and related support people, watched the video transmission every day of the regatta. We received comments from many people of those that expressed their surprise, excitement, and hopes for the future of sailing. Some comments were "I was surprised by the high sense of realism that I have never experienced before", "It made it easy to understand the race situation", and "If this style of spectating becomes common, the number of sailing fans will

increase rapidly". For our aim of creating "a sense of realism, as if the race was being held in front of you", we were able to create the experience of "warping into the race space itself" by fusing the powerful, actual-size race images displayed on the offshore wide-vision display floating on the sea with the actual surface of the sea, sky, and other real spaces.

2.1.5 Conclusion Remarks

Using commercial 5G and our in-house ultra-realistic communication technology Kirari!, we successfully transmitted live ultra-wide video images (with 12K horizontal resolution) via a 55-m-wide offshore wide-vision display installed at the Enoshima Yacht Harbour site and a similar but smaller display at the MPC at Tokyo Big Sight in Tokyo. At both sites, the live video transmissions were highly evaluated by athletes, officials, and international media. The communication technology used in this project will enable live viewing not only within a competition venue but also to remote locations, including overseas ones. Even during the COVID-19 pandemic, this project can be ranked as a showcase for achieving a remote world that NTT is aiming for. From now onwards, we will promote further research and development on communication technologies, mainly in the fields of sports and entertainment, using 5G and the All-Photonics Network of IOWN (Innovative Optical and Wireless Network) as an infrastructure.

2.2 5G×Swimming Competitions

2.2.1 Project Overview

In swimming competitions, the means to obtain "competition information" such as athlete information, "times and standings" for spectators watching on-site is limited to electronic bulletin boards, making it a challenge to provide appropriate information. To solve this problem, we have realized a measure to transmit athlete information, standings, times and other information in real-time to Augmented Reality (AR) devices worn by spectators via low-latency communication using 5G so that they can obtain competition information without changing their line of sight and feel a sense of presence and unity at the competition venue. Figure 8 shows an image of a spectator watching a competition, and Figure 9 shows an image of the user interface (UI) that can be viewed on the AR device.

An overview of this project is given below

Figure 8 Image of a Spectator Wearing an AR Device at a Swimming Competition (©2021-All rights reserved NTT DOCOMO)

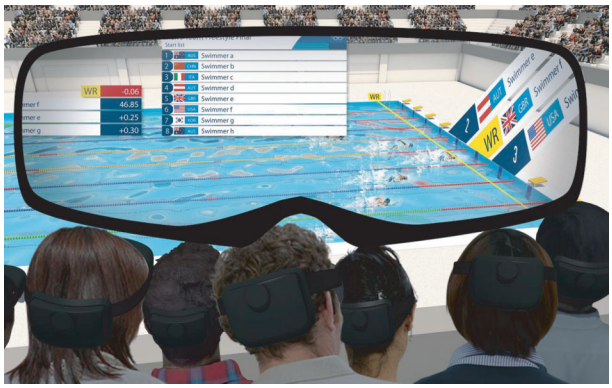

Figure 9 An example of the Image that Can Be Viewed with an AR Device (©2021-International Olympic Committee-All Rights Reserved)

- Period : July 25 to 27, 2021 (Tokyo 2020 Olympic Games), August 27 to 29, 2021 (Tokyo 2020 Paralympic Games)
- Venue : Tokyo Aquatics Centre
- Total number of participants : Tokyo 2020 Olympic Games : 129 people, Tokyo 2020 Paralympic Games : 242 people (spectators were athletes and stakeholders only)

2.2.2 System Configuration

The following is an overview of this project. First, stats data such as the times of each athlete and athlete information are obtained, processed by the AR system prepared by the project, processed into UI content, and transmitted to the network. The contents are transmitted in real-time via 5G to spectators wearing AR glasses. Up to now, when such content was transmitted over a telecommunications network, delays inevitably occurred, for example, when information to display the world record line is transmitted, it is delivered to the AR

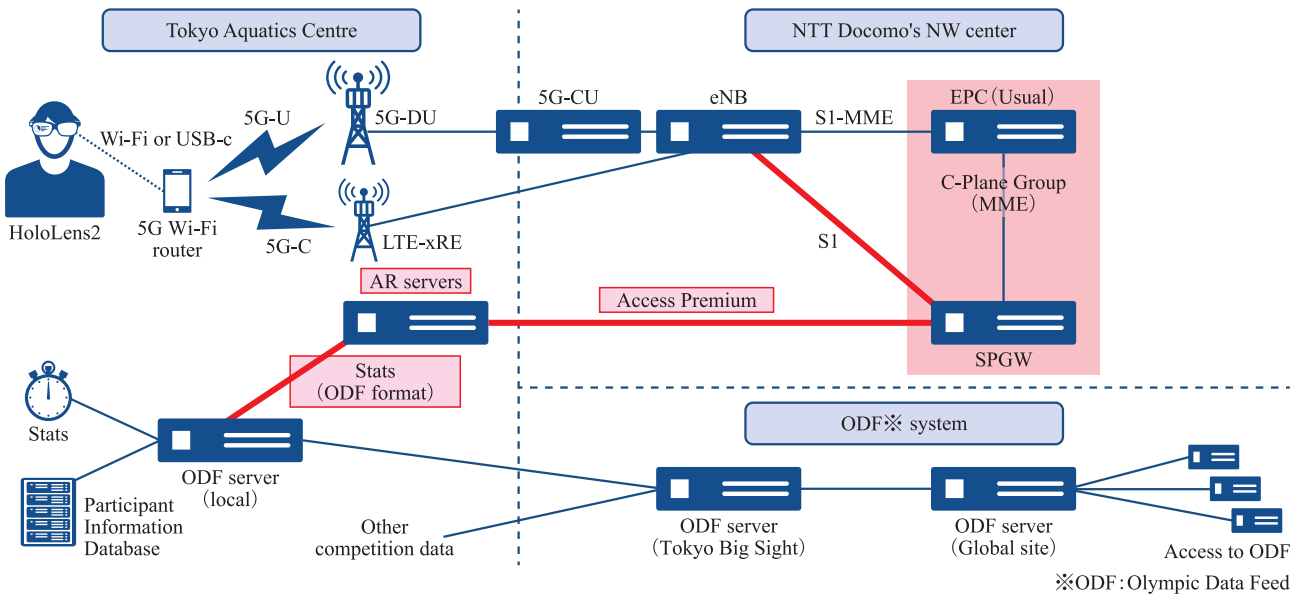

Figure 10 System Configuration (©2021-All rights reserved NTT DOCOMO)

glasses later than the actual time, making it extremely difficult to match the world record line with the athlete seen through the AR glasses. It was challenging to match the world record line with the athlete seen through the AR glasses. The use of "5G" in this project reduced the delay to nearly "0", so the time gap between the actual race and the displayed content was virtually eliminated, allowing spectators to enjoy watching the race without any discrepancies in content, such as the finish time.

2.2.3 Technology

A commercial 5G base station was installed at the Tokyo Aquatics Centre, where the swimming competitions of the Tokyo 2020 Games were held, and content was transmitted to the AR devices via the base station.

The system configuration used in this project is shown in Figure 10.

Since 5G alone is insufficient to process stats data, athlete information, etc., and ultimately deliver them to the AR glasses, the data was obtained directly at the venue, rather than via the Internet, to get as close to real-time as possible.

Future challenges include handling the data provided (e.g., when the number of items increases), developing algorithms to select the required items from a large amount of data and process the contents without delay, and developing more attractive contents in combination with other technologies (e.g., displaying e reproduction of the actual image of swimming competitions in the past, rather than the world record line, on the AR glasses).

2.2.4 Results

The measures were implemented without any significant problems during the Games period. Although the Games were held without spectators and for a short duration, a total of 371 people, mainly parties related to the Tokyo 2020 Olympic Games and the Tokyo 2020 Paralympic Games, participated in the project. Many people commented, "It will be a next-generation way to watch the games", "It was an excellent idea", "It was a very good idea to be able to see the world record line", and "The fireworks display when a world record was achieved was the best", etc. We received many positive comments, and some people who experienced the system once said they would recommend it to others. On the other hand, we also received comments such as, "I don't want to do this because it would ruin my hair", "My eyes get tired", and "I would like to see more images from underwater", which indicate the issues to be improved in the future. Regarding our goal "obtain the necessary information as if you were watching TV at home while feeling the presence at the venue", we believe that we were able to provide a new spectator experience based on the praise we received from the many people who experienced the system.

Although we had some technical issues, such as some missing stats data, by creating the necessary information based on other information, we produced results

that satisfied the spectators who experienced the project. Although there are still issues to be addressed in the future, we were able to achieve excellent results in an environment that demands a very high level of performance, such as the Tokyo 2020 Games.

2.2.5 Conclusion

We provided a new spectator experience using AR glasses by utilizing commercial 5G. A total of 371 people experienced the system, which was highly praised. The communication technology used in this project can be applied within the same competition venue and in other competitions. In the future, we expect further development of services by combining 5G with other technologies while taking advantage of its real-time features.

2.3 5G×Golf

2.3.1 Project Overview

Golf competitions are held on 18 holes, so following one's favorite player requires to walk a considerable distance, and it isn't easy to see what is going on at other holes. The difficulty increases during competitions in the summer months, such as July and August, when the Tokyo 2020 Olympic Games were held. Based in above, we took advantage of the large-capacity transmission feature of 5G to implement a measure that allows users to watch high-quality videos of competitions across multiple holes in a comfortable environment, such as a lounge.

By operating a tablet installed in the lounge, spectators can view videos from multiple holes simultaneously. An image of the screen is shown in Figure 11.

An overview of the project is given below.

- Period : July 31 to August 1, 2021 (men), August 6 to 7, 2021 (women)
- Venue : Kasumigaseki Country Club
- Number of Users : Family lounge users : 90 (Actually, the number was higher because some people voluntarily tried the tablets (spectators were Games stakeholders only).

2.3.2 System Configuration

Among the 18 holes, we targeted videos from six holes from 13 to 18, which were expected to be very exciting. We obtained multiple videos (2K high-definition images) for TV broadcasting installed at the venue and selected the footage that everyone most wanted to see from among the multiple camera videos at each hole, such as the athletes in action, and transmitted them together over the network. This large volume of information was transmitted to tablets set up in the lounge using the high-speed, large-capacity features of 5G. Users could simultaneously view six videos from holes 13 to 18 and tap one of them to view the video of their favorite hole on a larger screen. In addition, information on the players, such as their rankings and scores of player at the time, is also transmitted simultaneously for the enjoyment of the audience. Furthermore, live information such as "▲▲ player has a chance of birdie" was also created by project members and transmitted for the enjoyment of the audience.

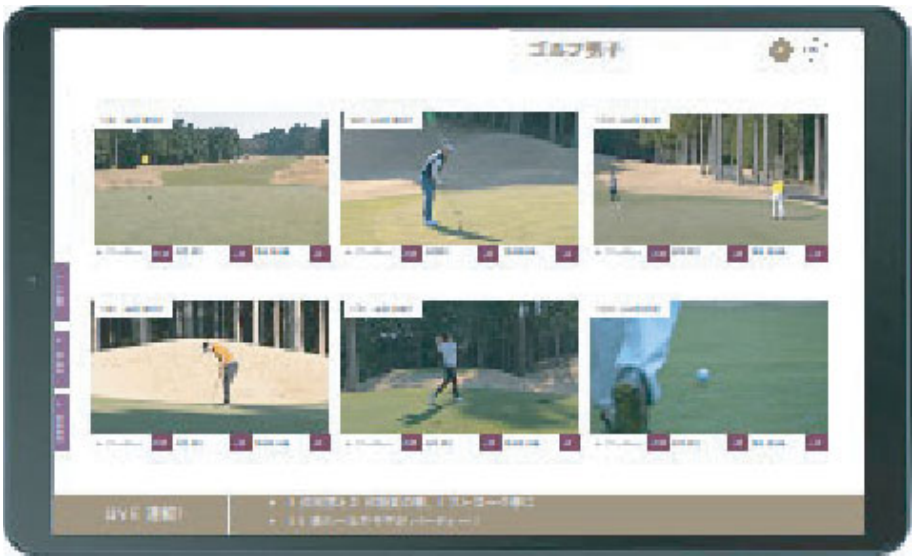

Figure 11 Image of the Screen (©2021-All rights reserved NTT DOCOMO)

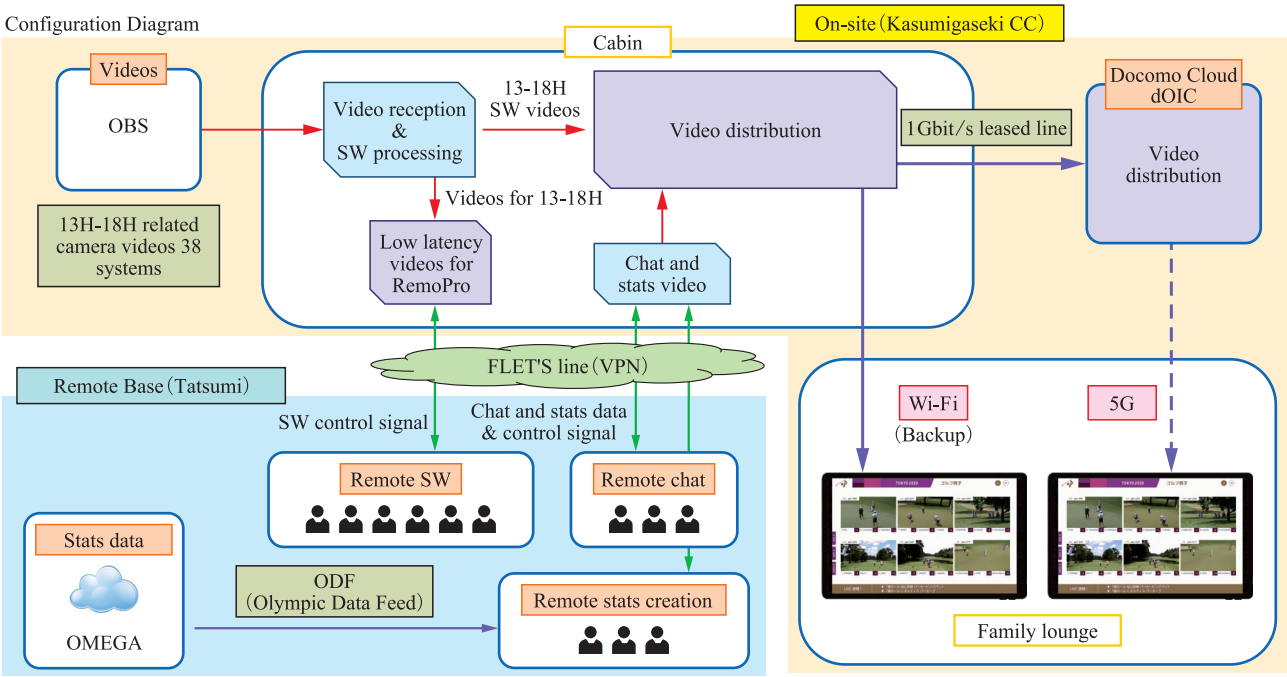

Figure 12 Network Configuration (©2021-All rights reserved NTT DOCOMO)

2.3.3 Technology

A commercial 5G base station was installed at the Kasumigaseki Country Club, where the golf competition for the Tokyo 2020 Games was held and users can enjoy services in the lounge while receiving the signal.

The configuration of the network used in this project is shown in Figure 12, where camera images from the OBS (Olympic Broadcast Service) were obtained directly from the venue, and the video to be played from each hole at that time was selected. Information on athletes and live information obtained via the Internet was converted into content and transmitted to the 5G network.

Because there were no spectators this time, the service was provided only on loaner tablets, but up to now, the service was envisioned to be provided to the spectators' own 5G-compatible devices. In this case, visitors must follow procedures such as downloading the application and accessing the website to use the service. Therefore, having a more comfortable UI/UX (User Experience) is one of the challenges. In addition, since spectators do not necessarily own devices with large screens such as tablets, providing content that can be enjoyed on smaller screens will also be challenging.

2.3.4 Results

The measures were implemented without significant problems during the Games period. Although the implementation period was short since the Games were held without spectators, the service was provided mainly to stakeholders over four days at the total during the Olympic Games, including the final rounds of the men's and women's competitions. Many people commented favorably on the service, saying, "It's good to be able to choose which hole to watch", "It's easy to operate", "The videos are smooth and easy to watch", and "It's good to be able to watch in a cool room". On the other hand, there were also comments such as "I felt it was inconvenient that I could not turn the page by swiping", and "How about including more detailed match data such as "how many yards of rough on the first swing" and "green putt" data" and "When two or more groups are on the hole, the video is not displayed". This made clear the issues that need to be improved in the future. Regarding our goal "High-quality images of competitions can be viewed simultaneously without leaving the room", we believe that we were able to provide a new spectator experience based on the praise we received from the many people who experienced the event.

By the way, although cable TV was installed in the venue, our service transmitted videos via 5G, and the videos were delivered to the tablets faster than cable TV because of the real-time feature of 5G. The video of the

putt-in in front of the lounge could be viewed in real-time at almost the same time as the actual competition, while the video shown on the cable TV had a slight delay, which revealed a new feature of this service : its real-time nature.

Technically, there was not enough time for rehearsals, and we had to go through some trial-and-error and could not provide the service to individual devices, which we had initially purpose to do because there were no spectators. Although there were other issues, we achieved excellent results at the Tokyo 2020 Olympic Games, an environment that demands a very high level of performance.

2.3.5 Conclusion

We provided a new experience of watching the Games using tablets using commercial 5G. A total of more than 90 people experienced the service, and it was highly praised. The communication technology used in this project can be applied within the same competition venue and in other competitions. In the future, it is expected that 5G will be combined with other technologies and further developed into services while taking advantage of its features, such as high capacity and real-time performance.

3. Review, Reflection, and Future Legacy

To realize one of the goals of the Tokyo 2020 Games, "the most innovative Games in history that will bring positive change to the world", we planned and implemented measures utilizing "5G", one of the most promising technologies of the future. The environment surrounding the Games changed drastically, as the Games were postponed for one year due to the effects of the COVID-19, and there was much discussion regarding the implementation of this project. However, the project members' desire to implement these measures to promote "Japan as a technological powerhouse" and the encouragement of the staff at each venue to entertain spectators by providing new experiences prompted the resumption of discussions in the direction of implementing the measures. Unfortunately, there were "no spectators" at the venues, but a sizeable number of people involved in the Games experienced the project and responded positively. Although further study is needed to make the service more attractive, we believe specific results were achieved this time. Regarding a new style of spectating, the project could be applied to other sports, and there are possibilities for services suited to those sports. The features of 5G have been embodied in a tangible form and the practical application of 5G is expected not only in sports but also in other fields, and further development is expected.

Finally, we would like to thank the many people who provided tremendous support and cooperation in planning and implementing the TOKYO2020 5G PROJECT. We want to take this opportunity to express our deepest gratitude. We would also like to thank Mr. Yoshiyuki Mihara of Nippon Telegraph and Telephone Corporation and Mr. Yusuke Kobayashi of NTT DoCoMo, Inc. for their support in writing this article. We thank you all.

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