Development of Bi-Directional CDN for Beyond 5G Video Services

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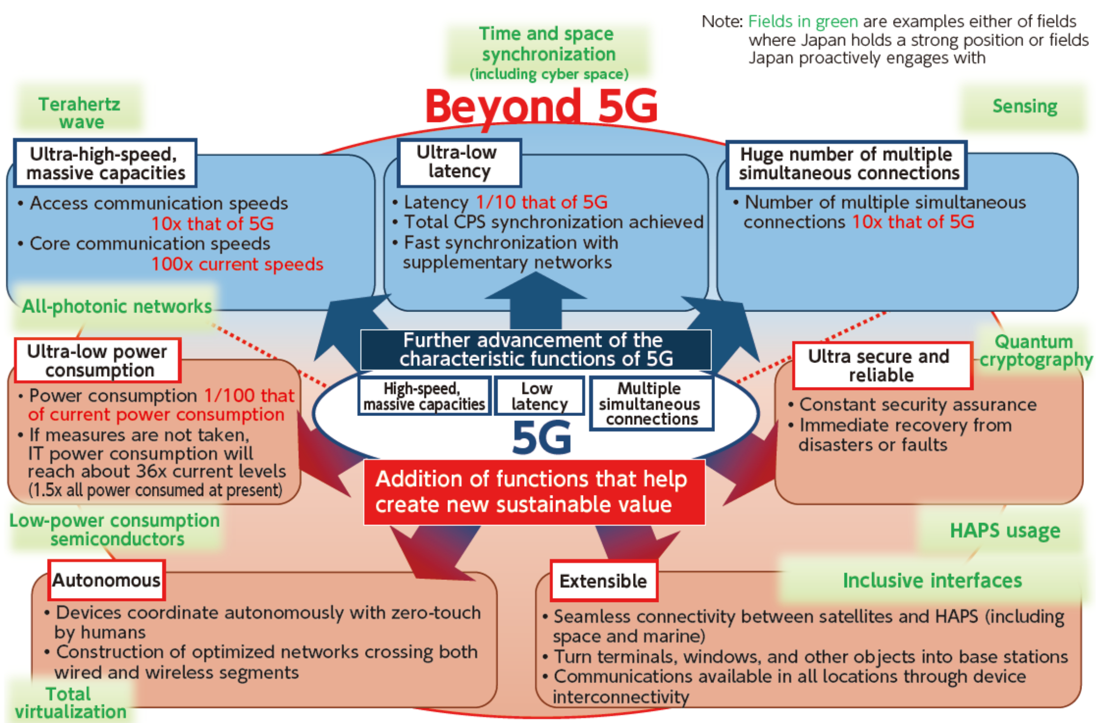
In Society 5.0, which aims to transform society by utilizing IoT and AI, a variety of video services are expected to be provided through the connection of autonomous robots to high-quality networks. This article describes the functions of the bi-directional CDN, which is required for Society 5.0 video services, and the prototypes that were developed.

Introduction

Over the years, mobile communication systems have evolved from a communications infrastructure to a life infrastructure. The fifth generation mobile communication system (5G) being introduced in various countries is foreseen to evolve into a social infrastructure that goes beyond a life infrastructure. The next generation, Beyond 5G (also known as 6G, hereafter referred to as B5G), is anticipated to integrate cyberspace with the real world (physical space) and play a core role as the backbone of Society 5.0.

B5G is not merely an extension of conventional mobile communications network, but it is considered an integrated network that includes both wired and wireless, and encompasses land, sea, air, and space. In addition to further enhancing the 5G's functions of "high-speed / massive capacity," "low latency," and "multiple simultaneous connections," there are high hopes it will realize new functions such as "ultra-low power consumption," "extensible communication coverage," "autonomy," and "ultra security/reliability."[1)]

OKI is currently developing a bi-directional CDN (Contents Delivery Network) technology, which applies CDN to two-way data communications. It is a control technology that meets system requirements of video



Source: "Beyond 5G Promotion Strategy−Roadmap towards 6G−"(2020)
https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/Beyond_5G_Promotion_Strategy-Roadmap_towards_6G-.pdf

Figure 1. Functions Required in B5G

services, such as reducing image distortions, avoiding live footage delays/stoppages, and synchronizing viewing between remote locations. The technology works in coordination with the Autonomous Network (AN) integration platform, which is currently being researched and developed as part of B5G. Together, they assess the network status of multiple carriers, both mobile and fixed, and make effective use of network resources (cache servers, route information, Multi-access Edge Computing (MEC)) to meet the demands of video services. Additionally, OKI is considering camera-equipped Autonomous Mobile Robots (AMR) as an application of bi-directional CDN technology, and made studies to adapt the technology to changes in the number of equipment using the service and changes in the contents of the service. The developed technology will be applied to other services (use cases) in an aim to maintain service quality, such as CDN control on the Internet for fixed TVs and mobile devices connected at homes.

Use Case of Bi-Directional CDN: Remote Zoo Tour Service

An example of bi-directional CDN use is Remote Zoo Tour Service (RZTS), where a group of family or friends use information and communication technology to tour a zoo. Currently, people who are unable to travel (**Figure 2 (1)**) cannot share in the enjoyment of taking a trip with their family or friends. Even if these people later hear about the trip from their family or friends (**Figure 2 (2)**), they cannot fully share the fun memories. To solve this issue, OKI is working to implement RZTS using bi-directional CDN, which will enable real-time communication during the trip (**Figure 2 (3)**) and allow people who are unable to travel share travel experiences.

RZTS is a system in which a guide or AMR moves around the zoo and delivers video to users via a network, and it aims to allow users in multiple remote locations to enjoy communication while watching the delivered video without feeling out of place. However, the issue with this system is that when delivering video to multiple remote locations, differences in the delivery route cause variations in the video display time. This leads to discrepancies in the communicated contents between users during the communication. The solution requires a B5G service that allows people in remote locations to watch synchronized videos of the zoo. Therefore, OKI has studied a synchronized viewing method that uses more advanced network control in coordinating the AN, bi-directional CDN, and AMR to synchronize playback between local and remote locations.

In conducting research and development of a bi-directional CDN that can be applied to a service that delivers high-definition video to users in multiple remote locations, OKI has developed a synchronization control method that dynamically measures delay and embeds delay to achieve video synchronization between remote locations based on the results of the AN network control (for example, selection of a network that minimizes delay and fluctuations in the MEC in a data center or the connecting network). Application of this method will enable synchronization of the video viewed by each user and users in remote locations can communicate smoothly while watching the video[2].

Prototype for Verifying Synchronized Viewing

The issue with RZTS is that when delivering video to multiple remote locations, the video display time varies

(1) Can't go on family trips. (2) Only hear stories from family. (3) Share experiences with family.

Figure 2. Remote Zoo Tour Service (RZTS)

depending on the delivery route. Therefore, a synchronized viewing prototype was developed and evaluated to verify the AN and bi-directional CDN controls for synchronized viewing of video captured by the guides or AMRs at the remote locations.

The synchronized viewing prototype was developed based on the assumption that a remote zoo tour like that shown in **Figure 2 (3)** would be conducted with users participating from two remote locations and viewing the video from the zoo on their respective equipment.

Figure 3 shows the configuration of the synchronized viewing prototype. Video data, which is captured with camera on a pseudo robot simulating an AMR and encoded, is sent to the bi-directional CDN. Next, the bi-directional CDN [packet branching] branches the video data into two, and the bi-directional CDN [delay measurement] measures the delay for each. The video data sent from the bi-directional CDN [delay measurement] is routed at the AN, selecting a route that reduces delay. Additionally, the bi-directional CDN [delay set] and the bi-directional CDN [synchronized viewing control] control delays that cannot be adjusted by the AN. Subsequently, the two video data viewed by the pseudo-users are synchronized.

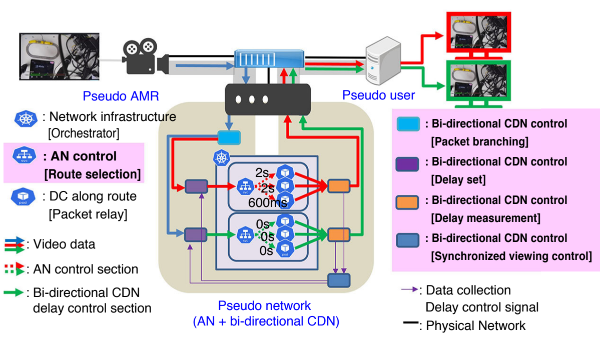


Figure 3. Configuration of Synchronized Viewing Prototype

Verification with the synchronized viewing prototype confirmed that by applying the developed bi-directional CDN, video discrepancies are eliminated and the two user equipment becomes synchronized. In the next step, coordination between the AN and bi-directional CDN was studied, and verification was conducted in an environment much closer to the configuration required for RZTS. Specifically, the study involved (1) implementation of an interface between the AN and bi-directional CDN; (2) improvements to the AN, bi-directional CDN, and AMR functions; and (3) verification when the number of nodes and equipment in the network is increased.

With respect to (1), network quality can be optimized by notifying the location information of the AMR and user equipment to the AN before the start of the service. For mobile devices, it is necessary to properly notify changes in location. Furthermore, it is necessary to consider a method for sending network requests from the bi-directional CDN to the AN, and method of monitoring the results of the AN operation on the lower layer networks.

Regarding (2), the functional improvements to the AN is to control the lower layer networks and measure network metrics, and it involves the collection of information necessary to change the network route. For the bi-directional CDN, improvements include video and audio encoding according to the user equipment, control function for reducing delays, and synchronized viewing based on information collected from other networks with the communication function. The AMR will require a service that can deliver video without disruption even when disruption occurs on a new network for B5G[3].

For (3), the number of network nodes and connected equipment was increased through the use of NICT's Integrated Testbed[4]. This allowed the evaluation to be performed on a scale larger than the synchronous viewing prototype.

Prototype with AN Coordination Function

It is expected that networks in the B5G era will be controlled by the AN. Therefore, it is desirable that network information (delay, route, etc.) used by the bi-directional CDN to perform synchronized viewing control be obtained from the AN, rather than being measured and collected by the bi-directional CDN itself. Towards implementing RZTS, it is necessary for the AN and bi-directional CDN to coordinate operation and provide normal operation of synchronized viewing control even when user equipment from a large number of remote locations are using the service. In coordinating the operation of the AN and bi-directional CDN, the following two points were studied: (1) sharing network information (delay) and (2) changing network routes, and a prototype as shown in **Figure 4** was developed.

In (1), a module that collects network information and is managed by both the AN and bi-directional CDN was designed. A method for each control unit to reference each other's network information was considered and implemented in the prototype. This coordination makes it possible to control synchronized viewing between multiple user equipment using the AN's network information, as shown by the blue arrow in **Figure 4**. In (2), an API for the data relay module on the network route was designed, allowing data sending and receiving destination to be changed according to the AN's request. This coordination allows route changes (optimization, bypassing failures, etc.) under the AN's control, as shown by the red arrow in **Figure 4**, to be reflected in the bi-directional CDN's delivery route, making it possible to keep the transfer delay time to a minimum during synchronized viewing control.

To verify operation, a coordination prototype that verifies synchronized viewing control between user equipment was implemented on NICT's integrated testbed at five locations across Japan. The five locations were set up with Central Data Center (CDC), Regional Data Centers (RDCs), and Edge Data Centers (EDCs) in **Figure 4** as one region each. Fifty-eight virtual machines were used for deploying modules, which was about three times more than the number used for the synchronized viewing prototype. The number of user equipment was also increased from two to five. In this verification, the video sent from the upload equipment was made to be received with uneven delays by five user equipment. This is based on the assumption that there will be more users participating in RZTS than with the synchronized viewing prototype, and that the users will participate from five remote locations.

The verification involved measuring the delay for each of the user equipment before and after activating the synchronized viewing control. To determine whether the operation was as expected after the synchronized viewing control was activated, the delay time for each of the five user equipment was checked, and it was determined that there was no problem if the delay times were the same. Furthermore, delays were measured in the same manner before and after activating the AN's network route optimization, and it was confirmed that the delay time from the upload equipment to the user equipment was shorter after activation.

The verification results of the coordination prototype confirmed that by coordinating the AN and bi-directional CDN operations, it is possible to control delay and synchronize the five user equipment. Moreover, since the network is constantly optimized and the network route can be changed, the delay can be kept to a minimum[5].

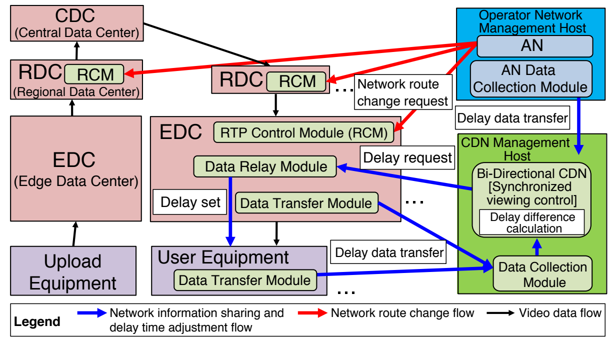


Figure 4. Configuration of Coordination Prototype

Conclusion and Future Initiatives

In Society 5.0, autonomous robots and other devices are expected to be connected to high-quality networks to provide a variety of video services. B5G, which will be the core of Society 5.0, is foreseen to integrate cyberspace with the real world, advance 5G, and realize new functions such as "autonomy."

Bi-directional CDN is a technology for Society 5.0 that coordinates with the autonomous network (AN), which autonomously maintains and manages the network, to avoid (reduce) video distortions and live footage delays/stoppages. OKI is conducting research and development of a bi-directional CDN technology, and it is also developing a system called the Remote Zoo Tour Service (RZTS), which allows multiple users in remote locations to enjoy communication while watching videos of the zoo without any sense of awkwardness. In the development, a synchronized viewing prototype using the synchronized viewing control of the bi-directional CDN technology, and an extended coordination prototype were developed. It was confirmed that through the effective coordination between the AN and bi-directional CDN, delays can be minimized while synchronizing user equipment.

In the effort to implement remote services such as RZTS into society, OKI will continue to work on resolving issues and conduct further research and development based on the prototypes that have been created. Furthermore, as Japan faces an aging society, OKI is looking to make its system available for new services to provide smooth communication t those with limited mobility.

Acknowledgement

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