New Transport QoE-control Technology Enabling High-definition/High-presence Content Distribution

Takafumi Okuyama, Ken-ichi Endo, Takuto Kimura, Arifumi Matsumoto, Toshihito Fujiwara, and Yasunobu Kasahara

Abstract

NTT is striving to support the growing demand for high-definition video delivery services and is therefore developing technologies for optimizing the deployment of servers for content providers and telecom operators and their communication networks and for providing a new means of delivery control. This article introduces content delivery network technology for achieving economical and high-quality delivery of high-definition, high-presence video content.

Keywords: CDN, QoE control, multicast conversion

1. Introduction

The development of 4K/8K video coding schemes and high-definition user terminals has led to the introduction of services for delivering various types of high-capacity video content over the network. In the existing video content delivery services, content providers cope with the volume of traffic by increasing the number of servers and the network bandwidth in proportion to the product of content volume and number of users. The amount of content and the number of users is expected to increase dramatically in the future market, but the potential expansion in facility resources is limited. It will therefore be difficult to maintain or improve the user's quality of experience (QoE) when viewing video content and to provide enjoyable services at low cost with this conventional approach (**Fig. 1**).

This situation calls for a new mechanism that can improve the efficiency of using and operating facilities, by using more appropriate delivery information. For example, this might necessitate changing the delivery settings according to the type of terminal or circuit and the network conditions while visualizing the user's QoE when viewing video content.

We introduce here high-definition/high-presence content delivery network (CDN)*1 technology that has been developed with the aim of providing next-generation, high-quality services while controlling facility expansion. The element technologies for constructing a CDN that are described here are QoE visualization technology for grasping the user's state of video content viewing, QoE control technology for optimizing the delivery method according to the user's usage format and usage conditions, real-time large-capacity delivery technology for delivering large-capacity live video in an efficient and stable manner, and manifest control technology for achieving flexible control of content delivery.

2. QoE visualization technology

To provide users with an effective and enjoyable

*1 CDN: A network targeting content delivery. Here, a network for delivering video content.

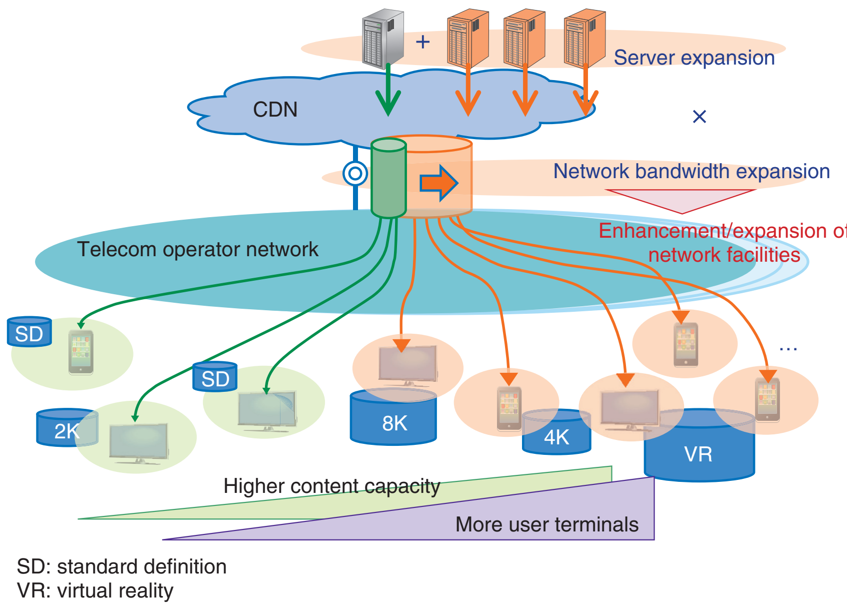

Fig. 1. Expansion of capacity and scale in existing content delivery network (CDN).

video content delivery service, it is necessary to observe the user's QoE when viewing video content and to control the CDN appropriately. This makes the visualization of QoE essential. Hypertext Transfer Protocol (HTTP) streaming*2 and the adaptive bit rate (ABR) system have come to be widely used recently in video content delivery services. In HTTP streaming, the viewing clients play back video content while downloading pre-divided video data (file segments/chunks) in sequence and storing the data in a buffer. Then the ABR system enables the viewing clients to dynamically adjust video quality (encoding bit rate) and download timing (pacing) to maintain the user QoE in accordance with the communication environment.

However, a major deterioration in the communication environment can impair the ABR operation and give rise to rebuffering, in which buffered data are depleted, and playback is temporarily suspended, resulting in a drop in QoE. In addition to such ABR-based autonomous operation by the viewing client, there are also control operations of the delivery server, various devices, and access lines, all of which make the visualization of QoE a difficult task.

The QoE visualization technology introduced here uses a QoE estimation model [1] proposed by the NTT laboratories to quantify the QoE of a video content delivery service using ABR. Specifically, this technology achieves QoE visualization by equipping the viewing client receiving video data with a function for collecting the video/audio encoding bit rate, video resolution, frame rate, and history of rebuffering, and by inputting such information collected while viewing video content into the QoE estimation model. At present, this model can estimate QoE for video content with Hi-Vision (high-definition television) screen resolution (1920 horizontal × 1080 vertical pixels) or less. Research and development of QoE estimation technology for high-resolution video content such as 4K/8K video is in progress.

The visualization of QoE makes it possible to respond quickly to a user's quality inquiry through operational actions such as assessment of conditions and cause analysis. In addition, such visualized information can be provided to content-delivery clients as evidence of the service state.

3. QoE control technology

In video content delivery services, both users and content providers need to maintain quality when

*2 HTTP streaming: A method for achieving live/on-demand video delivery using an ordinary HTTP server instead of a special video server. HTTP Live Streaming (HLS) and Dynamic Adaptive Streaming over HTTP (DASH), also known as MPEG (Moving Picture Experts Group)-DASH, are examples of HTTP streaming that have found widespread use.

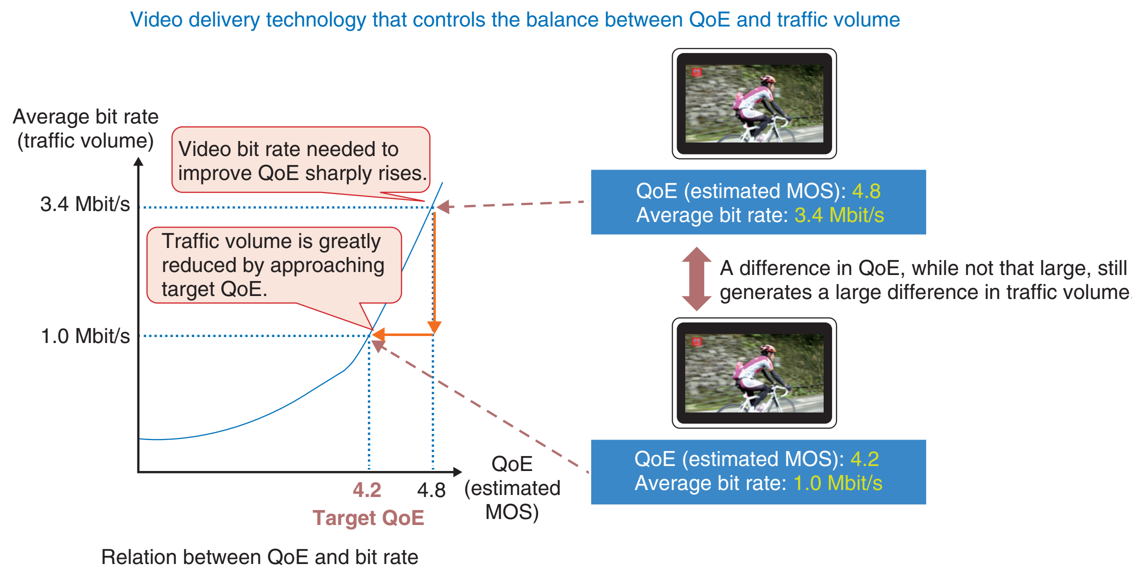

Fig. 2. QoE control technology.

delivering video content and to reduce traffic costs for delivery. The user, on one hand, feels dissatisfied if the quality of video content drops excessively, but if quality rises to a level higher than necessary, the traffic volume increases, resulting in higher communication charges. Therefore, it is necessary to reduce the traffic volume while maintaining a certain level of quality. The content provider, on the other hand, should prepare for a rapid increase in content volume or number of users by reducing the traffic volume within a range that is not unsatisfactory to the user. QoE control technology meets these needs by effectively manipulating the balance as desired between quality and accompanying traffic.

QoE control technology controls this balance by using the relationship between bit rate and QoE. This relationship between traffic volume (average bit rate) and QoE (estimated mean opinion score (MOS)[*3]) is shown in **Fig. 2**. As shown, raising the QoE from 4.2 to 4.8 requires the bit rate to be increased by more than three times from 1 Mbit/s to 3.4 Mbit/s. This tells us that in a high QoE region, a threefold increase in bit rate does not result in a dramatic improvement in QoE. Therefore, we make use of such QoE characteristics by setting a QoE target value given by the content provider or user. Our QoE control technology controls the bit rate of video content to achieve the minimum QoE delivery satisfying that target value. This prevents the QoE and traffic volume from becoming higher than necessary. In addition, performing optimization calculations here makes it possible to select a bit rate that generates the least amount of traffic for the same QoE.

This technology enables the provision of a video delivery service that can keep traffic cost to a minimum while maintaining service quality at a level required by the content provider or user. Therefore, we expect this technology to reduce network load significantly while maintaining QoE. In fiscal year 2017, we performed a field trial using NTT Plala's video delivery service for smartphones and succeeded in demonstrating the effectiveness of this technology in an actual service.

4. Real-time large-capacity delivery technology

Real-time large-capacity delivery technology achieves efficient and stable delivery of large-scale live/linear video content. Ordinary video delivery systems are achieved by sending HTTP-based unicast traffic between the video delivery server and terminals. However, if this ordinary scheme is applied to deliver real-time large-capacity video data as in the live delivery of popular content, viewing demand can

*3 MOS: A value quantifying the level of quality subjectively felt by humans with respect to a target of evaluation (audio/video media, etc.) based on an opinion score as specified by ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) Recommendation P.800.

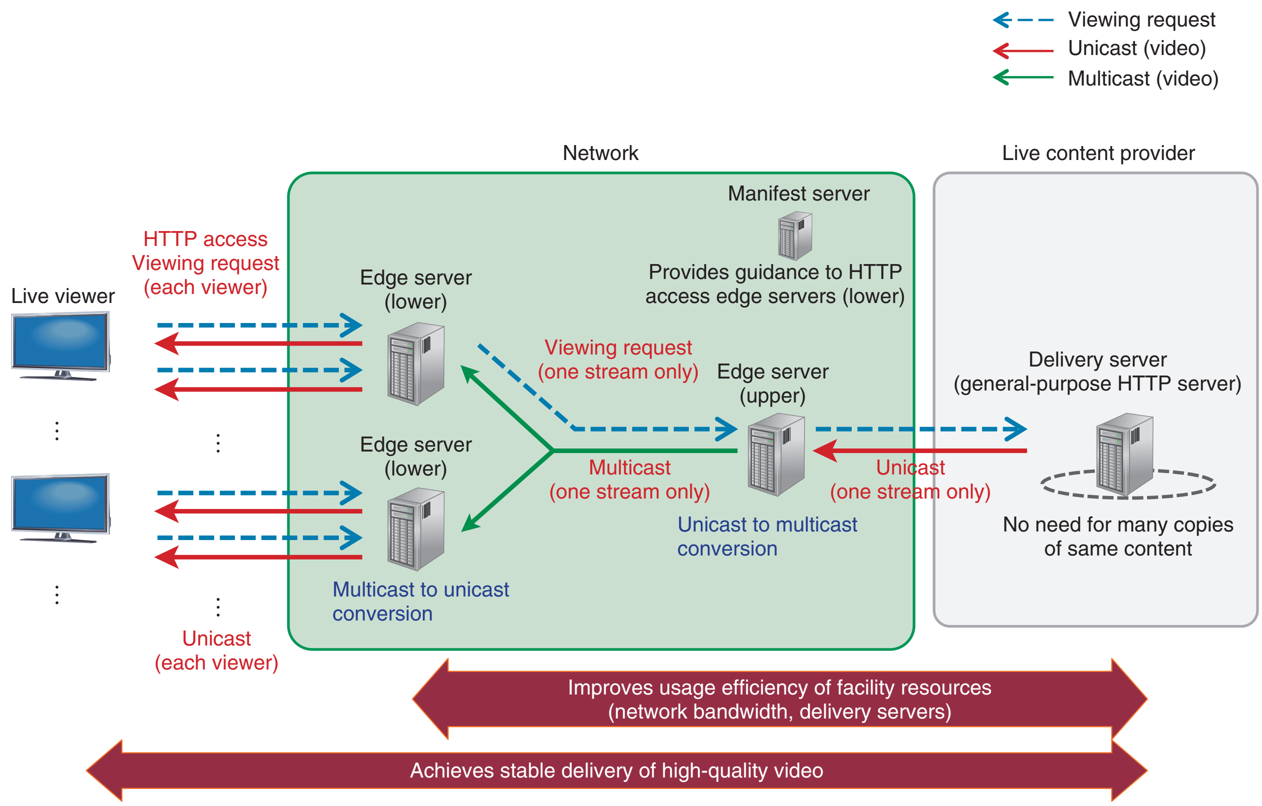

Fig. 3. Unicast/multicast conversion technology.

easily peak, thereby greatly increasing the load on facilities such as delivery servers and the network itself. Such facilities may not be able to bear that load, resulting in a severe deterioration in QoE.

In contrast, real-time large-capacity delivery technology delivers video data via multicast*4 only in the CDN, while leaving the HTTP-based unicast interface unchanged at each delivery server and terminal. This scheme avoids duplicate delivery of the same video content, which improves facility usage efficiency even for the servers of content providers and achieves stable content delivery (**Fig. 3**).

Specifically, this technology involves placing an upper edge server at the network entrance facing the delivery server, converting traffic from unicast to multicast, placing multiple lower edge servers at the network exit connected to terminals on the opposite side, and converting the traffic from multicast to unicast. The video content is transferred via multicast in the network zone between the upper edge server and lower edge servers. Here, instead of relying on server performance as in the conventional method, data are copied at multicast-supporting routers within the network, which makes for efficient video delivery.

Additionally, for the same video content, traffic from the delivery server to the upper edge server and from the upper edge server to the lower edge servers consists of a single stream regardless of the number of users viewing content simultaneously. This technology can therefore drastically reduce traffic in the network compared to the unicast-only scheme while delivering high-quality video in a stable manner to each user. Moreover, while a system using conventional multicast technology requires delivery servers and terminals that support multicast transmission, this technology enables servers and terminals to use the existing HTTP-based system, thereby easing the burden of procuring and installing new equipment for both content providers and viewing users.

5. Manifest control technology

Manifest control technology can achieve flexible

*4 Multicast: The simultaneous transmission of a single set of data to specific terminals or switches.

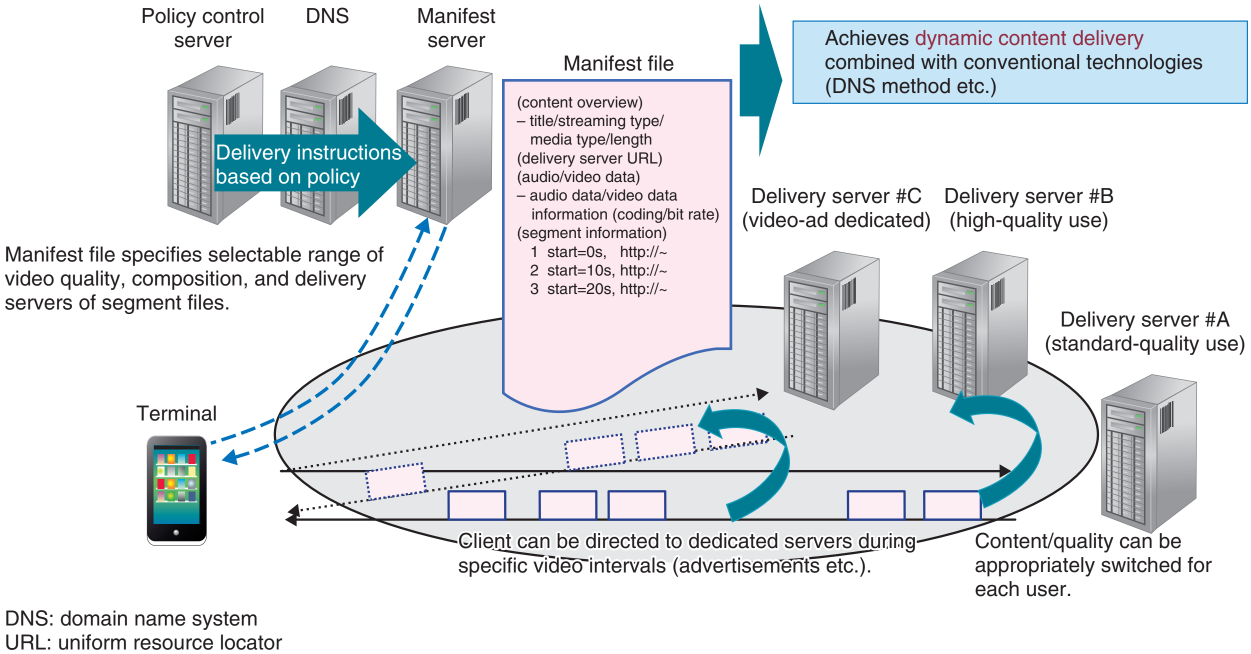

Fig. 4. Manifest control technology.

control of content delivery such as by specifying the bit rate of video content to the client in QoE control technology and directing the client to specified edge servers (lower) in real-time large-capacity delivery technology.

When a user makes a request to view video content, the client will request video-content files. For this purpose, major HTTP streaming schemes use a manifest file (e.g., a playlist in HLS or an MPD (Media Presentation Description) in MPEG-DASH). A manifest file contains information on how the video content is divided into segment files at what levels of video quality and from what locations the segment files should be requested [2]. With manifest control technology, the manifest server, on receiving a request from the client for a manifest file, sends the file based on the client's identification information. This approach achieves efficient delivery control that is dynamically operated (**Fig. 4**). Specifically, manifest control technology achieves flexibility through diverse types of delivery control such as switching content, limiting the selectable range of video quality for ABR, directing the client to dedicated servers during specific video intervals (advertisements etc.), and load balancing of global cache servers.

With conventional technology, the domain name system (DNS) directs the client to the CDN cache servers where video content files are downloaded when the client starts to play back content (DNS method). Here, however, DNS can only roughly identify the client by a group such as Internet service providers, and it takes time for DNS changes to be fixed in the network. Thus, the disadvantage of the DNS method is that it cannot identify the client finely or handle the load balancing promptly. With this in mind, we combined manifest control with the DNS method to achieve scalability and fine control.

6. Future development

We are conducting trials of the video content delivery technologies introduced here and will use the results to continue researching delivery platform technologies that are essential to the development of 4K/8K video coding schemes and high-definition user terminals.

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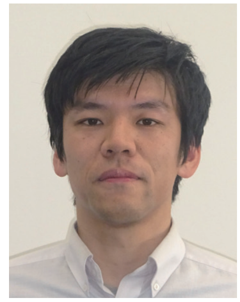
Takafumi Okuyama
Senior Research Engineer, NTT Network Technology Laboratories.

He received a B.E. and M.E. in information and computer sciences from Tokyo Institute of Technology in 2005 and 2007. He joined NTT Service Integration Laboratories in 2007. From 2010 to 2014, he was with NTT Communications, where he worked as a mobile application engineer. He is currently researching and developing a content delivery network for video streaming, a communication quality analysis/control method for VoIP (voice over Internet protocol), and video services.

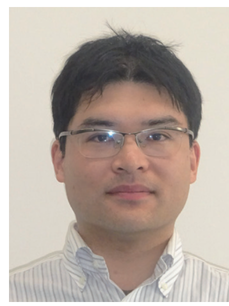


Arifumi Matsumoto
Senior Research Engineer, Communication Quality Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.

He received a B.E. and M.E. in information sciences from Kyoto University in 2002 and 2004. His research interests are emerging network technologies such as IPv6, multihoming, and mobility. He is currently researching communication quality control.

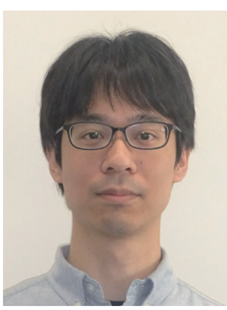
Ken-ichi Endo
Senior Research Engineer, Network Architecture Innovation Project, NTT Network Technology Laboratories.

He received a B.E. and M.S. in electronic engineering from the University of Yamanashi in 1984 and 1986. He joined NTT LSI Laboratories in 1986. He has been with NTT Network Technology Laboratories since 2012, where he is studying distribution of next-generation video content.



Toshihito Fujiwara
Senior Research Engineer, Access Network Service Systems Project, NTT Access Network Service Systems Laboratories.

He received a B.E., M.S., and Ph.D. in engineering from the University of Tsukuba in 2002, 2004, and 2011. He joined NTT Access Network Service Systems Laboratories in 2004, where he has been researching and developing video delivery and video transmission systems.



Takuto Kimura
Researcher, Communication Quality Group, Communication Traffic & Service Quality Project, NTT Network Technology Laboratories.

He received a B.E. and M.E. in information and computer sciences from Tokyo Institute of Technology in 2011 and 2013. He joined NTT in 2013 and has been engaged in research of communication quality control. He received the Young Researcher's Award from the Institute of Electronics, Information and Communication Engineers in 2017.

Yasunobu Kasahara
Senior Research Engineer, Access Network Service Innovation Group, Access Network Service Systems Project, NTT Access Network Service Systems Laboratories.

He received a B.E. and M.E. in electronic engineering from Nihon University, Chiba, in 1996 and 1998. He joined NTT in 1998 and has worked on the development of optical access systems such as asynchronous transfer mode systems, passive optical networks, and layer 2 switches. He is currently involved in research and development of content distribution technologies for emerging services.