5G-AV-QoS Technology

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1. Introduction

The fifth-generation mobile communications system (5G) features high speed and large capacity, low latency, and massive connectivity. A high-speed and large-capacity transmission path will enable real-time transmission of 4K or 8K high-definition video, while low latency is expected to enable bidirectional communications via videophones or other devices using high-definition video.

This paper introduces the development of high-definition video transmission technology at Panasonic Corporation.

2. 5G-AV-QoS Technology

Panasonic's 5G-AV-QoS technology[1] transmits video and audio data in real time while maintaining high-quality video and audio over a packet network.

Problems in real-time transmission when using a packet network originate in the fact that a communications path cannot be exclusively occupied in contrast to a conventional circuit switched network. Since multiple connections share the packet network, congestion can occur when the communications network becomes crowded resulting in packet loss if the capacity of the network is exceeded. In addition, a delay in packet arrival can occur since a large volume of packets may be held up in router equipment.

Panasonic's video transmission technology aims to achieve high-quality video transmission in a packet network. This paper describes congestion control, dynamic sending-rate control, and sending-rate control with radio-unit assist as key functions of this technology.

2.1 Congestion control

"Congestion" is a state in which a packet network is filled with communications data. This state can cause packet loss or latency to occur. Congestion control is a function that controls the data-sending rate at the sending side to prevent a state of congestion from occurring.

The Internet and the 5G core network are typical of networks that use a packet network based on Internet Protocol (IP). In addition, data transmission using a packet network generally makes use of Transport Control Protocol (TCP) for data communications such as Hyper Transfer Protocol (HTTP) for displaying information on a browser and File Transfer Protocol (FTP) for transferring files. Here, TCP is equipped with a resend function when packet loss occurs and a congestion control function for controlling the data-sending rate when congestion occurs. This TCP congestion control function prevents a specific connection from transmitting a large volume of data that would monopolize the packet network and enables multiple connections to share the transmission bandwidth. In addition, User Datagram Protocol (UDP) has come to be used for real-time transmission as in voice communications (Voice over IP). UDP is oriented to real-time transmission since it enables data to be transmitted at a fixed rate through application-side control. Furthermore, unlike TCP, UDP does not include a congestion control function, which makes it necessary to control the data-sending rate to prevent congestion from the application side. In the case of audio data, the amount of data is relatively small, which means little impact on the communications of other users. However, video transmission, which transfers a large amount of data, can significantly affect other users making congestion control an important function. TCP Friendly Rate Control (TFRC)[2] that enables coexistence with data communications using TCP is known to be a congestion control system that can be used with UDP.

Panasonic's 5G-AV-QoS adopts a congestion control system based on TFRC, which calculates the sending rate using the Round Trip Time (RTT) value and the packet loss rate. The TFRC sending rate is calculated using Eq. (1) in Figure 1. Here, the RTT value (R in Eq. (1)) exhibits variation, so in Eq. (2), a weighted average of R is calculated between a past RTT value (Rsample) and the last RTT value (Rlast) using a filter constant q. Sending rate (X) becomes large when RTT is small. If congestion occurs, RTT increases and sending rate (X) drops. The sending rate (X) also drops when the packet loss rate (p) increases.

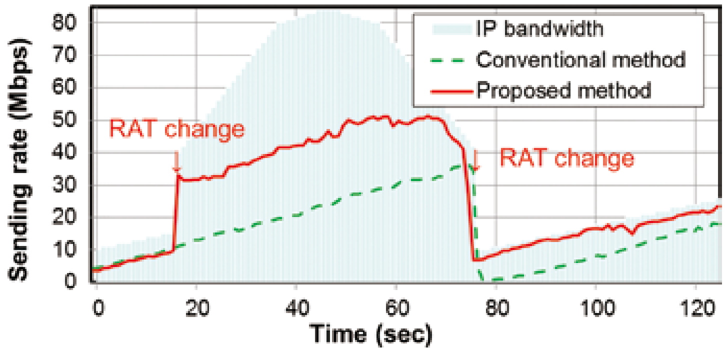
■ **Figure 1: Sending-rate equation**

$$X = \frac{s}{R\sqrt{\frac{2bp}{3}} + t_{RTO}\left(3\sqrt{\frac{3bp}{8}}\,p(1+32p^2)\right)} \quad \cdots \text{(Eq. 1)}$$

$$R = q\,R_{last} + (1-q)\,R_{sample} \quad \cdots \text{(Eq. 2)}$$

X: sending rate
s: packet size
R: Round-trip time calculated from R_{last}, R_{sample}, and q (Eq. (2))
b: max. number of packets acknowledged by a single acknowledgement
p: packet loss event rate
T_{RTO}: retransmission timeout value
R_{last}: last round-trip time
R_{sample}: past round-trip time
q: filter constant

■ Figure 2: Simulation results of sending-rate control with radio-unit assist[4]



2.2 Dynamic sending-rate control

Sending-rate control is a function that dynamically adjusts the resolution of the transmitted video and the compression ratio of the video codec in accordance with the transmission bandwidth. The bandwidth of the transmission path is calculated by the sending-rate equation described above and the resolution of the video and the compression ratio of the video codec are determined according to that sending rate.

5G-AV-QoS supports the H.265/MPEG-HHEVC and H.264/MPEG-4 AVC video codecs. Which of these codecs to use can be selected by settings made when beginning video transmission. Resolution can be changed, for example, by compressing an input 4K image to Full HD, which would considerably reduce the amount of data sent. It is also possible to make settings that fix video resolution while dynamically adjusting only the compression ratio.

2.3 Sending-rate control with radio-unit assist

The 5G system enables use of the millimeter-wave band, which means that high-speed and large-capacity data transmission can be expected. However, as frequencies become higher, the distance that electromagnetic waves can travel becomes shorter thereby reducing the cell size of radio communications. When controlling the sending rate through congestion control for user communications while moving, the sending rate can only be raised gradually, and by the time the sending rate has been sufficiently raised, the user may have already passed through a cell enabling high-speed data transmission. In other words, sending-rate control on its own may not enable effective use of the bandwidth of a high-frequency cell.

At Panasonic, in addition to sending-rate control through congestion control as described above, we have been studying sending-rate control with radio-unit assist that passes handover information from the radio unit to the video-transmission unit[3][4]. The results of simulating the use of this function are shown in Figure 2. When using the method based only on sending-rate control (green broken line), it can be seen that the sending rate rises only gradually in entering a 5G New Radio (5G-NR) cell. In contrast, when using sending-rate control with radio-unit assist (red solid line), the sending rate is able to suddenly jump on being notified by the radio unit that a handover to 5G-NR has occurred. It is also possible to set the sending rate lower on being notified by the radio unit that the user is leaving the 5G-NR cell.

3 Application Examples

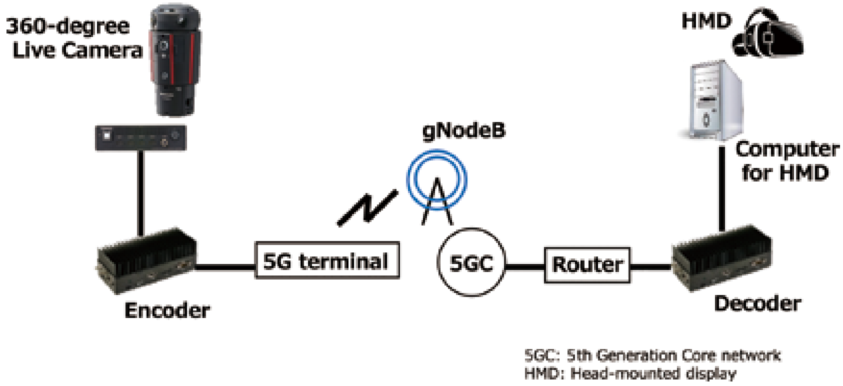
Panasonic participated in the 5G Systems Integrated Verification Trial overseen by the Ministry of Internal Affairs and Communications (MIC) and conducted verification trials on applications and services using a high-definition video transmission system[5].

Configuration of the high-definition Virtual Reality (VR) video transmission system used in the verification trial is shown in Figure 3. This system used Panasonic's 360-degree Live Camera (AW-360C10GJ/AW-360B10GJ)[6] to shoot video. The camera performs real-time stitching of video from four camera systems and outputs uncompressed 360-degree 4K/30p video (3840 x 2160) in a 2:1 equirectangular format. This data is then compressed by an encoder and transmitted in IP packets. Next, the receiver side inputs the 360-degree video output from a decoder into a personal computer for head-mounted display (HMD) use and finally outputs the video to the HMD using Panasonic-developed software. A user wearing the HMD can have a VR experience in which he or she feels present at a remote location (a site in which the 360-degree Live Camera is installed). The following introduces mobile remote conferencing, mobile remote museum, and mobile remote guidance as verification trials using this high-definition VR video transmission system.

3.1 Mobile remote conferencing

In January 2019, we conducted a verification trial of mobile remote conferencing using 5G in Kamiyama town, Tokushima prefecture. In the trial, a 5G mobile station was mounted in an automobile and a participant riding in the automobile participated in the conference while wearing a HMD. The conference room was equipped with the 360-degree Live Camera and 360-degree video of the conference room was sent to the participant riding in the automobile. A view of this conference room is shown in Figure 4. Here, the subject attending the conference from the moving automobile participated in the meeting with a sense of actually being in the conference room through VR video viewed on the HMD.

■ Figure 3: High-definition VR video transmission system



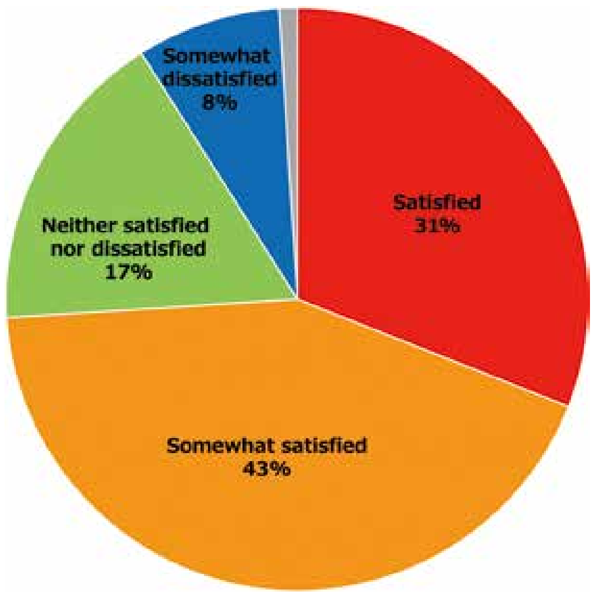
■ Figure 4: View of mobile remote conferencing with VR video transmission system

3.2 Mobile remote museum

In February 2019, we conducted a verification trial of a mobile remote museum connecting the Fukui Prefectural Dinosaur Museum and the Tokyo SKYTREE TOWN. In this trial, a 5G base station was installed within the museum and video from inside the museum was sent to Tokyo while moving a 360-degree Live Camera and 5G mobile station. On the Tokyo side, a participant wearing a HMD had a visual experience as if he or she were actually moving through the museum and experienced an even greater sense of presence at that location by actually conversing with a researcher present at the museum.

We assessed user acceptance of such a use case of a mobile remote museum by administering a questionnaire after conducting a similar trial in December 2018. In the questionnaire, a person experiencing the mobile remote museum was asked to select from "satisfied, somewhat satisfied, neither satisfied nor dissatisfied, somewhat dissatisfied, dissatisfied." Results of the questionnaire are shown in Figure 5. Out of a total of 452 respondents, 74% replied "satisfied" or "somewhat satisfied." Users described their impressions with such comments as "It was nice to see things that I usually don't see." "I enjoyed viewing in real time." and "I felt as if I was actually there."

■ Figure 5: Results of questionnaire on satisfaction with mobile remote museum



3.3 Mobile remote guidance

In January 2020, we conducted a verification trial of mobile remote guidance using 5G in Eiheiji town, Fukui prefecture. In this trial, the 360-degree Live Camera was installed inside a snow-removal vehicle and a user at a remote location (control center) gave advice to the vehicle operator while examining the video from within the vehicle. A view of this verification trial is shown in Figure 6 and a view of examining the video received from the snow-removal vehicle is shown in Figure 7. In the latter figure, the video displayed on the monitor is the same video seen by the HMD wearer. Users experiencing this application gave comments such as “It was actually easy to use.” and “I felt as if I was actually operating the vehicle, more than I expected.” This was because describing the situation was easy even from a remote location since video was provided in addition to audio and because viewing by HMD made it possible to give direct instructions as in ordinary conversation in the manner, for example, of “Clear the snow drift on your left.”

4. Conclusion

This paper introduced Panasonic’s 5G-AV-QoS video transmission technology using 5G. It also presented mobile remote conferencing, mobile remote museum, and mobile remote guidance as promising services and applications using high-definition video transmission.

■ Figure 6: View of verification trial of mobile remote guidance

■ Figure 7: View of giving guidance to snow-removal vehicle operator

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https://panasonic.biz/cns/sav/products/aw-360/index.html

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