IIR

Internet
Infrastructure
Review

Nov.2022
Vol. 56

Periodic Observation Report

Broadband Traffic Report: COVID's 3rd Year Brings Lull in Traffic

Focused Research

Live-Streaming the Spring Festival in Tokyo—Our Report

IIJ
Internet Initiative Japan

Internet Infrastructure Review
November 2022 Vol.56

Executive Summary

Nearly three years have now passed since the initial outbreak of COVID-19 at the end of 2019. Over that time, the whole gamut of our daily lives across work and play has moved online, partly in response to social restrictions designed to stop the spread, and we have thus observed a global increase in Internet traffic. While many countries are lifting restrictions, the virus continues to mutate, and we are certainly aware that the future remains unpredictable.

International tensions between democratic and authoritarian regimes also continue to escalate, and half a year has now passed since Russia began its military invasion of Ukraine. From the perspective of economic security, this has cast into the spotlight the importance of supply chain risks relevant to the communications infrastructure that underpins the Internet.

An end to the global semiconductor shortages that have emerged since autumn 2020 remains elusive. The shortages have been attributed to a confluence of factors, including the COVID-19 pandemic, hostility between democratic and authoritarian regimes, and the invasion of Ukraine. Some are of the view that the situation will start moving toward a resolution from the latter half of this year, but the prospects remain unclear for some of these factors, so the situation will continue to bear close watching.

As the world grows increasingly uncertain, I feel that the Internet will play an increasingly important role in terms of the underlying infrastructure of our society and daily lives. Development of the Internet began back in the 1960s, and to this day, new Internet technologies are still being developed, and the discussion around rule-making and governance on the use of the Internet is ongoing.

Two important conferences related to the Internet will take place in Japan in 2023. IETF 116, which will focus on technology development, is slated for March, and IGF 2023, on Internet governance, is slated for November or December. Given our involvement with the Internet, we will be paying close attention to these events.

The IIR introduces the wide range of technology that IIJ researches and develops, comprising periodic observation reports that provide an outline of various data IIJ obtains through the daily operation of services, as well as focused research examining specific areas of technology.

Our periodic observation report in Chapter 1 provides our analysis of IIJ's fixed broadband and mobile traffic. We have been performing this analysis for some time now, and the numbers show that traffic continues to increase and that fixed broadband continues to shift from PPPoE to IPoE. Our analysis on usage by port also bears out the shift from HTTP (TCP/80) to HTTPS (TCP/443) and to QUIC (UDP/443).

Our focused research report in Chapter 2 describes our work live-streaming the Spring Festival in Tokyo, of which IIJ is a sponsor. This music festival has been running since 2005, but since 2020, the COVID-19 pandemic has resulted in some performances not going ahead and measures such as attendance limits being imposed. As such, we have been live-streaming the festival on the Internet so that as many people as possible can enjoy the music on offer. This is a real-life report from members of the team that set up systems for efficiently broadcasting from multiple venues and implemented features to make the experience enjoyable for viewers.

Through activities such as these, IIJ strives to improve and develop its services on a daily basis while maintaining the stability of the Internet. We will continue to provide a variety of services and solutions that our customers can take full advantage of as infrastructure for their corporate activities.

Junichi Shimagami

Mr. Shimagami is a Senior Executive Officer and the CTO of IIJ. His interest in the Internet led to him joining IIJ in September 1996. After engaging in the design and construction of the A-Bone Asia region network spearheaded by IIJ, as well as IIJ's backbone network, he was put in charge of IIJ network services. Since 2015, he has been responsible for network, cloud, and security technology across the board as CTO. In April 2017, he became chairman of the Telecom Services Association of Japan's MVNO Council, and in June 2021, he became a vice-chairman of the association.

Broadband Traffic Report: COVID's 3rd Year Brings Lull in Traffic

1.1 Overview

In this report, we analyze traffic over the broadband access services operated by IIJ and present the results each year[*1*2*3*4*5]. Here, we again report on changes in traffic trends over the past year, based on daily user traffic and usage by port. Now in the third year of the COVID-19 pandemic, the solid increase in traffic we reported on last year has continued, albeit with the growth rate slowing slightly, and so far we see no noticeable changes in that overall trend.

Figure 1 plots the overall average monthly traffic trends for IIJ's fixed broadband services and mobile services. IN/OUT indicates the direction from the ISP perspective. IN represents uploads from users, and OUT represents user downloads. Because we cannot disclose specific traffic numbers, we have normalized the data, setting the OUT observations for January 2020, just before the pandemic, for both services to 1.

Broadband services traffic fell a little from autumn last year when Japan's COVID-19 case numbers settled down, and after rising in January–February when case numbers picked up again, traffic has been hovering roughly around the same level. Over the past year, broadband IN traffic increased 13% and OUT traffic increased 17%. These growth figures are down a little from the year-earlier figures of 20% and 23%.

The broadband figures include IPv6 IPoE traffic. IPv6 traffic on IIJ's broadband services comprises both IPoE and PPPoE traffic. As of June 2022, IPoE accounted for roughly 40% of all traffic, at 39% of IN and 41% of OUT broadband traffic overall, year-on-year increases of 8 and 11 percentage points, respectively. With PPPoE congestion having become quite noticeable amid COVID-19, users are increasingly shifting to IPoE, and use of IPoE thus continues to rise.

Mobile services traffic had remained range-bound amid COVID-19 up until we reported last year, but it subsequently began rising from summer. It fell a little when case numbers increased again in January–February, but it has been rising since. Over the past year, mobile IN traffic increased 23% and OUT traffic increased 8%.

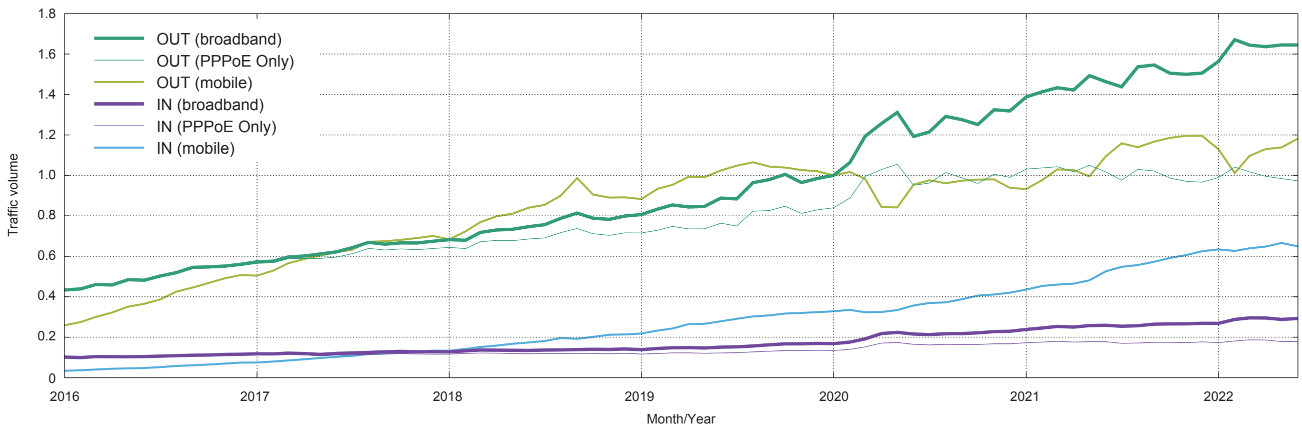

Figure 1: Monthly Broadband and Mobile Traffic

*1 Kenjiro Cho. Broadband Traffic Report: Broadband Traffic Report: COVID-19's Impact in its 2nd Year. Vol. 52. pp4-11. September 2021.

*2 Kenjiro Cho. Broadband Traffic Report: The Impact of COVID-19. Vol. 48. pp4-9. September 2020.

*3 Kenjiro Cho. Broadband Traffic Report: Moderate Growth in Traffic Volume Ongoing. Vol. 44. pp4-9. September 2019.

*4 Kenjiro Cho. Broadband Traffic Report: Download Growth Slows for a Second Year Running. Vol. 40. pp4-9. September 2018.

*5 Kenjiro Cho. Broadband Traffic Report: Traffic Growth Slows to a Degree. Internet Infrastructure Review. Vol. 36. pp4-9. September 2017.

We now look at broadband traffic by time of day on weekdays amid COVID-19. Traffic volume here is the sum of PPPoE and IPoE. Figure 2 shows traffic for the following seven weeks. To illuminate the initial changes taking place under COVID-19 in 2020, we show the week of February 25, 2020, before Japan's school closures, the week of April 20, 2020, corresponding to Japan's first state of emergency, and the week of June 22, 2020, after the state of emergency was lifted. And to illuminate changes that occurred later on, we then jump forward about half a year to the week of January 18, 2021, and then to the weeks of July 5, 2021, January 17, 2022, and July 4, 2022. We plot hourly average traffic volume figures for Monday–Friday for each of these weeks. The lines in the lower part of each plot represent uploads, but we again focus on download volume.

Comparing February and April 2020 to see the impact of the first state of emergency, we see that traffic was up substantially in the daytime and that it also increased during evening peak hours. When the state of emergency was lifted in June, the additional daytime traffic fell to less than half what it had been, but peak hours saw almost no decline. Over the last two years, traffic during the peak hours of 20:00–22:00 has seen a fairly consistent increase. Meanwhile, in both 2021 and 2022, daytime traffic was up significantly in January but not much in July. This probably reflects that in January of both years, people spent more time at home amid increases in COVID-19 case numbers, whereas the COVID-19 situation was relatively calm at the start of both Julys. So over the past two years, traffic has seen a solid increase during the nighttime peak hours, while increases during daytime hours have been influenced by the rates of people staying at home in response to COVID-19.

1.2 About the Data

As with previous reports, for broadband traffic, our analysis uses data sampled using Sampled NetFlow from the routers that accommodate the fiber-optic and DSL broadband customers of our personal and enterprise broadband access services. For mobile traffic, we use access gateway billing information to determine usage volumes for personal and enterprise mobile services, and we use Sampled NetFlow data from the routers used to accommodate these services to determine the ports used.

Because traffic trends differ between weekdays and weekends, we analyze traffic in one-week chunks. In this report, we look at data for the week of May 30 – June 5, 2022, and compare those data with data for the week of May 31 – June 6, 2021, which we analyzed in the previous edition of this report.

Results are aggregated by subscription for broadband traffic, and by phone number for mobile traffic as some subscriptions cover multiple phone numbers. The usage volume for each broadband user was obtained by matching the IP address assigned to users with the IP addresses observed. We gathered statistical information by sampling packets using NetFlow. The sampling rate was set to around 1/8,192, taking into account router performance and load. We estimated overall usage volumes by multiplying observed volumes by the reciprocal of the sampling rate. Note that IPoE traffic is not included in the analysis of traffic by port, as detailed data is not available because we use Internet Multifeed Co.'s transix service for IPoE.

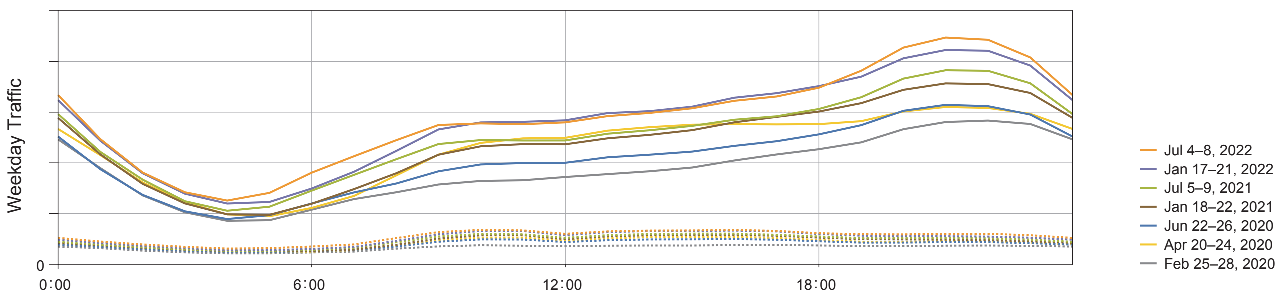

Figure 2: Hourly Average Broadband Traffic on Weekdays

1.3 Users' Daily Usage

First, we examine daily usage volumes for broadband and mobile users from several angles. Daily usage indicates the average daily usage calculated from a week's worth of data for each user.

Since our 2019 report, we have used daily usage data only on services provided to individuals. The distribution is heavily distorted if we include enterprise services, where usage patterns are highly varied. So to form a picture of overall usage trends, we determined that using only the personal user data would yield more generally applicable, easily interpretable conclusions. Starting with this report, we also include IPoE user data. Note that the analysis of usage by port in the next section does include enterprise data because of the difficulty of distinguishing between individual and enterprise usage.

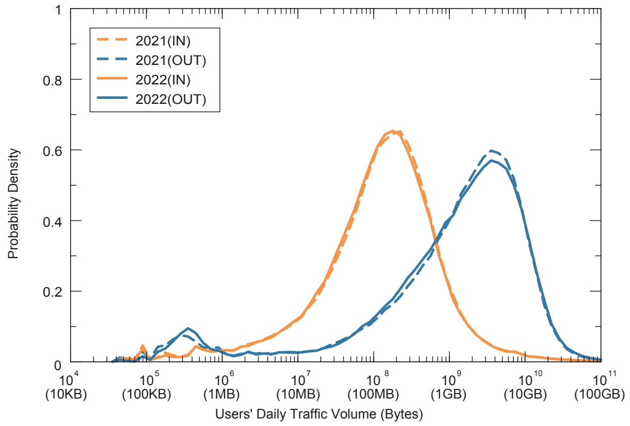

Figure 3: Daily Broadband (PPPoE) User Traffic Volume Distribution Comparison of 2021 and 2022

Figures 3 and 4 show the average daily usage distributions (probability density functions) for broadband (PPPoE and IPoE) and mobile users. Each compares data for 2021 and 2022 split into IN (upload) and OUT (download), with user traffic volume plotted along the X-axis and user frequency along the Y-axis. The X-axis shows volumes between 10KB (10^4) and 100GB (10^{11}) using a logarithmic scale. Most users fall within the 100GB (10^{11}) range, with a few exceptions.

The IN and OUT traffic distributions in the figures are close to a log-normal distribution, which looks like a normal distribution on a semi-log plot. A linear plot would show a long-tailed distribution, with the peak close to the left and a slow gradual decrease toward the right. The OUT distribution is further to the right than the IN distribution, indicating that download volume is more than an order of magnitude larger than upload volume.

First, we look at the broadband PPPoE distributions in Figure 3. Both the IN and OUT distributions have barely changed between 2021 and 2022. A close look reveals that the 2022 OUT distribution peak is ever so slightly lower while the midrange of the left side of the distribution is commensurately a little higher, indicating that the proportion of relatively low-usage users has risen a bit.

The broadband IPoE distributions in Figure 4 are shifted further to the right than the PPPoE distributions, and overall usage is much higher than for PPPoE. The distributions are also narrower than for PPPoE and almost symmetrical.

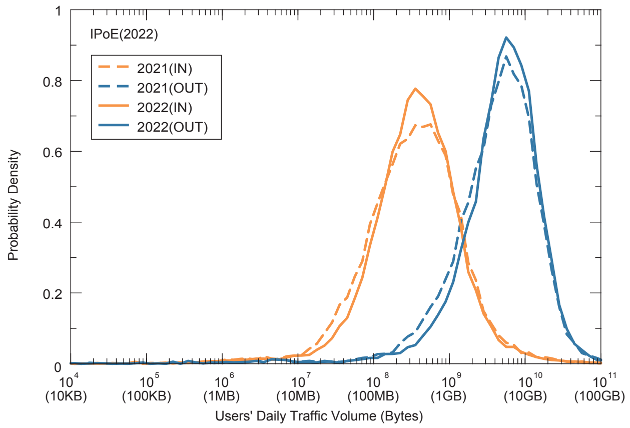

Figure 4: Daily Broadband (IPoE) User Traffic Volume Distribution Comparison of 2021 and 2022

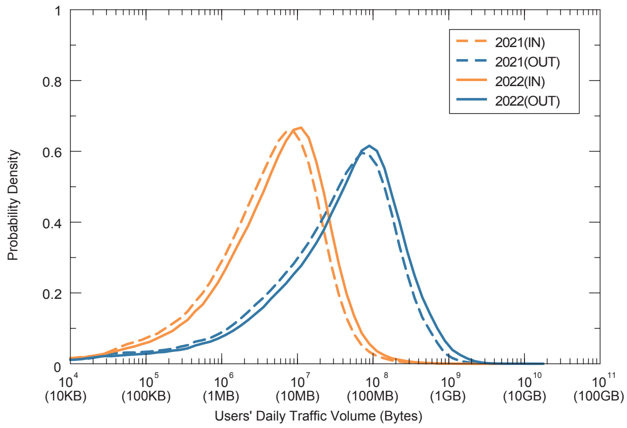

Figure 5: Daily Mobile User Traffic Volume Distribution Comparison of 2021 and 2022

While the proportion of low-usage users on the left side of the distributions is smaller, there is not much difference for high-usage users on the right of the distributions. The IPoE distributions do not look much different from last year, but the peaks are slightly higher, and in contrast to PPPoE, the proportion of observations near the mode increased.

So the overall broadband distributions for both PPPoE and IPoE have hardly changed. Meanwhile, with the migration from PPPoE to IPoE progressing, the proportion accounted for by IPoE is rising, so overall traffic volume is increasing.

The peaks of the mobile distributions in Figure 5 have moved a little to the right since last year, indicating that overall traffic has increased. Mobile usage volumes are significantly lower than for broadband, and limits on mobile data usage mean that heavy users, which fall on the right-hand side of the distribution, account for only a small proportion of the total. There are also no extremely heavy users. The variability in each user's daily usage volume is higher for mobile than for broadband owing to there being users who only use mobile data when out of the home/office as well as limits on mobile data.

Table 1 shows trends in the mean and median daily traffic values for broadband PPPoE users as well as the mode (the most frequent value, which represents the peak of the distribution). When the peak is slightly off the center of the distribution, the distribution is adjusted to bring the mode toward the center. Comparing 2021 and 2022, the IN mode fell from 200MB to 178MB and the OUT mode was unchanged at 3,981MB, translating into growth factors of 0.9 for IN and 1 for OUT. Meanwhile, because the means are influenced by heavy users (on the right-hand side of the distribution), they are significantly higher than the corresponding modes, with the IN mean at 698MB and the OUT mean at 4,291MB in 2022. The 2021 means were 684MB and 4,225MB, respectively.

As Table 2 shows, IPoE usage is much higher than PPPoE usage. This is probably because relatively high-usage users are moving to IPoE first, or in other words, because many of the low-usage users still linger on PPPoE. In 2022, the IN mode was 398MB and the OUT mode was 6,310MB, while the means were IN 1,007MB and OUT 7,700MB. The 2021 modes were IN 447MB and OUT 6,310MB, and the means were IN 1,110MB and OUT 7,169MB.

Table 1: Trends in Mean and Mode of Broadband (PPPoE) Users' Daily Traffic Volume

	IN(MB/day)			OUT(MB/day)		
Year	Mean	Median	Mode	Mean	Median	Mode
2007	436	5	5	718	59	56
2008	490	6	6	807	75	79
2009	561	6	6	973	91	100
2010	442	7	7	878	111	126
2011	398	9	9	931	144	200
2012	364	11	13	945	176	251
2013	320	13	16	928	208	355
2014	348	21	28	1124	311	501
2015	351	32	45	1399	443	708
2016	361	48	63	1808	726	1000
2017	391	63	79	2285	900	1259
2018	428	66	79	2664	1083	1585
2019	479	75	89	2986	1187	1995
2020	609	122	158	3810	1638	3162
2021	684	136	200	4225	1875	3981
2022	698	130	178	4291	1778	3981

Table 2: Trends in Mean and Mode of Broadband (IPoE) Users' Daily Traffic Volume

	IN(MB/day)			OUT(MB/day)		
Year	Mean	Median	Mode	Mean	Median	Mode
2021	1110	312	447	7169	4285	6310
2022	1007	336	398	7700	4935	6310

All of the mobile traffic metrics were up, as Table 3 shows. In 2022, the IN mode was 10MB and the OUT mode was 89MB, while the means were IN 13MB and OUT 114MB. The 2021 modes were IN 8MB and OUT 71MB, and the means were IN 10MB and OUT 86MB.

Figures 6, 7, and 8 plot per-user IN/OUT usage volumes for random samples of 5,000 users. The X-axis shows OUT (download volume) and the Y-axis shows IN (upload volume), with both using a logarithmic scale. Users with identical IN/OUT values fall on the diagonal.

The cluster spread out below and parallel to the diagonal in each of these plots represents typical users with download volumes an order of magnitude higher than upload volumes. For broadband PPPoE traffic, there was previously a clearly recognizable cluster of heavy users spread out thinly about the upper right of the diagonal, but this is now no longer discernible. Variability between users in terms of usage levels and IN/OUT ratios is wide, indicating that there is a diverse range of usage styles. On IPoE, there is less variability between users than with PPPoE, and the proportion of low-usage users is small. For mobile traffic, the pattern of OUT being an order of magnitude larger also applies, but usage volumes are much lower than for broadband. For both broadband and mobile, there is almost no difference between these plots and those for 2021.

Traffic is heavily skewed across users, such that a small proportion of users accounts for the majority of overall traffic volume. For example, the top 10% of broadband users account for 50% of total OUT and 78% of total IN traffic, while the top 1% of users account for 16% of OUT and 53% of IN traffic.

Table 3: Trends in Mean and Mode of Mobile Users' Daily Traffic Volum

	IN(MB/day)			OUT(MB/day)		
Year	Mean	Median	Mode	Mean	Median	Mode
2015	6.2	3.2	4.5	49.2	23.5	44.7
2016	7.6	4.1	7.1	66.5	32.7	63.1
2017	9.3	4.9	7.9	79.9	41.2	79.4
2018	10.5	5.4	8.9	83.8	44.3	79.4
2019	11.2	5.9	8.9	84.9	46.4	79.4
2020	10.4	4.5	7.1	79.4	35.1	63.1
2021	9.9	4.7	7.9	85.9	37.9	70.8
2022	12.8	6.0	10.0	113.7	49.2	89.1

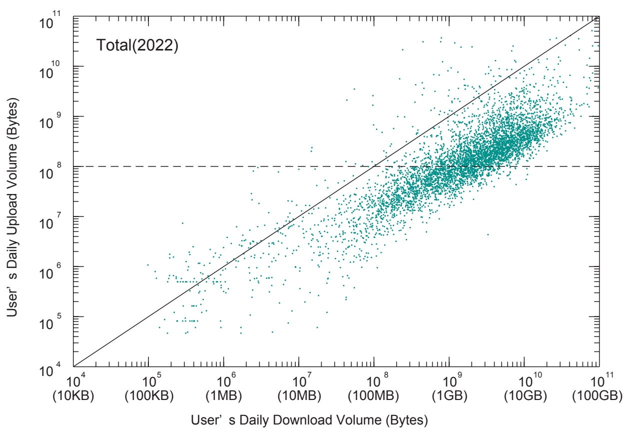

Figure 6: IN/OUT Usage for Each Broadband (PPPoE) User

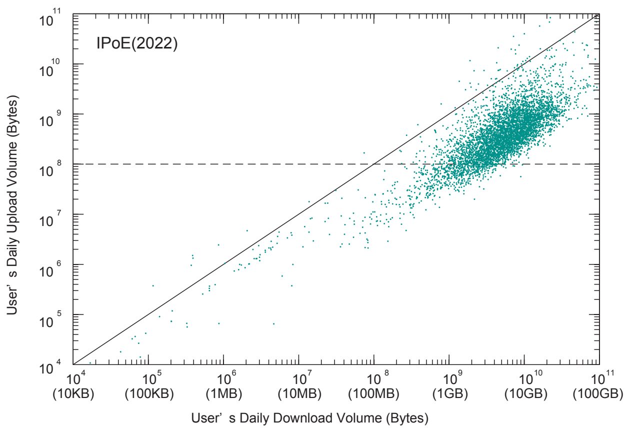

Figure 7: IN/OUT Usage for Each Broadband (IPoE) User

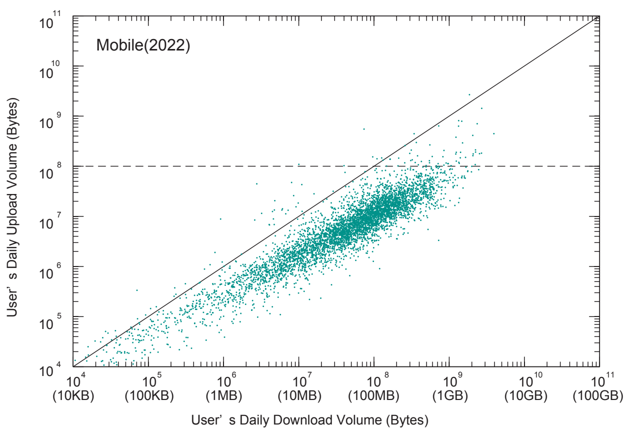

Figure 8: IN/OUT Usage for Each Mobile User

The skew has increased just slightly from last year. On IPoE, the skew is smaller than for PPPoE, with the top 10% of users accounting for 39% of OUT and 64% of IN traffic and the top 1% of users accounting for 11% of OUT and 36% of IN traffic. As for mobile, the top 10% of users account for 50% of OUT and 49% of IN traffic, while the top 1% account for 13% of OUT and 16% of IN traffic. The skew in OUT traffic has increased just slightly from last year.

1.4 Usage by Port

Next, we look at a breakdown of traffic and examine usage levels by port. Recently, it has become difficult to identify applications by port number. Many P2P applications use dynamic ports on both ends, and a large number of client/server applications use port 80, which is assigned to HTTP, to avoid firewalls. Hence, generally speaking, when both parties are using a dynamic port numbered 1024 or higher, the traffic is likely to be from a P2P application, and when one of the parties is using a well-known port lower than 1024, the traffic is likely to be from a client/server application. In light of this, we take the lower of the source and destination port numbers when breaking down TCP and UDP usage volumes by port.

Table 4 shows the percentage breakdown of broadband users' usage by port over the past five years. In 2022, 72% of all traffic was over TCP connections, largely unchanged from 2021. The proportion of traffic over port 443 (HTTPS) was 56%, a 2-point increase from last year. The proportion of traffic over port 80 (HTTP) fell from 12% to 9%. The figure for UDP port 443, which is used by the QUIC protocol, was largely unchanged at 16%.

TCP dynamic port traffic, which had been in decline, looks to have leveled out at 6%. Individual dynamic port numbers account for only a tiny portion, with the most commonly used port 31000 only making up 0.9%. Port 1935, which is used by Flash Player, makes up 0.2%, but almost all other traffic is VPN related.

Table 4: Broadband Users' Usage by Port

year	2018	2019	2020	2021	2022
protocol port	(%)	(%)	(%)	(%)	(%)
TCP	**78.5**	**81.2**	**77.2**	**71.9**	**71.6**
(< 1024)	68.5	73.3	70.5	65.8	65.4
443(https)	40.7	51.9	52.4	53.5	55.7
80(http)	26.5	20.4	17.2	11.6	8.9
183	0.0	0.0	0.0	0.1	0.2
22(ssh)	0.1	0.2	0.2	0.2	0.1
993(imaps)	0.2	0.3	0.2	0.1	0.1
(>= 1024)	10.0	7.9	6.7	6.1	6.2
31000	0.1	0.2	0.4	0.6	0.9
8080	0.3	0.5	0.4	0.4	0.3
1935(rtmp)	0.7	0.3	0.4	0.2	0.2
UDP	**16.4**	**14.1**	**19.4**	**24.5**	**24.3**
443(https)	10.0	7.8	10.5	15.9	16.3
4500(nat-t)	0.2	0.3	0.6	0.8	0.8
8801	0.0	0.0	1.1	0.9	0.6
ESP	**4.8**	**4.4**	**3.2**	**3.3**	**3.8**
GRE	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**
IP-ENCAP	**0.2**	**0.2**	**0.1**	**0.1**	**0.1**
ICMP	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 5 shows the percentage breakdown by port for mobile users. The figures are close to those for broadband on the whole. This is likely because apps similar to those for PC platforms are now also used on smartphones, and because the proportion of broadband usage on smartphones is rising.

Broadband data only include PPPoE, not IPoE, and so do not necessarily reflect the trend in fixed broadband overall. Comparing IPv4 and IPv6 on mobile, port 443 accounts for a higher proportion of both TCP and UDP usage on IPv6, and there is probably a similar trend in the case of IPoE.

Table 5: Mobile Users' Usage by Port

year	2018	2019	2020	2021	2022
protocol port	(%)	(%)	(%)	(%)	(%)
TCP	**76.6**	**76.9**	**75.5**	**70.3**	**71.6**
443(https)	52.8	55.6	50.7	44.4	42.3
80(http)	16.7	10.3	7.4	5.0	4.1
993(imaps)	0.3	0.3	0.2	0.2	0.1
1935(rtmp)	0.1	0.1	0.1	0.1	0.1
UDP	**19.4**	**17.3**	**18.0**	**23.8**	**24.4**
443(https)	10.6	8.3	9.3	16.3	17.9
4500(nat-t)	4.5	3.0	1.8	3.7	2.7
1701(12tp)	0.0	0.4	0.9	0.0	0.8
8801	0.0	0.0	1.4	0.7	0.3
3480	0.0	0.0	0.4	0.3	0.1
ESP	**3.9**	**5.8**	**6.4**	**5.8**	**3.9**
GRE	**0.1**	**0.0**	**0.1**	**0.1**	**0.0**
ICMP	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Figure 9 compares overall broadband traffic for key port categories across the course of the week from which observations were drawn in 2021 and 2022. We break the data into four port buckets: TCP ports 80 and 443, and dynamic TCP ports (1024 and up), and UDP port 443. The data are normalized so that peak overall traffic volume on the plot is 1. The overall peak is around 19:00–23:00. When compared, there is almost no difference between 2021 and 2022, and it appears that the migration from HTTP to HTTPS has largely run its course for now.

Figure 10 shows the trend for TCP ports 80 and 443 and UDP port 443, which account for the bulk of mobile traffic. Here too, there is almost no change from 2021. When compared with broadband, we note that mobile traffic levels remain high throughout the day, from morning through night. The plot shows that usage times differ from those for broadband, with three separate mobile traffic peaks occurring on weekdays: morning commute, lunch break, and evening around 17:00–22:00.

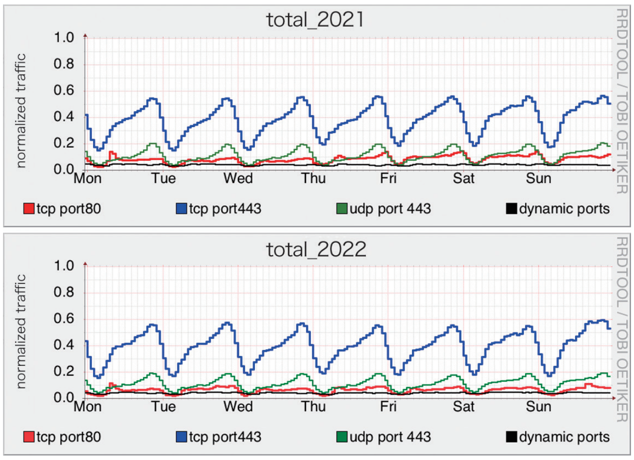

Figure 9: Broadband Users' Port Usage Over a Week
2021 (top) and 2022 (bottom)

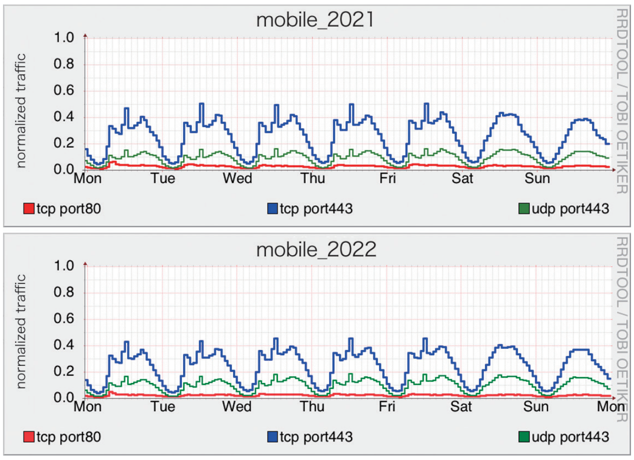

Figure 10: Mobile Users' Port Usage Over a Week
2021 (top) and 2022 (bottom)

1.5 Conclusion

In summary, the trends in traffic we reported on last year have continued to hold over the past twelve months, which marked COVID-19's third year, with no major changes apparent. Daytime broadband traffic does look to have been shaped by the rate at which people stayed home in response to infection case numbers, but it is steadily rising during the peak hours. Growth in overall traffic volume has been solid, driven by the migration to IPoE, but beyond that, there has not been much change in individual users' usage volumes. Hence, while it is evident that online conferencing and video streaming are establishing themselves as the norm, looking at the past year in isolation, we do not really see any major changes in the services users use or how they use them.

Kenjiro Cho
Research Director, Research Laboratory, IIJ

Live-Streaming the Spring Festival in Tokyo —Our Report

2.1 Introduction

The Spring Festival in Tokyo is one of Japan's largest classical music festivals, held once a year at music halls, museums, and other venues around Ueno. Originally the Tokyo Opera Nomori, which began in 2005, the festival in its current format has been adding color to Ueno's spring scene since 2009. The 2019 event was huge, featuring 208 performances across all venues, but most of the performances were canceled in 2020 when COVID-19 hit, leaving only 14 performances that year.

In 2021, the festival went ahead under restrictions to prevent the spread of COVID-19—a maximum attendance of 5,000 or a 50% venue capacity limit—so to make up for the limitations on physical attendance, we live-streamed all 60 performances held across the 14 venues.

In 2022, as in 2021, we live-streamed almost all of the 56 performances across 14 venues. With over 10 venues being streamed and some performance or other taking place every day over the festival's month-or-so running time, on some days we streamed as many as four performances simultaneously. To stream multiple performances at a time, in 2021 we carted a whole lot of equipment to the Tokyo Bunka Kaikan, one of the venues, and set up a temporary streaming center to record and broadcast the events. This year, however, we established our streaming center at IIJ's headquarters in Iidabashi and greatly increased the level of operations performed remotely via FLET'S and mobile connectivity in an attempt to reduce streaming costs, including those associated with personnel resources.

This report takes you behind the live-streaming scenes by explaining our process for deciding on system configurations and the IP technology we used, along with some added color on the trials and tribulations of making everything work.

2.2 Live-Streaming Specifications and Solutions

In 2022, the music festival organizers asked us if we could offer an increased range of payment options while keeping ticket prices reasonable to boost live-stream viewership. We added in-app smartphone (iOS/Android) payment support to make it easier to buy tickets. And we had to do a full review of costs to ensure ticket prices would be reasonable. Our goal with the live-streaming specifications was to keep a lid on costs everywhere we could, including how we deployed equipment and staff and how we configured our systems, while not impairing the user experience.

■ Consideration 1: Minimizing equipment

Up until 2021, we brought several cameras to each venue so we could switch camera angles according to what was happening in the performance, but our uniform approach in 2022 was to install a single 4K camera in the back row of each venue to capture the entire scene. This made it possible to greatly reduce the amount of equipment brought into the venues. On the other hand, it meant that the viewer would also be seeing a full-angle image of the performance. So to make up for the video feed not being switched to focus on the highlights of each performance, we incorporated zoom and pan features into the video player to give viewers control over the viewport. Also, although the song list is posted on the player page, it is not visible in fullscreen mode, so we added a feature to the player to let viewers check the song list while in fullscreen mode as well.

■ Consideration 2: On-site staff deployments

Since the performance venues change daily and are public facilities, we are not able to set and leave our broadcast equipment within the venues for the whole duration of the festival. Hence, we had to set things up before the start of every performance, and time was very tight at times depending on what time performances were scheduled to start on the day in question. Laying cables within the venue was particularly challenging. Stability is important when transmitting video, so we were using wired connections, and this meant laying cables 100m long in large venues, which required several staff to work together. To reduce the workload for on-site staff, tasks such as focusing the camera, adjusting brightness, and performing audio level and LR tests were accomplished remotely rather than by staff at the venue.

■ Consideration 3: Remote production

Up until 2021, we set our streaming center up at the Tokyo Bunka Kaikan in Ueno, from where we performed the work involved in transmitting the video to viewers, which included recording, video feed switching, and subtitling, and we had to bring a huge amount of equipment to Ueno to enable us to stream four performances at once. Setting the streaming center up at IIJ's headquarters in Iidabashi in 2022 obviated the need for people to travel, transport equipment, and build and operate a separate center. Staff responsible for feed switching no longer needed to travel to Ueno, which reduced not only the costs but also the workload on staff. To prevent problems arising with the remote setup, we decided on how staff would communicate with each other, what the procedures would be for installing and checking equipment, and so on before the festival, and we set rules on updating our operating procedures as needed and swiftly communicating these changes to staff. These efforts are what made the remote production setup work.

Based on these three considerations, we decided on the following specifications: the event would only be live streamed with no archives kept, video would be at most

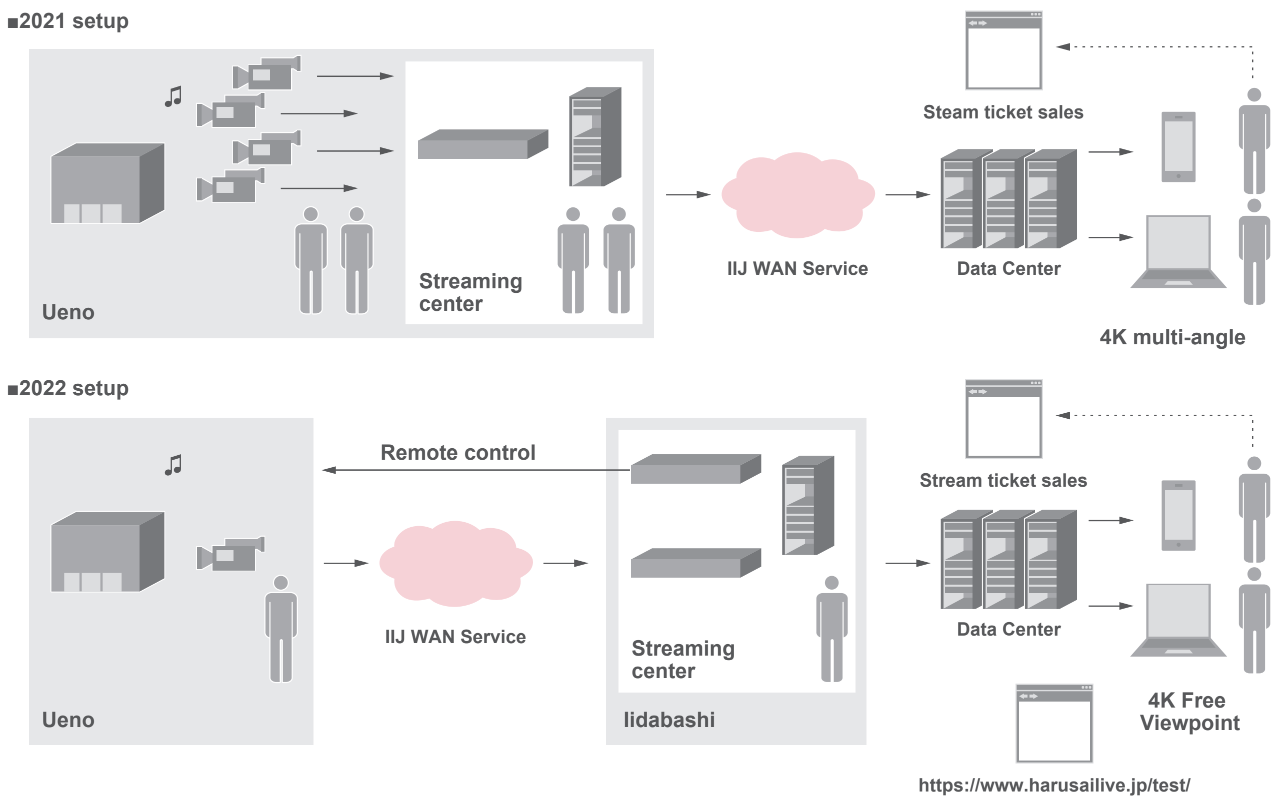

Figure 1: Live-Streaming System Configuration Comparison (2021 & 2022)

4K (with some 2K feeds), and sound would be recorded at AAC 256kbps. In 2021, streaming tickets cost ¥1,500–2,500 (tax inclusive, same below), while in 2022 we set a relatively affordable price of around ¥1,100 per performance (with some available for ¥730).

2.3 Live-Streaming System Configuration

We now describe how we set up the live-streaming system.

■ Cameras

We used Panasonic's AW-UE100K 4K integrated cameras. We selected this model because its size would be unobtrusive at the venues and because it supported remote PTZ (pan, tilt, and zoom). The AW-RP60G controller equipped with a PTZ joystick allowed us to move the camera through the horizontal and vertical planes as well as control zoom in/out, image brightness, and so forth easily from a remote location (IIJ headquarters). This let the on-site staff concentrate on the physical installation of the cameras, cables, and so on, thus reducing the on-site staffing requirement.

■ Transmitting video from Ueno to IIJ headquarters

For the main 4K transmission circuit, we used the IIJ Multi Product Controller Service (https://www.iij.ad.jp/en/biz/mpc/), which enables centralized management and integrated operation of networked devices, and built a Layer 3 VPN using IPv6 loopback on the FLET'S Hikari Next service. The high-performance IIJ router SEIL/X4, which we used as the VPN adapter, retrieves its own configuration data from its management server when powered on and wired up, so there is no need to have engineers on site to configure and check the device. And because the status of all devices is available at glance on the router's control panel, it is very useful in situations, such as the festival, when there are multiple devices to manage.

When we measured network bandwidth ahead of the performances, there were differences depending on the

Figure 2: Camera and Controller

Tripod and camera placed at back of venue

1. Set up tripod and camera at venue
2. Check camera level/tilt remotely and ask venue staff to adjust tripod
3. Use controller to remotely adjust view angle and brightness
4. Send L and R audio signals from venue and check remotely for left/right stereo alignment

Figure 3: Equipment Setup Procedure at Venue

Figure 4: Transmitting Video from Ueno to IIJ

Figure 5: Illustration of LiveU Backup Connection

time of day, but we were getting around 200Mbps over the VPN tunnel, which is sufficient bandwidth for effectively transmitting video.

We used LiveU (https://www.liveu.tv/ja) video transmission devices as a backup and virtually bundled together multiple mobile carriers' connections, over which we transmitted video in HD. The LiveU system allows multiple SIMs to be installed to enable the transmission of more video data over multiple mobile connections, and is even used by broadcasters for live coverage. We used LTE contracts for the SIMs because 5G was not yet available at the venues.

Reception was poor at some venues, and some of them jammed mobile signals during the performances, so we needed to know the quirks of each individual venue to determine where to install the LiveU units. Some trial and error was involved in selecting installation spots, but we were generally able to transmit in HD without issue at bit rates of around 10–15Mbps.

■ Transmission protocols

Our video resolution and frame rate was 4K at 30p. Uncompressed, this would take as much as 6Gbps, so we compressed it to around 30Mbps using H.265 and transmitted it to IIJ headquarters using the SRT protocol.

SRT stands for Secure Reliable Transport and is a video transport protocol published by HaiVision in 2014 to facilitate the transmission of video via the Internet. A range of vendors have adopted it since it was open-sourced in 2017, and the SRT Alliance had over 500 members as of June 2022; IIJ is also a member (https://www.srtalliance.org/). SRT is based on UDP, and while maintaining low latency, it also provides more packet recovery features than TCP, and supports encryption using AES. As one of the leading protocols for transmitting video over broadband services and the like where bandwidth is not guaranteed, it can be expected to be adopted on an increasing number of devices going forward.

■ Transmitting and buffering

Our connection had an effective bandwidth of 200 Mbps, so we figured we would be able to transmit using SRT at around 30Mbps without any problems, but when we actually tried it out, the system was generating annoying little noises every few minutes. The error counter did not rise when this happened, so we were unable to identify the cause, but we were able to resolve it by setting a larger buffer size on the receiving device.

A larger buffer increases the broadcast delay, but this was not a problem because the content we were dealing with was concerts, so strictly real-time coverage was not really a major imperative. When live-streaming sports and other such events, however, low latency is a must, so the settings need to be adjusted according to the characteristics of the connection being used.

■ Subtitles

The operas were not performed in Japanese. Lohengrin is sung in German and Turandot in Italian, so in the case of large concert halls, Japanese translations appeared

Figure 6: Player with Subtitle Support

on displays on both sides of the stage. Although there were no such in-venue subtitles for songs performed at art galleries and museums, we had to include subtitles for users watching via stream. In 2021, we hardcoded the subtitles into the video, but in 2022, we provided subtitles using the setup shown in Figure 7. This meant that users were able to easily turn subtitles on and off during the performances.

To display the subtitles at the right time, the operator needs to keep the subtitling system in time with the song. But the engineers alone cannot handle the timing. To deal with this issue, music festival staff who properly understood the content helped our engineers to display the right subtitles at the right time. We built a system to insert the subtitles into the video data in the form of ID3 metadata in real time in accordance with the instructions issued, and we set our operations up so that we could control this subtitling system remotely in response to instructions from staff positioned at the side of the stage. These timing instructions are issued in real time, but the video is transmitted with a few seconds' delay, so our subtitling system includes an appropriate delay to ensure the text appears at the right time.

■ Streaming center at IIJ headquarters

We were in charge of coordinating the video feeds of the performances coming in from the venues in Ueno, inserting on-screen text before the performance, during intermission, and at the end, and transcoding the video into a format viewable by end users and streaming it out. As the photo shows, we had displays as well as switchers and other equipment lined up in our workspace to enable us to process up to four performances simultaneously. We used a network monitoring tool (Zabbix) to visualize network communications and bandwidth (video bitrate), letting us easily determine venue status and see the status of our communications systems at a glance, and this turned out to be an important means of telling what was happening from a remote location.

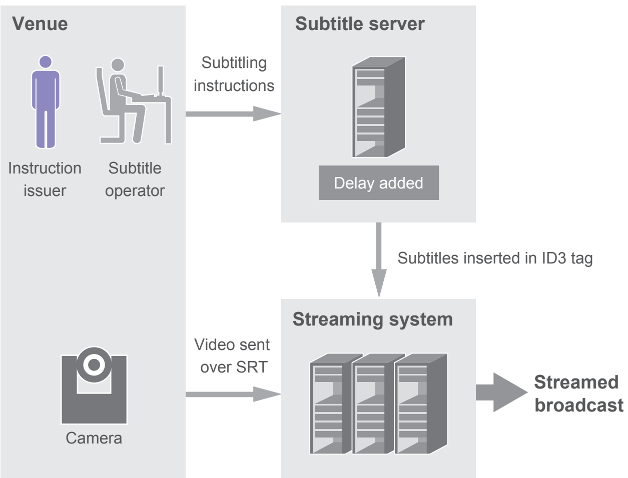

Figure 7: Subtitling System Diagram

Figure 8: Streaming Center at IIJ Headquarters

Communication tools

Communication among remotely located team members is key to making remote production work. It is common to use an intercom system at live events, but on this occasion, we used Slack (chat room tool) and set up a channel for each venue. Although this created the extra work of typing text messages, it also let us check on progress at other venues at a glance and made it easy to go back through the timeline and follow our workflow history, so it provided excellent visibility. It also proved to be very useful in enabling the festival organizers to share certain details with us, such as information on encores, which is often sorted out on the day of the performance. That said, we did note individual differences in terms of when team members posted and how granular the information they provided was. This was a reminder that with any tool, we need to make sure everyone is fully aware of why we are using the tool and what the communication rules are.

2.4 Conclusion

Preparations for the Spring Festival in Tokyo 2023 are already underway, and we have started selecting and testing new equipment to push remote production even further. In light of the results and lessons learned this year, we will be working to provide an even better streaming experience ahead.

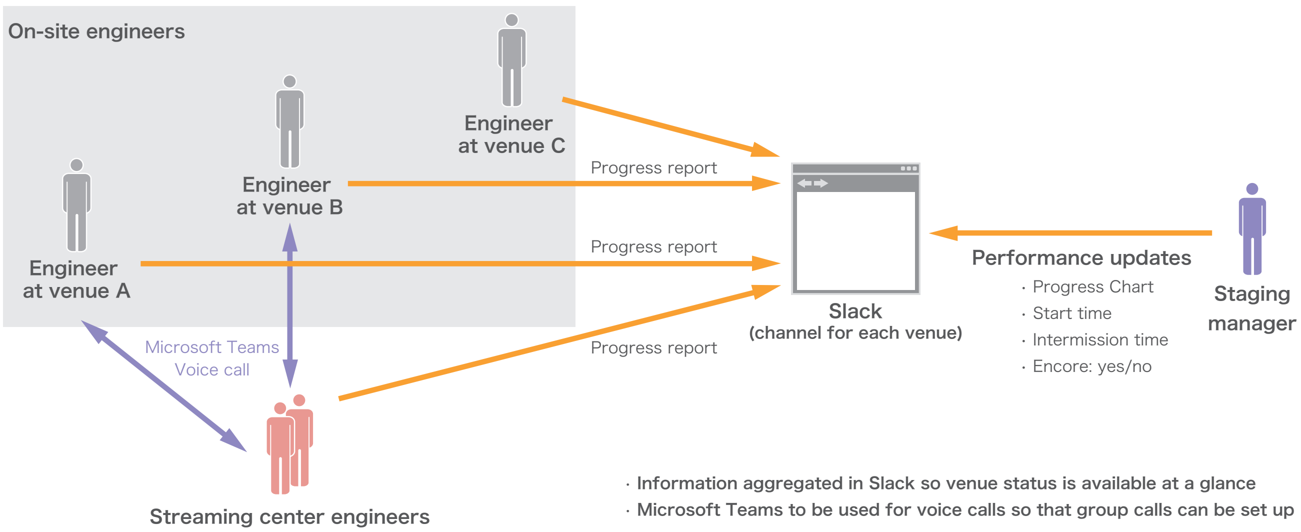

Figure 9: How We Communicated Depending on the Situation

Hiro Okada
xSP System Services, Network Division, IIJ
Intrigued by the Internet, Mr. Okada joined IIJ in April 2000. After working in sales, he went on to work in business customer connection services. Since 2015, he has worked in streaming/broadcast-related business. He is involved in starting up paid streaming platforms, studios, etc.

Fumitaka Watanabe
Streaming Businesses Section, xSP System Services, Network Division, IIJ
Having previously worked in the digitization and development of broadcasting services, from the launch of BS digital broadcast channels through to advanced BS broadcasting, Mr. Watanabe currently focuses on developing and proposing solutions for increasingly diverse video streaming/broadcasting services, including simulcasting and VOD/live-streaming.

November 2022 Vol.56

Internet Initiative Japan

About Internet Initiative Japan Inc. (IIJ)

IIJ was established in 1992, mainly by a group of engineers who had been involved in research and development activities related to the Internet, under the concept of promoting the widespread use of the Internet in Japan.

IIJ currently operates one of the largest Internet backbones in Japan, manages Internet infrastructures, and provides comprehensive high-quality system environments (including Internet access, systems integration, and outsourcing services, etc.) to high-end business users including the government and other public offices and financial institutions.

In addition, IIJ actively shares knowledge accumulated through service development and Internet backbone operation, and is making efforts to expand the Internet used as a social infrastructure.

IIJ-MKTG020-0054

Internet Initiative Japan Inc.

Address: Iidabashi Grand Bloom, 2-10-2 Fujimi, Chiyoda-ku,
Tokyo 102-0071, Japan
Email: info@iij.ad.jp URL: https://www.iij.ad.jp/en/