Internet Trends as Seen from IIJ Infrastructure —2023

Internet services provider IIJ operates some of the largest network and server infrastructure in Japan. Here, we report on Internet trends over the past year based on information obtained through the operation of this infrastructure. In particular, we analyze changes in trends from the perspective of BGP routes, DNS query analysis, IPv6, and mobile.

Topic 1

BGP and Routes

We start by looking at IPv4 full-route information advertised by our network to other organizations (Table 1) and the number of unique IPv4 addresses contained in the IPv4 full-route information (Table 3).

The number of routes increased by only 14,000 over the year, the smallest increase since we started this periodic observation report. That growth has remained in a downtrend since peaking in 2018 (see Figure 1), and it looks like the total might not reach the one-million milestone. We observed declines in the number of /20 and /21 routes for the first time this year. The number of routes with /13 – /18 prefixes is falling, and the increase in /22 – /24 routes was only a third of last year's figure, as a result of which the number of unique IPv4 addresses fell by close to 13 million (0.4%).

Next, we look at IPv6 full-route information (Table 2) and the number of unique IPv6 /64 blocks in the IPv6 full-route information (Table 3).

The total number of routes grew by about the same as last year, reaching roughly 180,000. While growth in the number of short-prefix routes was small, 60% of the growth (including other routes) was accounted for by routes without any information on shorter prefixes, which adds to the number of unique address blocks, and as such

Table 1: Number of Routes by Prefix Length for Full IPv4 Routes

Date	/8	/9	/10	/11	/12	/13	/14	/15	/16	/17	/18	/19	/20	/21	/22	/23	/24	total
Sep. 2014	16	12	30	90	261	500	983	1702	13009	7013	11659	24527	35175	37560	54065	47372	268660	502634
Sep. 2015	18	13	36	96	261	500	999	1731	12863	7190	12317	25485	35904	38572	60900	52904	301381	551170
Sep. 2016	16	13	36	101	267	515	1050	1767	13106	7782	12917	25229	38459	40066	67270	58965	335884	603443
Sep. 2017	15	13	36	104	284	552	1047	1861	13391	7619	13385	24672	38704	41630	78779	64549	367474	654115
Sep. 2018	14	11	36	99	292	567	1094	1891	13325	7906	13771	25307	39408	45578	88476	72030	400488	710293
Sep. 2019	10	11	37	98	288	573	1142	1914	13243	7999	13730	25531	40128	47248	95983	77581	438926	764442
Sep. 2020	9	11	39	100	286	576	1172	1932	13438	8251	14003	25800	40821	49108	101799	84773	473899	816017
Sep. 2021	16	13	41	101	303	589	1191	2007	13408	8231	13934	25276	41915	50664	106763	91436	497703	853591
Sep. 2022	16	13	39	101	298	592	1208	2064	13502	8292	13909	25051	43972	52203	109071	96909	536520	903760
Sep. 2023	16	14	39	102	298	577	1196	2064	13490	8245	13809	25059	43863	51012	109514	98178	550621	918097

Table 2: Number of Routes by Prefix Length for Full IPv6 Routes

Date	/16-/28	/29	/30-/31	/32	/33-/39	/40	/41-/43	/44	/45-/47	/48	total
Sep. 2014	134	481	133	6025	1447	825	248	709	592	7949	18543
Sep. 2015	142	771	168	6846	1808	1150	386	990	648	10570	23479
Sep. 2016	153	1294	216	8110	3092	1445	371	1492	1006	14291	31470
Sep. 2017	158	1757	256	9089	3588	2117	580	1999	1983	18347	39874
Sep. 2018	168	2279	328	10897	4828	2940	906	4015	2270	24616	53247
Sep. 2019	192	2671	606	12664	6914	3870	1566	4590	4165	34224	71462
Sep. 2020	205	3164	641	14520	9063	4815	2663	5501	4562	45160	90294
Sep. 2021	223	3628	705	20650	13050	10233	4170	11545	5204	61024	130432
Sep. 2022	298	4247	895	21926	15147	12509	4108	13840	6994	73244	153208
Sep. 2023	316	4357	923	23228	17427	14828	5518	16453	9579	86881	179510

the number of unique /64 blocks increased sharply, rising another 30% over the previous year. The IPv6 rollout and expansion of IPv6 networks is evidently progressing nicely.

Lastly, let's also look at IPv4/IPv6 full-route Origin AS figures (Table 4). In the past year, an additional 2048 32-bit only ASNs were allocated to APNIC, and 3072 to RIPE NCC.

The decrease in 16-bit Origin ASNs was again smaller than in the previous year. The number of 32-bit-only Origin ASNs also fell heavily, but this reflects many of the IPv6-only ASes, which saw a huge increase in the APNIC region last year, no longer appearing in the route information. Routes that were advertised by those ASes are now generally being advertised by different ASes thought to be the same organization, so we surmise that these organizations have consolidated IPv6 routes advertisements that were temporarily coming from a different AS.

The number of IPv4＋IPv6 32-bit-only ASes exceeded the number of 16-bit ASes for the first time. We also observed the first decrease in 32-bit-only ASes, and we will be watching the data next year closely to see whether a dual-stack configuration is to become the mainstream going forward, at least for new ASes.

Table 3: Total Number of Unique IPv4 Addresses in Full IPv4 Routes and Total Number of Unique IPv6 /64 Blocks in Full IPv6 Routes

Date	No. of IPv4 addresses	No. of IPv6 /64 blocks
Sep. 2014	2,705,751,040	62,266,023,358
Sep. 2015	2,791,345,920	31,850,122,325
Sep. 2016	2,824,538,880	26,432,856,889
Sep. 2017	2,852,547,328	64,637,990,711
Sep. 2018	2,855,087,616	258,467,083,995
Sep. 2019	2,834,175,488	343,997,218,383
Sep. 2020	2,850,284,544	439,850,692,844
Sep. 2021	3,036,707,072	461,117,856,035
Sep. 2022	3,068,374,784	532,578,391,219
Sep. 2023	3,055,604,992	700,359,397,494

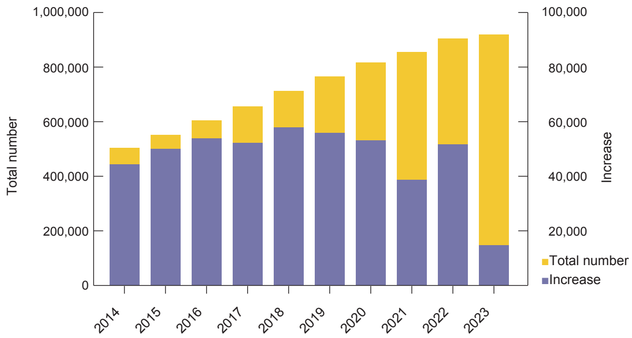

Figure 1: Total Number of Full IPv4 Routes and Annual Increases

Table 4: IPv4/IPv6 Full-Route Origin AS Numbers

ASN	16-bit(1-64495)					32-bit only(131072-4199999999)				
Advertised route	IPv4+IPv6	IPv4 only	IPv6 only	total	(IPv6 -enabled)	IPv4+IPv6	IPv4 only	IPv6 only	total	(IPv6 -enabled)
Sep. 2014	7405	34555	128	42088	(17.9%)	868	4749	55	5672	(16.3%)
Sep. 2015	8228	34544	137	42909	(19.5%)	1424	6801	78	8303	(18.1%)
Sep. 2016	9116	33555	158	42829	(21.7%)	2406	9391	146	11943	(21.4%)
Sep. 2017	9603	32731	181	42515	(23.0%)	3214	12379	207	15800	(21.7%)
Sep. 2018	10199	31960	176	42335	(24.5%)	4379	14874	308	19561	(24.0%)
Sep. 2019	10642	31164	206	42012	(25.8%)	5790	17409	432	23631	(26.3%)
Sep. 2020	11107	30374	229	41710	(27.2%)	7653	19668	574	27895	(29.5%)
Sep. 2021	11465	29219	302	40986	(28.7%)	9514	21108	5242	35864	(41.1%)
Sep. 2022	11613	28398	369	40380	(29.7%)	10816	22211	5764	38791	(42.7%)
Sep. 2023	11770	27617	460	39847	(30.7%)	12640	22128	2067	36835	(39.9%)

Topic 2

DNS Query Analysis

IIJ provides a full resolver to enable DNS name resolution for its users. Here, we discuss the state of name resolution, and analyze and reflect upon data from servers provided mainly for consumer services, based on a day's worth of full resolver observational data obtained on October 18, 2023.

The full resolver provides a name resolution function that replies to DNS queries from user devices. Specifically, to resolve a name, it starts by looking at the IP address of an authoritative name server for the root zone (the highest level zone), which it queries, and then goes through other authoritative nameservers to find the records it needs. Queries repeatedly sent to the full resolver can result in increased load and delays, so the information obtained is cached, and when the same query is received again, the response is sent from the cache. Recently, DNS-related functions are implemented on devices that lie on route paths, such as consumer-level routers and firewalls, and these devices are sometimes also involved in relaying DNS queries and applying control policies. Some applications, such as Web browsers, also have their own implementations of name resolver functionality and in some cases resolve names based on a policy that differs from the OS settings.

ISPs notify users of the IP address of full resolvers via various protocols, including PPP, DHCP, RA, and PCO, depending on the connection type, and they enable automatic configuration of which full resolver to use for name resolution on user devices. ISPs can notify users of multiple full resolvers, and users can specify which full resolver to use by altering settings in their OS, browser, or elsewhere. When more than one full resolver is configured on a device, which one ends up being used depends on the device's implementation or the application, so any given full resolver is not aware of how many queries a user is sending in total. When running full resolvers, therefore, this means that you need to keep track of query trends and always try to keep some processing power in reserve because changes in behavior or status on the user end can conceivably result in a sudden increase in queries to a given resolver.

Observational data on the full resolver provided by IIJ show fluctuations in user query volume throughout the day, with volume hitting a daily trough of about 0.15 queries/sec per source IP address at around 3:10 a.m., and a peak of about 0.36 queries/sec per source IP address at around 10:05 p.m. Overall volume was up 0.02pt vs. the previous year. The peak growth rate looks to have slowed a bit vs. 2022, but the uptrend is ongoing. The breakdown shows that IPv4 accounted for around 60% of queries and IPv6 for around 40%, pretty much the same pattern as in 2022.

Recent years have seen a tendency for queries to rise briefly at certain round-number times, such as on the hour marks in the morning. The number of query sources also increases, with a particularly noticeable pattern around 6 a.m. and 7 a.m., which is possibly due to tasks scheduled on user devices and increases in automated network access that occur when devices are activated by, for example, an alarm clock function. There are also increases in query volume at 14 and 9 seconds before each hour mark. Mirroring the pattern seen in recent years, query volume rises sharply at the hour mark and then tapers off gradually, but with the sudden spikes that occur ahead of the hour mark, query volume quickly returns to roughly where it had been. Hence, because a large number of devices are sending queries in almost perfect sync, we surmise that lightweight, quickly completed tasks of some sort are being executed. For example, there are mechanisms for completing basic tasks, such as connectivity tests or time synchronization, before bringing a device fully out of sleep mode, and we posit that the queries used for these tasks are behind the spikes.

Turning to protocols, UDP accounted for almost all (98.581%) of the queries. That said, TCP queries have been rising over the last few years, from 0.189% of total in 2021 to 0.812% in 2022 and 1.419% in 2023. Possibly the main driver of this is an increase in queries using DNS over TLS (DoT). DoT basically uses TCP port 853 to send queries, so an increase in the use of DoT results in an increase in TCP queries.

Looking at the query record types, A records that query the IPv4 address corresponding to the host name, AAAA records that query IPv6 addresses, and HTTPS records used to resolve Web services account for 96% of the total. The trends in A and AAAA queries differ by IP protocol, with more AAAA record queries being seen for IPv6-based queries. Of IPv4- based queries, around 57% are A record queries and 17% AAAA record queries (Figure 2). With IPv6-based queries, meanwhile, AAAA record queries account for a higher share of the total, with around 38% being A record and 35% being AAAA record queries (Figure 3). Compared with the previous year, we observe 3-percentage-point drops in A record queries for both IPv4 and IPv6. HTTPS records, which we started to see in 2020, accounted for some 20% of IPv4 and 24% of IPv6 queries, marking steady increases of 5 percentage points for IPv4 and 3 percentage points for IPv6. In the IPv4 space in particular, HTTPS records are being queried more often than AAAA records, from which we can infer that there are more implementations that support HTTPS records. SVCB records, which we started to see last year, accounted for 0.26% for IPv4 and 0.60% for IPv6 queries, and while still only a small fraction of the total, those queries are increasing steadily. This may be attributable to the progressing implementation of Discovery of Designated Resolvers (DDR), a newly proposed protocol designed to allow clients to detect encryption-capable full resolvers.

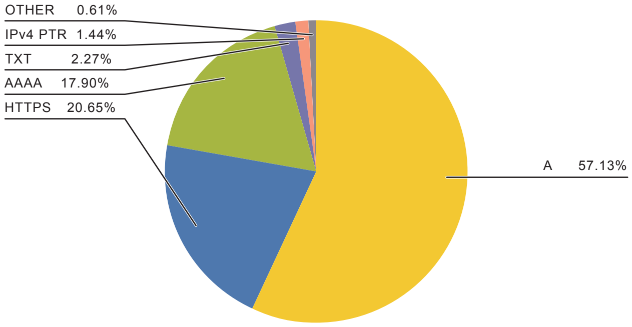

Figure 2: IPv4-based Queries from Clients

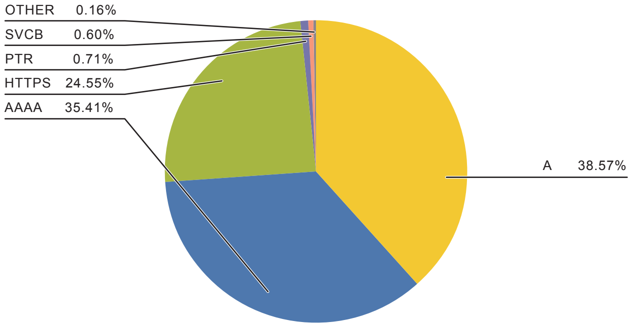

Figure 3: IPv6-based Queries from Clients

Topic 3

IPv6

In this section, we again report on the volume of IPv6 traffic on the IIJ backbone, source ASNs, and the main protocols used. Also in this edition, we go over the state of IPv6 connections on mobile services by device OS, which we also covered last year and back in 2019.

■ Traffic

Figure 4 shows traffic measured using IIJ backbone routers at core POPs (points of presence—3 in Tokyo, 2 in Osaka, 2 in Nagoya). The data cover the eight months from February 2 to September 30, 2023. In 2023, Covid-19 was downgraded to a Class 5 infectious disease in Japan, and social and economic activity is starting to resemble what it was pre-pandemic, but the data on Internet traffic volumes during the period show IPv6 remaining flat and IPv4 increasing only slightly. Yet both IPv6 and IPv4 traffic appear to be increasing to an extent when viewed alongside figures for the same day of the previous year (lighter lines on the graph).

Figure 5 graphs traffic indexed to 100 as of February 1, 2023. As noted, traffic volumes remained mostly flat from the start of the year with no major changes throughout.

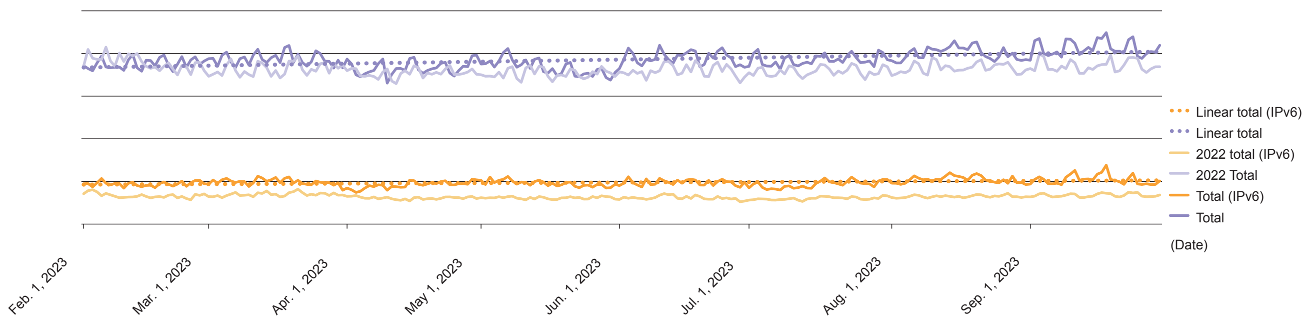

Figure 4: Traffic Measured on Backbone Routes at IIJ's Core POPs

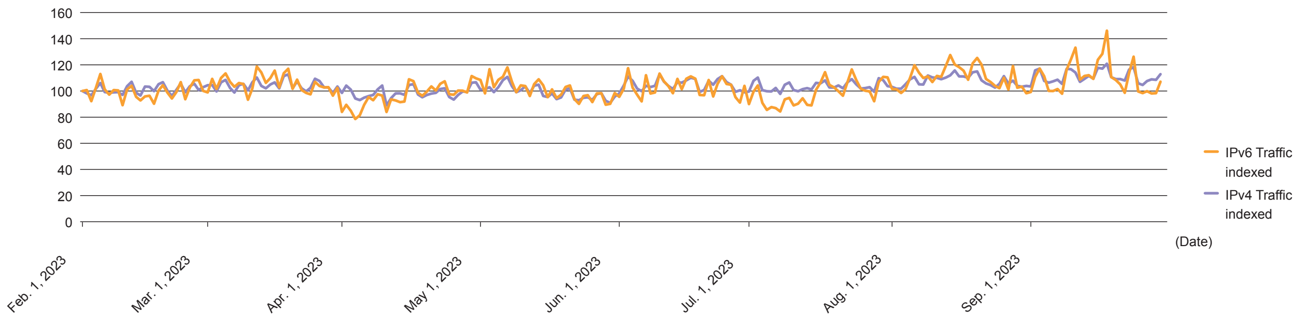

Figure 5: Traffic Indexed to 100 as of February 1

Next, Figure 6 shows IPv6 as a proportion of total traffic. This moves between a minimum of 17% and a maximum of 23%. White no major trends are discernible, the figures are roughly 5 points above the year-earlier level, indicating that IPv6 traffic is growing.

Table 5 tracks the IPv6 ratio over the past six years. We showed this dataset last year as well, but we have discovered that the 2021 and 2022 figures we presented were in error. We offer our apologies and correct them in this edition.

■ Traffic Source Organization (BGP AS)

Next, Figures 7 and 8 show the top annual average IPv6 and IPv4 traffic source organizations (BGP AS Number) for February 1 – September 30, 2023.

Traffic within IIJ accounts for around 60% of the total. Excluding that, Company A, a major Japanese content provider came in at No. 1, as was the case in IIR Vol. 57 (https://www.iij.ad.jp/en/dev/iir/057.html). At No. 2 with about the same share was Company B, a major US search provider, while at No. 3, Company C made its first

Table 5: IPv6 as a Proportion of Total Traffic Over the Past 6 Years

	2017年 IIR Vol.37	IIR Vol. 41, 2019	IIR Vol. 45, 2020	IIR Vol. 49, 2021	IIR Vol. 53, 2022	IIR Vol. 57, 2023	IIR Vol. 61, 2024
IPv6 ratio	4%	6&	10%	10%	~~16%~~ **11.2%**	~~17.8%~~ **15.1%**	20.1%

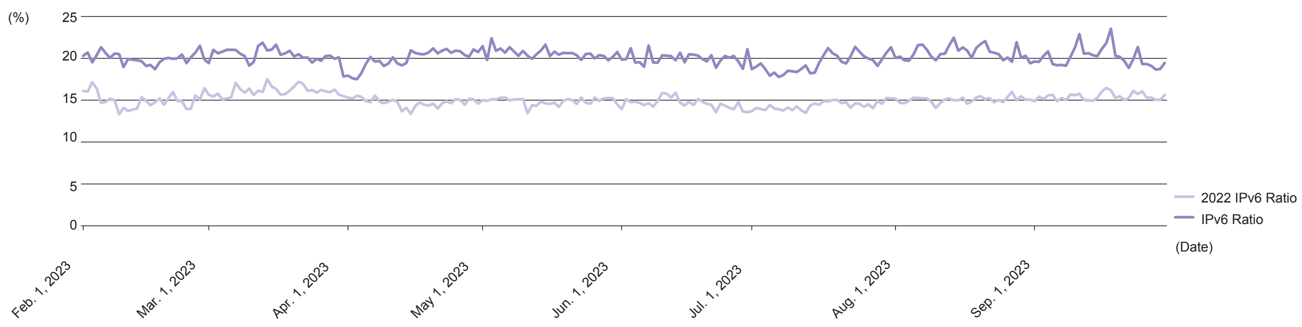

Figure 6: IPv6 as a Proportion of Total Traffic

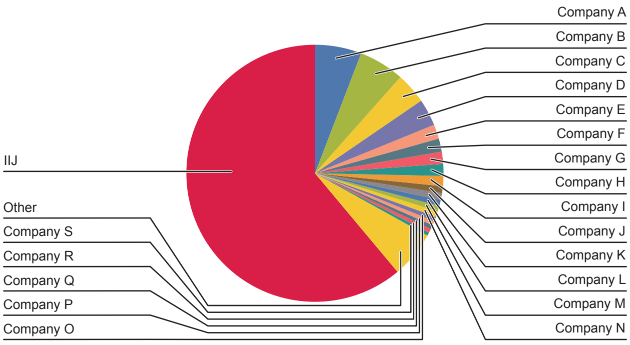

Figure 7: Annual Average IPv6 Traffic by Source Organization (BGP AS Number)

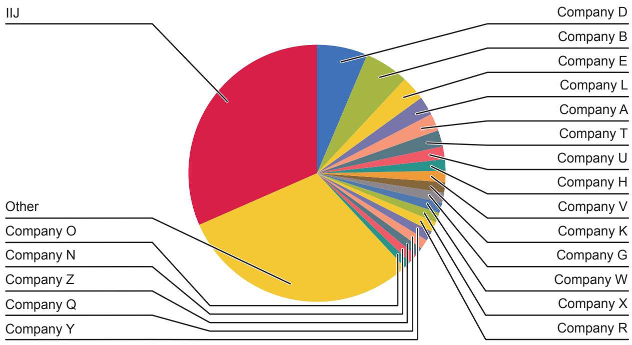

Figure 8: Annual Average IPv4 Traffic by Source Organization (BGP AS Number)

appearance in the rankings. The biggest movers were Company H, a US cloud operator, which went from No. 16 to No. 8 and Company M, a US CDN, which went from No. 5 to No. 13. Company M had an acquisition last year and so may be reorganizing its network.

Protocols Used

Figure 9 plots IPv6 traffic according to protocol number (Next Header) and source port number, and Figure 10 plots IPv4 traffic according to protocol number and source port number (for the week of Monday, October 2 – Sunday, October 8, 2023).

In the IPv6 space, TCP80 (HTTP) moved from 4th last year into 5th this time around, switching places with ESP (IPSec), possibly a sign of progressing migration to HTTPS and QUIC. Traffic volumes for 6th place and below are small, and the rankings can be expected to shift around a lot depending on the time period chosen.

An interesting point to note on the graph is the change in traffic volume from around 7:00 p.m. to around 10:00 p.m. on October 8, corresponding to the peak at the far right of Figure 9. A considerable increase for TCP443 (HTTPS) is evident. A quick investigation reveals that this coincides with a match between Japan and Argentina in the 2023 Rugby World Cup in France, and a Volleyball World Cup match between Japan and the US, which also served as a qualifier for the Paris Olympics. We don’t know which match had the biggest impact, but it does feel like streaming over IPv6 is becoming commonplace.

IPv6 on Mobile Devices

Following on from IIR Vol. 57 (https://www.iij.ad.jp/en/dev/iir/057.html), we again look at IPv6-enabled rates on personal mobile service (IIJmio Mobile Service) connections. In addition to differences by device OS, in this edition we also look at whether there are differences depending on device manufacturer.

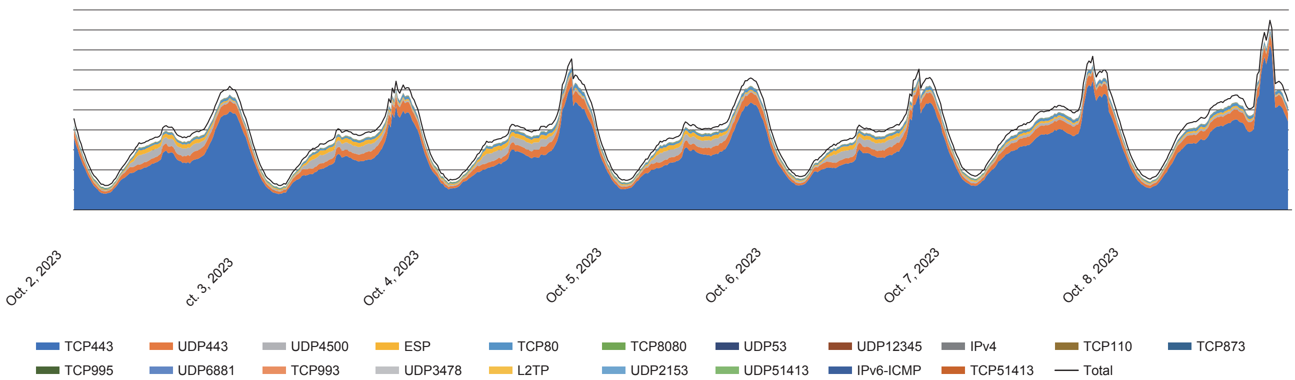

Figure 9: Breakdown of IPv6 Traffic by Source Port Number

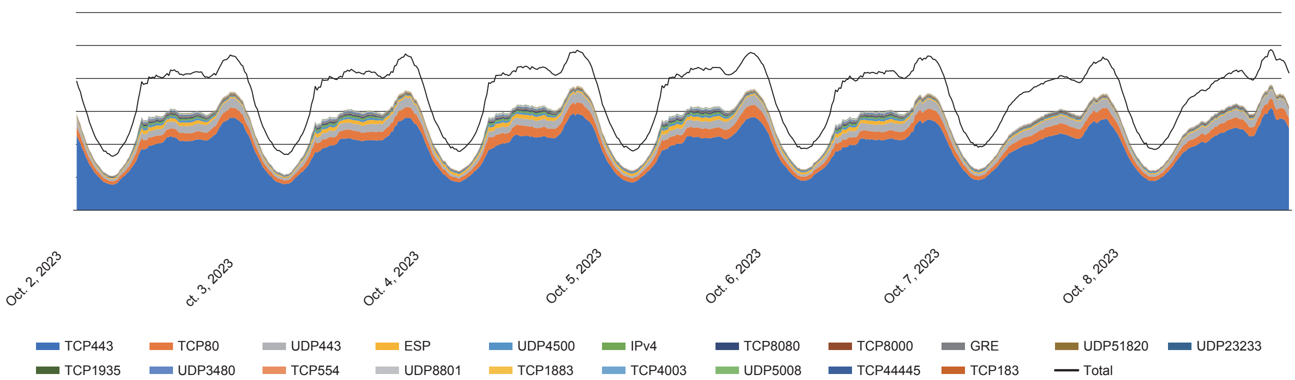

Figure 10: Breakdown of IPv4 Traffic by Source Port Number

In last year's survey, IPv6-enabled connections accounted for the majority at 56.3% of total. As of 3:30 p.m. on Friday, October 20, 2023, that figure was up slightly (2.43 points) to 58.73%. Comparing Apple iOS and Android, IPv6 was enabled on 86.37% of Apple iOS connections, a slight increase of 0.67 points vs. last year, while IPv6 was enabled on 25.82% of Android connections, a 4.12-point increase vs. last year.

Next, we look at IPv6-enabled rates by manufacturer for the top 20 devices connected to the IIJmio Mobile Service. Figure 11 graphs the top 20 spots, but because the top-ranked Apple is so far ahead of the pack in terms of connection count, the lower-ranked bar-graph entries are, unfortunately, difficult to make out. We cannot provide specific numbers, but Apple devices account for 54.3% of IIJmio connections and thus single-handedly take an absolute majority. The IPv6-enabled rate for Apple devices was up slightly vs. the previous survey (85.7%) to 86.35%.

In 2nd place, trailing 1st by a large margin, is a Sharp device. Unfortunately, only 2.73% of these devices had IPv6 enabled, suggesting that IPv6 is not enabled by default in the device's APN profile. On Android devices, the PDP-Type in the APN configuration can be set to IPv4, IPv6, or IPv4v6, but most users probably stick with the default setting or use automatic APN configuration, so we imagine that the IPv6-enabled rates vary greatly depending on the factory default settings.

For 3rd place and below, we only look at manufacturers with high IPv6-enabled rates. Google, in 3rd place, has an extremely high IPv6-enabled rate (89.63%), higher even than Apple's. Motorola, in 7th, also exceeds Apple in this regard with a reading of 89.12%.

Sony and Sony Mobile appear in 10th, 11th, 12th, and 17th place. If these were combined, Sony would leapfrog Huawei to come in at 5th place. Sony's overall IPv6-enabled rate would be 14.7% in this case, which, while not all that high, would be at the high end among Japanese manufacturers.

From an overall perspective, the US manufacturers have high IPv6-enabled rates, while manufacturers from Japan, China, and so forth tend to have low IPv6-enabled rates.

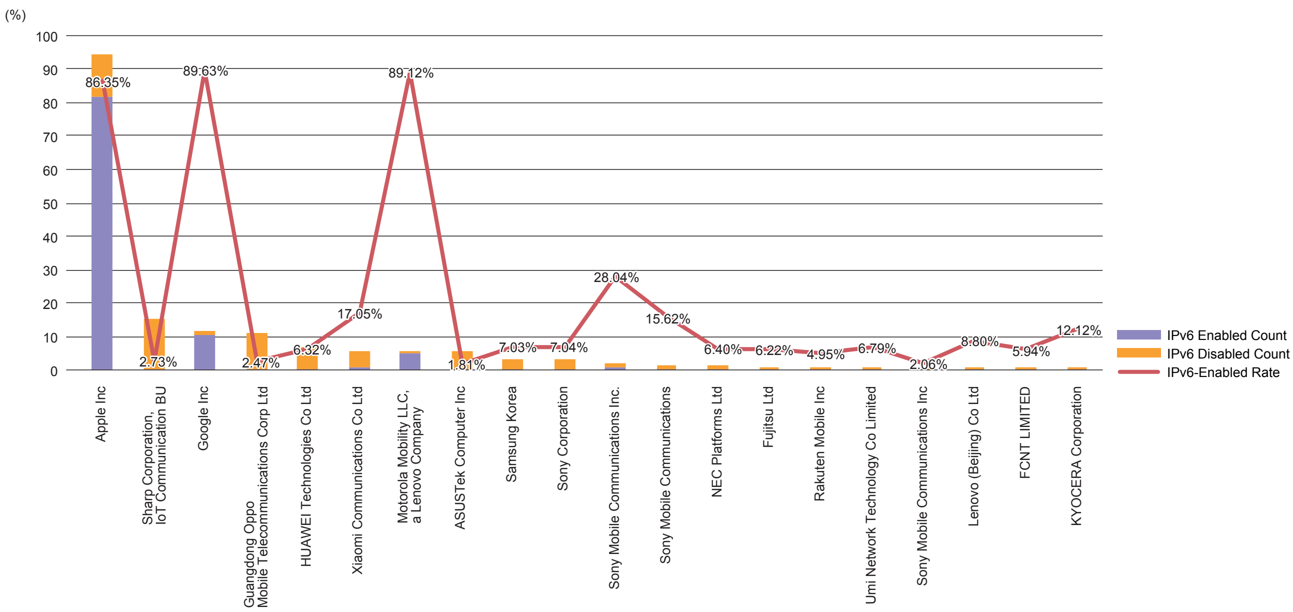

Figure 11: IPv6 Support by Manufacturer (Top 20)

Summary

We have examined traffic on the IIJ backbone core, source ASNs, and main protocols used. Although traffic volumes were range-bound throughout the year, they were up vs. the previous year, and IPv6 usage rates increased over year-earlier levels, reaching their highest point in the past seven years. While it may not be clear because we do not provide names for the origin ASes, we observed growth for some surprising countries. With major CDN operators seemingly having made decent progress on IPv6 support, we appear to be entering an era in which IPv6 is used/enabled pretty much as a matter of course.

Over the past few years (more than a decade?), a lot of services around the world have come to use HTTP(S), including APIs, making it impossible to tell what the app or use case is by looking at the TCP/UDP ports alone. Even so, it seems evident that there is relatively more usage of HTTPS/QUIC over IPv6. One can imagine that with relatively recently built systems, companies are increasingly adopting HTTPS/QUIC and enabling IPv6 along with this too.

In the mobile space, we are seeing IPv6-enabled rates rising on devices running Android OS, but manufacturers in Japan and Asia appear to be lagging those in the US. No doubt there are various reasons for this, but we ask you to consider setting PDP Type to IPv4v6 in your default APN settings so that even more users can get onto IPv6 without any fuss.

We will continue to watch the IPv6 situation from a range of angles and provide updates as new developments come to light.

Topic 4

Mobile 3G, LTE (Including 5G NSA)

Mobile traffic patterns have been affected by the Covid pandemic over the past few years. A key development for Japan in the last year was the May 8, 2023 downgrade of Covid-19 from the “Novel Influenza and Other Diseases” category (or a Class 2 disease) to a Class 5 infectious disease. Here we take a look at traffic over the past year in light of that, based on observations covering October 1, 2022 – September 30, 2023.

Firstly, NTT Docomo will terminate 3G communication services at the end of March 2026, and here we report on the current 3G traffic situation.

3G traffic as a percent of total (Figure 12) is as follows. On consumer services, 3G is virtually nonexistent, accounting for only around 0.033% of all traffic on average. In business services, it averages 4.25% of total. 3G’s share of business

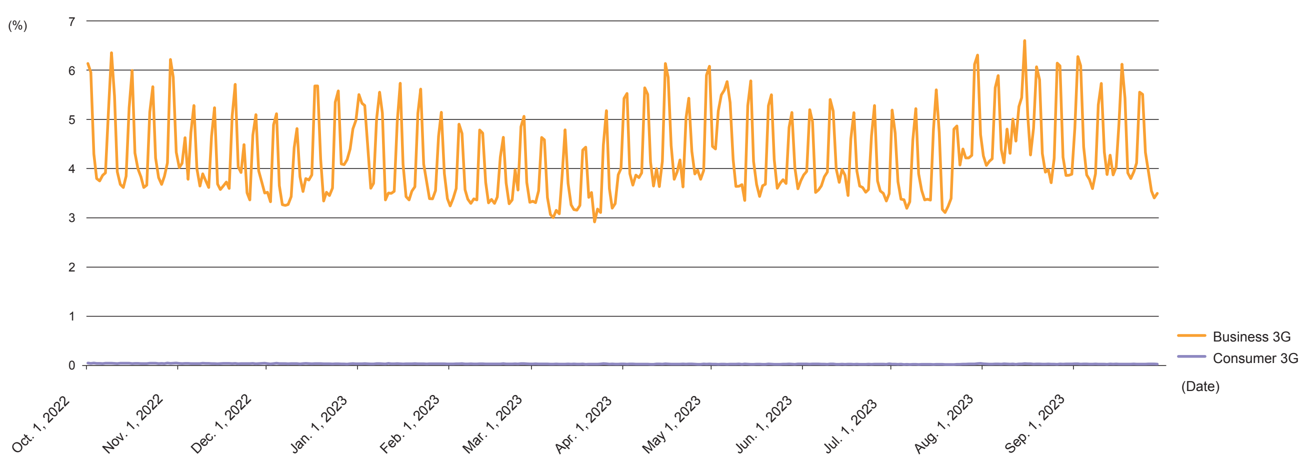

Figure 12:3G Communications as a Proportion of Total Traffic

services traffic remains pretty much range bound, so the degree to which 3G traffic on business services declines over the remaining two years will certainly bear watching.

Next, we look at traffic and session counts on business services. Here, we graph traffic volume (Figure 13) and session counts (Figure 14) for business services indexed to October 1, 2022.

First we look at traffic volumes. LTE traffic volume remained in a gradual uptrend throughout the year, with that uptrend going through slight acceleration spurts from April 2023 and July 2023. This likely reflects the consolidation of contact points with carriers facilitating better traffic flows outside of peak periods and thus leading to more stream-lined usage. When we reported on 3G traffic last year, it was in decline, but it has been in a gradual uptrend over

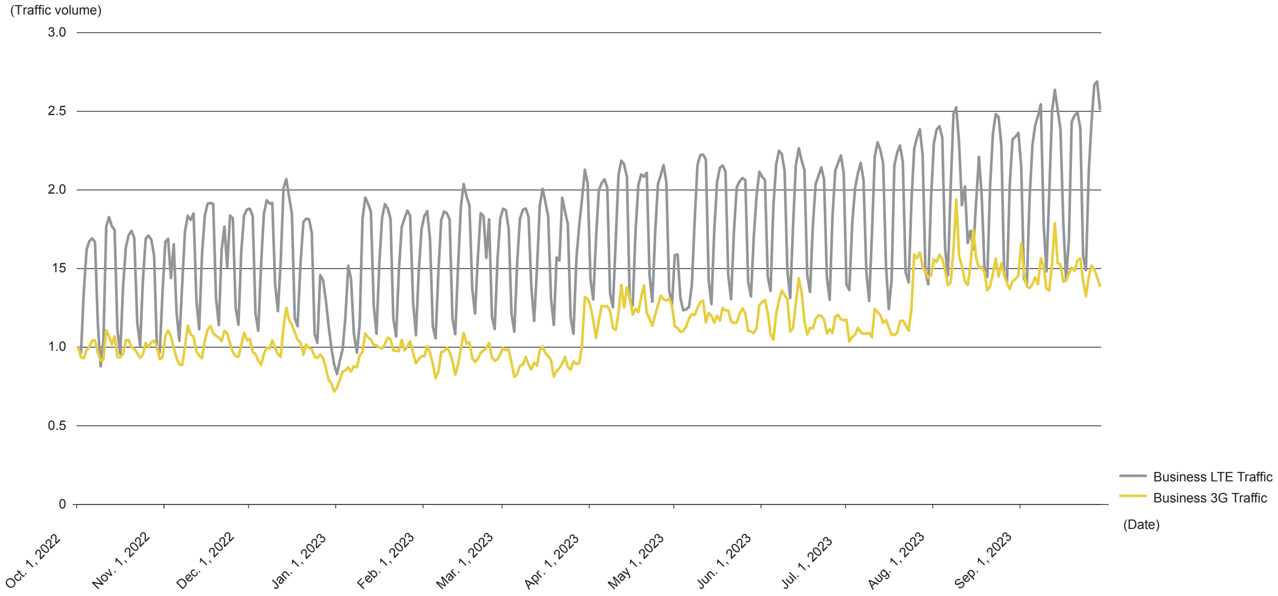

Figure 13:Traffic Volume on Business Services

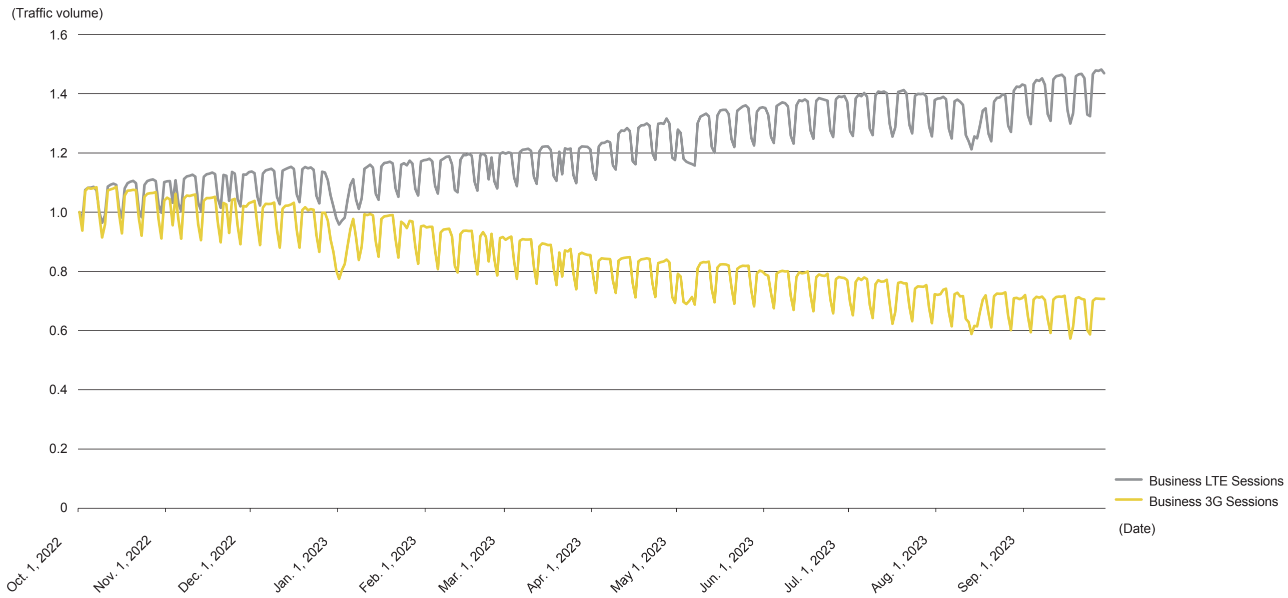

Figure 14:Session Counts on Business Services

the past year. Like LTE traffic volume, 3G traffic also saw spurts of acceleration from April 2023 and July 2023. This also likely reflects the effects of consolidating carrier contact points.

Looking at session counts, we see that, similar to traffic volume, LTE session count remained in a gradual uptrend throughout the year, with somewhat larger increases in both April 2023 and May 2023. This period is prone to

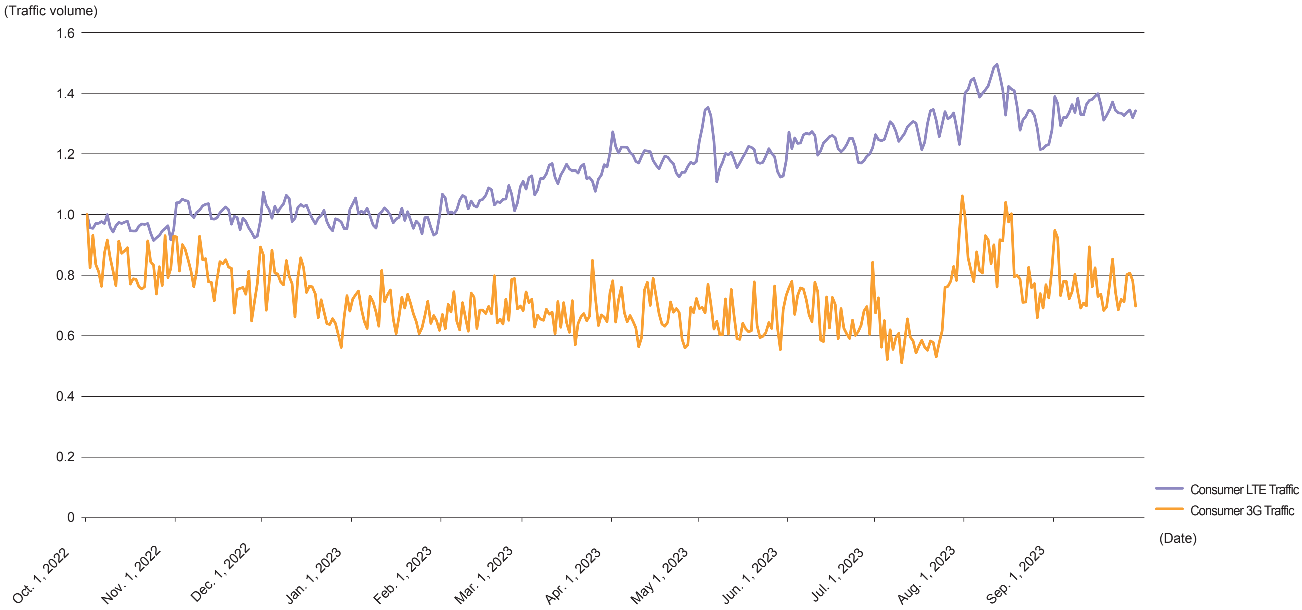

Figure 15: Traffic Volume on Consumer Services

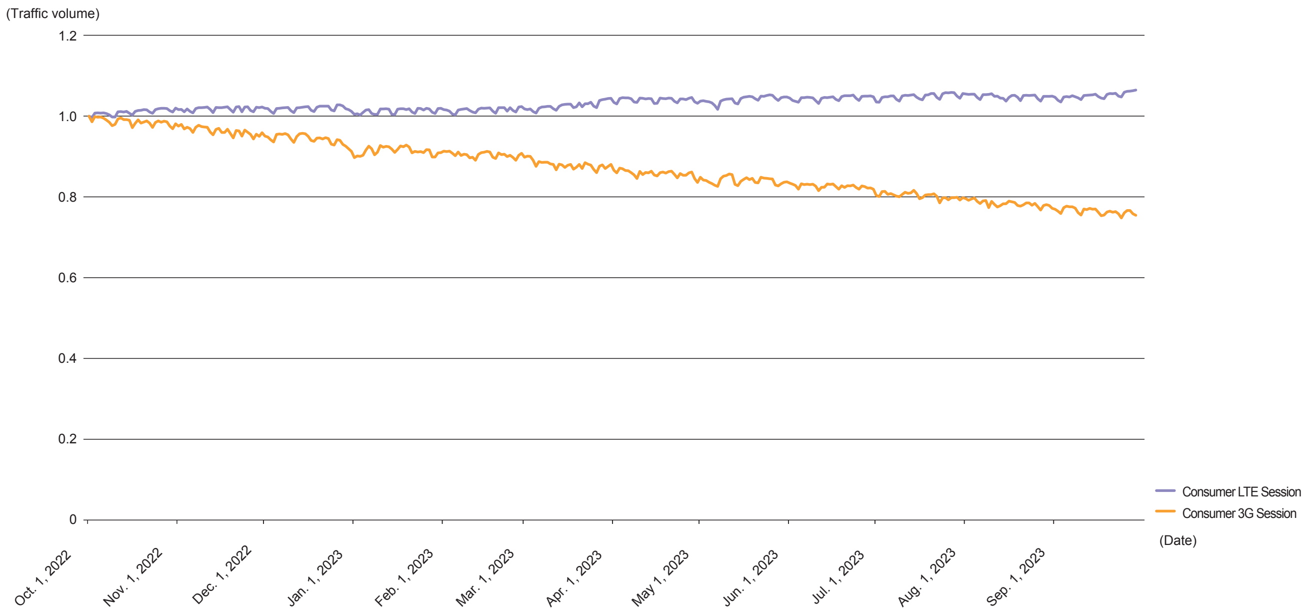

Figure 16: Session Counts on Consumer Services

change as it coincides with the start of the fiscal year for many Japanese companies, but in 2023, it is possible that a change in corporate workstyles due to the reclassification of Covid-19 may have driven increased use of mobile services. The 3G session count, in contrast to 3G traffic volume, remains in an intermittent decline and fell by around 30%. The decline in session count suggests that the 3G exodus is progressing, but we will continue striving to ensure service stability while keeping tabs on these data.

Next, we look at traffic and session counts on consumer services. Here, we graph traffic volume (Figure 15) and session counts (Figure 16) for consumer services indexed to October 1, 2022.

As mentioned, LTE accounts for almost all traffic related to consumer services, and as such, we focus on trends in LTE traffic here. We note no standout changes in consumer services traffic through February 2023, with traffic volumes remaining at around the same level since October 2022. Owing to the timing of consumer service coupon handouts, traffic volumes were high at the beginning of the month and then tended to decline toward the end of the month, rising again at the start of the following month. This monthly trend continued to repeat itself and was prominent up to around February 2023. The trend subsequently changed, with traffic volume then moving into an ongoing uptrend. This is likely due to the effects of the consolidation of carrier contact points, as mentioned earlier. Traffic volume also increased briefly during Japan's Golden Week holiday period, around the time of May 1, 2023, which is consistent with the usual annual pattern. And traffic volume increased substantially from the end of July 2023 onward, which, again, we think is likely due to the consolidation of carrier contact points. There was, similarly, a considerable effect on 3G communications as well.

The session count data indicate a moderate rise in LTE throughout the year. Meanwhile, 3G has seen an intermittent decline, over the year falling to 80% of its October 1, 2022 level. While we do not disclose specific data here, the absolute numbers indicate that we are on track for the discontinuation of 3G.

1.BGP and Routes
Tomohiko Kurahashi
Technology Development Section, Operation Technology Department, Infrastructure Engineering Division, IIJ

2.DNS Query Analysis
Yoshinobu Matsuzaki
Technology Development Section, Operation Technology Department, Infrastructure Engineering Division, IIJ

3.IPv6
Taisuke Sasaki
Mobile Technology Department, Infrastructure Engineering Division, IIJ

4.Mobile 3G, LTE (Including 5G NSA)
Tsuyoshi Saito
General Manager, Mobile Technology Department, Infrastructure Engineering Division, IIJ