Internet Trends as Seen from IIJ Infrastructure —2022

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 annual increase in the number of routes returned to over 50,000, with the total number of routes surpassing 900,000. Yet we are observing a downtrend in this route growth off of the 2018 peak (Figure 1), so what the following year's figures will bring is something that is already on our mind. The total number of unique IPv4 addresses increased by a bit less than 32 million (roughly double vs. the year before last), but when the impact of routes advertised by AS749, which account for last year's large increase is excluded, the number of routes actually looks to have fallen by around 1.16 million.

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).

While the total number of routes surpassed 150,000, the size of the increase was only a bit over 50% of the previous year's (around 23,000 routes). The increase in the number

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. 2013	16	11	30	93	250	480	903	1613	12748	6652	10971	22588	32202	34900	48915	42440	244822	459634
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

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. 2013	117	256	92	5249	1067	660	119	474	266	5442	13742
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

of unique /64 blocks, meanwhile, was around 3.4 times larger than in the previous year (71.46 billion blocks). This is likely due to the large increase in the number of short-prefix routes (/20 – /31), from which we surmise that the rollout of IPv6 by large network organizations (mobile communication carriers etc.) has progressed. Note that routes for which there is no information on shorter prefixes, which contribute to the additional number of unique blocks, accounted for 45.2% of the increase.

Lastly, let's also look at IPv4/IPv6 full-route Origin AS figures (Table 4). In the past year, an additional 4094 32-bit-only AS numbers were allocated to APNIC and 1024 to LACNIC. Both the decrease in 16-bit Origin Autonomous System Numbers (ASNs) and the increase in 32-bit-only Origin ASNs were smaller than in the previous year. The latter was less than 40% of the previous year's increase, and as a result, 32-bit-only ASNs only came to 49.0% as a proportion of all Origin ASNs. IPv6-enabled ASNs, which advertise IPv6 routes, also increased, but with the growth rate slipping below 10% for the first time in the last 10 years. While the changes were relatively small this past year, whether this trend continues or whether it turns out to be a temporary phenomenon due to the contraction in economic activity amid the Covid pandemic is something that will bear watching for in the coming year's figures.

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. 2013	2,638,256,384	20,653,282,947
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

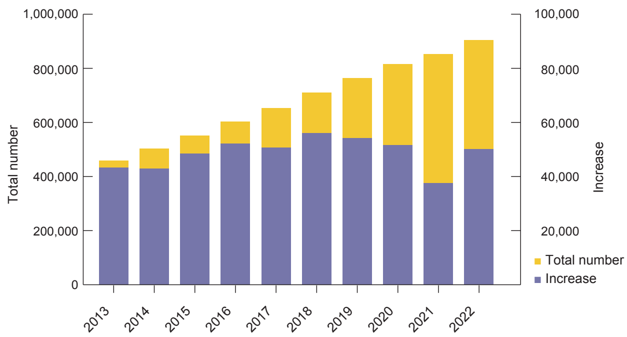

Figure 1: Total Number of Full IPv4 Routes and Annual Increases

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. 2013	6579	34108	131	40818	(16.4%)	496	3390	28	3914	(13.4%)
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%)

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 5, 2022.

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, and add full resolvers, 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.

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 0.13 queries/sec per source IP address at around 4:25 a.m., and a peak of about 0.34 queries/sec per source IP address at around 10:00 p.m. The overnight trough is only up 0.01pt vs. 2021, not a huge change, whereas the evening peak has grown by 0.04pt. The growth rates look to have slowed a bit vs. 2021, but the uptrend is ongoing. The breakdown shows that IPv4 accounted for around 59% of queries and IPv6 for around 41%, pretty much the same pattern as in 2021.

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. Mirroring the pattern also observed in 2021, at the hour mark, query volume rises sharply 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.

Looking at the query record types, A records that query the IPv4 address corresponding to the host name and AAAA records that query IPv6 addresses account for around 80% 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 60% are A record queries and 20% AAAA record queries (Figure 2). With IPv6-based queries, meanwhile, AAAA record queries account for a higher share of the total, with around 40% being A record and 36% being AAAA record queries (Figure 3). Compared with the previous year, we observe 4-percentage-point drops in A record queries for both IPv4 and IPv6.

HTTPS-type records, which we started to see in 2020, accounted for some 15% of IPv4 and 21% of IPv6 queries, marking steady increases of 4 percentage points for IPv4 and 3 percentage points for IPv6. Meanwhile, SRV record queries have fallen as a percent of total for both IPv4 and IPv6, and thus we now group these into the "other" category.

Also in the IPv6 space, we are seeing an increase in new SVCB record queries, although they still only account for a meager 0.12% of total. This may be attributable to Discovery of Designated Resolvers (DDR), a newly proposed protocol for allowing clients to detect encryption-capable full resolvers. In this proposed protocol, a client configured with an unencrypted resolver first queries the _dns.resolver.arpa. SVBC record. When replying to this query, the resolver can include the necessary information to inform the client of encrypted resolvers that support DNS-over-HTTPS (DoH), DNS-over-TLS (DoT), or DNS-over-QUIC (DoQ). Many IPv6-capable clients are newer implementations subject to software updates, and we surmise that this may explain the increase in these queries using the new specification.

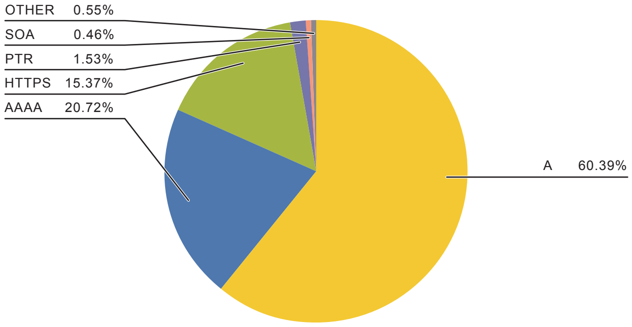

Figure 2: IPv4-based Queries from Clients

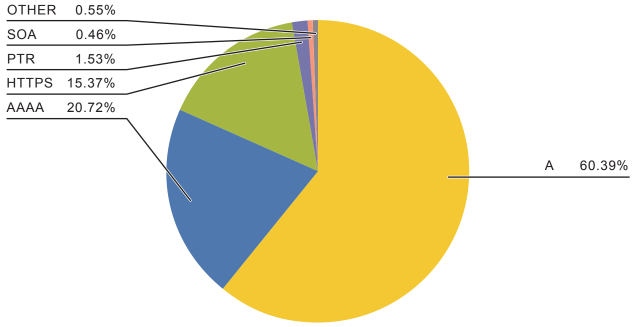

Figure 3: IPv6-based Queries from Clients

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, for the first time in three years since we last covered the topic in IIR Vol. 45 (https://www.iij.ad.jp/en/dev/iir/045.html), we go over the state of IPv6 connections according to differences in mobile device OS.

■ 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 nine months from January 1 to September 30, 2022.

IPv6 and IPv4 traffic was generally range-bound through 2022. This is fairly odd given that IPv4 had so far been growing at a rate of a few percent and IPv6 at a rate in the 10–20% range. Looking back over the past few years, we note a slight stalling in 2020 due to Covid followed by a large rebound in 2021, and this may be why there is no notable trend this year.

Like last year, Figure 5 graphs traffic indexed to 1 as of January 4, 2022, the first business day of the year. Both

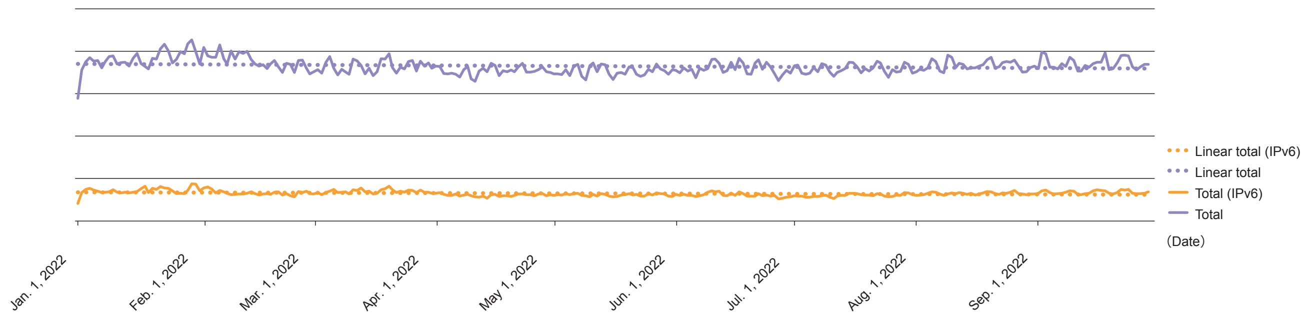

Figure 4: Traffic Measured on Backbone Routes at IIJ's Core POPs

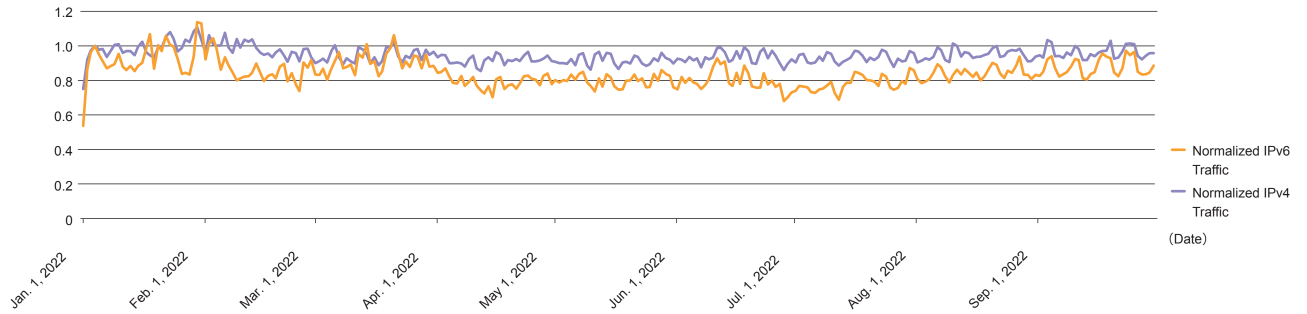

Figure 5: Traffic Indexed to 1 as of January 4

IPv4 and IPv6 look to have declined slightly rather than staying completely flat.

Next, Figure 6 shows IPv6 as a proportion of total traffic. While it exceeded 22% at the start of the year, it generally moved in a range of 16–20%, with the nine-month average being 17.8%.

Table 5 tracks the IPv6 ratio over the past five years.

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 January 1 – September 30, 2022.

In our previous edition of this report in IIR Vol. 53 (https://www.iij.ad.jp/en/dev/iir/053.html), we reported that Company A, a major Japanese content provider, ranked second in IPv6 traffic. In 2022, though, this provider came in at No. 1 with a share of 8.8%. At No. 2 with 7.9% was Company B, which had held the top spot until 2021, and at No. 3 with 3.6%, like in 2021, was Company C, a major US CDN operator. Company G, a major Japanese content provider, is also working its way up with a share of 1.7% + 0.6% (has multiple ASs for each business), and it is evident that Japanese content providers are gradually rolling out IPv6 support.

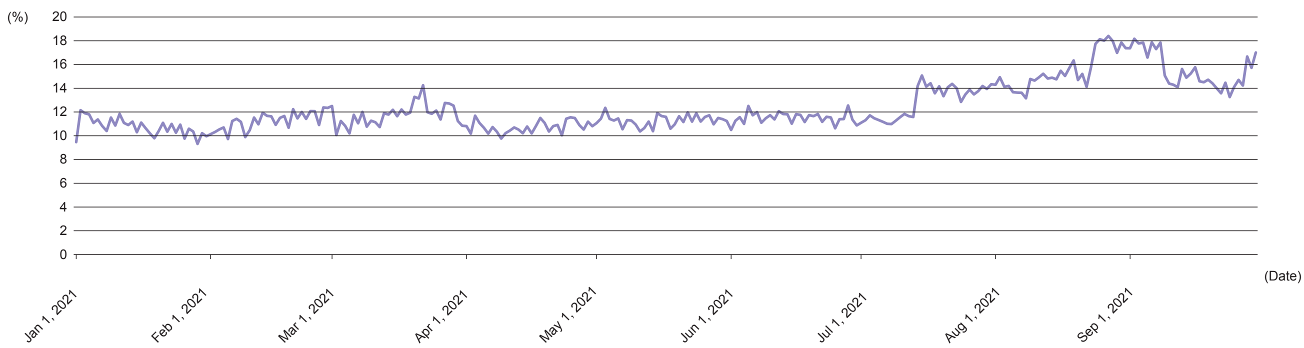

Figure 6: IPv6 as a Proportion of Total Traffic

Table 5: IPv6 as a Proportion of Total Traffic

	IIR Vol. 37, 2018	IIR Vol. 41, 2019	IIR Vol. 45, 2020	IIR Vol. 490, 2021	IIR Vol. 53, 2022
IPv6 ratio	4%	6%	10%	10%	16%

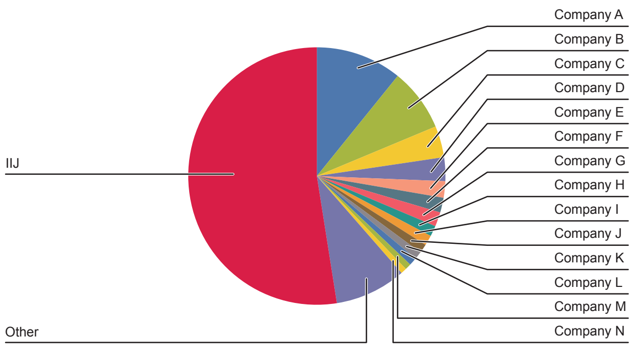

Figure 7: Annual Average IPv6 Traffic by Source Organization (BGP AS Number)

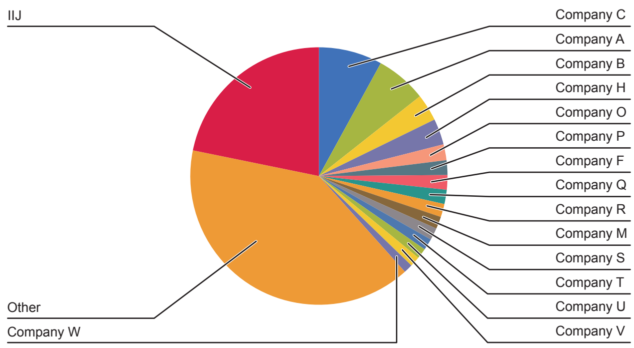

Figure 8: Annual Average IPv4 Traffic by Source Organization (BGP AS Number)

■ 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 3 – Sunday, October 9, 2022).

In the IPv6 space, ESP (IPSec) fell from 3rd place in 2021 to 5th place while UDP4500 (NAT Traversal IPSec), in a figurative role reversal, moved up from 5th to 3rd place. NAT is basically not used on IPv6, but perhaps the use of NAT-T ports has to do with standardizing of implementations. IPv6 traffic has also grown during the daytime on Saturdays and Sundays relative to weekdays, but ESP and UDP4500 traffic is down considerably, so one can imagine they are being used mainly for remote work and the like.

The IPv4 trends look mostly unchanged from 2021. Interestingly, IPv4 traffic seems to be falling a little more on weekends than on weekdays, while IPv6 traffic seems to be increasing. This could perhaps mean that IPv6 usage rates are higher in the home than on corporate networks. This is only speculation as we have no definite evidence at this point, but it is something we hope to investigate if the opportunity presents.

■ IPv6 Across Different Mobile Device OSs

In IIR Vol. 45 in 2019 (https://www.iij.ad.jp/en/dev/iir/045.html), we presented the results of our investigation into whether there were any differences across mobile OSs in terms of whether IPv6 was enabled or disabled on personal mobile service (IIJmio Mobile Service) connections. At the time, IPv6 was enabled on 48% and disabled on 52% of all

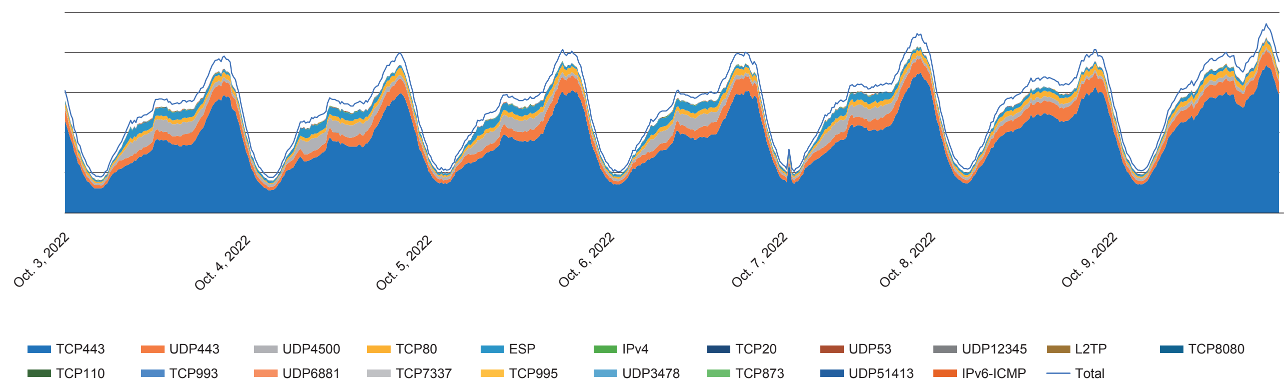

Figure 9: Breakdown of IPv6 Traffic by Source Port Number

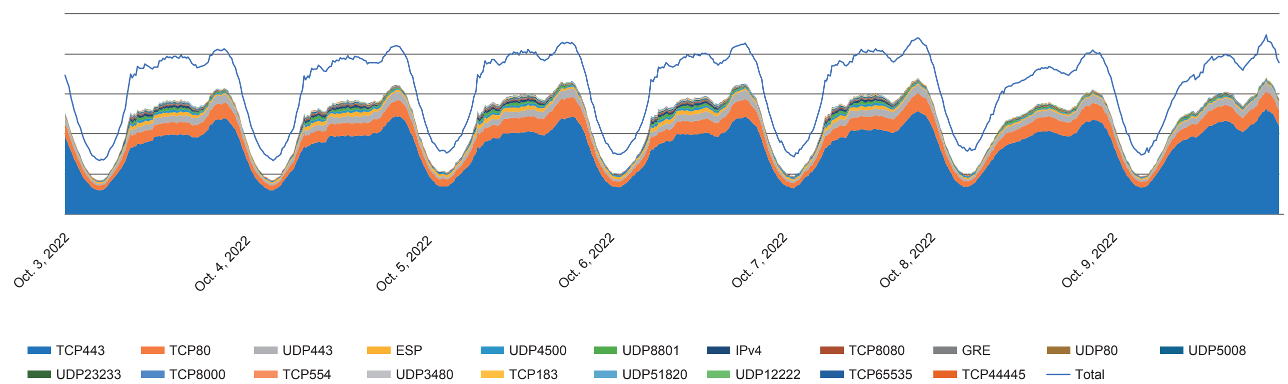

Figure 10: Breakdown of IPv4 Traffic by Source Port Number

IIJmio Mobile connections, so less than half of connections were over IPv6.

On this occasion, we look at connection rates and device OSs based on data from around 10:30 a.m. on Monday, October 17, 2022.

First, as Figure 11 shows, IPv6 is now enabled on over half of connections (56.3%). Also, we have not included a graph here, but the traffic ratio was 7 (IPv4) : 3 (IPv6) (around 6:00 p.m. on weekdays, when traffic is relatively heavy). Clearly, it seems that IPv6 has seen substantial growth in terms of both number of connections and traffic.

Next, we look at the IPv6 connections across mobile OSs. To do this, the pie chart in Figure 12 breaks mobile devices connected to the IIJmio Mobile Service into three groups—Apple iOS (iPhones and iPads), Android, and other (mobile routers and dongles etc.)—based on part of the IMEI (TAC: first 8 digits) matched against the GSMA database.

IPv6 was enabled on a fairly high 85.7% of iOS connections. That said, IPv6 was enabled on 90.8% of connections when we reviewed the data three years ago, so the proportion has declined.

IPv6 was enabled on 21.7% of Android connections. This is a 7.6-point increase from our 14.08% IPv6 reading for Android three years ago. Yet there still remains a huge difference in the IPv6-enabled rate relative to iOS.

For other devices (Wi-Fi routers, USB dongles, IoT devices, etc.), IPv6 was enabled on 25% of connections. It is surprising that IPv6 is enabled on more of these devices than on Android, and this possibly indicates that IPv6-capable Wi-Fi routers are also on the rise. That said, almost all of the devices connected were smartphones and tablets, so these other devices only have a minimal presence.

■ Summary

We have examined traffic on the IIJ backbone core, source ASNs, and main protocols used. Although traffic volumes were range-bound or in a slight decline from the beginning of the year, IPv6 usage rates increased vs. a year earlier, reaching a six-year high. Data on source ASNs showed that the IPv6 traffic of Japanese content providers is growing. There were no major changes with the main protocols, and for both IPv6 and IPv4, web-based protocols remained at the forefront, followed by VPN protocols.

We have also looked at IPv6 connections across mobile device OSs. On mobile services, over half of all terminals were IPv6-enabled, and around 30% of traffic was IPv6. By OS, IPv6 was enabled on over 80% of Apple iOS devices, while IPv6 was disabled on 80% of Android devices, mirroring the situation three years ago, but the Android IPv6 connection rate had increased.

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

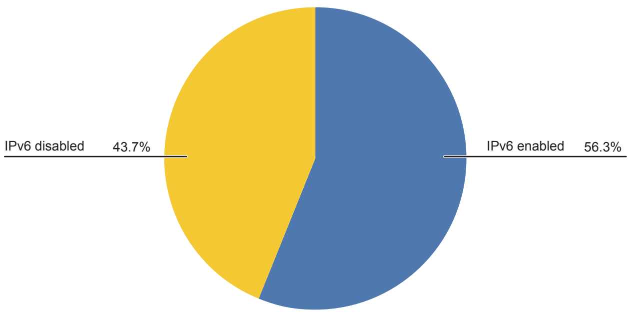

Figure 11: Proportion of Connections with IPv6 is Enabled

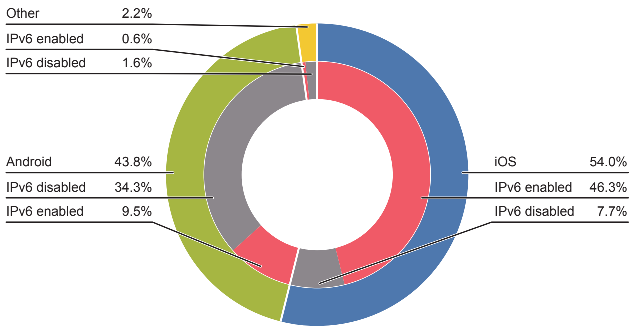

Figure 12: OSs on IPv6-enabled Devices

Topic 4

Mobile 3G, LTE

Mobile traffic patterns have been affected by the Covid pandemic over the past few years. Here, we summarize what's happened with traffic in the past year, based on observations covering October 1, 2021 – September 30, 2022.

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

3G traffic as a percent of total (Figure 13) is as follows. On consumer services, 3G communications are virtually non-existent, accounting for only around 0.05% of total traffic. In business services, 3G averages 6.4% of total. Looking at the trends, it remained in a very moderate decline up until April 2022, but that downtrend looks to have accelerated since May 2022.

Next, we look at traffic and session counts on business services. Here, we graph traffic volume (Figure 14) and session counts (Figure 15) for business services indexed to October 1, 2021.

Looking at traffic volumes, we see that LTE traffic volume remained in a gradual uptrend throughout the year, with that uptrend appearing to have accelerated just slightly from June 2022. And as mentioned above, 3G traffic volume was in a slight decline up until April 2022, with the downtrend then accelerating from May 2022.

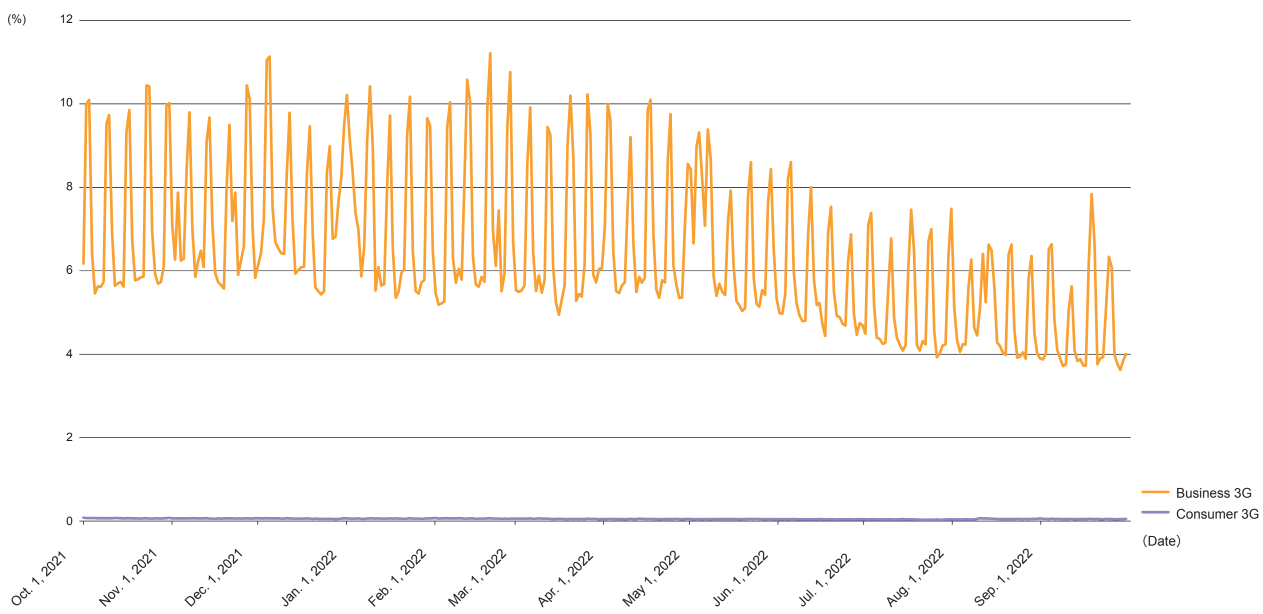

Figure 13:3G Communications as a Proportion of Total Traffic

Looking at session counts, we see that, similar to traffic volume, LTE session count was in a gradual uptrend throughout the year, with that uptrend appearing to have accelerated just slightly from July 2022. The 3G session count remained roughly in line with the base date of October 1, 2021 up until December 2021, with an intermittent downtrend appearing after 2022 got underway.

On business services, traffic trends are affected by the progress of customers' plans to migrate from 3G to LTE. As someone in charge of mobile services equipment, I am pleased to see 3G decline, given that it is on the way, and LTE increase, so we will be keeping tabs on the decline in 3G communications as we continue to provide stable infrastructure.

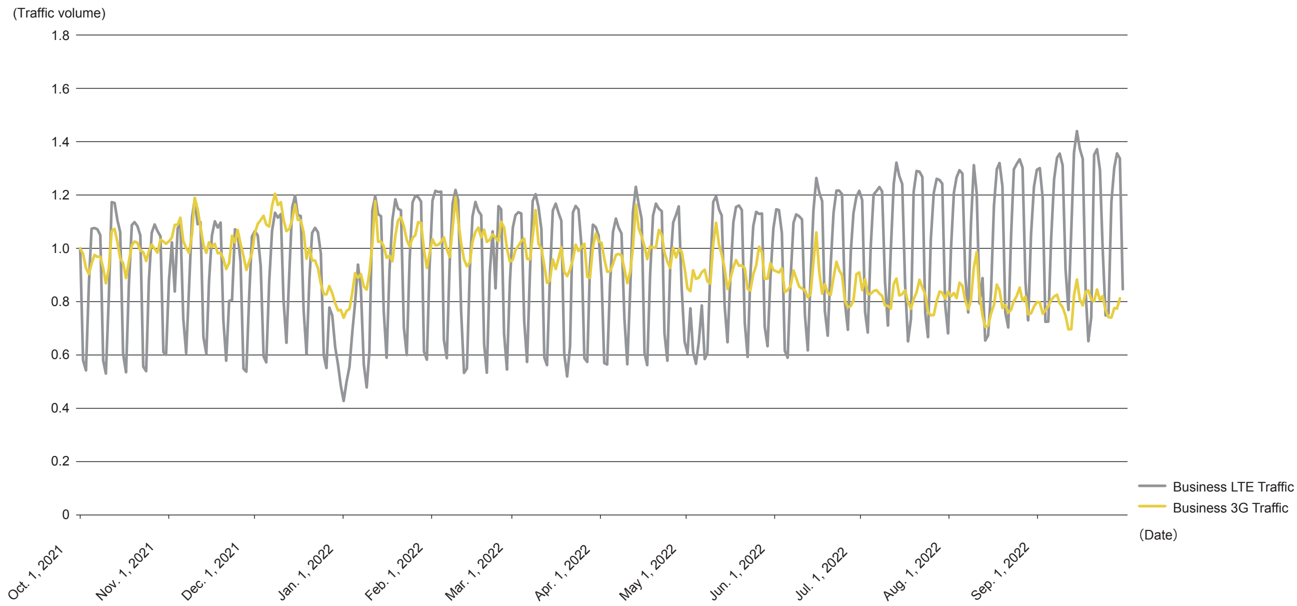

Figure 14:Traffic Volume on Business Services

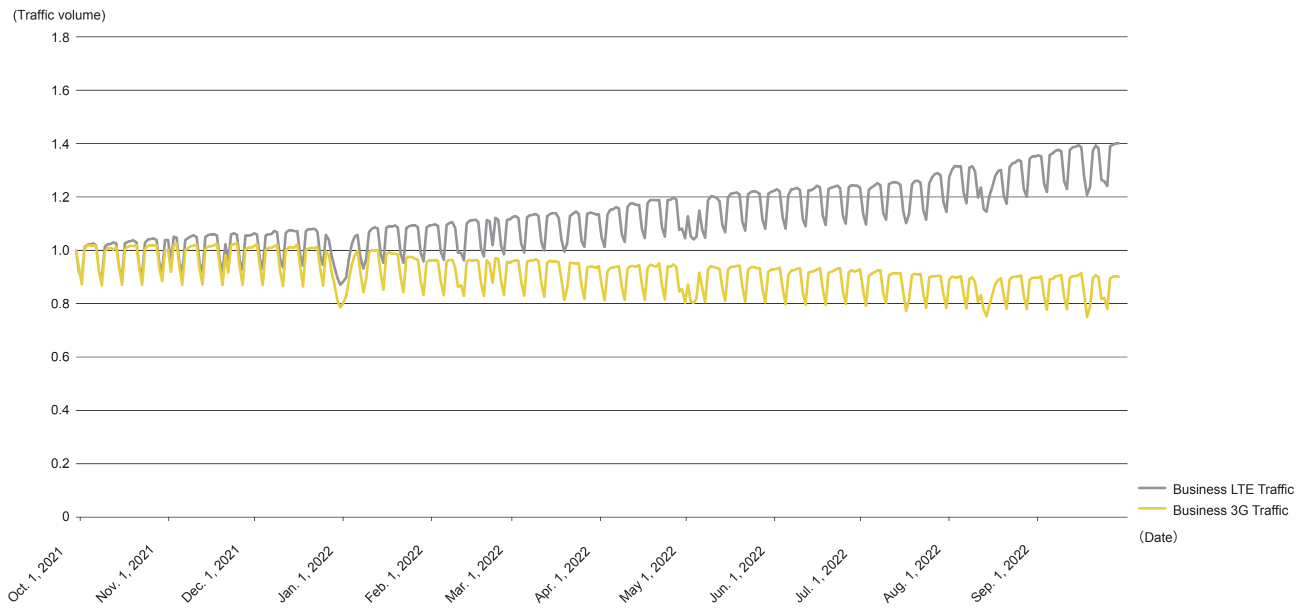

Figure 15:Session Counts on Business Services

Next, we look at traffic and session counts on consumer services. Here, we graph traffic volume (Figure 16) and session counts (Figure 17) for consumer services indexed to October 1, 2021.

In terms of traffic volumes, LTE remained largely range-bound up until late February 2022 amid Covid quasi-state of emergency measures implemented by the Tokyo Metropolitan Government, but it increased steadily from

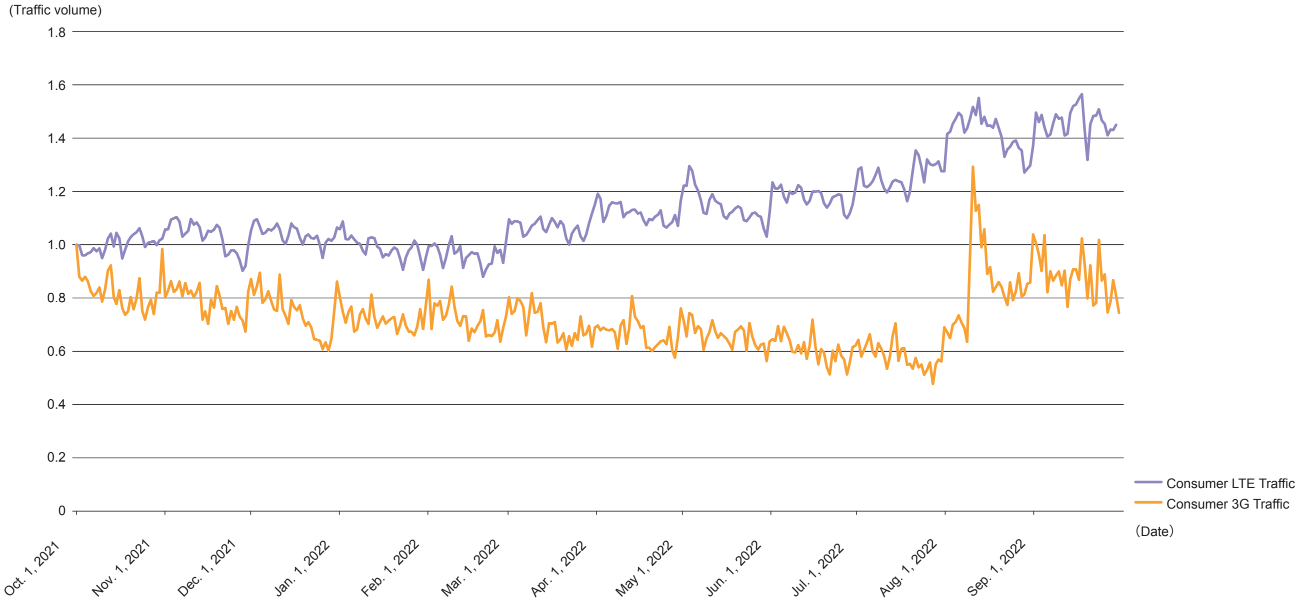

Figure 16: Traffic Volume on Consumer Services

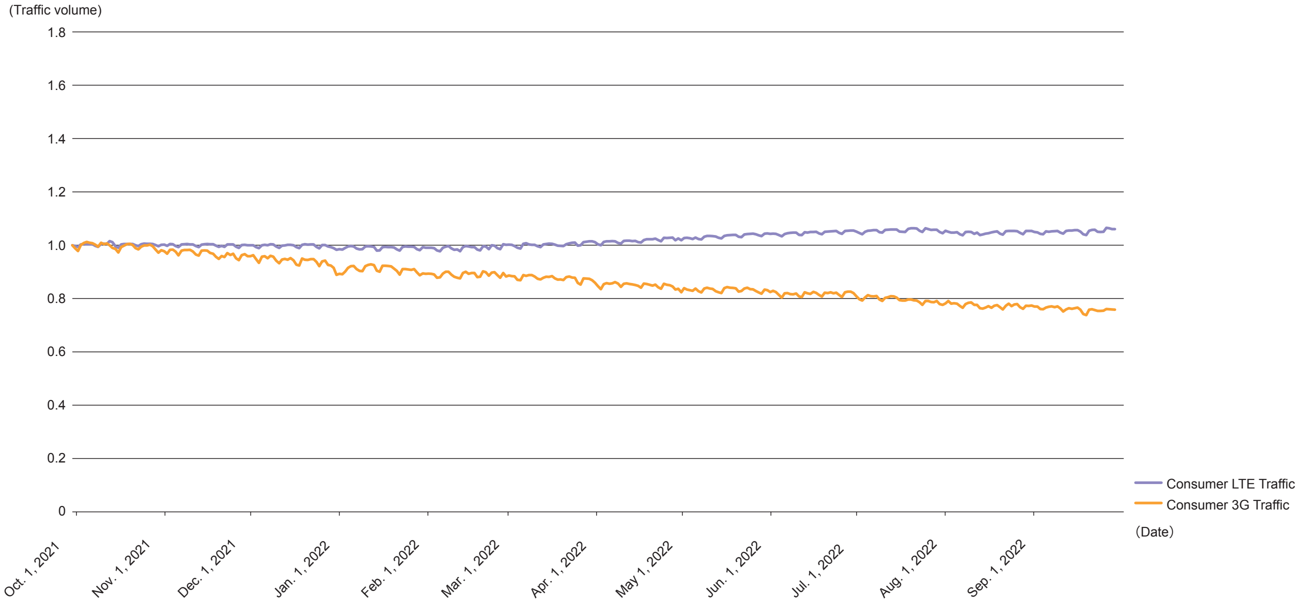

Figure 17: Domestic Interconnection Traffic

March onward, reaching roughly 1.4x the index date's level. Traffic volume increased substantially from early August in particular, but this is attributable to enhancements in infrastructure capacity. 3G traffic also had been in a steady decline but surged sharply in early August, similar to LTE traffic. This probably reflects infrastructure capacity enhancements, as with LTE. While it does look like there was a large effect on 3G traffic, as explained earlier, 3G communications are virtually non-existent relative to LTE as a proportion of total on consumer services, so even a small effect will appear as though there has been a large impact.

Looking at the session counts, meanwhile, the LTE session count remained largely range-bound throughout the year with a modest increase. And the 3G session count stayed in a downtrend throughout the year.

LTE accounts for almost all of the communications on consumer services, and although session count remained unchanged, traffic increased to around 1.4x the index date's level over the year. In other words, traffic volume per session is simply increasing. This no doubt means that the more you can accomplish on a smartphone, the more traffic per session will tend to increase, and while this may raise all sorts of difficult issues on the infrastructure side of things, we hope to continue coming up with solutions going forward.

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