

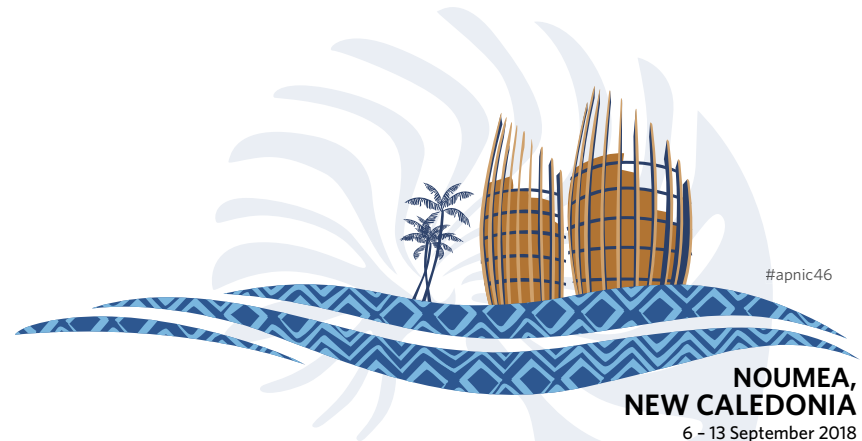
An IPv6 Update

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#apnic46

**NOUMEA,
NEW CALEDONIA**

6 - 13 September 2018

Measuring the Internet

- APNIC Labs operates a very large network measurement system
- The measurement is based on a scripted online advertisement
- The Ad script instructs the browser to retrieve a small set of URLs:
 - Each URL retrieval requires the resolution of a DNS name and fetch a small web object
 - We construct the DNS names to be unique (to eliminate caching) and steer the DNS and Web requests to our servers
 - We can infer the properties of the end host platform by looking at the DNS and web behaviours

Measuring the Internet

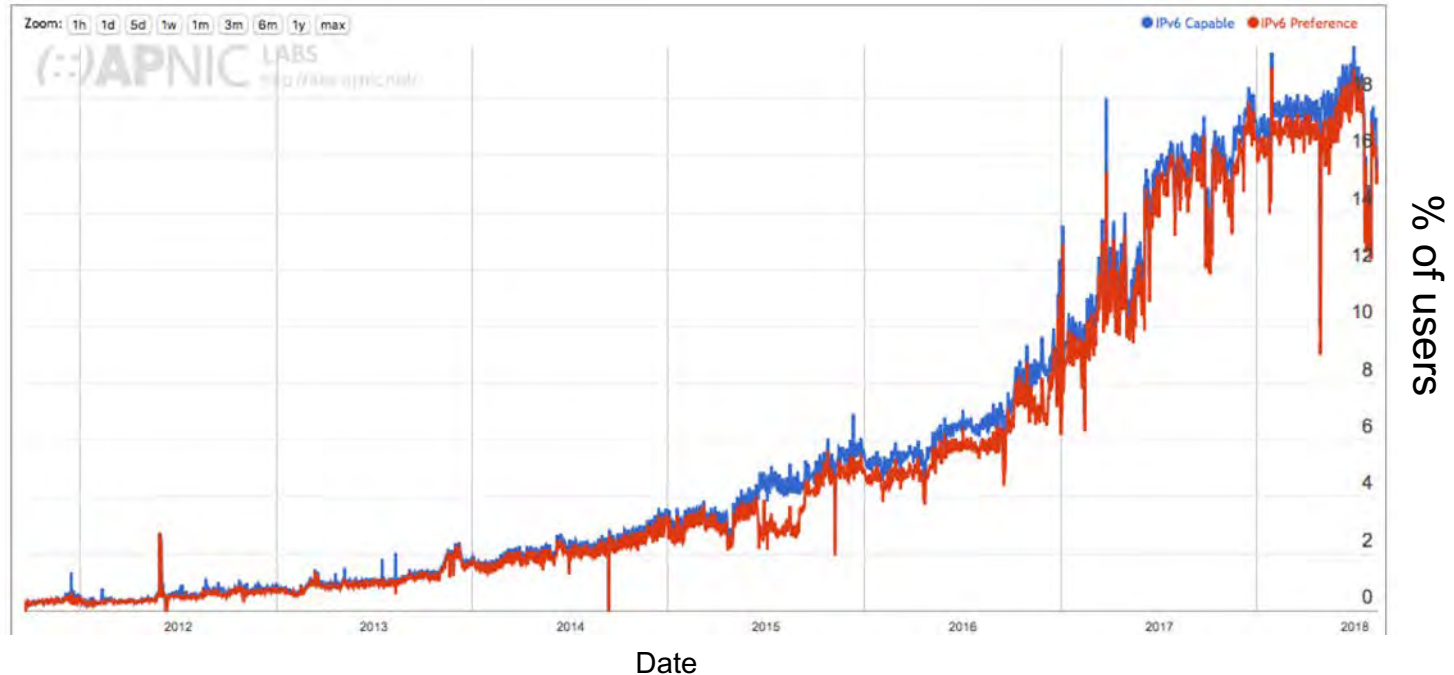
- The Ad runs at some 7M - 10M measurements per day
- The advertisement platform tries to present the ad to new end systems all the time
- We use a set of Ad parameters to try and achieve a uniform presentation rate across the Internet
 - There is a skew to over-present the Ad in some economies – we weight the results per-economy to represent an ideal uniform random sample set to compensate for this skew so that we reflect “all of the Internet” results
- This tracks the “eyeball” Internet on both wired and mobile platforms

Measuring IPv6 Deployment

- This is a web-based measurement:
 - “IPv6-Capable” means that the user can retrieve an IPv6-only web object
 - “IPv6-Preferred” means that the user used IPv6 to retrieve a dual stack web object
- We are interested in the longer term picture of both measurements

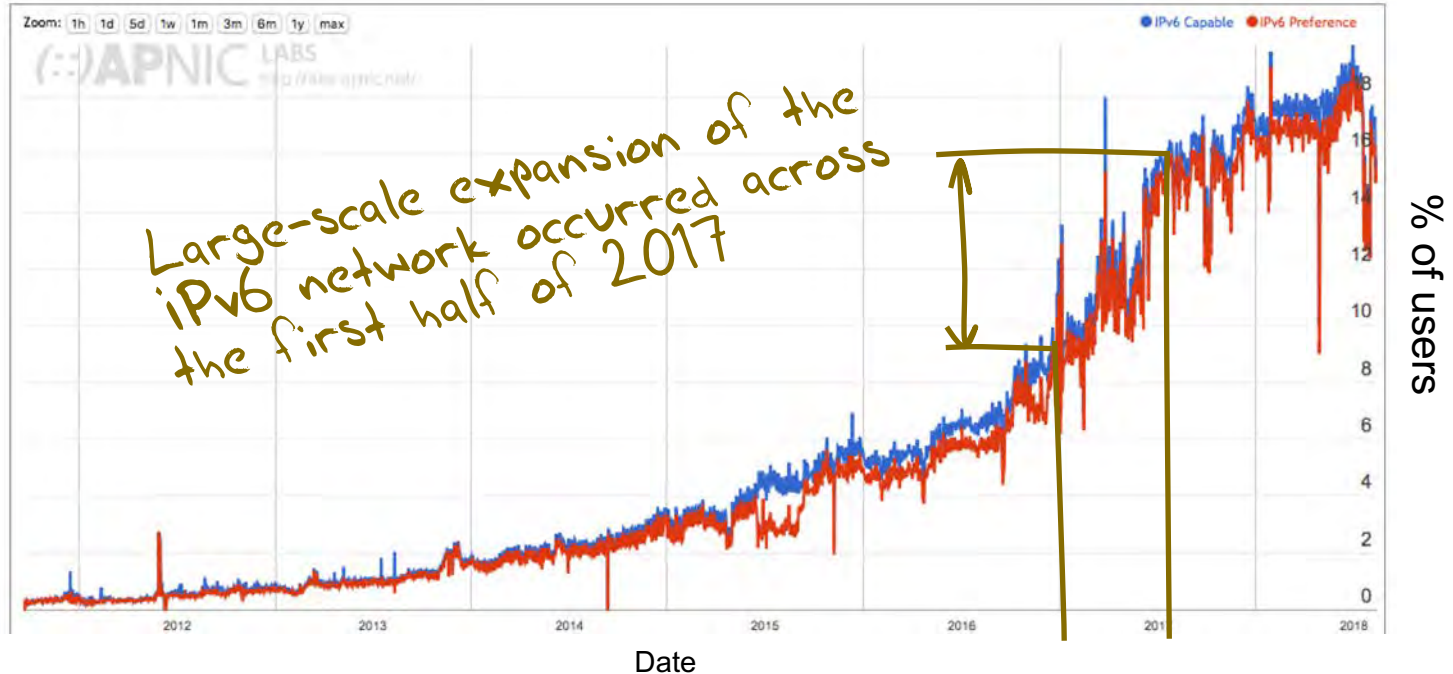
IPv6 Capable and Preferred Deployment

2011 to 2018



IPv6 Capable and Preferred Deployment

2011 to 2018



IPv6 Capable and Preferred Deployment

2012 to 2018

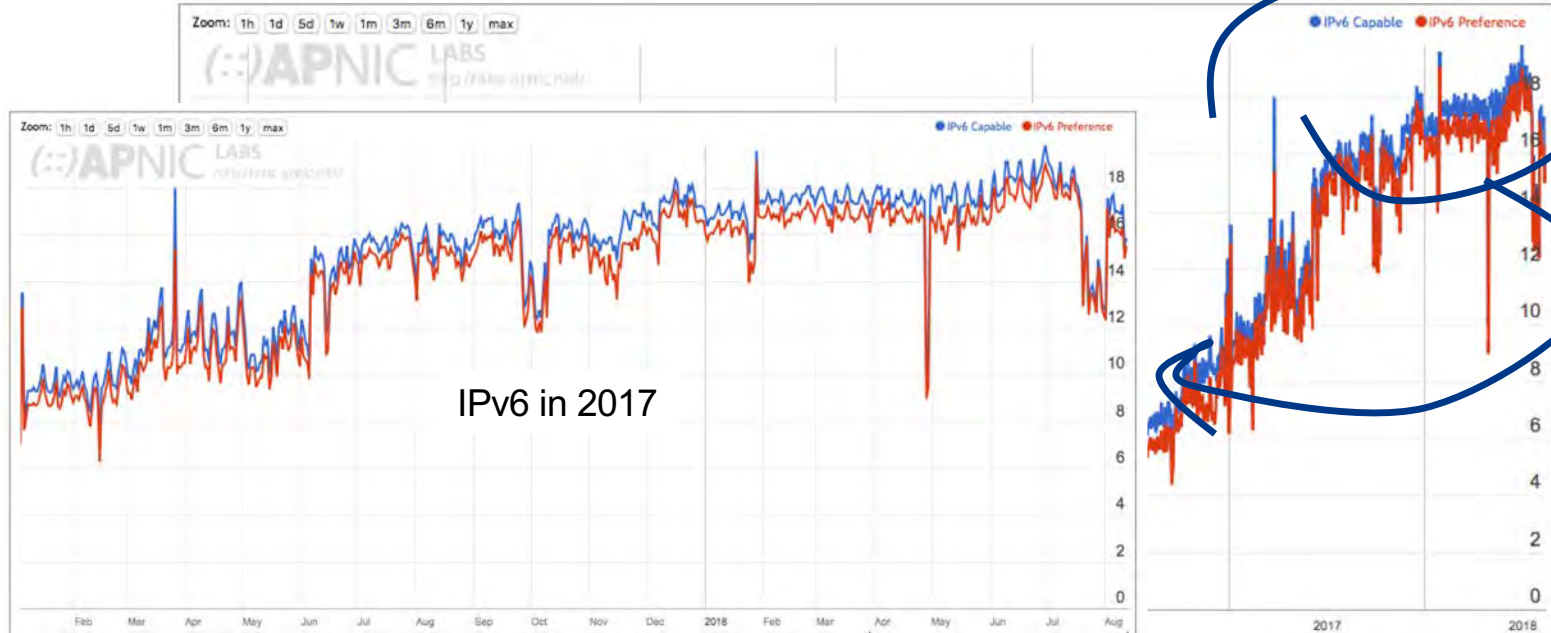


Oops!

That was our measurement system!

IPv6 Capable and Preferred Deployment

The Long Term Picture: 2012 to 2018



Aside: What's going on?



After resolution of experiment issues, the August numbers are still lower than late June

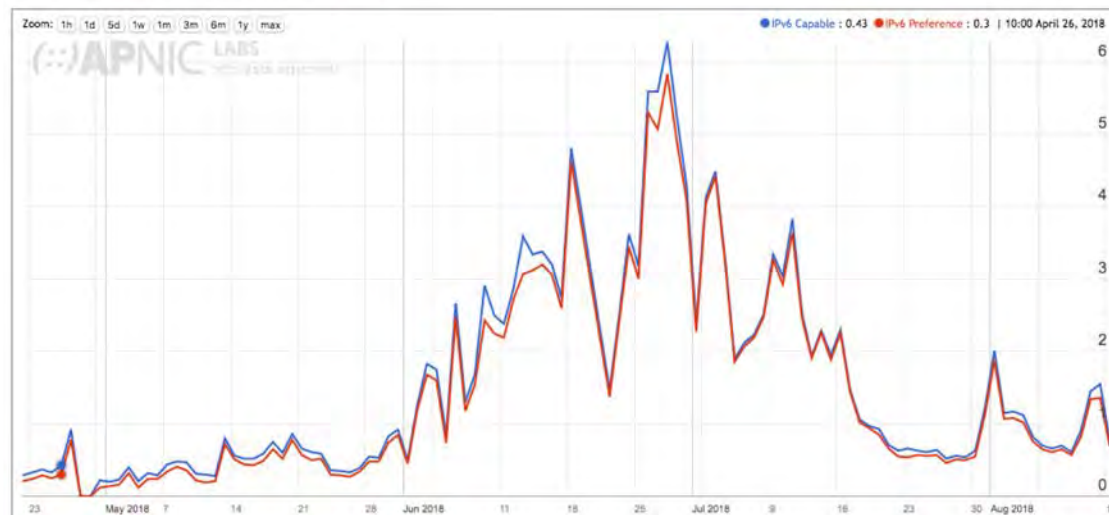
Experiment issues

Aside: What's going on?



This is probably due to China

Use of IPv6 for China (CN)



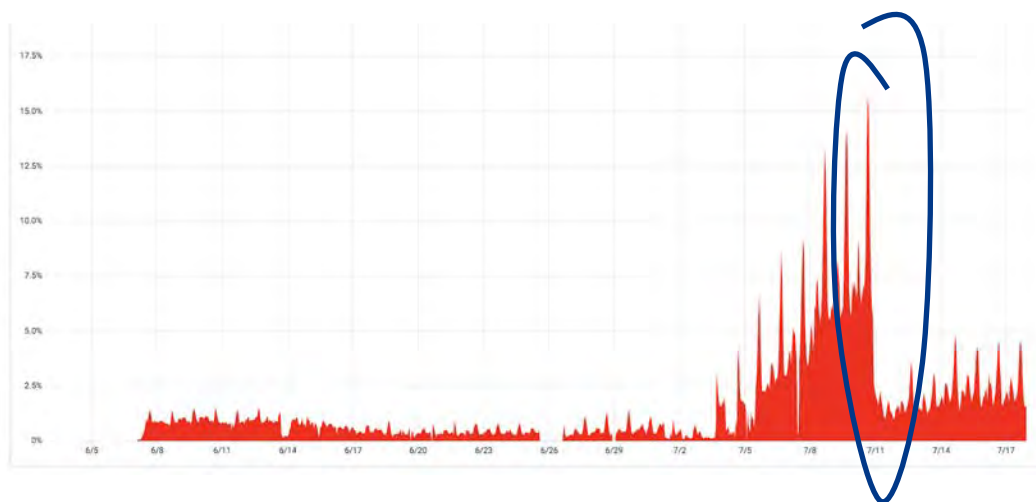
Aside: What's going on?

Cloudflare saw it too:



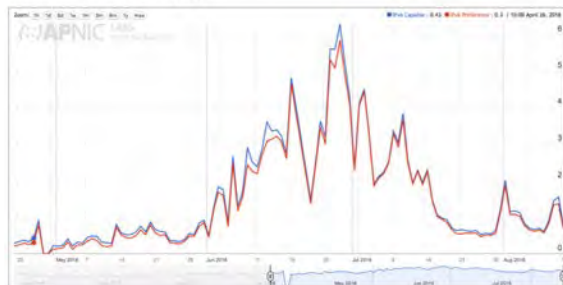
IPv6 in China

19 Jul 2018 by Tom Paseka



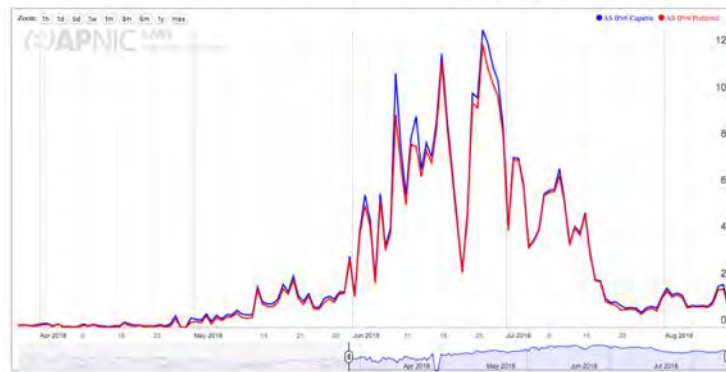
Aside: What's going on?

Use of IPv6 for China (CN)



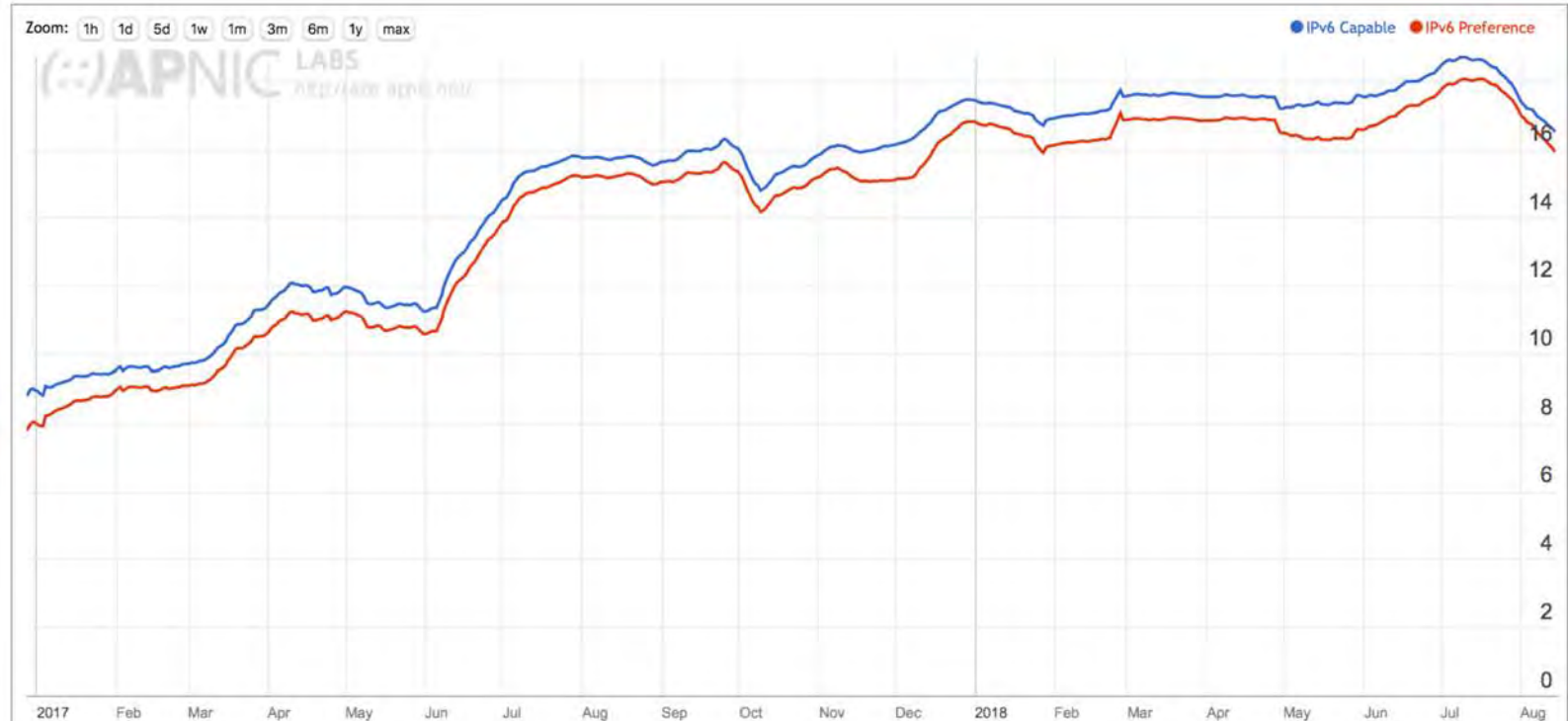
My guess is that ChinaNet Backbone (AS4134) performed a rapid enabling of IPv6 in June and early July and then backed out of this in mid July.

IPv6 Per-Country Deployment for AS4134: CHINANET-BACKBONE No.31,



2017

The most recent 20 months – Jan 2017 to August 2018



What the?

The pace of adoption of IPv6 in the Internet appears to have slowed down over the past 12 months

Why?

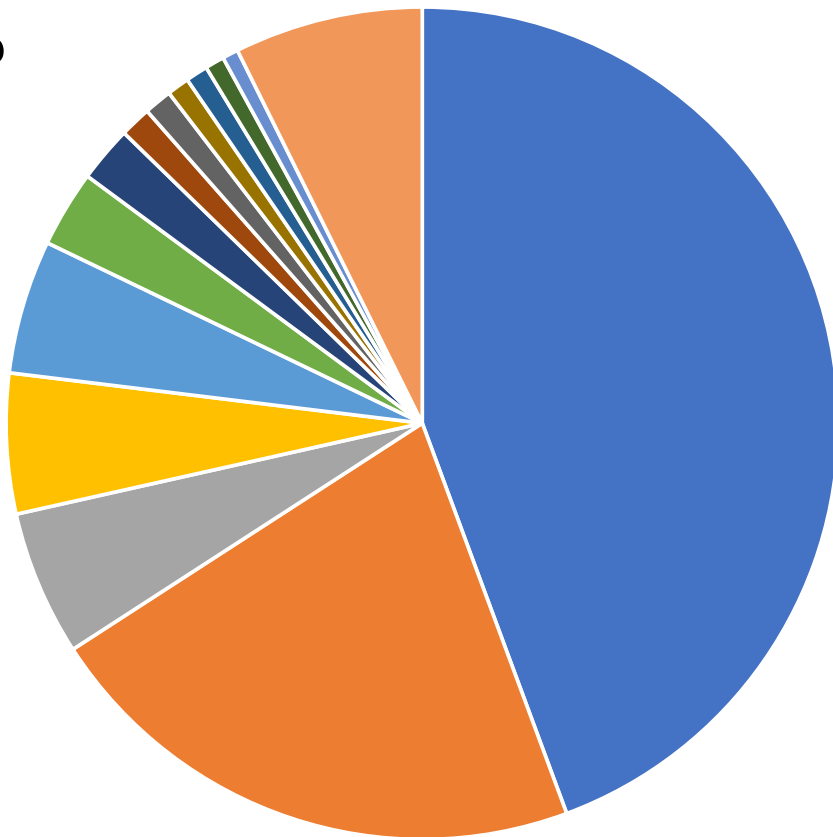
Why has IPv6 Deployment Growth slowed?

- One explanation is the factors that are driving IPv6 deployment are no longer as effective as they were
- What factors have driven IPv6 growth to date?
- Lets look at the IPv6 network and see what we can establish as common factors behind IPv6 deployment

Where is IPv6?

This is the distribution of IPv6 users across the 13 economies with the largest IPv6 using populations.

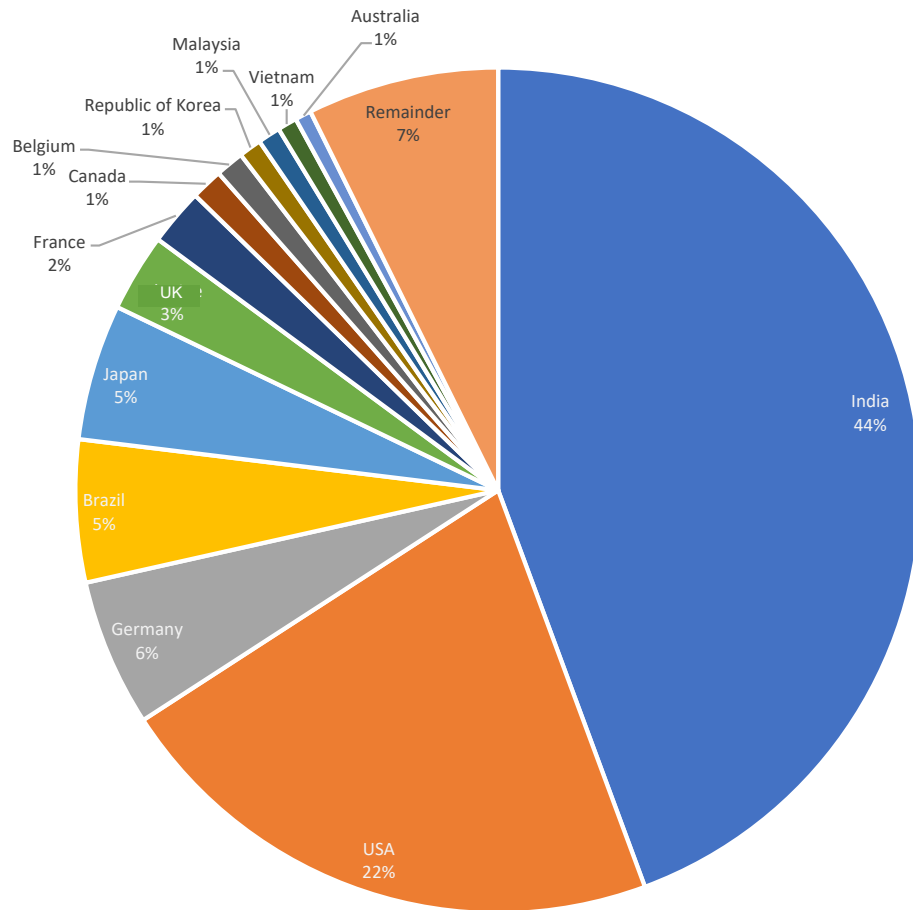
Can you guess which economy has the largest IPv6 user population?



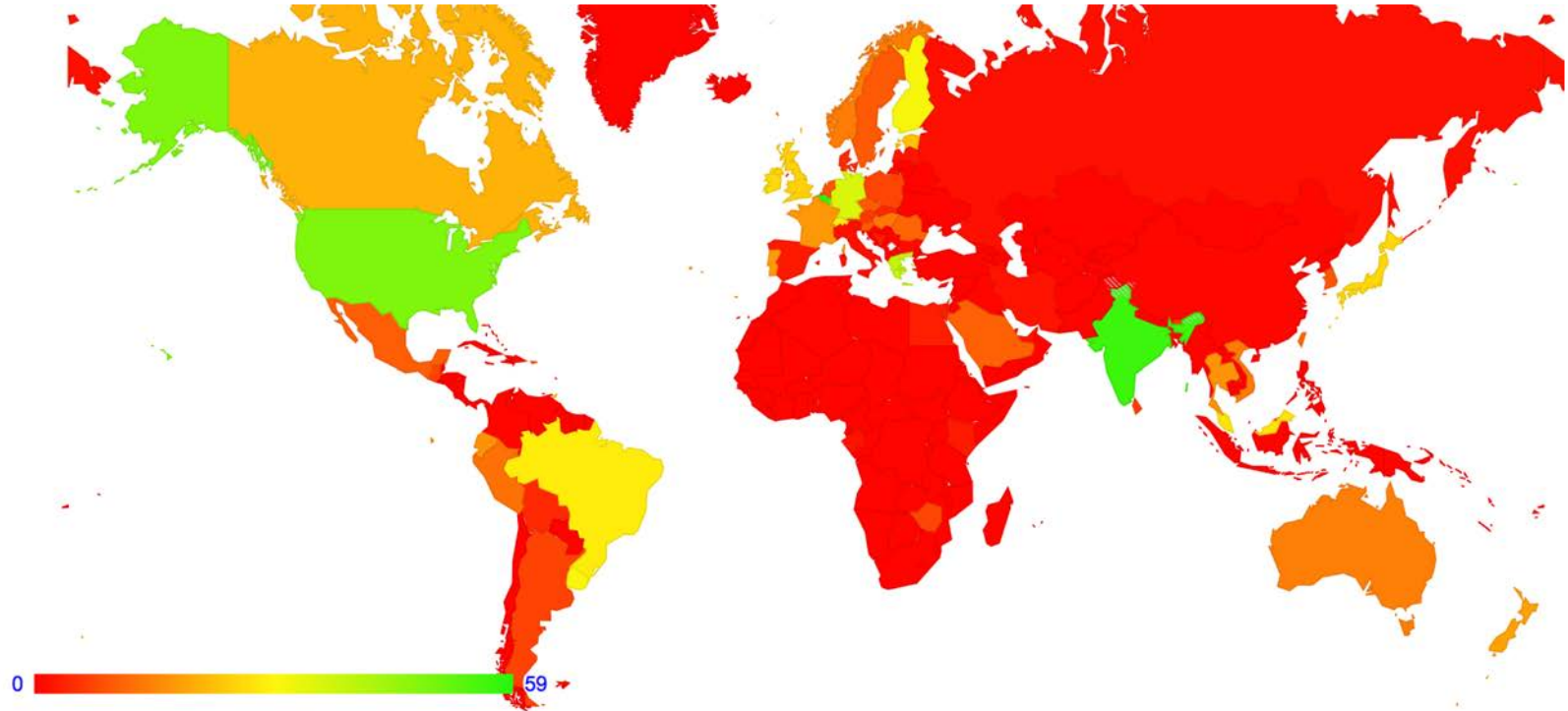
Where is IPv6?

India	242M	44%
USA	117M	21%
Germany	30M	6%
Brazil	30M	6%
Japan	28M	5%
UK	17M	3%
France	12M	2%
Canada	7M	1%
Belgium	6M	1%
Malaysia	5M	1%
Rep. of Korea	5M	1%
Vietnam	4M	1%
Australia	3M	1%

The percentages in this table reflect the percentage of the total IPv6 user population who have been geolocated into a particular economy



Where is IPv6?



Where is IPv6?



Which ISPs have the most IPv6 Users?

Rank	ASN	AS Name	CC	Users (est.)	V6 Users (est.) ▼
2	AS55836	RELIANCEJIO-IN Reliance Jio Infocomm Limited	IN	251,075,110	229,277,492
7	AS7922	COMCAST-7922 - Comcast Cable Communications, LLC	US	48,473,067	35,053,659
13	AS7018	ATT-INTERNET4 - ATT Services, Inc.	US	26,851,247	20,804,880
22	AS22394	CELLCO - Cellco Partnership DBA Verizon Wireless	US	19,527,737	16,758,991
8	AS45271	ICLNET-AS-AP Idea Cellular Limited	IN	39,678,528	15,932,493
9	AS38266	HUTCHVAS-AS Vodafone Essar Ltd., Telecommunication - Value Added Services	IN	35,455,791	15,286,220
28	AS21928	T-MOBILE-AS21928 - T-Mobile USA, Inc.	US	15,519,807	14,640,384
15	AS3320	DTAG Internet service provider operations	DE	21,601,367	13,559,548
34	AS5607	BSKYB-BROADBAND-AS	GB	13,631,308	12,709,861
14	AS28573	CLARO S.A.	BR	24,194,187	11,980,647
16	AS2516	KDDI KDDI CORPORATION	JP	21,199,626	10,769,938
29	AS20057	ATT-MOBILITY-LLC-AS20057 - ATT Mobility LLC	US	15,255,757	9,207,718
1	AS4134	CHINANET-BACKBONE No.31,Jin-rong Street	CN	288,140,066	8,337,111
27	AS3215	AS3215	FR	16,399,063	7,559,238
18	AS17676	GIGAINFRA Softbank BB Corp.	JP	20,558,221	6,950,422
5	AS45609	BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for GPRS Service	IN	79,131,648	6,747,335
46	AS22773	ASN-CXA-ALL-CCI-22773-RDC - Cox Communications Inc.	US	11,517,788	6,239,976
65	AS10507	SPCS - Sprint Personal Communications Systems	US	7,758,201	5,916,019
19	AS4713	OCN NTT Communications Corporation	JP	20,046,134	5,820,446
38	AS18881	TELEFNICA BRASIL S.A	BR	12,991,705	5,620,660
12	AS8151	Uninet S.A. de C.V.	MX	29,006,144	5,335,773
17	AS45899	VNPT-AS-VN VNPT Corp	VN	20,690,269	4,770,424
89	AS26599	TELEFNICA BRASIL S.A	BR	6,427,295	4,691,685
92	AS31334	KABELDEUTSCHLAND-AS	DE	6,313,738	4,602,093
50	AS7738	Telemar Norte Leste S.A.	BR	10,331,706	4,479,685
51	AS27699	TELEFNICA BRASIL S.A	BR	9,995,706	4,473,544
49	AS2856	BT-UK-AS BTnet UK Regional network	GB	11,006,249	4,180,082
53	AS12322	PROXAD	FR	9,622,199	4,055,164
102	AS9644	SKTELECOM-NET-AS SK Telecom	KR	5,385,256	3,701,561

IPv6 Deployment Drivers

- IPv6 was developed to provide a solution for the projected exhaustion of the free pool of IPv4 addresses
- We've exhausted that IPv4 address pool, yet IPv6 is deployed across less than 20% of the Internet
- Whatever motivated new deployment of IPv6 has not been strongly in evidence in recent months
- Do we even know common motivations for an ISP to deploy IPv6 across its infrastructure?
- Let's look at some common theories and see if the numbers support the theory

Theories of IPv6 Deployment

- You need to be a rich ISP to afford IPv6 deployment

Theories of IPv6 Deployment

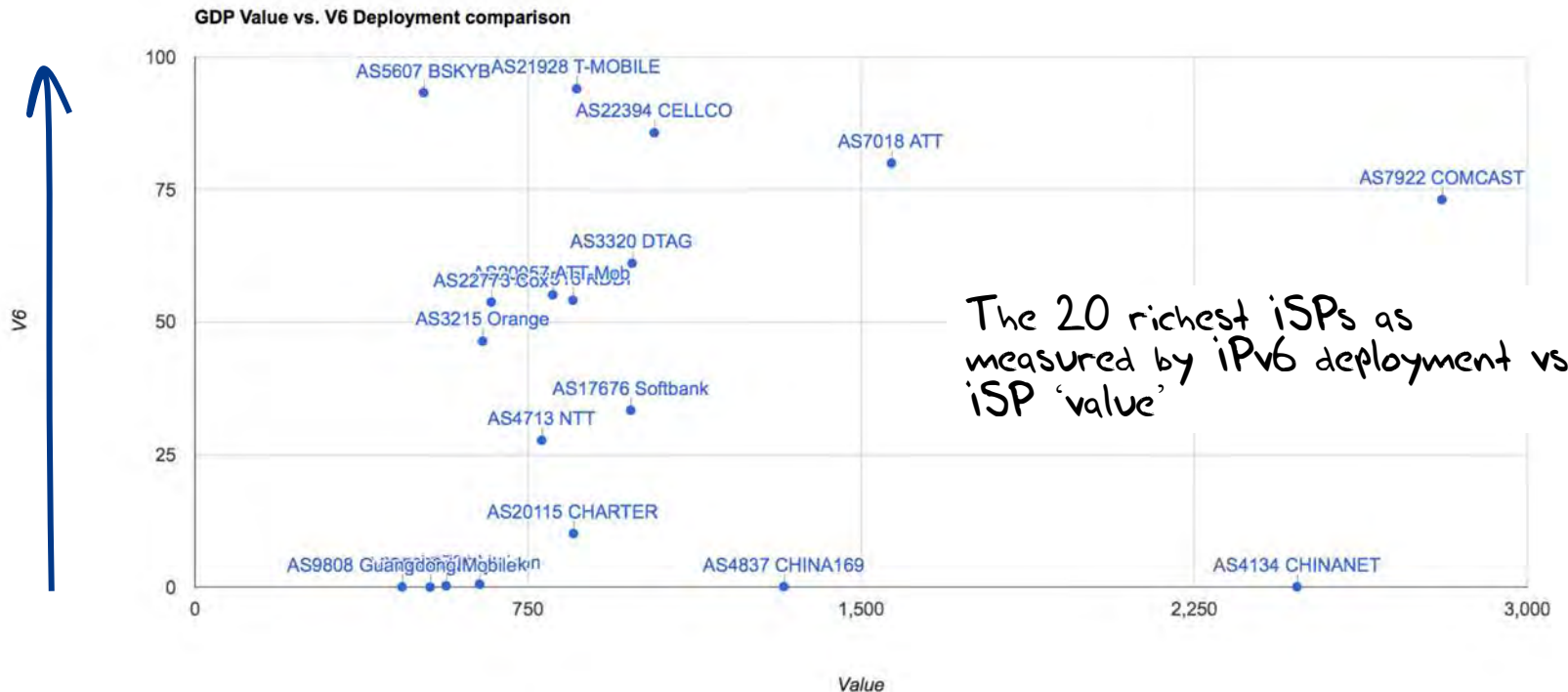
- You need to be a rich ISP to afford IPv6 deployment
- Let's measure the “wealth” of an ISP by the aggregate wealth of its customer base
 - Wealth of the customer base can be measured using GDP per capita
 - Aggregate wealth of an ISP's customer base is GDP per capita times the ISP's estimated customer population

"Rich" ISPs with IPv6 Deployments

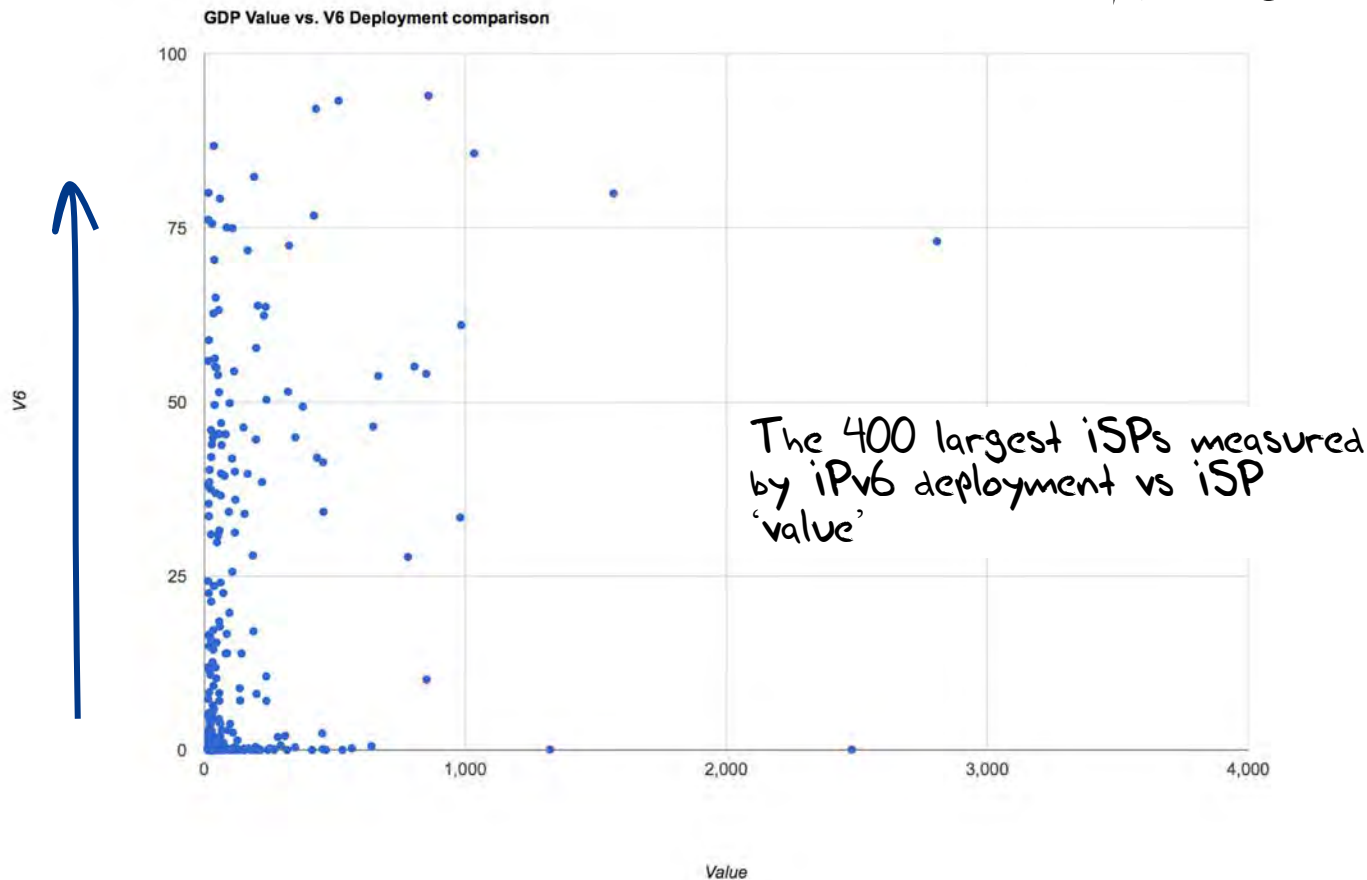
- Rank ISPs by GDP per Capita x Est. Number of Customers
- 12 of the “richest” 20 ISPs have IPv6 deployments of 33% or more across their customer bases

Rank	ASN	AS Name	CC	Users (est.)	Value (GDP x Users)	V6 Users (est)	% of AS
1	AS7922	COMCAST-7922 - Comcast Cable Communications, LLC	US	48,473,067	2,752,833,947,997	35,053,659	72.32
2	AS4134	CHINANET-BACKBONE No.31,Jin-rong Street	CN	288,140,066	2,275,730,241,268	8,337,111	2.89
3	AS7018	ATT-INTERNET4 - ATT Services, Inc.	US	26,851,247	1,524,909,168,377	20,804,880	77.48
4	AS22394	CELLCO - Celco Partnership DBA Verizon Wireless	US	19,527,737	1,108,999,711,967	16,758,991	85.82
5	AS4837	CHINA169-BACKBONE CHINA UNICOM China169 Backbone	CN	118,842,928	938,621,445,344	110,475	0.09
6	AS3320	DTAG Internet service provider operations	DE	21,601,367	911,880,106,538	13,559,548	62.77
7	AS21928	T-MOBILE-AS21928 - T-Mobile USA, Inc.	US	15,519,807	881,385,359,337	14,640,384	94.33
8	AS20057	ATT-MOBILITY-LLC-AS20057 - ATT Mobility LLC	US	15,255,757	866,389,695,787	9,207,718	60.36
9	AS2516	KDDI KDDI CORPORATION	JP	21,199,626	825,937,428,960	10,769,938	50.8
10	AS45090	CNNIC-TENCENT-NET-AP Shenzhen Tencent Computer Systems Company Limited	CN	104,127,368	822,397,952,464	822	0
11	AS17676	GIGAINFRA Softbank BB Corp.	JP	20,558,221	800,948,290,160	6,950,422	33.81
12	AS4713	OCN NTT Communications Corporation	JP	20,046,134	780,997,380,640	5,820,446	29.04
13	AS20115	CHARTER-NET-HKY-NC - Charter Communications	US	12,907,010	733,002,004,910	1,666,704	12.91
14	AS22773	ASN-CXA-ALL-CCI-22773-RDC - Cox Communications Inc.	US	11,517,788	654,106,698,308	6,239,976	54.18
15	AS701	UUNET - MCI Communications Services, Inc. dba Verizon Business	US	11,333,299	643,629,383,509	113,558	1
16	AS3215	Orange	FR	16,399,063	618,556,257,297	7,559,238	46.1
17	AS4808	CHINA169-BJ China Unicom Beijing Province Network	CN	77,221,140	609,892,563,720	82,517	0.11
18	AS5607	BSKYB-BROADBAND-AS	GB	13,631,308	541,135,664,984	12,709,861	93.24
19	AS5089	NTL	GB	12,901,322	512,156,680,756	1,232	0.01
20	AS4766	KIXS-AS-KR Korea Telecom	KR	17,576,258	483,909,535,256	402,520	2.29

"Rich" ISPs with IPv6 Deployments



"Rich" ISPs with IPv6 Deployments




IPv6 is not exclusively deployed by big ISPs in rich countries

- 73% of IPv6 users are serviced by ISPs outside the 'richest' top 20
- Major ISPs with IPv6 deployments with "richness" rank > 20:
 - Reliance JIO – India (40%, Rank: 25)
 - Vodaphone India (3%, Rank: 111)
 - ICLnet India (2.5%, Rank: 129)
 - Claro, Brazil (1.7%, Rank: 53)
 - Kabel Deutschland, Germany (1%, Rank: 31)
 - SK Telecom, Korea (1%, Rank: 56)
 - Sprint, US (1%, Rank: 27)
 - Telefonica Brazil (1%, Rank: 109)

Rank order of value of customer base

Percent of the World's IPv6 User pool



You **don't** need to sell services to rich customers to deploy IPv6

- But it helps!
- Outside of China, the correlation of the aggregate wealth of the an ISP's customer base to IPv6 deployment is pretty high
- But it's not the entire story...

Theories of IPv6 Deployment

- You need to be a rich ISP to afford IPv6 deployment
- You need to be growing quickly to be forced into IPv6 deployment

Rapidly Growing ISPs

- ISPs with high growth in their customer base are now under high IPv4 address stress
- Does this growth-related stress alter their perceptions of the risk / benefits of IPv6 adoption and spur IPv6 deployment?

Rapid Growing ISPs

Aggregate growth of the estimated customer base in the past 16 months

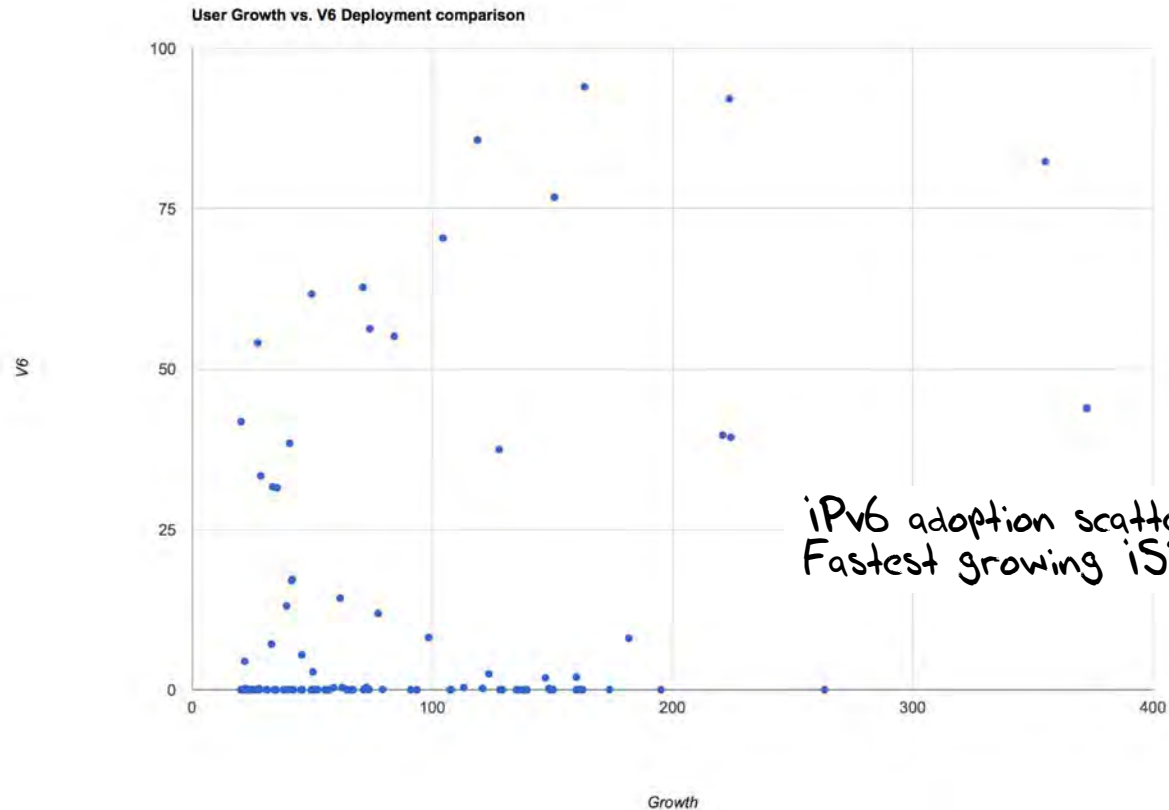


Rank	AS	AS Name	CC	Users (4/18)	Users (1/17)	Growth	V6 Deployment	V6 Growth
1	AS131445	AIS3G-2100-AS-AP Advance Wireless Network	TH	4,949,903	1,047,844	372%	43.9%	43.9%
2	AS9644	SKTELECOM-NET-AS SK Telecom	KR	6,924,914	1,521,612	355%	82.3%	56.0%
3	AS37075	ZAINUGAS	UG	3,712,755	1,021,996	263%	0.0%	0.0%
4	AS38266	HUTCHVAS-AS Vodafone Essar Ltd. Telecommunication - Value Added Services	IN	46,470,030	14,332,740	224%	39.4%	39.4%
5	AS55836	RELIANCEJIO-IN Reliance Jio Infocomm Limited	IN	256,083,676	79,115,818	224%	92.1%	19.6%
6	AS45271	ICLNET-AS-AP Idea Cellular Limited	IN	38,185,995	11,901,462	221%	39.7%	32.8%
7	AS132061	REALMOVE-AS-AP Realmove Company Limited	TH	3,056,882	1,035,635	195%	0.0%	0.0%
8	AS9605	DOCOMO NTT DOCOMO INC.	JP	5,145,742	1,826,417	182%	8.1%	8.0%
9	AS56047	CMNET-HUNAN-AP China Mobile communications corporation	CN	7,061,429	2,579,417	174%	0.0%	-0.1%
10	AS21928	T-MOBILE-AS21928 - T-Mobile USA Inc.	US	15,074,933	5,725,701	163%	94.0%	16.2%
11	AS56041	CMNET-ZHEJIANG-AP China Mobile communications corporation	CN	19,375,512	7,379,958	163%	0.0%	0.0%
12	AS4761	INDOSAT-INP-AP INDOSAT Internet Network Provider	ID	7,544,134	2,889,955	161%	0.0%	0.0%
13	AS33771	SAFARICOM-LIMITED	KE	10,914,396	4,199,062	160%	2.0%	2.0%
14	AS24389	GRAMEENPHONE-AS-AP GrameenPhone Ltd.	BD	5,245,821	2,018,349	160%	0.0%	0.0%
15	AS10507	SPCS - Sprint Personal Communications Systems	US	7,366,500	2,936,890	151%	76.8%	48.4%
16	AS23693	TELKOMSEL-ASN-ID PT. Telekomunikasi Selular	ID	15,129,489	6,043,987	150%	0.0%	0.0%
17	AS197207	MCCI-AS	IR	7,219,921	2,897,240	149%	0.0%	0.0%
18	AS56048	CMNET-BEIJING-AP China Mobile Communicaitons Corporation	CN	3,676,952	1,479,558	149%	0.2%	0.1%
19	AS5410	ASN-BOUYGTEL-ISP	FR	7,451,600	3,015,444	147%	1.9%	1.9%
20	AS59257	CMPAKLIMITED-AS-AP CMPak Limited	PK	6,145,443	2,567,186	139%	0.0%	0.0%
21	AS24203	NAPXLNET-AS-ID PT Excelcomindo Pratama (Network Access Provider)	ID	7,356,017	3,083,799	139%	0.0%	0.0%
22	AS30986	SCANCOM	GH	4,197,932	1,762,571	138%	0.0%	0.0%
23	AS15897	VODAFONETURKEY	TR	3,906,400	1,653,584	136%	0.0%	0.0%
24	AS41202	UNITEL	UZ	3,232,529	1,375,341	135%	0.0%	0.0%
25	AS9808	CMNET-GD Guangdong Mobile Communication Co.Ltd.	CN	58,907,760	25,705,680	129%	0.0%	-0.3%
26	AS20978	AVEA-TELEKOMUNIKASYON Istanbul	TR	3,470,414	1,521,081	128%	0.0%	0.0%
27	AS4818	DIGIIX-AP DiGi Telecommunications Sdn. Bhd.	MY	2,645,084	1,161,006	128%	37.5%	33.6%
28	AS45609	BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for GPRS Service	IN	65,933,383	29,499,640	124%	2.5%	2.4%
29	AS12389	ROSTELECOM-AS	RU	19,056,734	8,626,606	121%	0.2%	0.2%
30	AS22394	CELLCO - Cellco Partnership DBA Verizon Wireless	US	18,137,318	8,289,013	119%	85.7%	-4.4%

Rapidly Growing ISPs

- **100** ISPs with more than 1M estimated customers grew their customer base by more than 20% over the past 16 months
- Only **26** of these ISPs had a IPv6 deployment above 10% of their user base

Rapidly Growing ISPs



It's probably not Rapid Growth

- It appears that at present most rapidly growing ISPs (93%) are using IPv4 addressing to sustain their rapid growth and are not making accelerated investments in IPv6-capable infrastructure
- In other words, rapid growth of an ISP's customer base does not necessarily motivate an accelerated IPv6 deployment

Theories of IPv6 Deployment

- You need to be a rich ISP to afford IPv6 deployment
- You need to be growing quickly to be forced into IPv6 deployment
- You are running very short of IPv4 addresses

Calculating Customers per IPv4 Address for each ISP

- Use the estimate of the customer population per ISP
- Analysis of the BGP routing table can give us the number of advertised IPv4 addresses per originating ASN
- We can then correlate the estimated customer population of an ISP with the span of IPv4 addresses originated by the ISP's ASN to give a ratio of customers per advertised IPv4 address

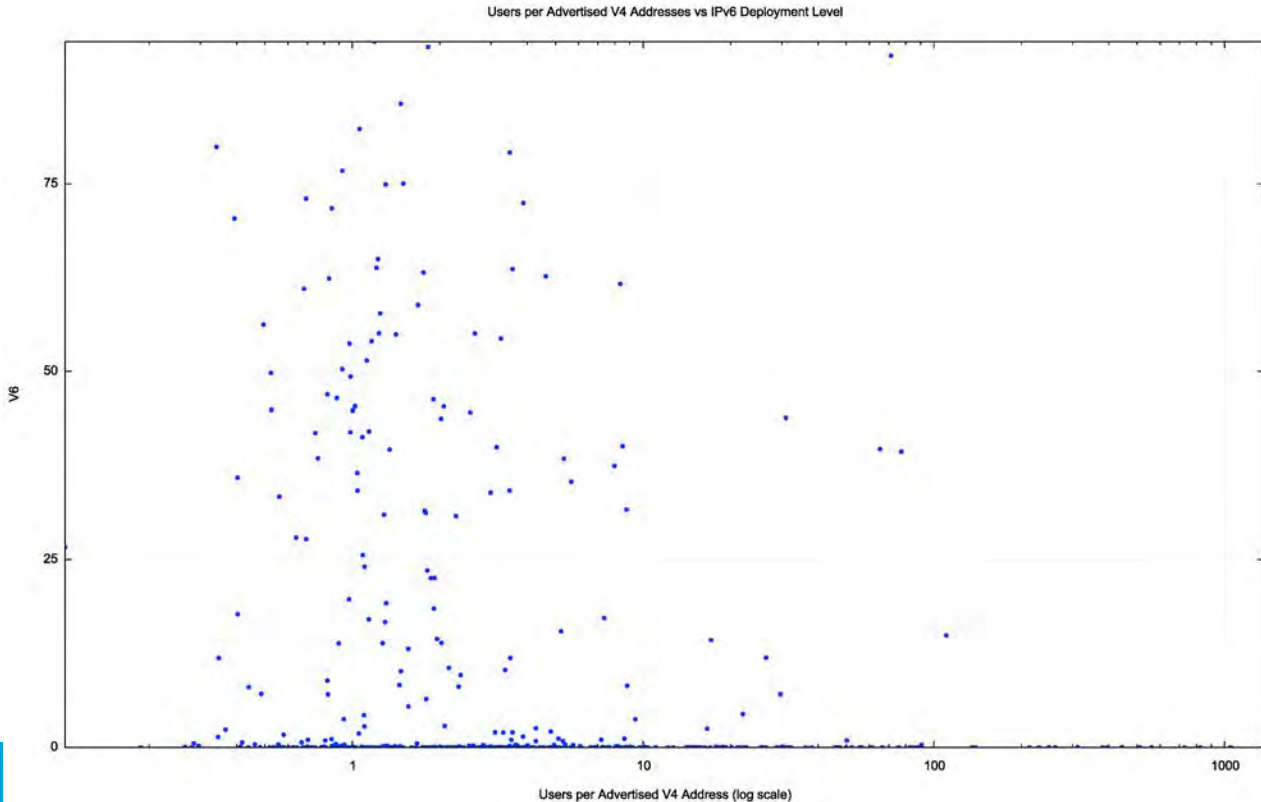
Customers per IPv4 Address

31 Largest ISPs
(measured by
estimated customer
count)

Rank	AS	AS Name	CC	Customers	V6 Deployment	IPv4 Adrrs	Ratio
1	AS4134	CHINANET-BACKBONE No.31,Jin-rong Street	CN	314,066,685	0.1%	108,130,048	2.9
2	AS55836	RELIANCJIO-IN Reliance Jio Infocomm Limited	IN	258,153,932	92.0%	3,593,728	71.8
3	AS4837	CHINA169-BACKBONE CHINA UNICOM China169 Backbone	CN	168,742,809	0.1%	56,185,087	3.0
4	AS45609	BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for GPRS Service	IN	63,831,937	2.5%	3,922,688	16.3
5	AS9808	CMNET-GD Guangdong Mobile Communication Co.Ltd.	CN	59,345,231	0.0%	18,679,040	3.2
6	AS7922	COMCAST-7922 - Comcast Cable Communications, LLC	US	49,428,872	73.1%	71,070,976	0.7
7	AS38266	HUTCHVAS-AS Vodafone Essar Ltd., Telecommunication - Value	IN	46,950,378	39.1%	601,344	78.1
8	AS45271	ICLNET-AS-AP Idea Cellular Limited	IN	37,367,503	39.4%	584,192	64.0
9	AS4812	CHINANET-SH-AP China Telecom (Group)	CN	33,473,934	0.0%	8,605,952	3.9
10	AS29465	VCG-AS	NG	31,884,360	0.0%	80,896	394.1
11	AS8151	Uninet S.A. de C.V.	MX	29,650,980	10.6%	13,811,456	2.1
12	AS7018	ATT-INTERNET4 - ATT Services, Inc.	US	27,706,446	80.4%	80,676,096	0.3
13	AS17676	GIGAINFRA Softbank BB Corp.	JP	25,236,640	34.1%	44,918,528	0.6
14	AS4808	CHINA169-BJ China Unicom Beijing Province Network	CN	24,271,679	0.4%	6,845,183	3.5
15	AS8452	TE-AS TE-AS	EG	24,001,210	0.0%	7,063,040	3.4
16	AS9121	TTNET	TR	23,330,067	0.0%	6,905,600	3.4
17	AS28573	CLARO S.A.	BR	23,235,033	44.1%	9,154,560	2.5
18	AS3320	DTAG Internet service provider operations	DE	23,161,869	61.6%	34,148,864	0.7
19	AS2516	KDDI KDDI CORPORATION	JP	21,673,865	54.8%	18,765,568	1.2
20	AS45899	VNPT-AS-VN VNPT Corp	VN	21,576,733	9.6%	6,419,136	3.4
21	AS4713	OCN NTT Communications Corporation	JP	20,142,292	27.8%	28,889,856	0.7
22	AS9299	IPG-AS-AP Philippine Long Distance Telephone Company	PH	19,641,329	0.0%	2,433,024	8.1
23	AS56046	CMNET-JIANGSU-AP China Mobile communications corporation	CN	19,601,569	0.0%	2,576,896	7.6
24	AS36873	VNL1-AS	NG	19,482,286	0.0%	34,560	563.7
25	AS56041	CMNET-ZHEJIANG-AP China Mobile communications corporation	CN	19,435,447	0.0%	2,939,904	6.6
26	AS12389	ROSTELECOM-AS	RU	18,933,027	0.2%	7,558,912	2.5
27	AS22394	CELLCO - Cellco Partnership DBA Verizon Wireless	US	17,989,130	85.9%	12,154,112	1.5
28	AS3215	France Telecom Orange	FR	16,987,008	46.5%	19,391,488	0.9
29	AS4766	KIXS-AS-KR Korea Telecom	KR	16,423,377	2.4%	44,733,472	0.4
30	AS56040	CMNET-GUANGDONG-AP China Mobile communications corpor	CN	16,065,132	0.2%	1,972,224	8.1
31	AS37148	globacom-as	NG	15,729,744	0.0%	18,688	841.7

Customers per IPv4 Address vs IPv6 Deployment

418 Largest ISPs
(measured by
estimated customer
count)



Running Short of IPv4 Addresses

- 418 ISPs have a customer population of over 1M
- 81 of these ISPs are not 'stressed' for IPv4 yet:
 - They have more than 1 IPv4 address per customer
 - 31 of these ISPs have a IPv6 deployment rate greater than 5% (38% of these 'unstressed' ISPs)
- 337 of these ISPs are 'stressed' for IPv4:
 - They have less than 1 IPv4 address per customer
 - 80 of these ISPs have an IPv6 deployment rate greater than 5% (23% of these 'stressed' ISPs)
- Unusually, those ISPs with a higher level of IPv4 address stress have a lower IPv6 deployment rate

Running very short of IPv4 Addresses

- 19 ISPs have more than 100 customers per advertised IPv4 address
- Only 1 of these ISPs has an IPv6 deployment rate of more than 5% (and its 'stress rate' is 100 customers per advertised IPv4 address)
 - Actually, only 1 has an IPv6 deployment more than 0.04%
- The other 18 ISPs have higher address 'stress rates' of between 135 to 1,370 customers per advertised IPv4 address and negligible IPv6 deployment levels
- It appears that acute IPv4 address overuse is not a major driver for IPv6 deployment

The Changing Internet

- IPv6 was designed as a solution to a different Internet
- The Client / Server CDN-centric Internet does not require each endpoint to have a globally unique permanent address
- Addresses are increasingly being used in the role of ephemeral session tokens, not as persistent endpoint identifiers
- This does NOT mean that IPv4 will last indefinitely – it won't
- But it does mean that many areas of the Internet are yet to experience major pressures to deploy IPv6 in a client/server context

Theories of IPv6 Deployment

- You need to be a rich ISP to afford IPv6 deployment
- You need to be growing quickly to be forced into IPv6 deployment
- You are running very short of IPv4 addresses
- Local conditions

National IPv6 Deployments

- Economies where 3 or more of the 6 largest ISPs have IPv6 deployment levels > 20%:
 - India (58%)
 - Belgium (58%)
 - USA (44%)
 - Germany (39%)
 - Greece (38%)
 - Japan (27%)
 - Brazil (26%)

India shows that competitive factors can drive IPv6 deployment across the major ISPs in a country, but this is not clear in all countries with significant IPv6 deployment

What Drives Deployment of IPv6?

- There is no major common factor at work here
- IPv6 deployment is **not** confined
 - to ISPs in countries with higher GDP per capita
 - to ISPs who are growing their user base the fastest
 - to ISPs that are experiencing the highest levels of IPv4 address stress
 - to national communities
- However, all these factors appear to help in individual cases

Back to our question...

- The pace of adoption of IPv6 in the Internet appears to have slowed down over the past 9 months
- What's going on?

Back to our question...

- The pace of adoption of IPv6 in the Internet appears to have slowed down over the past 12 months
- What's going on?

We're not sure!

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Thanks!



NOUMEA, NEW CALEDONIA
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