

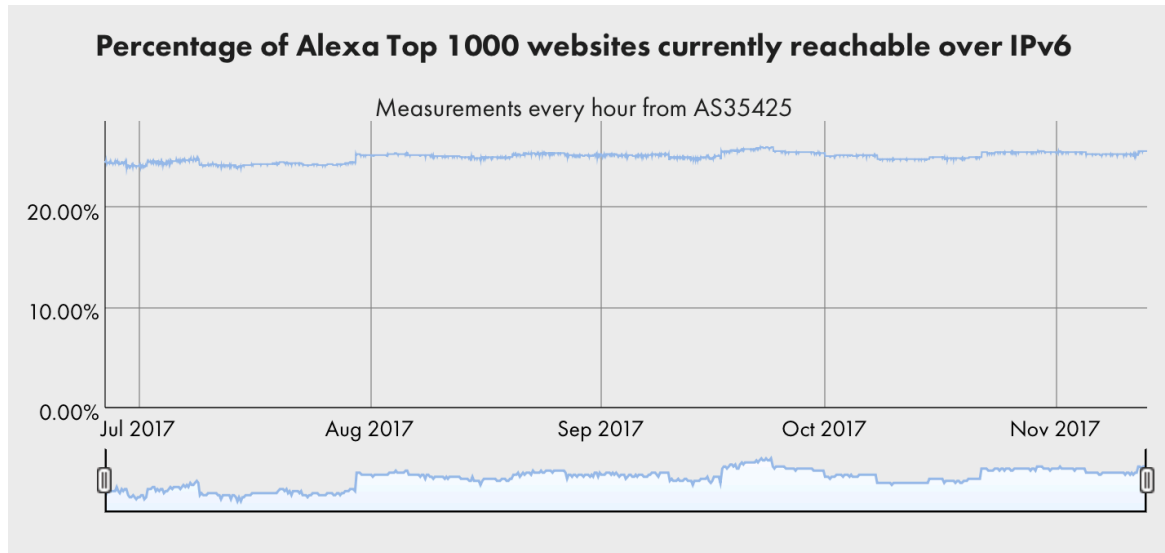
Measuring IPv6

Geoff Huston
APNIC

Measuring IPv6

How can we “measure” the uptake of IPv6?

– Alexa Lists: Dual Stack services

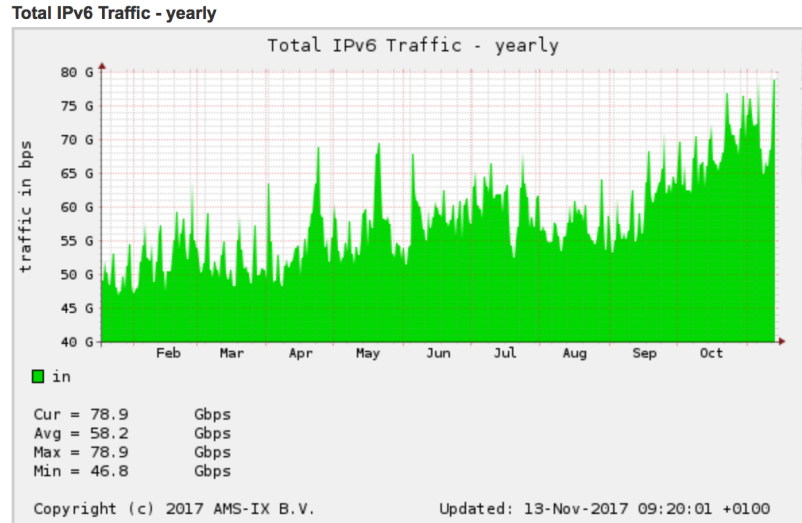


Steady at some 24% of sites for the past 5 months

Measuring IPv6

How can we “measure” the uptake of IPv6?

– IX stats: IPv6 traffic stats



30% increase in traffic volumes
over the past 12 months

What should be be looking for?

- Generating measurements from the network is endless!
 - There are many aspects of the network infrastructure that can be measured
- But are they helpful measurements?
- In some ways measuring the infrastructure is getting it backwards!
- If we want to know what users can (or cannot) do, then why not measure the user?

User-Centric measurements

- How fast is your Internet connection?
- How reliable is your connection?
- How fast is your DNS service?
- Can you retrieve a web object over IPv6?
- Given a choice of IPv6 and IPv4 what protocol will your browser prefer to use to retrieve a web object?

Measuring as a User

- How can we “see” the Internet as users see it?
- One approach is to put measurement equipment at the edge of the Internet
 - RIPE Atlas, CAIDA Archipelago, Sam Knows, etc
- Another approach is to get users to run the measurement tests
 - ICSI Netalyser, Google M-Lab
- We can ride on the back of a widely distributed software platform
 - And insert a measurement script into this environment

We use Ads!

The screenshot shows a news website interface with a dark header. The header contains the logo 'ekantipur' on the left and a navigation bar on the right with icons for various languages (English, नेपाली) and a settings gear. Below the header, there are three article snippets arranged horizontally. Each snippet includes a title, a short text description, a 'Read Full Story' link, and social media sharing icons for Facebook and Twitter. The first snippet is titled 'confiscated' and describes yellow lentils smuggled across the border. The second snippet is titled '\$150,000' and features a photo of a man and a woman. The third snippet is titled 'school building' and describes a new school building in Sindhupalchowk. Below the article snippets is a large advertisement for APNIC, which includes the text 'Thank you for helping us measure the Internet.' and a small icon of a globe. At the bottom of the screenshot, there is a partial view of another article snippet titled 'Manang and Mustang in grip of freezing cold' from 'kathmandu:post'.

ekantipur

confiscated

Millions worth of yellow lentils smuggled across the border from India's Khamiya village was intercepted by Parsa police on Monday morning. [Read Full Story »](#)

\$150,000

[Read Full Story »](#)

school building

The quake-damaged school building of Sita Devi Lower Secondary School at Batashe in Sindhupalchowk district has received a new nine-roomed building, thanks to the financial assistance provided by the foreign tourists. [Read Full Story »](#)

English नेपाली All

APNIC Thank you for helping us measure the Internet.

Manang and Mustang in grip of freezing cold

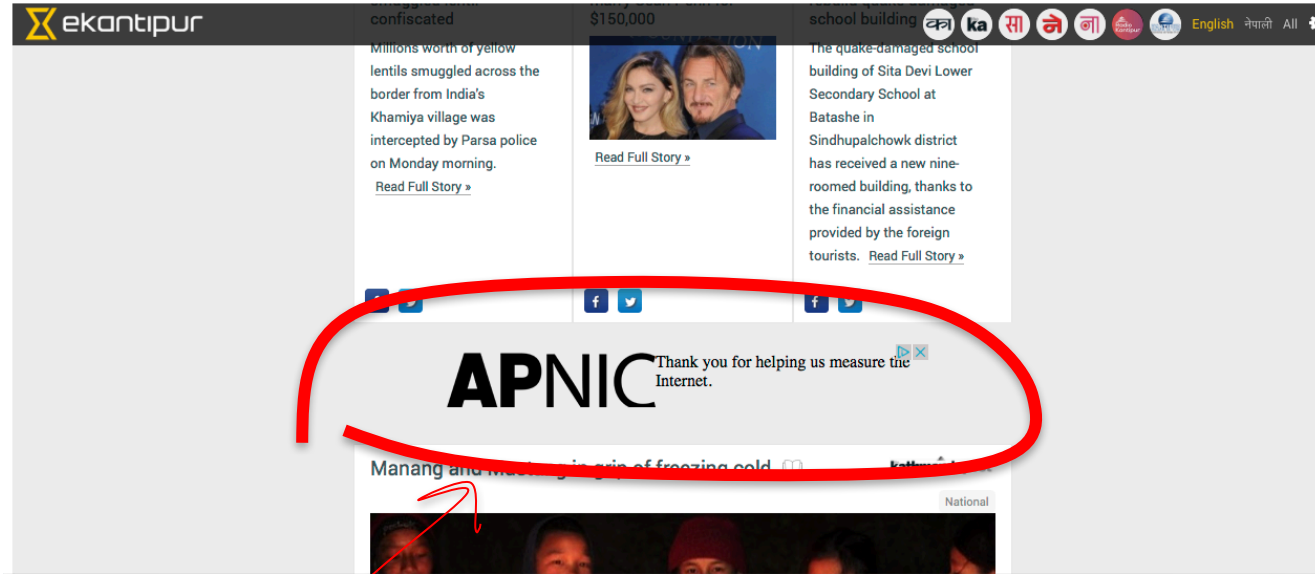
kathmandu:post

National

APNIC's Measurement Technique

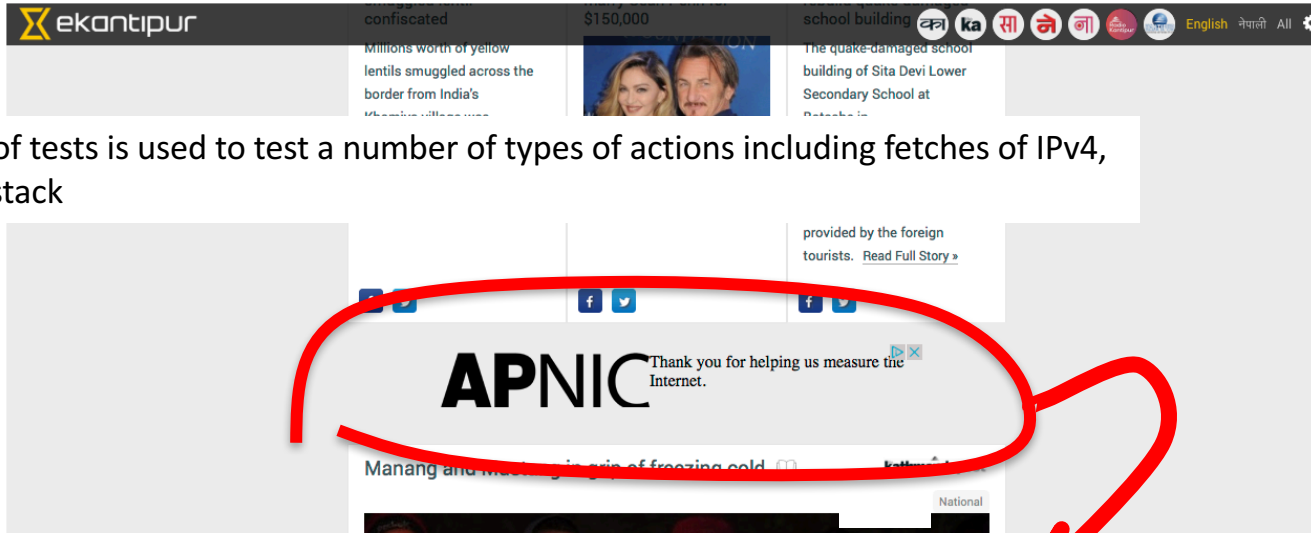
- Embed a test script in an online ad
- Have the script generate a set of URLs to fetch
 - Each script uses unique names to avoid caching distortion
- Direct all the DNS and the HTTP traffic to a set of measurement servers
- Examine the traffic profile seen at the server

How We Measure

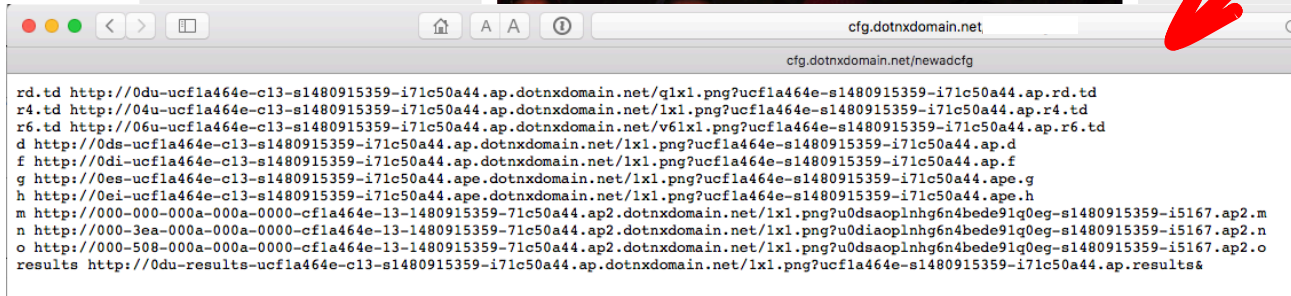


We use an online ad to present a sequence of small fetches to the user's browser

How We Measure



The sequence of tests is used to test a number of types of actions including fetches of IPv4, IPv6 and Dual stack



How We Measure

We use full packet capture to record all packet activity at the experiment's servers

```
01:15:56.373486 IP 2001:388:1000:128:d267:e5ff:feef:a842.40836 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [..], seq 4085296132, ack 4865296132, win 0, options [nop,nop,TS val 4865296132 ecr 0], length 0
01:15:56.373492 IP 2001:388:1000:128:d267:e5ff:feef:a842.40836 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [P..], seq 1:222, ack 1, win 1026, options [nop,nop,TS val 4865296132 ecr 0], length 221
01:15:56.386494 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.40836: Flags [..], ack 222, win 232, options [nop,nop,TS val 763257743 ecr 4865296132], length 0
01:15:56.386644 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.40836: Flags [P..], seq 1:293, ack 222, win 232, options [nop,nop,TS val 763257743 ecr 4865296132], length 292
01:15:56.392169 IP 2001:388:1000:128:d267:e5ff:feef:a842.40836 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [F..], seq 222, ack 293, win 1026, options [nop,nop,TS val 4865296350 ecr 763257743], length 0
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01:16:00.160813 IP 202.150.221.222.62150 > 139.162.2.194.80: Flags [S], seq 2110718859, win 65535, options [nop,nop,wscale 6,sackOK,TS val 4865307919 ecr 0], length 0
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01:16:00.484018 IP 202.150.221.222.62150 > 139.162.2.194.80: Flags [..], ack 1, win 1040, options [nop,nop,TS val 4865308242 ecr 763261314], length 0
01:16:00.484040 IP 202.150.221.222.62150 > 139.162.2.194.80: Flags [P..], seq 1:222, ack 1, win 1040, options [nop,nop,TS val 4865308242 ecr 763261314], length 221
01:16:00.807080 IP 139.162.2.194.80 > 202.150.221.222.62150: Flags [..], ack 222, win 235, options [nop,nop,TS val 763261411 ecr 4865308242], length 0
01:16:00.807231 IP 139.162.2.194.80 > 202.150.221.222.62150: Flags [P..], seq 1:293, ack 222, win 235, options [nop,nop,TS val 763261411 ecr 4865308242], length 292
01:16:00.807654 IP 202.150.221.222.62150 > 139.162.2.194.80: Flags [F..], seq 222, ack 293, win 1040, options [nop,nop,TS val 4865308566 ecr 763261411], length 0
01:16:00.130793 IP 139.162.2.194.80 > 202.150.221.222.62150: Flags [F..], seq 293, ack 223, win 235, options [nop,nop,TS val 763261500 ecr 4865308566], length 0
01:16:00.130801 IP 202.150.221.222.62150 > 139.162.2.194.80: Flags [..], ack 294, win 1040, options [nop,nop,TS val 4865308889 ecr 763261500], length 0
01:16:20.244000 IP 2001:388:1000:128:d267:e5ff:feef:a842.31238 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [S..], seq 1290830881, win 65535, options [nop,nop,wscale 6,sackOK,TS val 4865320002 ecr 0], length 0
01:16:20.457379 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.31238: Flags [S..], seq 1740849535, ack 1290830882, win 28560, options [nop,nop,TS val 763264905 ecr 4865320002,nop,wscale 7], length 0
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01:16:20.670820 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.31238: Flags [S..], seq 1740849535, ack 1290830882, win 28560, options [nop,nop,TS val 763264969 ecr 4865320215], length 0
01:16:20.670879 IP 2001:388:1000:128:d267:e5ff:feef:a842.31238 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [..], ack 1, win 1026, options [nop,nop,TS val 4865320215 ecr 763264969], length 292
01:16:20.671386 IP 2001:388:1000:128:d267:e5ff:feef:a842.31238 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [F..], seq 224, ack 293, win 1026, options [nop,nop,TS val 4865320429 ecr 763264969], length 0
01:16:20.804786 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.31238: Flags [..], seq 293, ack 225, win 232, options [nop,nop,TS val 763265033 ecr 4865320429], length 0
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01:16:30.829388 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.64866: Flags [S..], seq 2178029185, ack 1648543163, win 28560, options [nop,nop,TS val 763269639 ecr 4865335784,nop,wscale 7], length 0
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01:16:30.829422 IP 2001:388:1000:128:d267:e5ff:feef:a842.64866 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [P..], seq 1:232, ack 1, win 1026, options [nop,nop,TS val 4865335908 ecr 763269639], length 231
01:16:30.845317 IP 2400:8901:f03c:91ff:fe08:6306.000 > 2001:388:1000:128:d267:e5ff:feef:a842.64866: Flags [..], ack 232, win 232, options [nop,nop,TS val 763269703 ecr 4865335908], length 0
01:16:30.845348 IP 2001:388:1000:128:d267:e5ff:feef:a842.64866 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [P..], seq 1:293, ack 232, win 232, options [nop,nop,TS val 763269703 ecr 4865335908], length 292
01:16:30.857208 IP 2001:388:1000:128:d267:e5ff:feef:a842.64866 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [F..], seq 223, ack 293, win 1026, options [nop,nop,TS val 4865336212 ecr 763269703], length 0
01:16:30.867237 IP 2001:388:1000:128:d267:e5ff:feef:a842.64866 > 2400:8901:f03c:91ff:fe08:6306.000: Flags [..], ack 294, win 1026, options [nop,nop,TS val 4865336425 ecr 763269703], length 0
```

Manang and ... origin of freezing cold ...

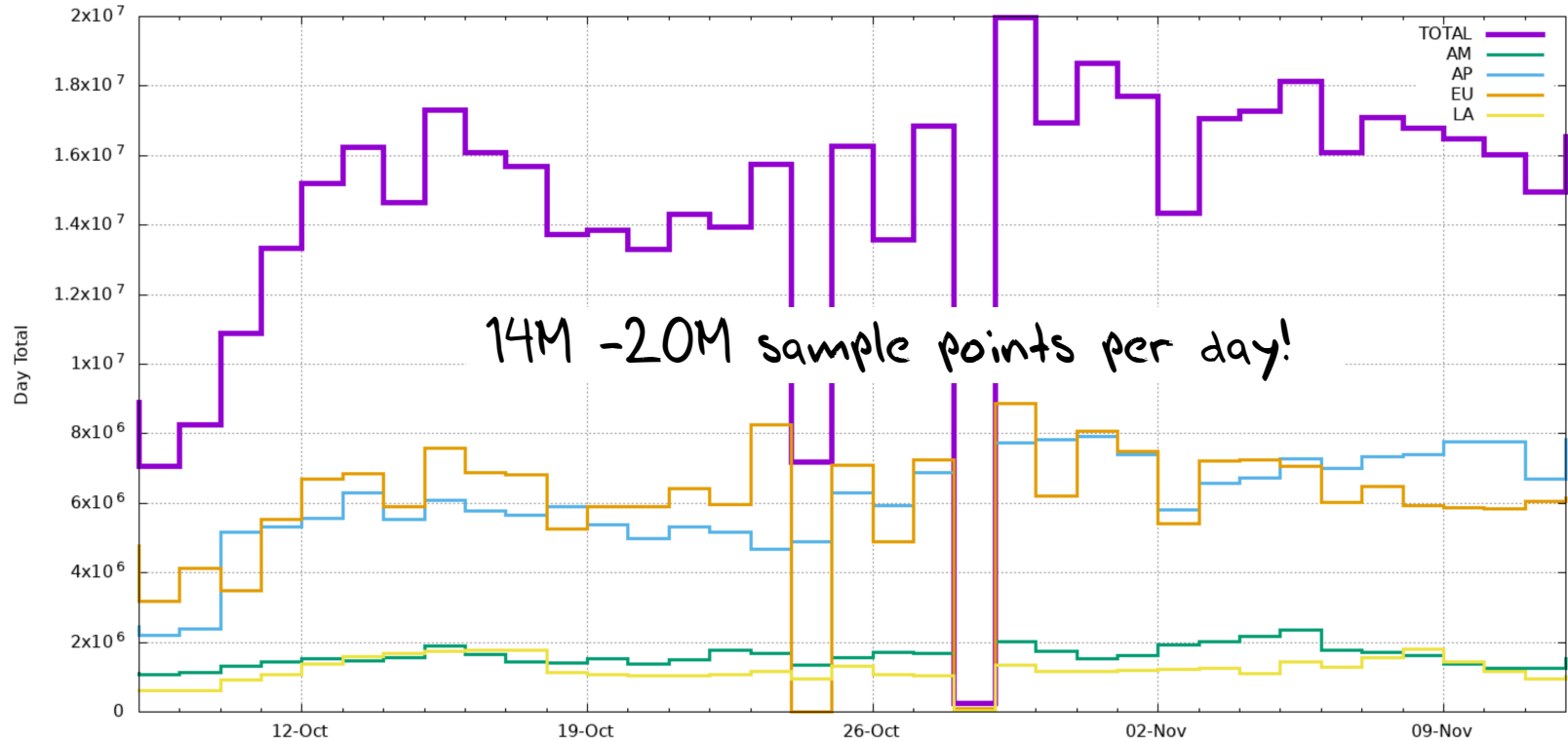
National

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cgf.dotnxdomain.net/
cgf.dotnxdomain.net/newadcfg

rd.td http://0du-ucfla464e-c13-s1480915359-i71c50a44.ap.dotnxdomain.net/g1x1.png?ucfla464e-s1480915359-i71c50a44.ap.rd.td
r4.td http://04u-ucfla464e-c13-s1480915359-i71c50a44.ap.dotnxdomain.net/lx1.png?ucfla464e-s1480915359-i71c50a44.ap.r4.td
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```

How Much do We Measure?

Daily Total Ad Impressions for Servers - Month: 08-Oct to 12-Nov



Measuring IPv6

In the Ad we have two URLs:

- one can only be fetched if the user is able to complete the fetch using IPv6 - IPv6 “CAPABLE”
- Another can be fetched using either IPv4 or IPv6 – we are interested in which protocol is “PREFERRED” when given the choice

We count the results and group it by economy and by network per day, giving up a long term picture about the global update of IPv6 in the Internet by users

Where are we today?

Originally we thought that the Internet would avoid complete IPv4 exhaustion and adopt IPv6 while there was still some IPv4 left in the unallocated address pools

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This has not happened!

Where are we today?

Originally we thought that the Internet would avoid complete IPv4 exhaustion and adopt IPv6 while there was still some IPv4 left in the unallocated address pools

This has not happened!

Then we thought that the reality of IPv4 exhaustion would prompt all service providers to accelerate their IPv6 deployment plans

Where are we today?

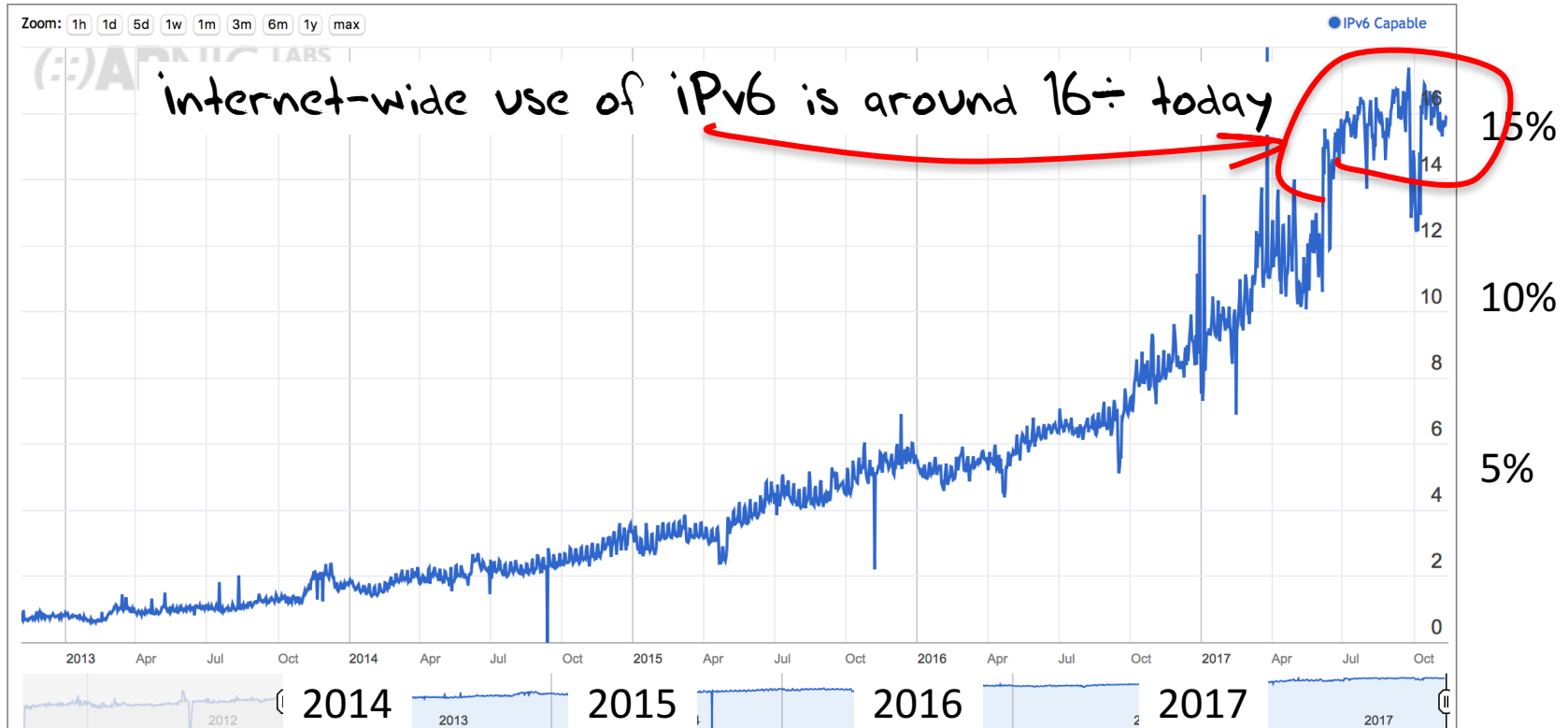
Originally we thought that the Internet would avoid complete IPv4 exhaustion and adopt IPv6 while there was still some IPv4 left in the unallocated address pools

This has not happened!

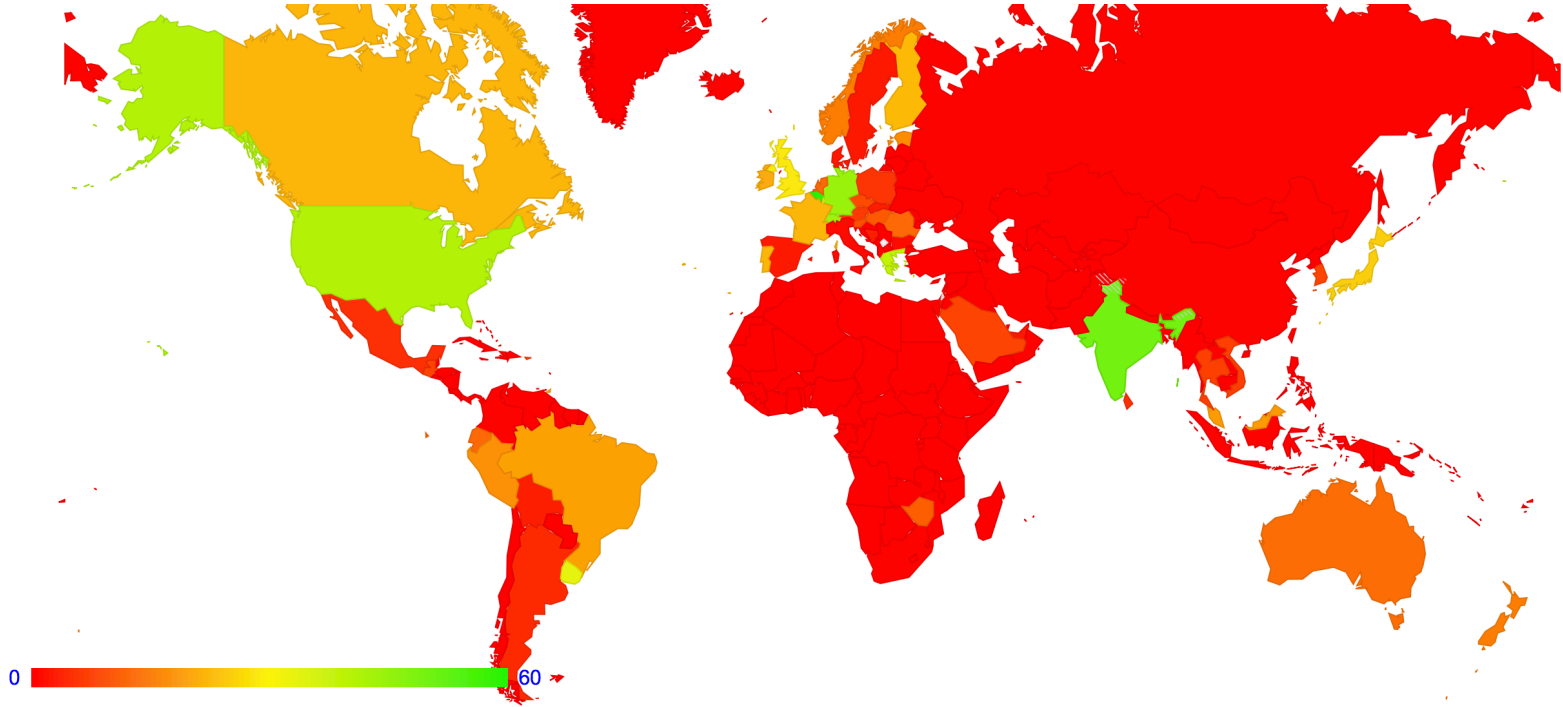
Then we thought that the real IPv4 exhaustion would prompt all ISPs to accelerate their IPv6 deployment plans

So far NATs appear to be used instead!

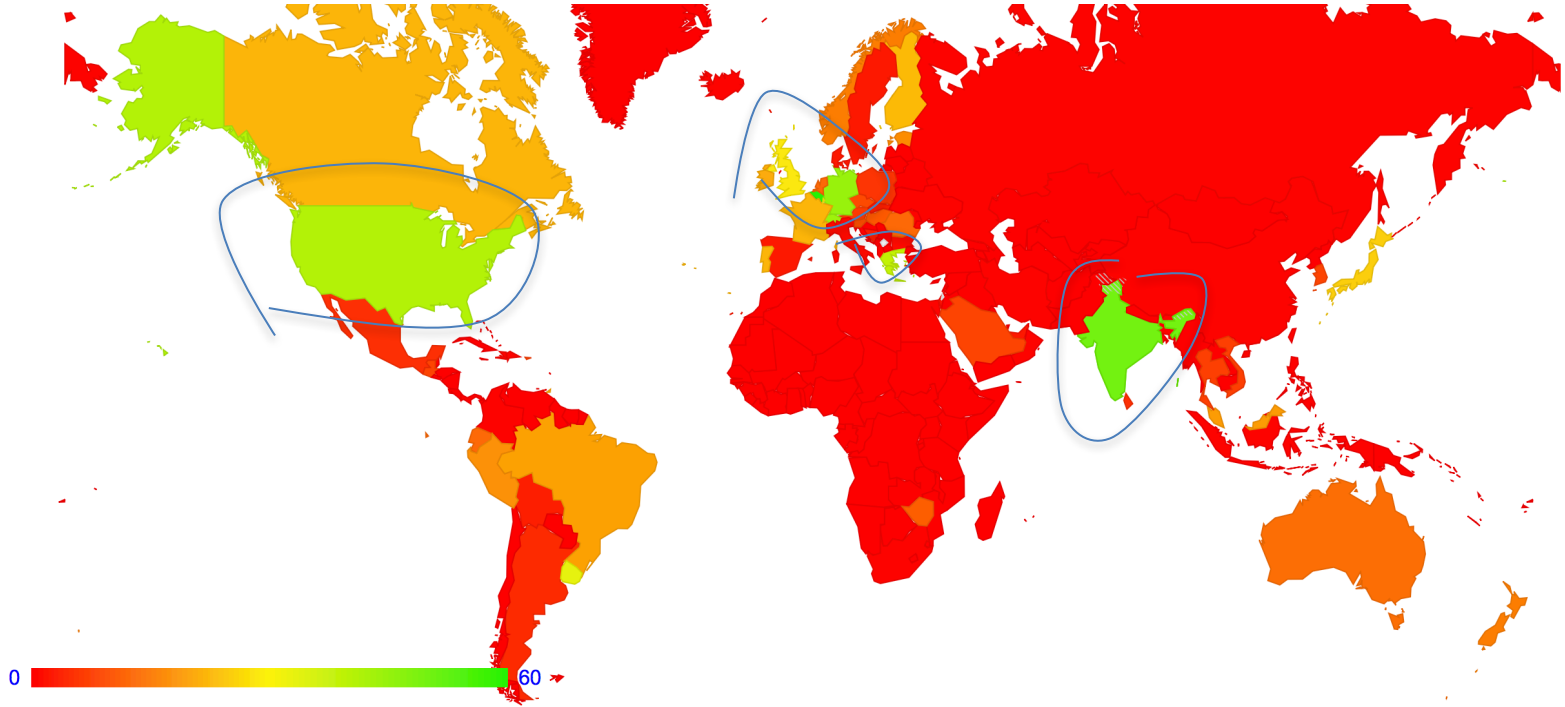
Global Uptake of IPv6



Where are these IPv6 Users?



Where are these IPv6 Users?



Where are IPv6 Users?



Which ISPs offer IPv6?

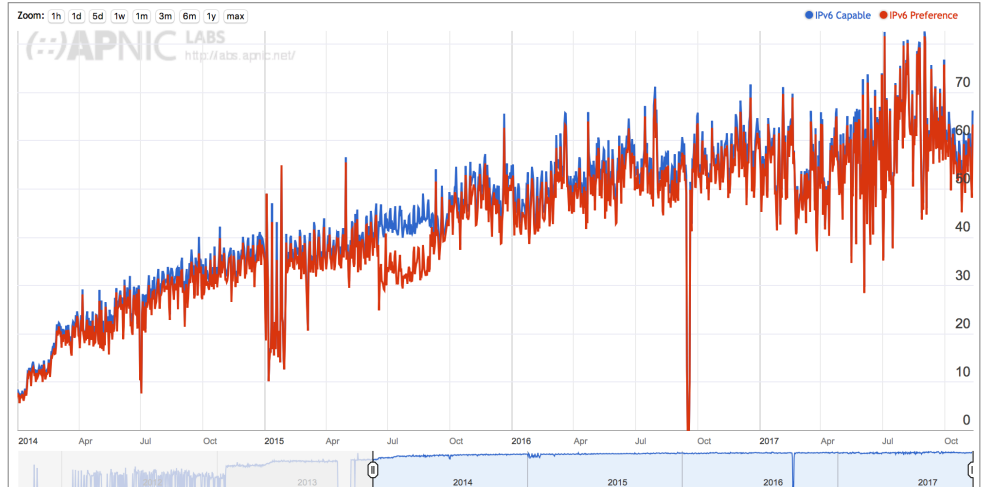
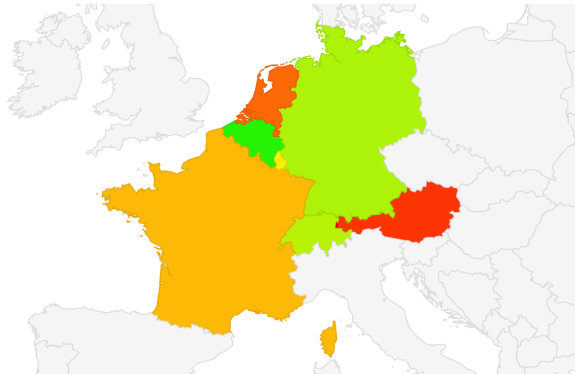
Visible ASNs: Customer Populations (Est.)



| ASN | AS Name | CC | Users (est.) | V6 Users (est) | % of AS |
|---------|--|--------------------|--------------|----------------|---------|
| AS55836 | RELIANCEJIO-IN Reliance Jio Infocomm Limited | IN | 253,329,150 | 224,493,397 | 88.62 |
| AS7922 | COMCAST-7922 - Comcast Cable Communications, LLC | US | 49,564,281 | 34,997,149 | 70.61 |
| AS7018 | ATT-INTERNET4 - ATT Services, Inc. | US | 28,690,839 | 23,505,271 | 81.93 |
| AS3320 | DTAG Internet service provider operations | DE | 22,771,877 | 13,881,372 | 60.96 |
| AS5607 | BSKYB-BROADBAND-AS | GB | 14,904,373 | 13,602,587 | 91.27 |
| AS21928 | T-MOBILE-AS21928 - T-Mobile USA, Inc. | US | 12,437,505 | 10,983,012 | 88.31 |
| AS22394 | CELLCO - Cellco Partnership DBA Verizon Wireless | US | 11,919,972 | 10,418,084 | 87.4 |
| AS2516 | KDDI KDDI CORPORATION | JP | 18,767,464 | 9,848,834 | 52.48 |
| AS28573 | CLARO S.A. | BR | 25,592,920 | 9,334,494 | 36.47 |
| AS45271 | ICLNET-AS-AP Idea Cellular Limited | IN | 30,477,688 | 9,073,769 | 29.77 |
| AS3215 | AS3215 | FR | 18,387,417 | 8,006,805 | 43.55 |
| AS17676 | GIGAINFRA Softbank BB Corp. | JP | 22,351,193 | 7,861,076 | 35.17 |
| AS31334 | KABELDEUTSCHLAND-AS | DE | 9,721,998 | 6,744,795 | 69.38 |
| AS22773 | ASN-CXA-ALL-CCI-22773-RDC - Cox Communications Inc. | US | 12,045,284 | 5,907,955 | 49.05 |
| AS18881 | TELEFNICA BRASIL S.A | BR | 17,021,711 | 5,599,772 | 32.9 |
| AS12322 | PROXAD | FR | 13,845,655 | 5,210,968 | 37.64 |
| AS20057 | ATT-MOBILITY-LLC-AS20057 - ATT Mobility LLC | US | 10,085,376 | 4,945,586 | 49.04 |
| AS4713 | OCN NTT Communications Corporation | JP | 21,780,913 | 4,717,811 | 21.66 |
| AS6830 | LGI-UPC formerly known as UPC Broadband Holding B.V. | DE | 6,442,545 | 4,422,213 | 68.64 |
| AS8151 | Uninet S.A. de C.V. | MX | 32,435,960 | 3,927,096 | 12.11 |
| AS27699 | TELEFNICA BRASIL S.A | BR | 9,705,648 | 3,836,841 | 39.53 |

0

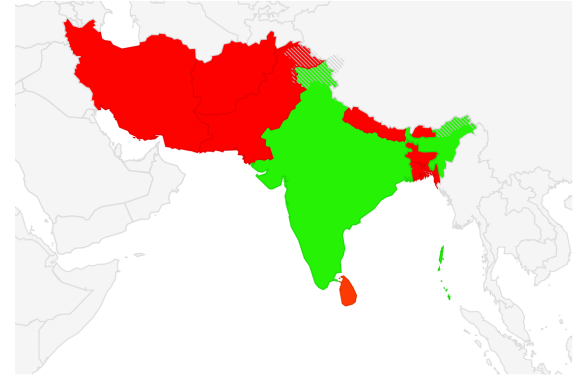
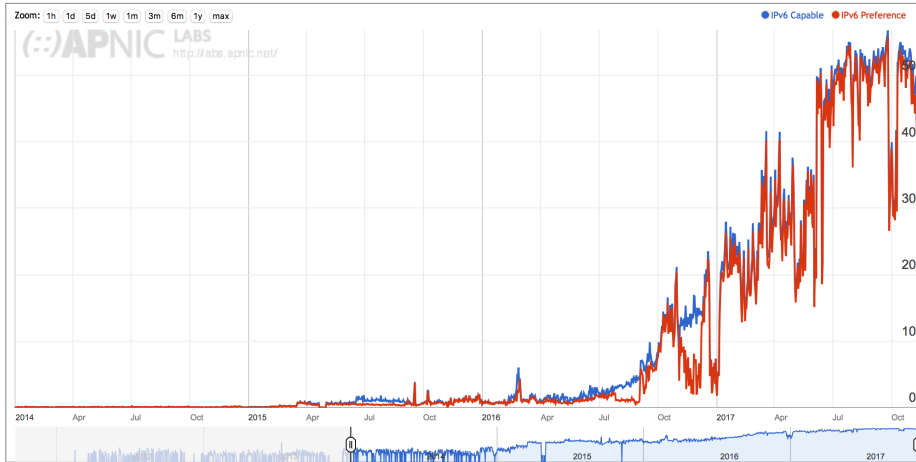
Belgium



| ASN | AS Name | IPv6 Capable | IPv6 Preferred | Samples |
|---------|---|--------------|----------------|---------|
| AS5432 | BELGACOM-SKYNET-AS | 58.54% | 56.32% | 793,654 |
| AS6848 | TELENET-AS | 75.67% | 73.65% | 451,616 |
| AS12392 | ASBRUTELE VOO | 77.52% | 74.81% | 208,118 |
| AS47377 | MES KPN Belgium Business NV has been acquired by Mobistar | 0.06% | 0.02% | 54,475 |
| AS21502 | ASN-NUMERICABLE | 0.01% | 0.01% | 37,213 |
| AS2611 | BELNET | 7.11% | 6.90% | 12,458 |
| AS44944 | BASE-AS Telenet Group BVBASPRL | 0.36% | 0.13% | 11,168 |

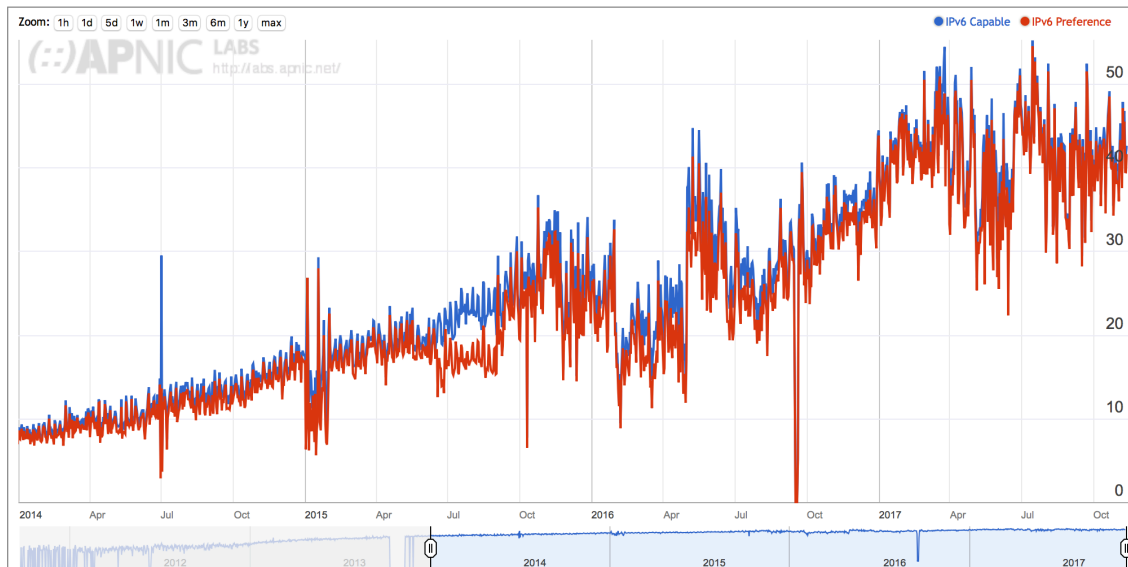
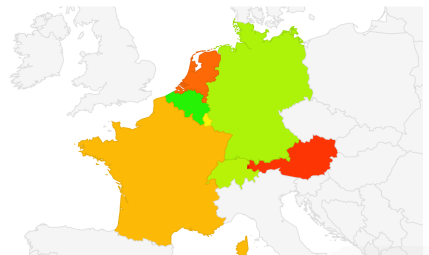
India

Use of IPv6 for India (IN)



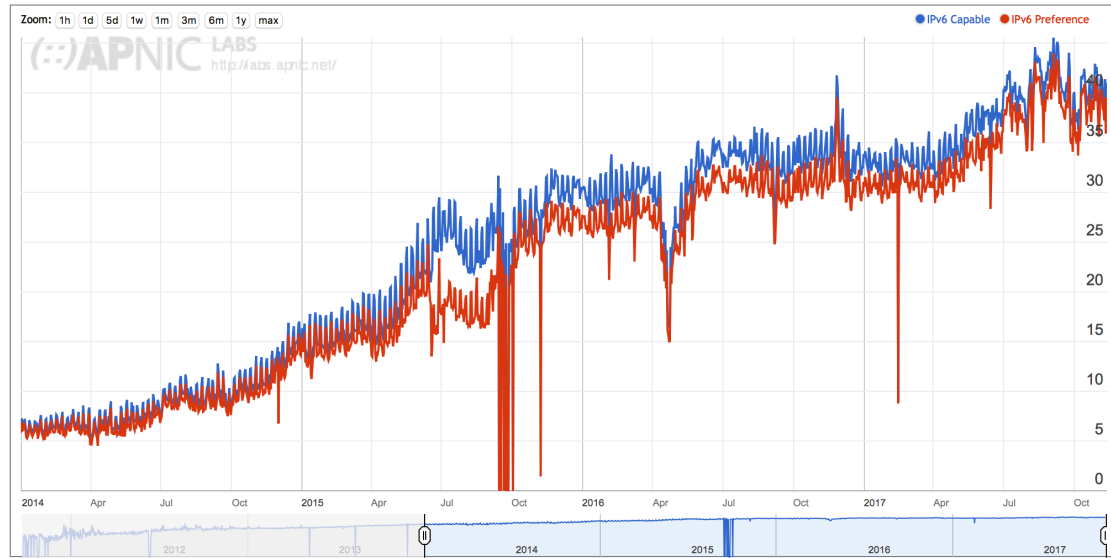
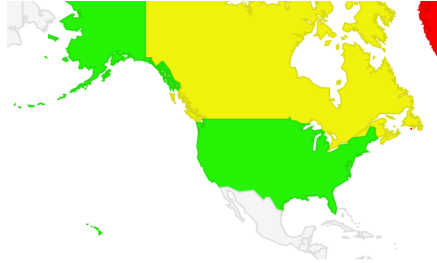
| ASN | AS Name | IPv6 Capable | IPv6 Preferred | Samples |
|---------|---|--------------|----------------|------------|
| AS55836 | RELIANCEJIO-IN Reliance Jio Infocomm Limited | 88.69% | 85.38% | 68,291,551 |
| AS45609 | BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for GPRS Service | 2.57% | 2.47% | 14,200,162 |
| AS45271 | ICLNET-AS-AP Idea Cellular Limited | 31.88% | 25.71% | 8,296,320 |
| AS38266 | HUTCHVAS-AS Vodafone Essar Ltd., Telecommunication - Value Added Services | 12.57% | 11.56% | 6,798,834 |
| AS9829 | BSNL-NIB National Internet Backbone | 0.03% | 0.02% | 6,189,645 |

Germany



| ASN | AS Name | IPv6 Capable | IPv6 Preferred | Samples |
|---------|--|--------------|----------------|-----------|
| AS3320 | DTAG Internet service provider operations | 60.89% | 59.73% | 2,056,846 |
| AS3209 | VODANET International IP-Backbone of Vodafone | 0.03% | 0.02% | 955,507 |
| AS31334 | KABELDEUTSCHLAND-AS | 68.63% | 67.59% | 825,355 |
| AS6830 | LGI-UPC formerly known as UPC Broadband Holding B.V. | 67.05% | 65.85% | 551,091 |
| AS6805 | TDDE-ASN1 | 4.96% | 4.86% | 539,929 |
| AS29562 | KABELBW-ASN | 55.85% | 54.89% | 268,299 |
| AS8422 | NETCOLOGNE | 21.60% | 20.93% | 101,555 |

United States

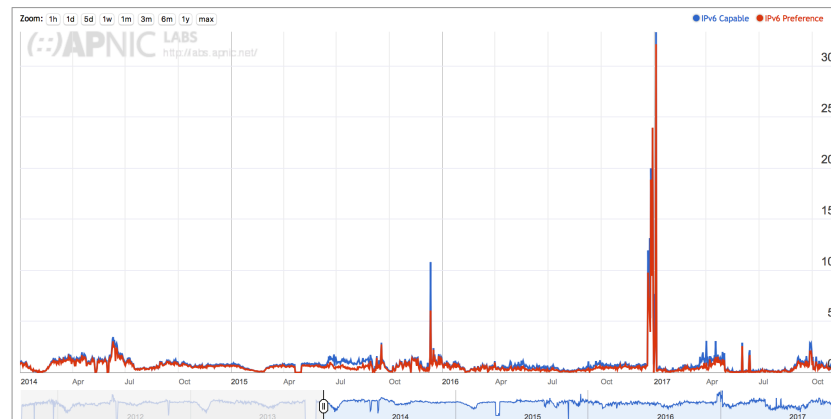


| ASN | AS Name | IPv6 Capable | IPv6 Preferred | Samples |
|---------|---|--------------|----------------|------------|
| AS7922 | COMCAST-7922 - Comcast Cable Communications, LLC | 70.69% | 68.03% | 15,778,372 |
| AS7018 | ATT-INTERNET4 - ATT Services, Inc. | 82.45% | 78.53% | 9,105,707 |
| AS20115 | CHARTER-NET-HKY-NC - Charter Communications | 11.93% | 11.27% | 5,549,054 |
| AS701 | UUNET - MCI Communications Services, Inc. dba Verizon Business | 0.26% | 0.02% | 4,533,275 |
| AS21928 | T-MOBILE-AS21928 - T-Mobile USA, Inc. | 88.85% | 87.62% | 3,954,016 |
| AS22773 | ASN-CXA-ALL-CCI-22773-RDC - Cox Communications Inc. | 49.01% | 46.80% | 3,891,026 |
| AS22394 | CELLCO - Cellco Partnership DBA Verizon Wireless | 87.83% | 84.23% | 3,860,221 |
| AS209 | CENTURYLINK-US-LEGACY-QWEST - Qwest Communications Company, LLC | 0.11% | 0.06% | 3,420,768 |
| AS20057 | ATT-MOBILITY-LLC-AS20057 - ATT Mobility LLC | 49.82% | 48.91% | 3,237,511 |
| AS10796 | SCRR-10796 - Time Warner Cable Internet LLC | 41.24% | 39.88% | 2,763,738 |
| AS20001 | ROADRUNNER-WEST - Time Warner Cable Internet LLC | 50.30% | 48.22% | 2,289,901 |

China



Use of IPv6 for China (CN)



| ASN | AS Name | IPv6 Capable | IPv6 Preferred | Samples |
|---------|--|--------------|----------------|-----------|
| AS4134 | CHINANET-BACKBONE No.31,Jin-rong Street | 0.34% | 0.25% | 5,756,637 |
| AS4837 | CHINA169-BACKBONE CHINA UNICOM China169 Backbone | 0.41% | 0.32% | 2,537,732 |
| AS9808 | CMNET-GD Guangdong Mobile Communication Co.Ltd. | 0.22% | 0.13% | 798,057 |
| AS4812 | CHINANET-SH-AP China Telecom (Group) | 0.21% | 0.13% | 648,471 |
| AS24444 | CMNET-V4SHANDONG-AS-AP Shandong Mobile Communication Company Limited | 0.09% | 0.06% | 516,368 |
| AS4808 | CHINA169-BJ China Unicom Beijing Province Network | 1.58% | 1.37% | 419,583 |
| AS56046 | CMNET-JIANGSU-AP China Mobile communications corporation | 0.21% | 0.11% | 364,250 |
| AS56041 | CMNET-ZHEJIANG-AP China Mobile communications corporation | 0.03% | 0.01% | 345,680 |
| AS56040 | CMNET-GUANGDONG-AP China Mobile communications corporation | 0.07% | 0.04% | 304,231 |
| AS4847 | CNIX-AP China Networks Inter-Exchange | 4.13% | 3.38% | 145,982 |
| AS4538 | ERX-CERNET-BKB China Education and Research Network Center | 29.21% | 23.94% | 126,205 |

Asia Ranking

| CC | Country | IPv6 Capable |
|----|--|--------------|
| IN | India, Southern Asia, Asia | 51.00% |
| JP | Japan, Eastern Asia, Asia | 25.08% |
| MY | Malaysia, South-Eastern Asia, Asia | 18.33% |
| TH | Thailand, South-Eastern Asia, Asia | 11.26% |
| MO | Macao Special Administrative Region of China, Eastern Asia, Asia | 9.27% |
| VN | Vietnam, South-Eastern Asia, Asia | 8.99% |
| KR | Republic of Korea, Eastern Asia, Asia | 8.85% |
| SA | Saudi Arabia, Western Asia, Asia | 7.25% |
| LK | Sri Lanka, Southern Asia, Asia | 6.32% |
| SG | Singapore, South-Eastern Asia, Asia | 4.68% |
| IL | Israel, Western Asia, Asia | 2.55% |
| AE | United Arab Emirates, Western Asia, Asia | 2.08% |
| CN | China, Eastern Asia, Asia | 0.72% |
| IR | Iran (Islamic Republic of), Southern Asia, Asia | 0.44% |
| TW | Taiwan, Eastern Asia, Asia | 0.38% |
| OM | Oman, Western Asia, Asia | 0.38% |
| HK | Hong Kong Special Administrative Region of China, Eastern Asia, Asia | 0.35% |
| ID | Indonesia, South-Eastern Asia, Asia | 0.21% |

Why this difference?

- Early adopters vs later adopters
 - Later adopters do not have a broad base of IPv4 installation, and have been pushed into using IPv6 as the common infrastructure with NAT64 edges (Jio in India is a good example)
 - Early adopters are not forced into IPv6 and can wait
- Carriage Economics
 - The economic returns in deploying IPv6 across an IPv4 infrastructure do not generate new revenues, nor generate operational savings or generate supply efficiencies
 - There is no “adoption pull” effect in IPv6

Why do it at all?

We don't think we can make IPv4 + NATS last forever

Deploying IPv6 is a case of timing, not choice

And the selection of timing is a case of risk determination:

Nobody wants to shift to dual stack too early – that incurs cost without revenue

But nobody wants to be the last “IPv4-only” network either!

For China

- Most ISPs in China are being cautious and waiting to see what others are doing
- But you can wait too long, and then you might have to perform a switchover at an inconvenient time
- Right now Chinese ISPs still have the luxury of choice in when to move to deploy IPv6
 - But that will not always be the case!

That's it!

<http://stats.labs.apnic.net/v6>