Measuring IPv6 Performance

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What are we looking at:

- How “reliable” are IPv6 connections?

- How “fast” are IPv6 connections?

What are we looking at:

- How “reliable” are IPv6 connections?

  Do all TCP connection attempts succeed?

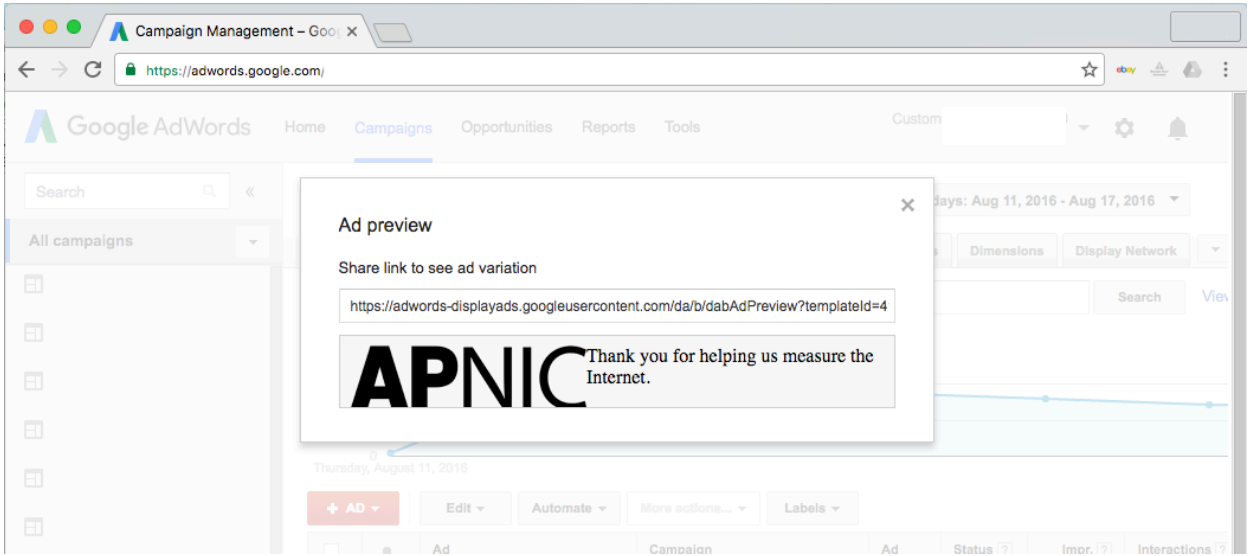
- How “fast” are IPv6 connections?

  is V6 slower than V4?

The Measurement Technique

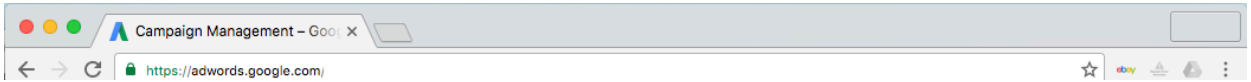
- Embed a script in an online ad
- Have the script generate a set of URLs to fetch
- Examine the packets seen at the server to determine reliability and RTT

How We Measure

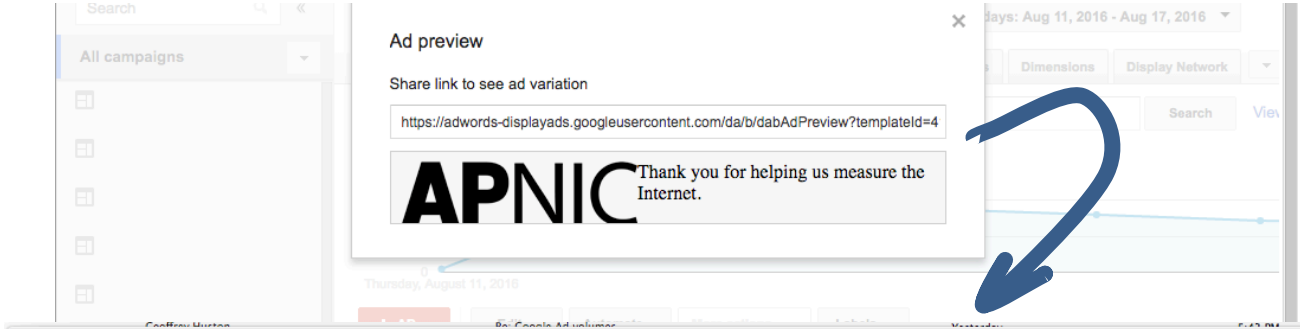


We use an online ad to present a sequence of small fetches to the user's browser

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 tcpdump to record all packet activity at the experiment's servers

```
tcp
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
01:15:56.160383 IP6 2001:388:1000:120:d267:e5ff:feef:a842.40836 > 2400:8901::f03c:91ff:fe98:63d6.80: Flags [S], seq 2414246339, win 65535, options [mss 1440,nop,wscale 6,sackOK,TS val 4065295910 ecr 0], length 0
01:15:56.373466 IP6 2400:8901::f03c:91ff:fe98:63d6.80 > 2001:388:1000:120:d267:e5ff:feef:a842.40836: Flags [S.], seq 2653147012, ack 2414246340, win 28560, options [mss 1440,sackOK,TS val 763257679 ecr 4065295918,nop,wscale 7], length 0
01:15:56.373486 IP6 2001:388:1000:120:d267:e5ff:feef:a842.40836 > 2400:8901::f03c:91ff:fe98:63d6.80: Flags [.], ack 1, win 1026, options [nop,nop,TS val 4065296132 ecr 763257679], length 0
01:15:56.373502 IP6 2001:388:1000:120:d267:e5ff:feef:a842.40836 > 2400:8901::f03c:91ff:fe98:63d6.80: Flags [P.], seq 1:222, ack 1, win 1026, options [nop,nop,TS val 4065296132 ecr 763257679], length 221
01:15:56.586494 IP6 2400:8901::f03c:91ff:fe98:63d6.80 > 2001:388:1000:120:d267:e5ff:feef:a842.40836: Flags [.], ack 222, win 232, options [nop,nop,TS val 763257743 ecr 4065296132], length 0
01:15:56.586644 IP6 2400:8901::f03c:91ff:fe98:63d6.80 > 2001:388:1000:120:d267:e5ff:feef:a842.40836: Flags [P.], seq 1:293, ack 222, win 232, options [nop,nop,TS val 763257743 ecr 4065296132], length 292
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01:15:56.805035 IP6 2001:388:1000:120:d267:e5ff:feef:a842.40836 > 2400:8901::f03c:91ff:fe98:63d6.80: Flags [.], ack 294, win 1026, options [nop,nop,TS val 4065296563 ecr 763257809], length 0
01:16:08.160813 IP 202.158.221.222.62158 > 139.162.2.194.80: Flags [S], seq 2110718059, win 65535, options [mss 1460,nop,wscale 6,sackOK,TS val 4065307919 ecr 0], length 0
01:16:08.484006 IP 139.162.2.194.80 > 202.158.221.222.62158: Flags [S.], seq 3450703102, ack 2110718060, win 28960, options [mss 1460,sackOK,TS val 763261314 ecr 4065307919,nop,wscale 7], length 0
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01:16:09.130801 IP 202.158.221.222.62158 > 139.162.2.194.80: Flags [.], ack 294, win 1040, options [nop,nop,TS val 4065308809 ecr 763261508], length 0
01:16:20.244088 IP6 2001:388:1000:120:d267:e5ff:feef:a842.31238 > 2400:8901::f03c:91ff:fe98:63d6.80: Flags [S], seq 1299030901, win 65535, options [mss 1440,nop,wscale 6,sackOK,TS val 4065320002 ecr 0], length 0
01:16:20.457379 IP6 2400:8901::f03c:91ff:fe98:63d6.80 > 2001:388:1000:120:d267:e5ff:feef:a842.31238: Flags [S.], seq 1740854555, ack 1299030902, win 28560, options [mss 1440,sackOK,TS val 763264905 ecr 4065320002,nop,wscale 7], length 0
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01:16:36.453841 IP6 2001:388:1000:120:d267:e5ff:feef:a842.64866 > 2400:8901::f03c:91ff:fe98:63d6.80: Flags [F.], seq 232, ack 293, win 1026, options [nop,nop,TS val 4065336212 ecr 763269703], length 0
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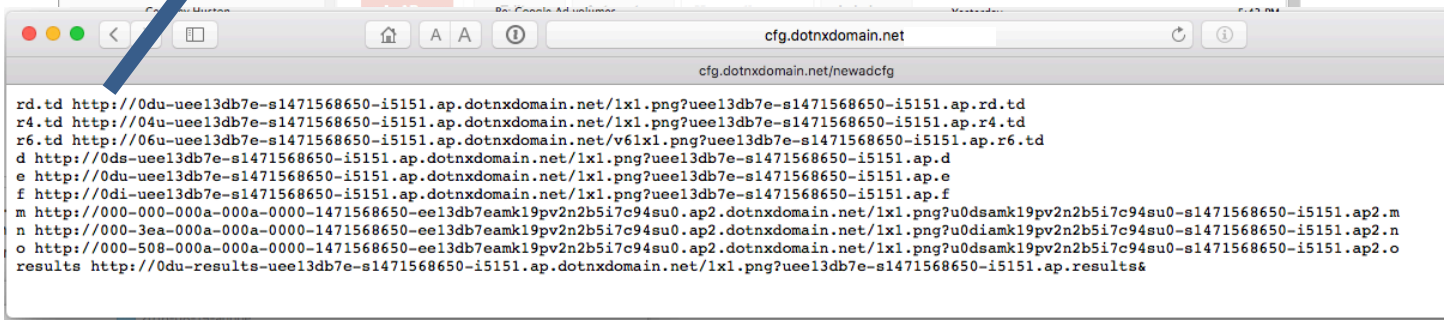
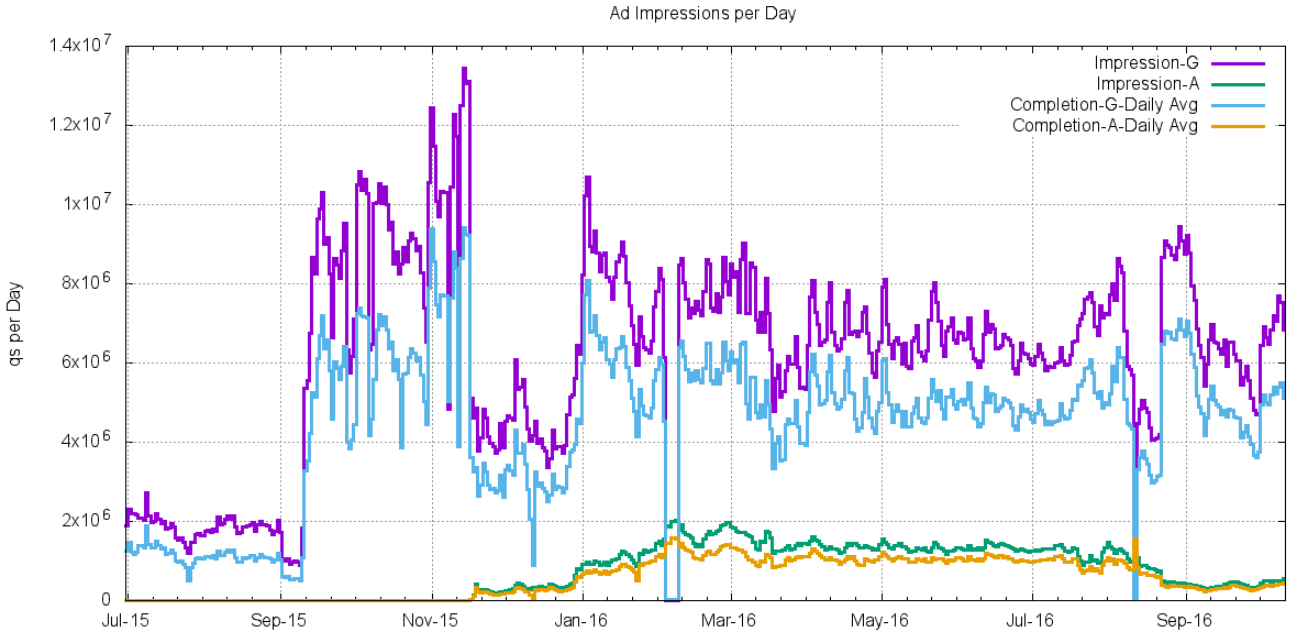


How Much do We Measure?



What are we looking at:

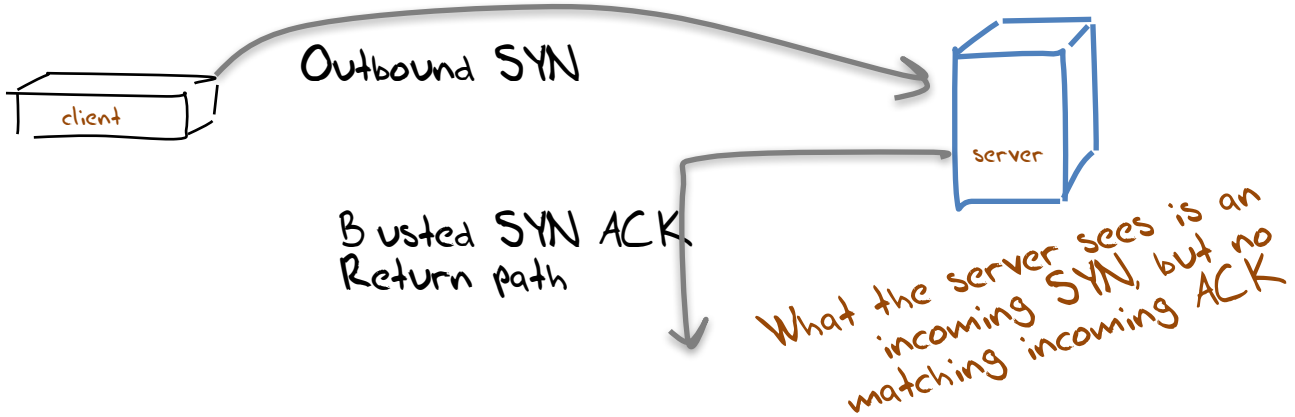
- How “reliable” are IPv6 connections?

Do all TCP connection attempts succeed?

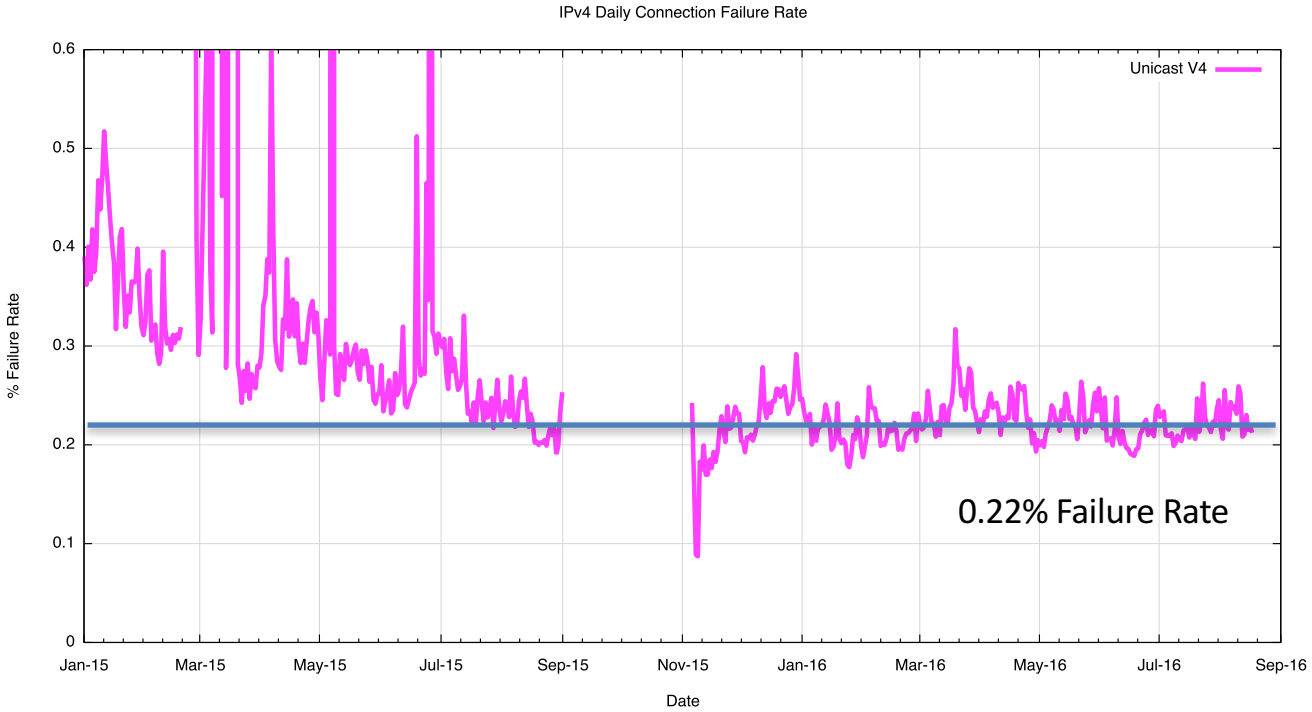
- How “fast” are IPv6 connections?

Is V6 slower than V4?

What we see: Connection Failure



IPv4 Connection Failure

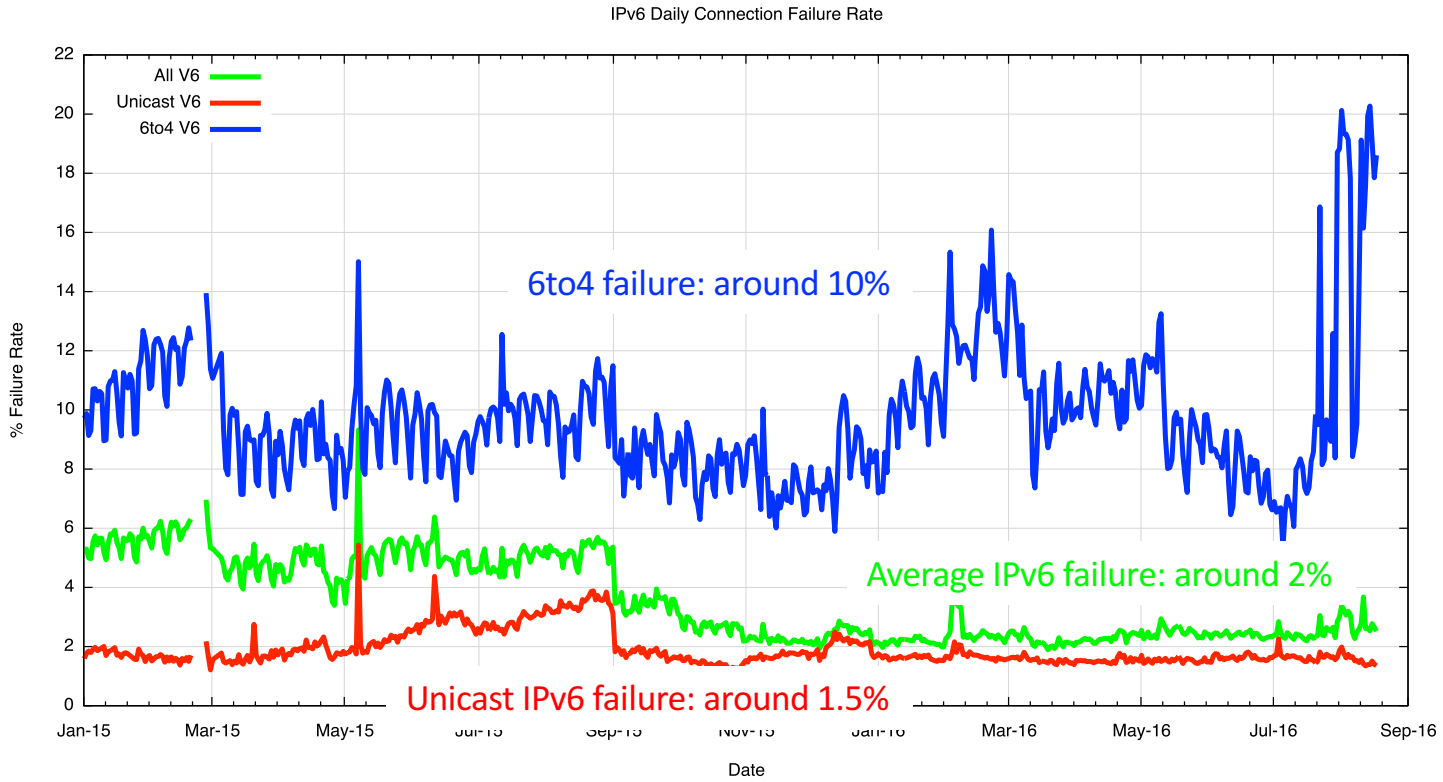


IPv4 Failures

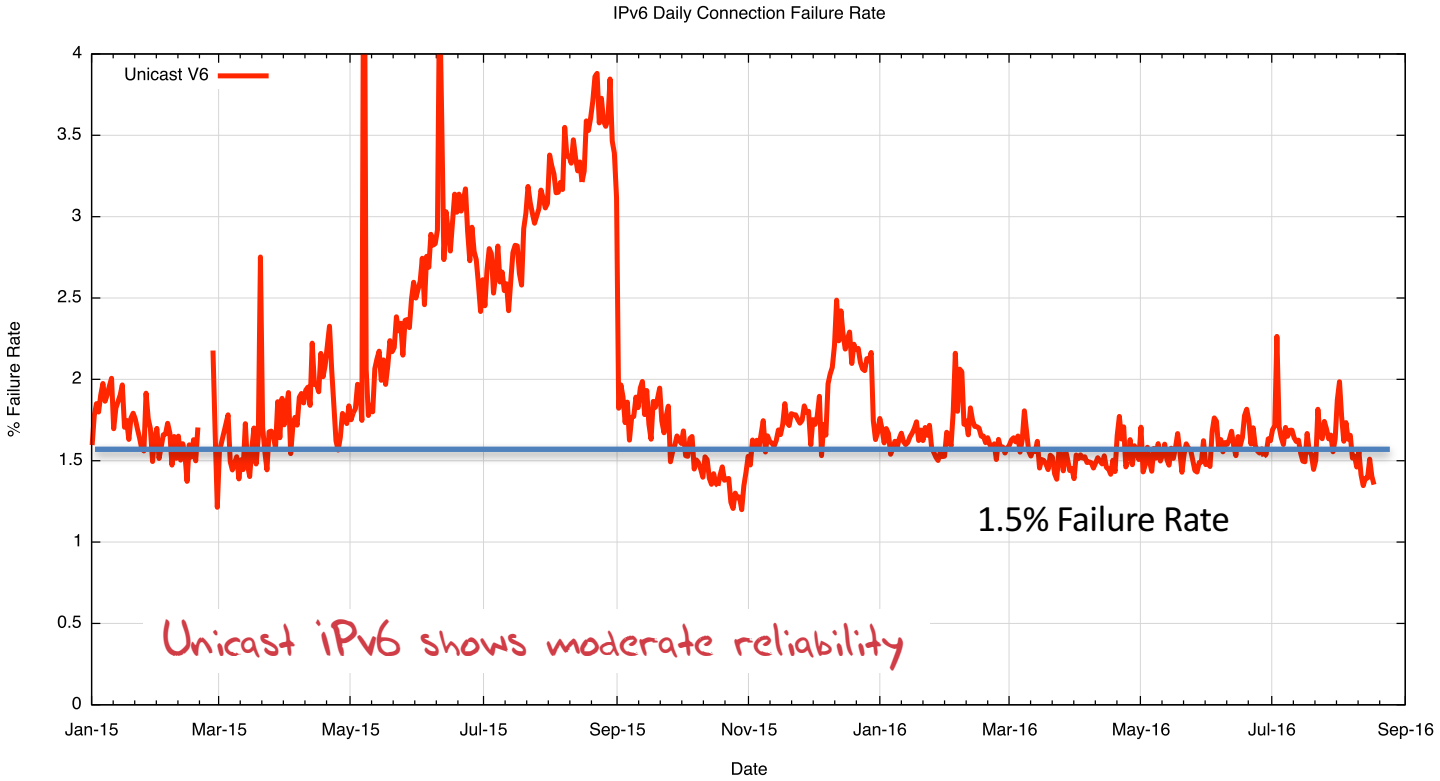
- IPv4 failures are around 1 in 500
- And we are pretty sure its NOT:
  - Auto-tunnelling
  - Lousy CPE firmware
  - Strange firewall filters

- So what is the reason for this residual asymmetric failure rate?
- Is it asymmetric routing connectivity?

Daily IPv6 Failures



Daily IPv6 Failures



IPv6 Failures

- 1.5% failure for unicast V6 is still unacceptable!
- Why is this happening?
  - Auto-tunnelling?
  - Lousy CPE firmware?
  - Strange firewall filters?
  - Asymmetric routing

Is IPv6 failure uniformly distributed?

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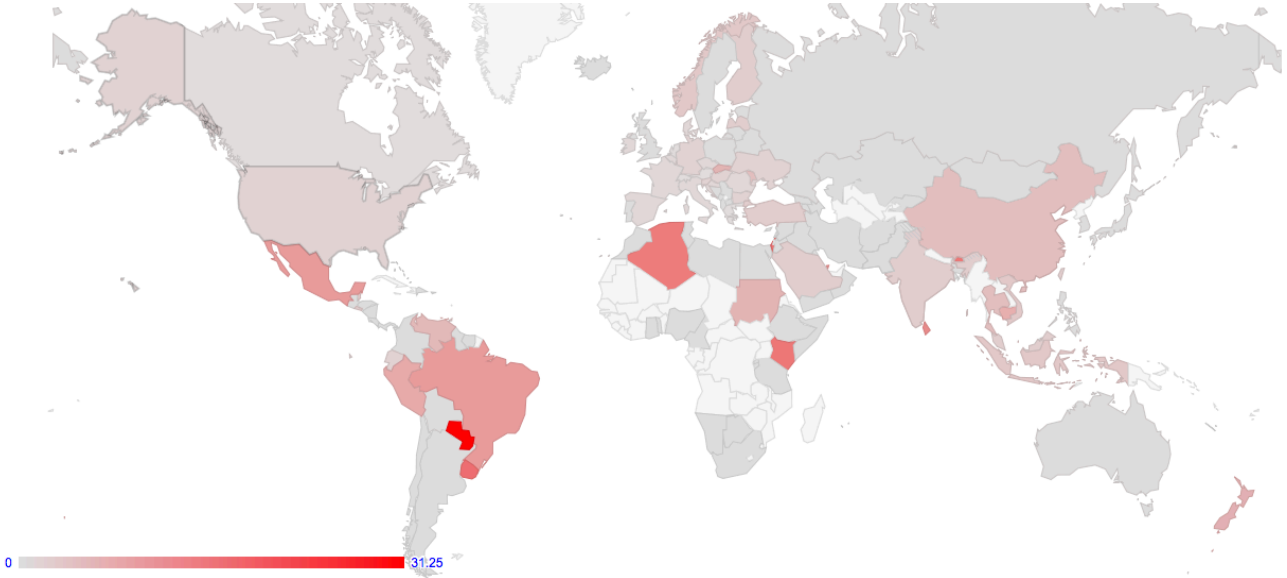

V6 Failure by Country

Code	Region	V6 Failure Rate	V6 Samples
LK	Sri Lanka, Southern Asia, Asia	45.26%	23,781
IL	Israel, Western Asia, Asia	19.04%	541
MX	Mexico, Central America, Americas	18.55%	469
BR	Brazil, South America, Americas	9.15%	72,847
UA	Ukraine, Eastern Europe, Europe	6.15%	1,301
PE	Peru, South America, Americas	5.95%	89,240
PH	Philippines, South-Eastern Asia, Asia	5.68%	669
CN	China, Eastern Asia, Asia	4.97%	21,433
NZ	New Zealand, Australia and New Zealand, Oceania	4.92%	1,544
MD	Republic of Moldova, Eastern Europe, Europe	4.64%	237
SA	Saudi Arabia, Western Asia, Asia	4.28%	14,291
DE	Germany, Western Europe, Europe	3.97%	85,635
EC	Ecuador, South America, Americas	3.80%	81,487
ZW	Zimbabwe, Eastern Africa, Africa	3.76%	319
VN	Vietnam, South-Eastern Asia, Asia	3.64%	32,791
NO	Norway, Northern Europe, Europe	3.57%	8,650
IE	Ireland, Northern Europe, Europe	3.31%	7,740
SI	Slovenia, Southern Europe, Europe	3.13%	3,641
FR	France, Western Europe, Europe	3.10%	63,077
FI	Finland, Northern Europe, Europe	3.03%	5,045
CZ	Czech Republic, Eastern Europe, Europe	3.00%	5,732
LU	Luxembourg, Western Europe, Europe	2.91%	3,683
HU	Hungary, Eastern Europe, Europe	2.86%	4,443
ID	Indonesia, South-Eastern Asia, Asia	2.62%	877
TT	Trinidad and Tobago, Caribbean, Americas	2.60%	3,839

V6 Failure by Network

ASN	AS Name	V6 Fail Rate	V6 Samples
AS20880	TELECOLUMBUS Tele Columbus AG, DE	69.05%	252
AS18001	DIALOG-AS Dialog Axiata PLC., LK	45.79%	23,743
AS42689	CABLECOM-AS Cablecom Networking Limited, GB, NL	22.16%	528
AS14868	COPEL Telecom S.A., BR	21.51%	1,813
AS8151	Uninet S.A. de C.V., MX	20.28%	281
AS47956	XFONE XFone 018 Ltd, IL	18.96%	559
AS18881	Global Village Telecom, BR	18.93%	25,485
AS26615	Tim Celular S.A., BR	16.42%	2,460
AS34779	T-2-AS T-2, d.o.o., SI	13.07%	459
AS13188	BANKINFORM-AS CONTENT DELIVERY NETWORK LTD, UA	9.76%	502
AS55430	STARHUBINTERNET-AS-NGNBN Starhub Internet Pte Ltd, SG	9.59%	772
AS6584	MICROSOFT-GP-AS - Microsoft Corporation, GB	9.35%	278
AS42652	DELUNET inexio Informationstechnologie und TelekommunikationKGaA, DE	8.16%	282
AS6805	TDDE-ASN1 Telefonica Germany GmbH Co.OHG, DE	7.77%	206
AS28753	LEASEWEB-DE Leaseweb Deutschland GmbH, DE	7.49%	227
AS197922	FIRSTHEBERG Techcrea Solutions Sarl, FR	7.33%	1,528
AS8167	Brasil Telecom SA - Filial Distrito Federal, BR	7.04%	1,591
AS23655	SNAP-NZ-AS Snap Internet Limited, NZ	6.80%	897
AS1659	ERX-TANET-ASN1 Taiwan Academic Network (TANet) Information Center, TW	6.42%	483
AS6147	Telefonica del Peru S.A.A., PE	5.96%	93,630
AS35804	ALNET-AS PP SKS-Lugan, UA	5.67%	476
AS4134	CHINANET-BACKBONE No.31,Jin-rong Street, CN	5.59%	7,659
AS38229	LEARN-LK Lanka Education Research Network, NREN, LK	5.54%	289
AS41164	GET-NO Get AS, NO	5.36%	728
AS19165	WEBPASS - Webpass Inc., US	5.28%	265
AS2852	CESNET2 CESNET z.s.p.o., CZ	5.14%	214
AS23910	CNGI-CERNET2-AS-AP China Next Generation Internet CERNET2, CN	4.96%	5,509
AS1547	IDK-NETWORK JSCC Interdnestrcom, MD	4.55%	242
AS5466	EIRCOM Eircom Limited, IE	4.41%	748

A cautionary note

- These are “single shot” measurements rather than sustained repeated test, so there is some noise component here
- Its also likely that connection failure is related to consumer equipment rather than network-level failure, as a network level failure would conventionally give a failure rate closer to 100%

What are we looking at:

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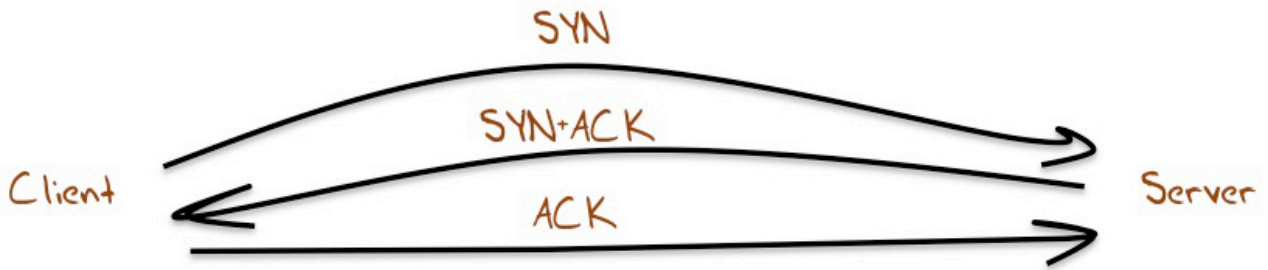
Do all TCP connection attempts succeed?

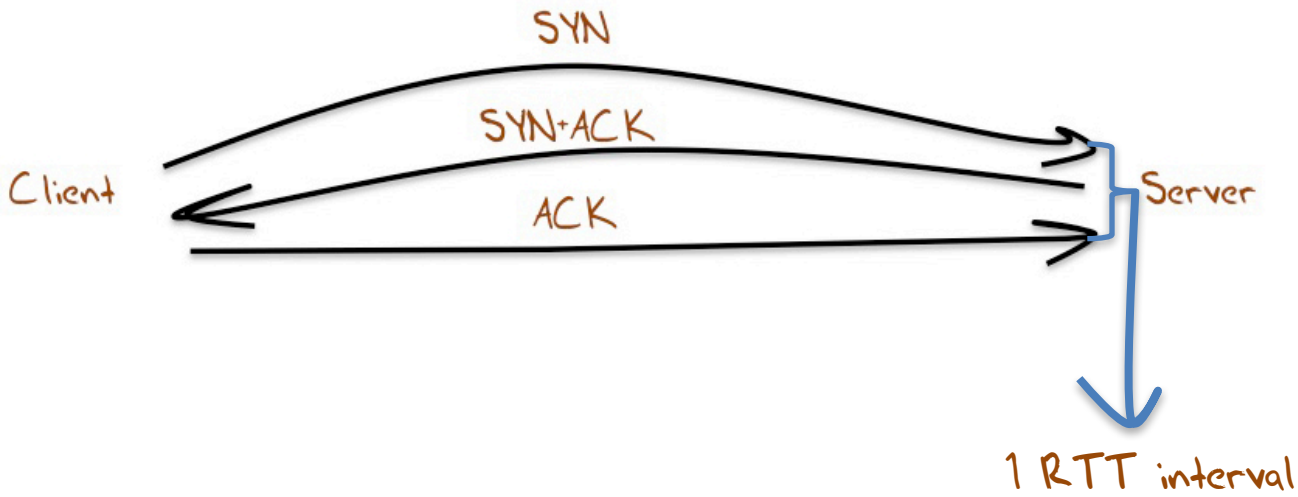
- How "fast" are IPv6 connections?

is V6 slower than V4?

Let's look at TCP SYNs



Let's look at TCP SYNs



Why SYNs?

- Every TCP session starts with a SYN handshake
- Its typically a kernel level operation, which means that there is little in the way of application level interaction with the SYN exchange
- On the downside there is only a single sample point per measurement

Generating a comparative RTT profile

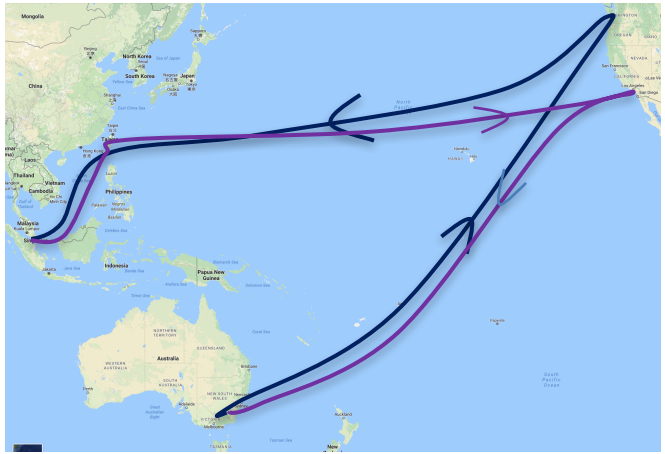
- For each successful connection couplet (IPv4 and IPv4) from the same endpoint, gather the pair of RTT measurements from the SYN-ACK exchanges
  - Use the server's web logs to associate a couplet of IPv4 and IPv6 addresses
  - Use the packet dumps to collect RTT information from the SYN-ACK Exchange
  - Use IPv6 RTT – IPv4 RTT as the metric

An Example of Path Divergence

$ traceroute from Singapore to Canberra, IPv4
traceroute to 202.158.xxxx.yyy, 30 hops max, 60 byte packets
1 103.3.60.3 0.672ms 0.796ms 0.899ms
2 139.162.0.9 0.754ms 0.708ms 0.732ms
3 te0-1-0-21.br03.sin02.pccwbtn.net 1.697ms 0.760ms 0.726ms
4 ntt.fe3-18.br01.sin02.pccwbtn.net 69.526ms 69.644ms 69.754ms
5 ae-10.r20.sngpsi05.sg.bb.gin.ntt.net 60.702ms 68.474ms 68.469ms
6 ae-8.r22.snjsca04.us.bb.gin.ntt.net 168.447ms 168.532ms 168.138ms
7 ae-19.r01.snjsca04.us.bb.gin.ntt.net 167.489ms 170.665ms 178.832ms
8 xe-0-8-0-21.r01.snjsca04.us.ce.gin.ntt.net 330.084ms 323.556ms 329.772ms
9 xe-1-0-1.pe1.msct.nsw.aarnet.net.au 330.020ms 323.738ms 334.474ms
10 et-3-3-0.pe1.rsby.nsw.aarnet.net.au 327.788ms 334.157ms 328.139ms
11 138.44.161.6 323.644ms 319.455ms 323.563ms
12 202.158.xxx.yyy 319.885ms 333.933ms 325.014ms

$ traceroute from Canberra to Singapore, IPv4
traceroute to 139.162.xxx.yyy, 64 hops max, 52 byte packets
1 202.158.x.y 0.682ms 0.388ms 0.313ms
2 xe-5-0-4-205.pe1.actn.act.aarnet.net.a 0.721ms 0.828ms 0.674ms
3 et-0-3-0.pe1.rsby.nsw.aarnet.net.au 4.548ms 4.733ms 4.533ms
4 et-7-1-0.pe1.brwy.nsw.aarnet.net.au 4.734ms 5.418ms 4.745ms
5 et-0-3-0.pe1.bkvl.nsw.aarnet.net.au 5.117ms 5.512ms 5.524ms
6 xe-0-0-0.bb1.b.sea.aarnet.net.au 148.017ms 148.019ms 148.131ms
7 ge3-0.cr02.sea01.pccwbtn.net (206.81.80.13) 148.469ms 148.059ms 148.429ms
8 tenge0-2-0-14.br03.sin02.pccwbtn.net 319.435ms 325.053ms 319.117ms
9 tenge0-2-0-15.br03.sin02.pccwbtn.net 319.257ms 332.560ms 323.415ms
10 linode.te0-1-0-21.br03.sin02.pccwbtn.net 323.723ms 323.627ms 323.587ms
11 139.162.aaa.bbb 334.609ms 347.243ms 347.220ms
12 139.162.xxx.yyy 325.186ms 338.209ms 325.603ms

iPv4



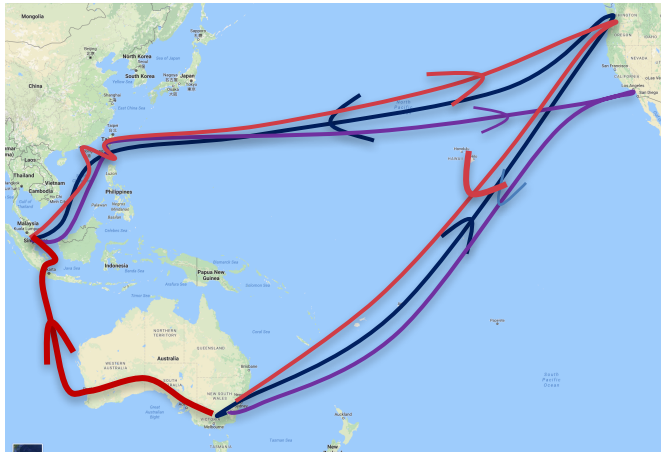
We are seeing path symmetry, bouncing off the US West Coast

An Example of Path Divergence

```
$ traceroute from Singapore to Canberra, IPv6
traceroute6 to 2001:388:1000:110:e4d:e9ff:x:y, 30 hops max, 80 byte packets
 1  2400:8901::5287:89ff:fe40:9fc1 0.897ms 0.912ms 1.051ms
 2  2400:8901:1111::1 0.851ms 0.827ms 0.792ms
 3  2001:cb0:2102:2:f::1 0.364ms  0.333ms  0.516ms
 4  2001:cb0:2102:2:f::1 0.502ms  0.461ms  0.431ms
 5  2001:cb0:21f0:1:17::2 2.512ms 2.176ms 3.445ms
 6  2001:cb0:21f0:1:17::2 2.354ms  2.382ms 1.238ms
 7  10gigabitethernet3-5.core1.sin1.he.net 1.080ms  1.034ms  1.020ms
 8  10ge1-5.core1.tyo1.he.net 88.053ms
    10ge1-16.core1.hkg1.he.net 39.369ms
    10ge1-5.core1.tyo1.he.net 88.084ms
 9  10ge1-5.core1.tyo1.he.net 88.157ms
    100ge8-1.core1.sea1.he.net 192.408ms  192.642ms
10  100ge8-1.core1.sea1.he.net 192.631ms  192.608ms  196.154ms
11  xe-1-0-1.pe2.brwy.nsw.aarnet.net.au 214.176ms 186.238ms 213.061ms
12  et-3-1-0.pe1.brwy.nsw.aarnet.net.au 211.298ms 211.300ms 214.200ms
13  et-1-1-0.pe1.rsby.nsw.aarnet.net.au 211.492ms 211.359ms 211.427ms
14  et-0-3-0.pe1.actn.act.aarnet.net.au 213.332ms 211.458ms  211.476ms
15  2001:388:1000:110:e4d:e9ff:x.y 213.274ms 213.199ms 213.169ms

$ traceroute from Canberra to Singapore, IPv6
traceroute6 to 2400:8901::f03c:91ff:a:b) 64 hops max, 12 byte packets
 1  2001:388:1000:110::x:y  0.808ms  0.899ms  1.586ms
 2  xe-5-0-4-205.pe1.actn.act.aarnet.net.au  1.633ms  0.646ms  0.578ms
 3  et-0-1-0.pe1.dksn.act.aarnet.net.au  0.682ms  0.649ms  0.694ms
 4  et-5-3-0.pe1.crlt.vic.aarnet.net.au  8.072ms  8.086ms  8.049ms
 5  et-5-1-0.pe1.wmlb.vic.aarnet.net.au  8.116ms  8.055ms  8.073ms
 6  et-0-3-0.pe1.adel.sa.aarnet.net.au  17.790ms  16.984ms  17.036ms
 7  et-1-1-0.pe1.prka.sa.aarnet.net.au  17.080ms  17.152ms
    et-0-3-0.pe1.eper.wa.aarnet.net.au  43.319ms
 8  et-0-3-0.pe1.knsg.wa.aarnet.net.au  43.357ms  43.443ms  43.353ms
 9  gigabitethernet-5-1-0.bb1.b.per.aarnet.net.au  43.849ms  43.919ms  43.850ms
10  so-0-0-0.bb1.a.sin.aarnet.net.au  92.219ms  92.275ms  92.189ms
11  as6939.singapore.megaport.com  212.347ms  212.426ms  212.471ms
12  * * *
13  2400:8901:1110::2  213.924ms 213.904ms  213.717ms
14  2400:8901::f03c:91ff:a:b  213.954ms  213.393ms  213.726ms
```

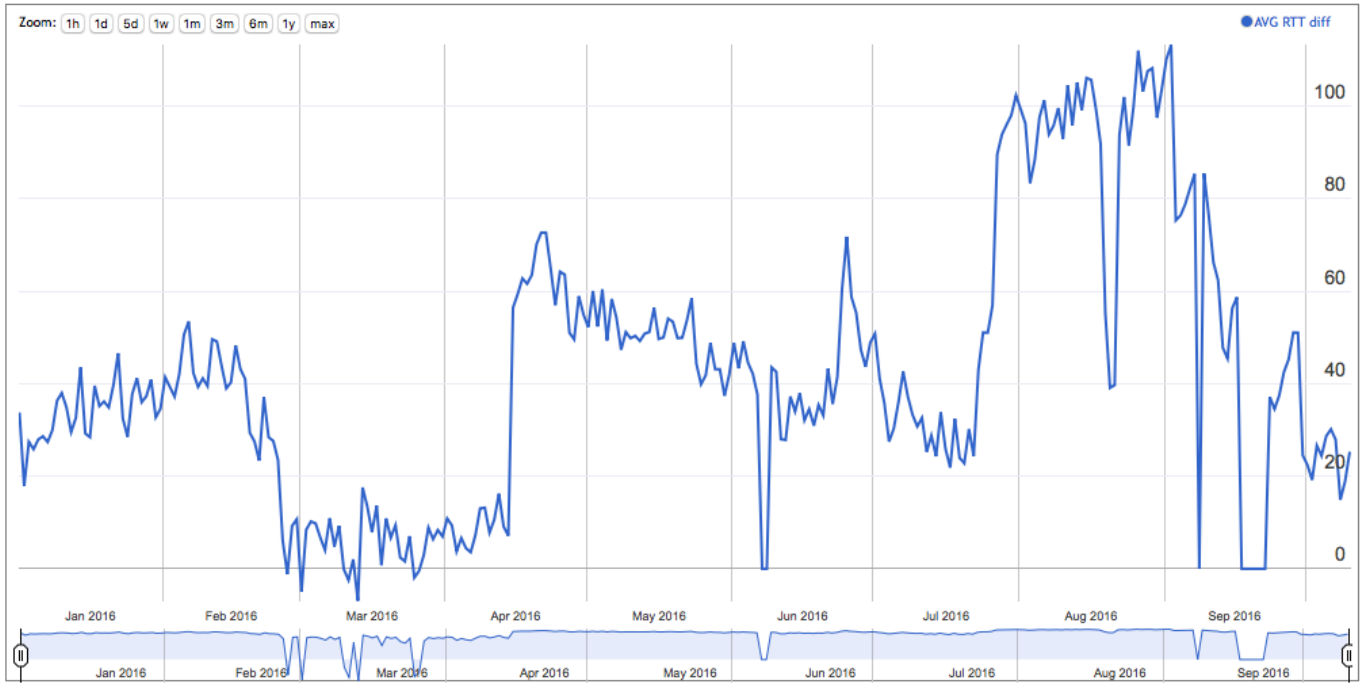
iPv4 - iPv6



in iPv6 we are seeing path asymmetry, with outbound packets
Crossing an Indian Ocean cable, and return packets bouncing off the US West Coast - the iPv6 RTT is 112 ms smaller

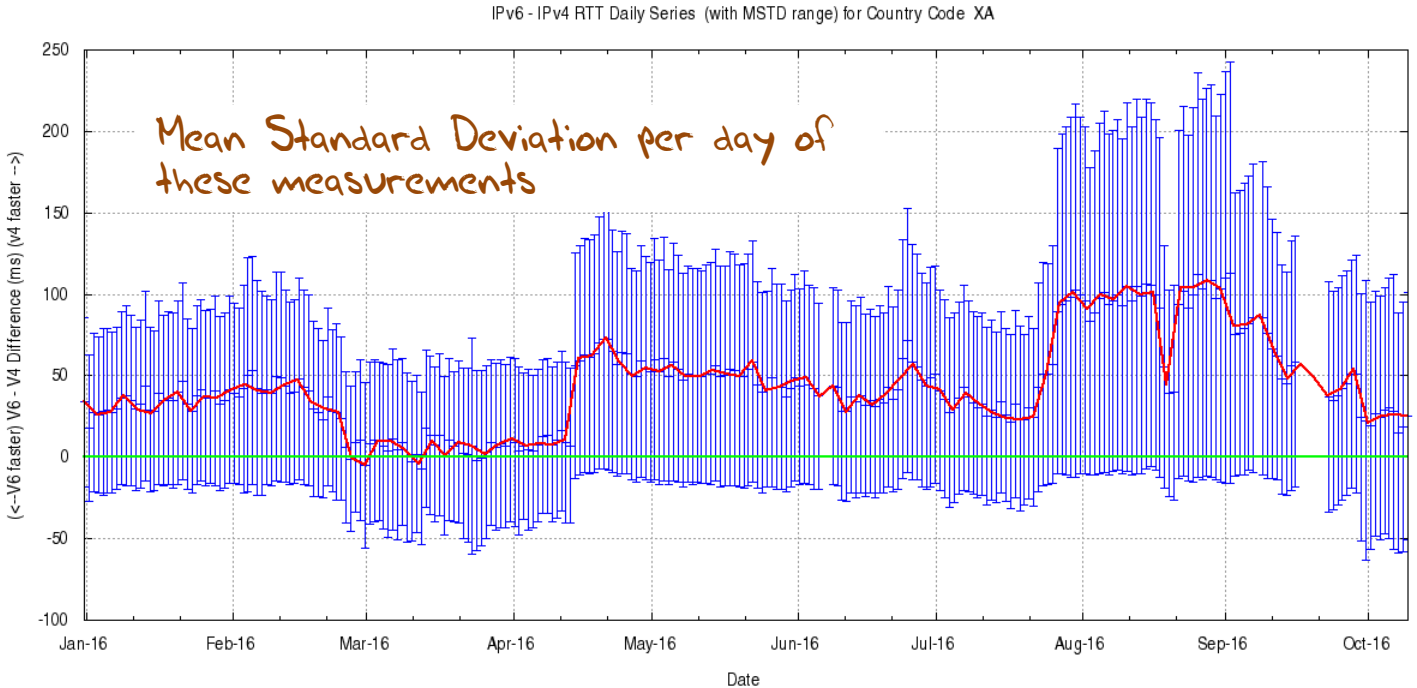
Global Results

Average RTT Difference (ms) (V6 - V4) for World (XA)

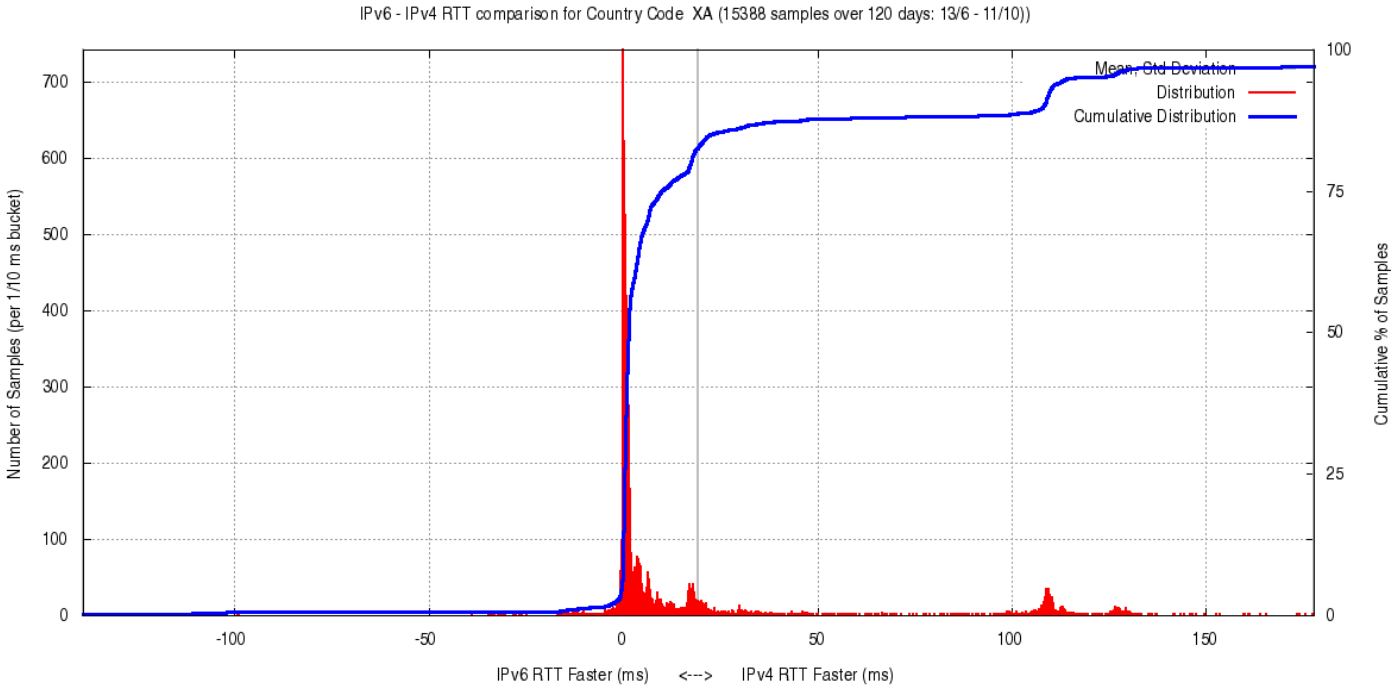


On average iPv6 is showing 20ms - 40ms slower that iPv4

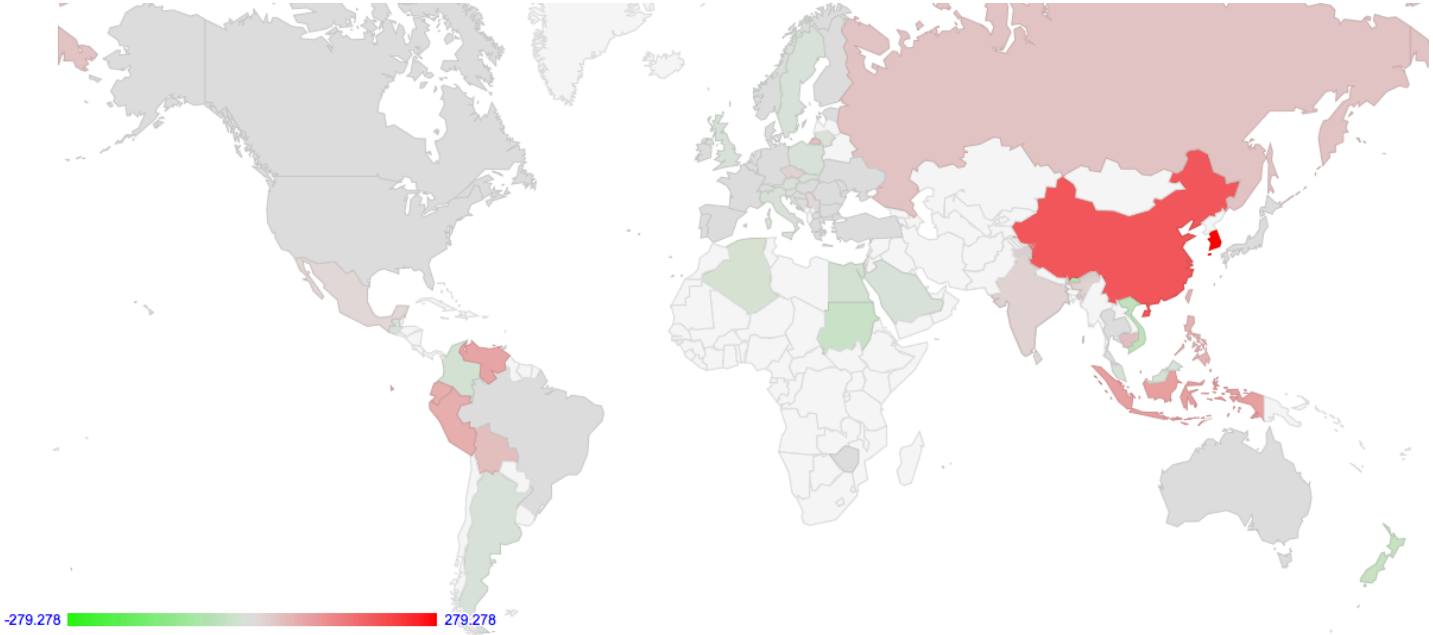
Global Results



RTT Diff Distribution

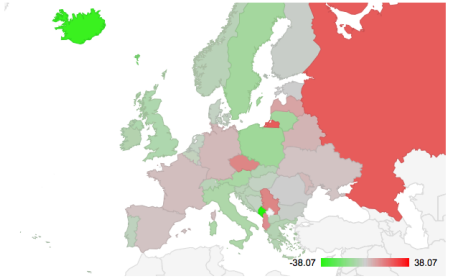


RTT Diff by Country



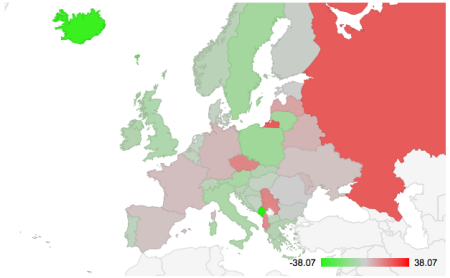
RTT Diff by Network

ASN	AS Name	RTT Diff (V6-V4) ▼	Samples
AS54994	QUANTIL - QUANTIL, INC, US	339.80 ms	183
AS9808	CMNET-GD Guangdong Mobile Communication Co.Ltd., CN	316.94 ms	366
AS7497	CSTNET-AS-AP Computer Network Information Center, CN	286.12 ms	568
AS4812	CHINANET-SH-AP China Telecom (Group), CN	214.82 ms	195
AS4538	ERX-CERNET-BKB China Education and Research Network Center, CN	205.10 ms	4,045
AS9644	SKTELECOM-NET-AS SK Telecom, KR	200.20 ms	2,576
AS21837	OPERASOFTWARE - Opera Software Americas LLC, AP	186.27 ms	233
AS23910	CNGI-CERNET2-AS-AP China Next Generation Internet CERNET2, CN	184.78 ms	18
AS36384	GOOGLE-IT - Google Incorporated, CH, US, IN, GB, SG	160.50 ms	1,303
AS4847	CNIX-AP China Networks Inter-Exchange, CN	158.25 ms	261
AS9930	TTNET-MY TIME dotCom Berhad, MY	157.58 ms	274
AS13301	UNITEDCOLO-AS United Gameserver GmbH, DE	156.51 ms	2,698
AS4134	CHINANET-BACKBONE No.31,Jin-rong Street, CN	151.85 ms	7,654
AS49505	SELECTEL OOO Network of data-centers Selectel, RU	150.74 ms	1,311
AS24961	MYLOC-AS myLoc managed IT AG, DE	149.34 ms	1,658
AS38466	UMOBILE-AS-AP U Mobile Sdn Bhd, MY	138.71 ms	1,018
AS4766	KIXS-AS-KR Korea Telecom, KR	130.99 ms	239
AS133165	DIGITALOCEAN-AS-AP Digital Ocean, Inc., SG	118.28 ms	85
AS1659	ERX-TANET-ASN1 Taiwan Academic Network (TANet) Information Center, TW	116.10 ms	368
AS17638	CHINATELECOM-TJ-AS-AP ASN for TIANJIN Provincial Net of CT, CN	108.30 ms	104
AS10030	CELCOMNET-AP Celcom Internet Service Provider, MY	106.12 ms	591
AS3462	HINET Data Communication Business Group, TW, CN	97.65 ms	420
AS4837	CHINA169-BACKBONE CNCGROUP China169 Backbone, CN	97.33 ms	2,218
AS9051	IncoNet Data Management sal, LB	91.41 ms	11
AS109	CISCOSYSTEMS - Cisco Systems, Inc., GB, IN, SG, US, AU, CN, EU, JP, NL	89.10 ms	2,205
AS9500	VODAFONE-TRANSIT-AS Vodafone NZ Ltd., NZ	87.76 ms	183
AS4713	OCN NTT Communications Corporation, JP	75.86 ms	1,898



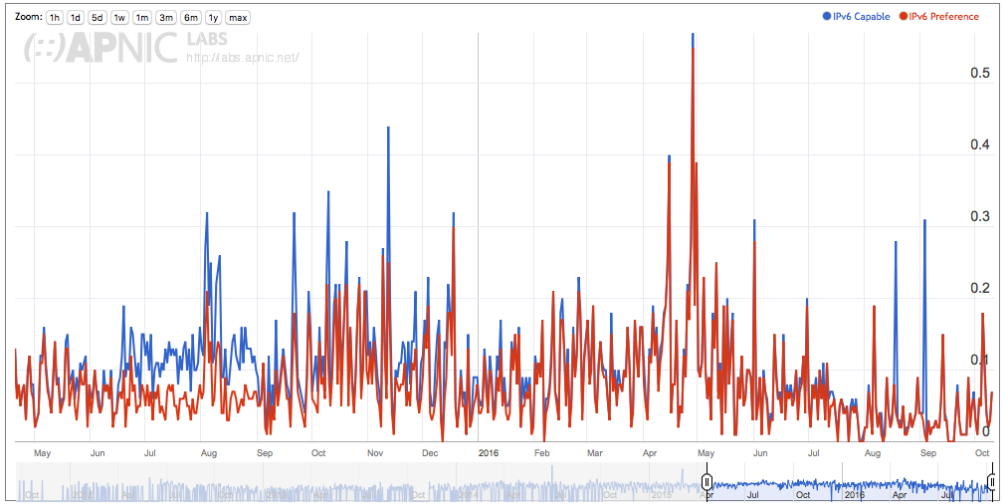
European Region V4 faster nets

ASN	AS Name	RTT Diff (V6-V4)	Samples
AS13301	UNITEDCOLO-AS United Gameserver GmbH, DE	156.51 ms	2,698
AS49505	SELECTEL OOO Network of data-centers Selectel, RU	150.74 ms	1,311
AS24961	MYLOC-AS myLoc managed IT AG, DE	149.34 ms	1,658
AS109	CISCOSYSTEMS - Cisco Systems, Inc., GB, EU, NL	59.83 ms	352
AS6584	MICROSOFT-GP-AS - Microsoft Corporation, GB	41.97 ms	221
AS5610	O2-CZECH-REPUBLIC O2 Czech Republic, a.s., CZ	15.81 ms	3,850
AS15169	GOOGLE - Google Inc., EU, CZ, IE, GB	15.66 ms	2,322
AS3301	TELIANET-SWEDEN TeliaSonera AB, SE	11.78 ms	255
AS1547	IDK-NETWORK JSCC Interdnestrcom, MD	5.64 ms	202
AS21321	ARETI-AS Areti Internet Ltd., DE, DK, FR, SE, RU, CZ, UA, ES	4.90 ms	151
AS13213	UK2NET-AS UK2 - Ltd, GB	4.83 ms	109
AS51604	EKAT-AS JSC ER-Telecom Holding, RU	4.80 ms	233
AS9009	M247 M247 Ltd, BE, GB, HU, RO, FR, DE, IT, NL	4.46 ms	357
AS12322	PROXAD Free SAS, FR	4.45 ms	20,657
AS29695	ALTIBOXAS Altibox AS, NO, DK	3.43 ms	255
AS6661	EPT-LU Entreprise des Postes et Telecommunications, LU	3.16 ms	2,391
AS719	ELISA-AS Elisa Oyj, FI	3.10 ms	309
AS57378	ROSTOV-AS JSC ER-Telecom Holding, RU	3.05 ms	124



European Region V6 faster nets

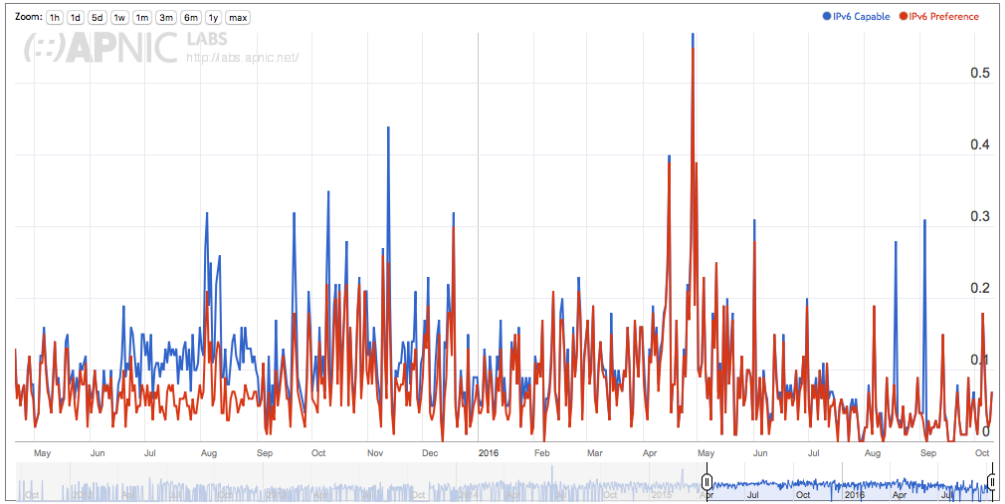
ASN	AS Name	RTT Diff (V6-V4) ▲	Samples
AS16202	PRIMACOM-AS PrimaCom Berlin GmbH, DE	-18.18 ms	398
AS5617	TPNET Orange Polska Spolka Akcyjna, PL	-12.45 ms	3,504
AS1257	TELE2, SE, EE	-12.03 ms	5,110
AS35244	KMS-DEAS AS for KMS Munich, DE	-11.84 ms	291
AS31034	ARUBA-ASN Aruba S.p.A., IT	-11.66 ms	112
AS5483	HTC-AS Magyar Telekom Plc., HU	-11.19 ms	83
AS41668	ERTH-KAZAN-AS JSC ER-Telecom Holding, RU	-10.83 ms	191
AS8767	MNET-AS M-net Telekommunikations GmbH, Germany, DE	-10.03 ms	1,148
AS9008	AS9008 Visual Online S.A., LU	-9.91 ms	131
AS13045	HTP-AS htp GmbH, DE	-8.98 ms	84
AS3223	VOXILITY Voxility S.R.L., RO	-8.14 ms	29
AS8359	MTS MTS PJSC, RU	-8.06 ms	300
AS5607	BSKYB-BROADBAND-AS Sky UK Limited, GB	-7.91 ms	48,716
AS12874	FASTWEB Fastweb SpA, IT	-7.85 ms	4,623
AS42652	DELUNET inexio Informationstechnologie und TelekommunikationKGaA, DE	-7.76 ms	229
AS8512	NIIFI (Nemzeti Informacios Infrastruktura Fejlesztesi Iroda), HU	-7.72 ms	120
AS6799	OTENET-GR Ote SA (Hellenic Telecommunications Organisation), GR	-7.66 ms	49,733
AS3320	DTAG Deutsche Telekom AG, DE	-7.17 ms	36,607
AS52207	TULA-AS JSC ER-Telecom Holding, RU	-6.65 ms	98



IPv6 in Spain:

Largest ISPs

ASN	AS Name	IPv6 Capable	IPv6 Preferred	Samples
AS3352	TELEFONICADEESPANA TELEFONICA DE ESPANA	0.00%	0.00%	1,387,835
AS12479	UNI2-AS France Telecom Espana SA	0.00%	0.00%	460,041
AS6739	ONO-AS VODAFONE ONO, S.A.	0.00%	0.00%	334,641
AS12715	JAZZNET Jazz Telecom S.A.	0.13%	0.12%	316,343
AS12430	VODAFONEES VODAFONE ESPANA S.A.U.	0.00%	0.00%	312,228
AS12338	EUSKALTEL Euskaltel S.A.	0.00%	0.00%	43,462
AS12334	R Cable y Telecomunicaciones Galicia, S.A.	0.01%	0.00%	42,221
AS29119	SERVIHOSTING-AS ServiHosting Networks S.L.	0.00%	0.00%	40,963
AS15704	AS15704 XTRA TELECOM S.A.	0.00%	0.00%	38,285
AS16299	XFERA Xfera Moviles SA	0.00%	0.00%	38,178
AS12357	COMUNITEL VODAFONE ESPANA S.A.U.	0.01%	0.01%	37,877
AS12946	TELECABLE Telecable de Asturias,SA	0.00%	0.00%	26,798
AS35699	ADAMOEU-AS Adamo Telecom Iberia S.A	0.00%	0.00%	20,585
AS50129	TVHORADADA Concisa, Comunicacion, Marketing y Servicios S.L.	0.01%	0.01%	15,668
AS34977	PROCONO-AS PROCONO S.A.	0.95%	0.92%	10,811

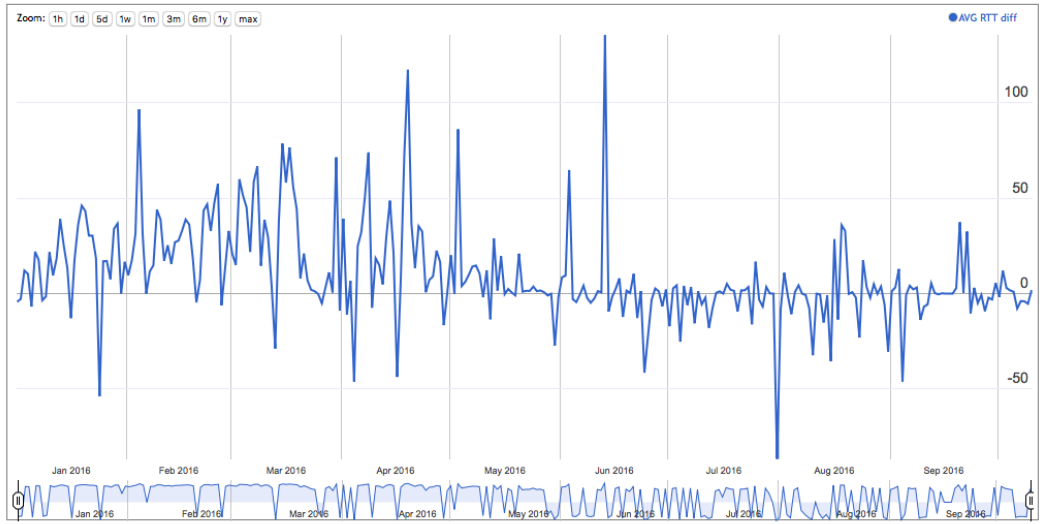


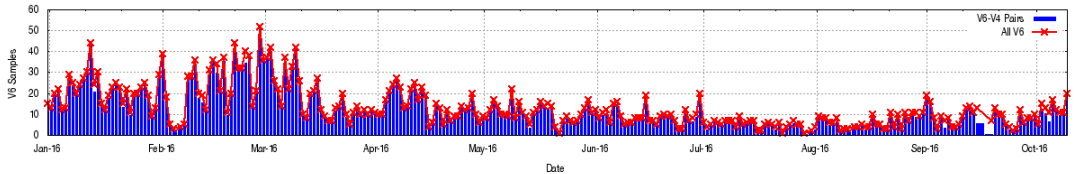
IPv6 in Spain:

IPv6 ISPs

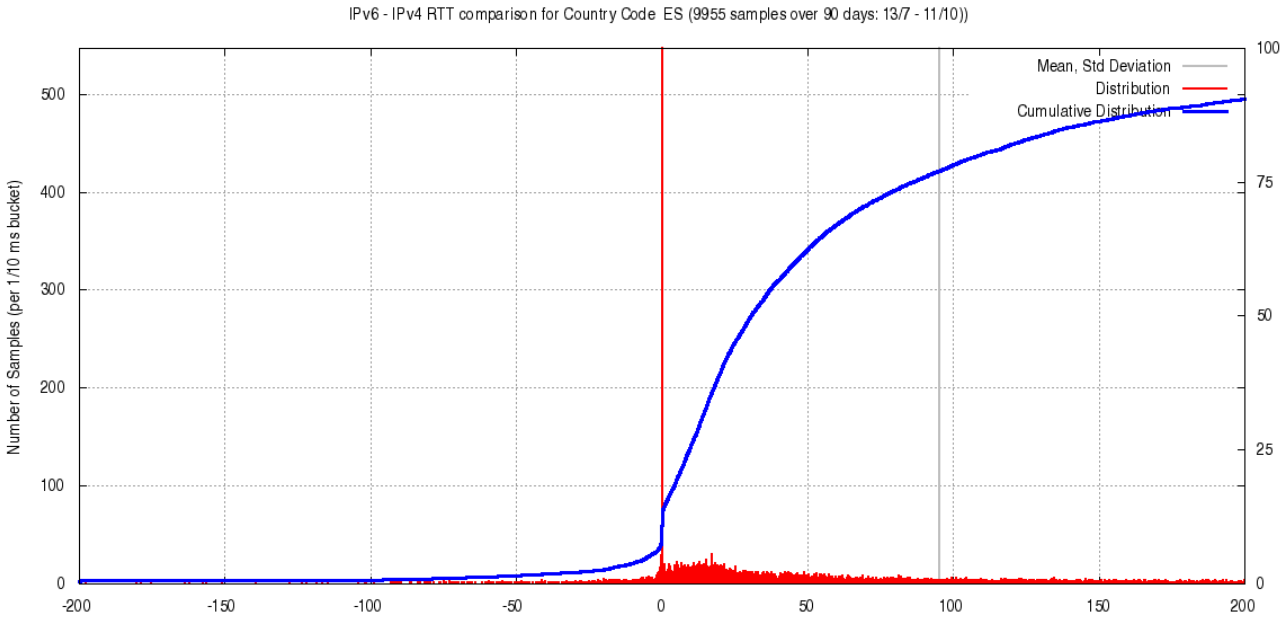
ASN	AS Name	IPv6 Capable	IPv6 Preferred	Samples
AS21321	ARETI-AS Areti Internet Ltd.	38.35%	0.14%	704
AS199736	IGUANA-AS Iguana Comunicacions S.L.	22.51%	19.37%	191
AS766	REDIRIS Entidad Publica Empresarial Red.es	7.90%	7.75%	5,459
AS50896	AS-REGION40 Trusov Ilya Igorevych	6.52%	6.52%	92
AS39020	COMVIVE-AS Comvive Servidores S.L.	3.65%	3.48%	2,244
AS49835	GUIFINET-AS Fundacio guifi.net	2.10%	1.88%	2,239
AS199581	DATARUSH Data Rush IT Services, S.L.	1.69%	1.69%	59
AS12386	ASALPI Orange Catalunya Xarxes de Telecomunicacions S.A.	0.97%	0.00%	925
AS34977	PROCONO-AS PROCONO S.A.	0.95%	0.92%	10,811
AS9009	M247 M247 Ltd	0.70%	0.70%	430
AS15699	ASADAM OGIC Informatica S.L.	0.65%	0.16%	2,467

Average RTT Difference (ms) (V6 - V4) for Spain (ES)



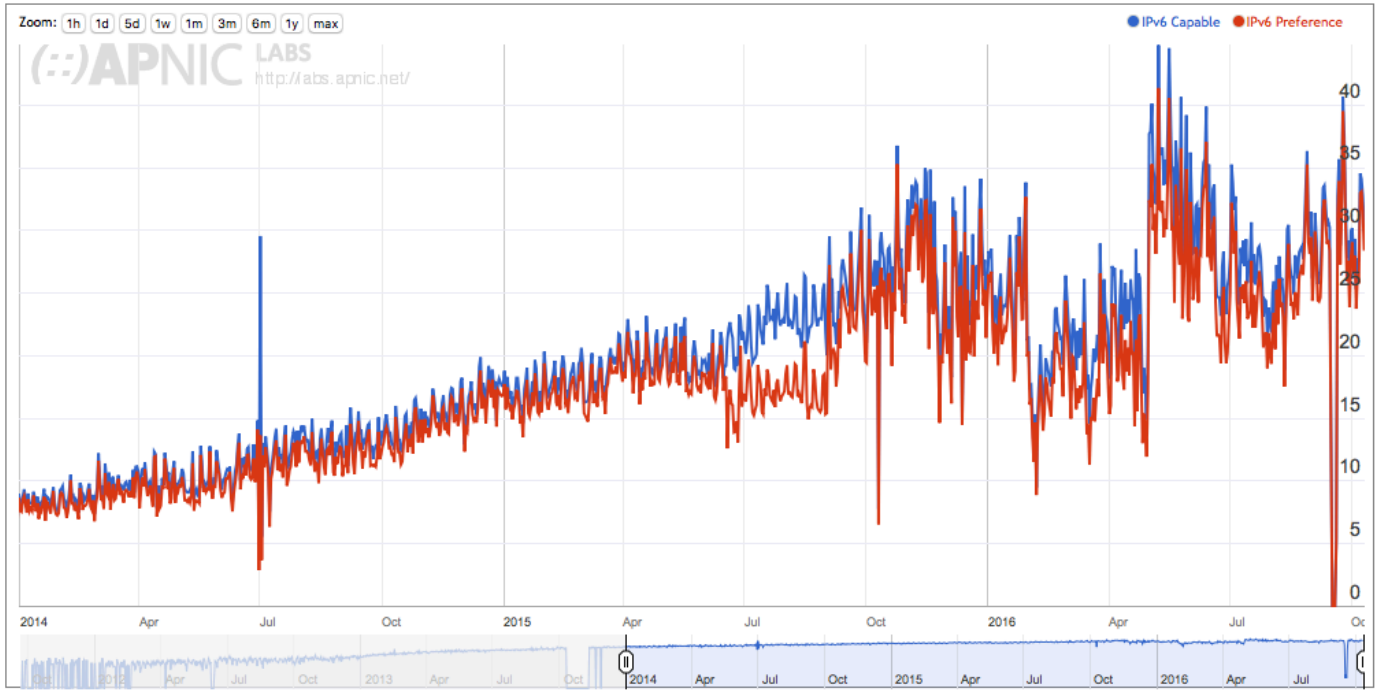


IPv6 in Spain - RTT Diff distribution



Germany

Use of IPv6 for Germany (DE)

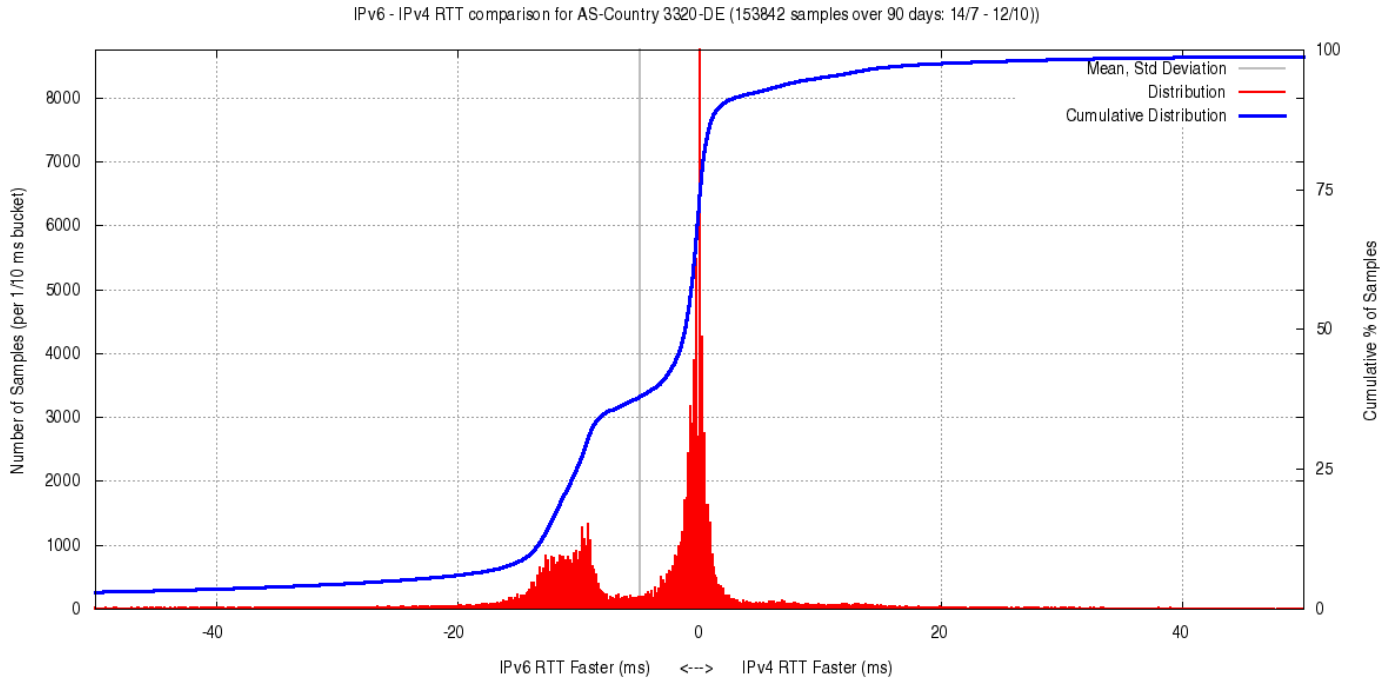


German IPv6 ISPs

ASN	AS Name	RTT Diff (V6-V4)	Samples	V6 Fail Rate	V6 Use Rate
AS3320	DTAG Deutsche Telekom AG	-6.97 ms	154,619	1.72%	46.40%
AS31334	KABELDEUTSCHLAND-AS Vodafone Kabel Deutschland GmbH	-5.00 ms	47,981	1.17%	63.25%
AS6830	LGI-UPC Liberty Global Operations B.V.	-5.41 ms	20,704	3.10%	44.67%
AS29562	KABELBW-ASN Kabel BW GmbH	-3.86 ms	13,169	2.73%	47.94%
AS24961	MYLOC-AS myLoc managed IT AG	141.97 ms	11,810	0.05%	75.42%
AS13301	UNITEDCOLO-AS United Gameserver GmbH	45.29 ms	6,997	0.00%	85.31%
AS8767	MNET-AS M-net Telekommunikations GmbH, Germany	-9.12 ms	4,028	2.10%	48.58%
AS29141	BKVG-AS Bradler Krantz GmbH Co. KG	-1.09 ms	2,741	0.25%	94.23%
AS15943	WTNET-AS wilhelm.tel GmbH	-6.01 ms	2,288	1.63%	65.81%
AS16202	PRIMACOM-AS PrimaCom Berlin GmbH	-15.62 ms	1,702	1.48%	66.94%
AS24940	HETZNER-AS Hetzner Online GmbH	0.83 ms	1,266	0.82%	3.97%
AS35244	KMS-DEAS AS for KMS Munich	-12.70 ms	1,120	1.07%	52.25%
AS28753	LEASEWEB-DE Leaseweb Deutschland GmbH	0.01 ms	880	1.84%	42.65%
AS42652	DELUNET inexio Informationstechnologie und TelekommunikationKGaA	-7.95 ms	865	5.00%	29.84%
AS51167	CONTABO Contabo GmbH	-2.59 ms	600	1.90%	84.39%
AS60294	DE-DGW FLNK GmbH	-3.55 ms	528	6.39%	48.95%
AS6805	TDDE-ASN1 Telefonica Germany GmbH Co.OHG	7.05 ms	523	5.53%	0.67%
AS201701	FFRL-AS Freifunk Rheinland e.V.	3.47 ms	335	1.69%	28.84%
AS20880	TELECOLUMBUS Tele Columbus AG	2.37 ms	327	66.37%	6.16%

RTT Diff for DTAG - AS3320

RTT Difference Distribution AS3320-DE: DTAG Deutsche Telekom AG (90 days)



Is IPv6 as "good" as IPv4?

Is IPv6 as "good" as IPv4?

Is IPv6 as **fast** as IPv4?

- Basically, yes
- IPv6 is faster about half of the time
- For 75% of unicast cases, IPv6 is within 10ms RTT of IPv4
- So they perform at much the same rate

(But that's just for unicast IPv6 - the use of 6to4 makes this a whole lot worse!)

Is IPv6 as "good" as IPv4?

Is IPv6 as **robust** as IPv4?

IPv4 average connection reliability currently sits at 0.2%

The base average failure rate of Unicast V6 connection attempts at 1.5% of the total V6 unicast connections is not brilliant.

(6to4 is terrible at this!)

It could be better.

It could be a whole lot better!

Is IPv6 as "good" as IPv4?

If you can establish a connection, then IPv4 and IPv6 appear to have comparable RTT measurements across most of the Internet

But the odds of establishing that connection are still weighted in favour of IPv4!

That's it!

http://stats.labs.apnic.net/v6perf