IPv6 Performance

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APNIC Labs
November 2015
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
Yes, that’s 10 M measurements per day!
Measurement Count

Log

Daily Measurements
V6 Capable

Date
01/07/11 01/01/12 01/07/12 01/01/13 01/07/13 01/01/14 01/07/14 01/01/15 01/07/15 01/01/16
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?
Connection Failure

Outbound SYN

Busted SYN ACK
Return path

What the server sees is an incoming SYN, but no matching incoming ACK
Compare two data sets

• The first data set has been collected across 2011
  – Teredo and 6to4 were still active as IPv6 mechanisms
  – Little in the way of other IPv6 services
• The second data set has been collected across 2015
  – Missing comparative IPv4 data for the period September – October 😞
2011 - Measuring Failure

Connection Failure Rate

V4 Failure Rate

V6 Failure Rate

Percent of Connections

Date

Why is this failure rate for V6 so incredibly high?
And why is the V4 relative failure rate dropping over time?

What is this spike?
What is going on with IPv4?
What is going on with IPv4?

The failure rate for V4 decreases as the volume of experiments increases – which implies that the number of “naked SYNs” being sent to the servers is not related to the number of tests being performed.

Aside from residual IPv4 failures in the image fetch due to device resets, connection dropouts, etc, the bulk of the recorded failures here is probably attributable to researchers bots doing all-of-address scanning on port 80.
What is going on with IPv4?

Connection Failures - IPv4

Syn attacks?

bot scanning on port 80?
What about IPv6?

Why is the base failure rate of all IPv6 connections sitting at 40%? This is amazingly bad!
V6 Failure Rate by Address Type

Connection Failure Rate - V6

V6 connection Failure Rate


- All V6
- Unicast
- 6to4
- Teredo

Teredo
All V6 Average
6 to 4
Unicast
6to4 Failure is Local Failure

6to4 failure appears to be related to two factors:

1. The client’s site has a protocol 41 firewall filter rule for incoming traffic (this is possibly more prevalent in AsiaPac than in Europe)

2. Load / delay / reliability issues in the server’s chosen outbound 6to4 relay (noted in the data gathered at the US server)

Even so, the 10% to 20% connection failure rate for 6to4 is unacceptably high!
V6 Unicast Failures

January – March 2012:
110,761 successful V6 connecting endpoints
6,227 failures
That’s a failure rate of 5.3%!

7 clients used fe80:: link local addresses
7 clients used fc00:/7 ULA source addresses
2 clients used fec0::/16 deprecated site local addresses
16 clients used 1f02:d9fc::/16
Nobody used 3ffe::/16 prefixes!
Data Set 2: Connection Failure in 2015

January–November 2015

24,212,563 IPv6 endpoints
352,919 Failure rate (4.1%)
Daily IPv6 Failures

Connection Failure Rate - 2015

V6 Failure Rate
Daily IPv6 Failures

Connection Failure Rate - 2015

HTML5 + TLS + Mobile Devices

RIP Flash!
6to4

6,634,660 6to4 endpoints

- 27% of all IPv6 used 6to4
- 9% failure rate within the set of 6to4 connections

This is still very high!
Daily IPv6 Failures

Connection Failure Rate - 2015

V6 Failure Rate
V6 Unicast Failure Rate
6to4 Failure Rate
Daily IPv6 Failures

- 6to4 failure rate has improved from 15%-20% in 2011 to 9% in 2015
- Teredo has all but disappeared
- Unicast failure rate is between 1.5% and 4% in 2015
  - Current unicast failure rate is 2%
## Origin AS's with High IPv6 Failure Rates

<table>
<thead>
<tr>
<th>AS</th>
<th>Failure Rate</th>
<th>Samples</th>
<th>AS Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS13679</td>
<td>99.69%</td>
<td>318</td>
<td>Centros Culturales de Mexico, A.C., MX</td>
</tr>
<tr>
<td>AS201986</td>
<td>94.74%</td>
<td>133</td>
<td>ARPINET Arpinet LLC, AM</td>
</tr>
<tr>
<td>AS5511</td>
<td>90.68%</td>
<td>161</td>
<td>OPENTRANSIT Orange S.A., FR</td>
</tr>
<tr>
<td>AS20880</td>
<td>72.56%</td>
<td>962</td>
<td>TELECOLUMBUS Tele Columbus AG, DE</td>
</tr>
<tr>
<td>AS17660</td>
<td>57.06%</td>
<td>1,041</td>
<td>DRUKNET-AS DrukNet ISP, BT</td>
</tr>
<tr>
<td>AS21107</td>
<td>46.64%</td>
<td>7,564</td>
<td>BLICNET-AS Blicnet d.o.o., BA</td>
</tr>
<tr>
<td>AS4755</td>
<td>40.82%</td>
<td>316</td>
<td>TATACOMM-AS TATA Communications formerly VSNL is Leading ISP, IN</td>
</tr>
<tr>
<td>AS37992</td>
<td>40.25%</td>
<td>159</td>
<td>THAMMASAT-BORDER-AS Thammasat University in thailand, TH</td>
</tr>
<tr>
<td>AS28580</td>
<td>39.64%</td>
<td>1,158</td>
<td>CILNET Comunicacaoe Informatica LTDA., BR</td>
</tr>
<tr>
<td>AS17412</td>
<td>35.58%</td>
<td>163</td>
<td>WOOSHWISELESSNZ Woosh Wireless, NZ</td>
</tr>
<tr>
<td>AS52207</td>
<td>33.62%</td>
<td>931</td>
<td>TULA-AS JSC &quot;ER-Telecom Holding&quot;, RU</td>
</tr>
<tr>
<td>AS4796</td>
<td>32.61%</td>
<td>414</td>
<td>BANDUNG-NET-AS-AP Institute of Technology Bandung, ID</td>
</tr>
<tr>
<td>AS30036</td>
<td>30.59%</td>
<td>17,001</td>
<td>MEDIACOM-ENTERPRISE-BUSINESS - Mediacom Communications Corp, US</td>
</tr>
<tr>
<td>AS9329</td>
<td>29.35%</td>
<td>184</td>
<td>SLTINT-AS-AP Sri Lanka Telecom Internet, LK</td>
</tr>
<tr>
<td>AS7477</td>
<td>28.10%</td>
<td>153</td>
<td>TEREDONN-AS-AP SkyMesh Pty Ltd, AU</td>
</tr>
<tr>
<td>AS52888</td>
<td>25.79%</td>
<td>190</td>
<td>UNIVERSIDADE FEDERAL DE SAO CARLOS, BR</td>
</tr>
<tr>
<td>AS28343</td>
<td>24.52%</td>
<td>681</td>
<td>TPA TELECOMUNICACOES LTDA, BR</td>
</tr>
<tr>
<td>AS210</td>
<td>22.27%</td>
<td>247</td>
<td>WEST-NET-WEST - Utah Education Network, US</td>
</tr>
<tr>
<td>AS29632</td>
<td>19.25%</td>
<td>239</td>
<td>NASSIST-AS NetAssist LLC, UA</td>
</tr>
<tr>
<td>AS20857</td>
<td>18.10%</td>
<td>105</td>
<td>TRANSIP-AS TransIP B.V., NL</td>
</tr>
</tbody>
</table>
# Origin AS's with Zero Failure Rates

<table>
<thead>
<tr>
<th>AS</th>
<th>Failure Rate</th>
<th>Count</th>
<th>Name and Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS3223</td>
<td>0.00%</td>
<td>3,138</td>
<td>VOXILITY Voxility S.R.L., RO</td>
</tr>
<tr>
<td>AS16265</td>
<td>0.00%</td>
<td>2,761</td>
<td>LEASEWEB-NETWORK LeaseWeb Network B.V., NL</td>
</tr>
<tr>
<td>AS24961</td>
<td>0.00%</td>
<td>2,644</td>
<td>MYLOC-AS myLoc managed IT AG, DE</td>
</tr>
<tr>
<td>AS39832</td>
<td>0.00%</td>
<td>1,945</td>
<td>NO-OPERA Opera Software ASA, NO</td>
</tr>
<tr>
<td>AS2686</td>
<td>0.00%</td>
<td>1,824</td>
<td>ATGS-MMD-AS - AT&amp;T Global Network Services, LLC, US</td>
</tr>
<tr>
<td>AS33070</td>
<td>0.00%</td>
<td>1,633</td>
<td>RMH-14 - Rackspace Hosting, US</td>
</tr>
<tr>
<td>AS55536</td>
<td>0.00%</td>
<td>1,351</td>
<td>PSWITCH-HK PACSWITCH GLOBAL IP NETWORK, HK</td>
</tr>
<tr>
<td>AS21191</td>
<td>0.00%</td>
<td>1,210</td>
<td>ASN-SEVERTTK Closed Joint Stock Company TransTeleCom, RU</td>
</tr>
<tr>
<td>AS22584</td>
<td>0.00%</td>
<td>1,165</td>
<td>NTELOS-PCS - Ntelos Inc., US</td>
</tr>
<tr>
<td>AS32780</td>
<td>0.00%</td>
<td>1,119</td>
<td>HOSTINGSERVICES-INC - Hosting Services, Inc., US</td>
</tr>
<tr>
<td>AS29854</td>
<td>0.00%</td>
<td>1,039</td>
<td>WESTHOST - WestHost, Inc., US</td>
</tr>
<tr>
<td>AS18144</td>
<td>0.00%</td>
<td>974</td>
<td>AS-ENECOM Energia Communications, Inc., JP</td>
</tr>
<tr>
<td>AS12510</td>
<td>0.00%</td>
<td>762</td>
<td>SAP_AG_WDF SAP SE, DE</td>
</tr>
<tr>
<td>AS21837</td>
<td>0.00%</td>
<td>757</td>
<td>OPERASOFTWARE - Opera Software Americas LLC, US</td>
</tr>
<tr>
<td>AS13213</td>
<td>0.00%</td>
<td>741</td>
<td>UK2NET-AS UK2 - Ltd, GB</td>
</tr>
<tr>
<td>AS9619</td>
<td>0.00%</td>
<td>672</td>
<td>SSD Sony Global Solutions Inc., JP</td>
</tr>
<tr>
<td>AS19994</td>
<td>0.00%</td>
<td>660</td>
<td>RACKSPACE - Rackspace Hosting, US</td>
</tr>
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<td>AS32934</td>
<td>0.00%</td>
<td>654</td>
<td>FACEBOOK - Facebook, Inc., US</td>
</tr>
<tr>
<td>AS25513</td>
<td>0.00%</td>
<td>639</td>
<td>ASN-MGTS-USPD OJS Moscow city telephone network, RU</td>
</tr>
<tr>
<td>AS2614</td>
<td>0.00%</td>
<td>608</td>
<td>ROEDUNET Agentia de Admin a Retelei Nationale de Informatica Educatie si Cercetare, RO</td>
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*Ranked by IPv6 measurement count*
# Origin AS's with Zero Failure Rates

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IPv6 Failures - Q3 2015

279,116 failing IPv6 addresses

- 143,357 6to4 addresses
  - 118 teredo addresses
  - 92 fe80:: local scope addresses
- 709 unallocated addresses
- 1,358 unannounced addresses

133,482 addresses from unicast allocated routed space

102,826 unique /64s
What about IPv4 Connection Failures?

2011: failure rate 0.2%
What about IPv4 Connection Failures?

2011: failure rate 0.2%

2015:

334,957,192 IPv4 endpoints
1,197,903 Connection Failures (0.3%)
IPv4 Connection Failure

Connection Failure Rate - 2015

V4 Failure Rate

Missing PCAP data
Comparison: Unicast
Comparison: Unicast
It's still not good!

IPv6 Unicast Failure rate: 1.8% (steady)

IPv4 Failure rate: 0.2% (and falling!)
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?
Let's dive into SYNs!
Why SYNs?

• Every TCP session starts with a SYN handshake

• It's 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
  • Plot the difference in RTT in buckets
2012 Data

Relative RTT, IPv6 to IPv4 (sec) for bilby on 2012/03/01

Teredo
6to4
global unicast

Count

Relative RTT, IPv6 to IPv4 (sec)
IPv6 is faster

IPv6 is slower

Teredo

6to4

global unicast

Number of samples (log scale)

RTT Difference (in fractions of a second)

2012 Data

Relative RTT, IPv6 to IPv4 (sec) for bilby on 2012/03/01
IPv6 is faster
IPv6 is slower

Number of samples (log scale)

RTT Difference (in fractions of a second)
IPv6 is faster
IPv6 is slower

2015 Data - November 2015

Number of samples (log scale)

RTT Difference (in fractions of a second)
IPv6 is slower
IPv6 is faster

2015 Data CDF (using 10ms resolution)

 Cumulative Distribution of Relative Time Difference

Proportion of samples

RTT Difference (in fractions of a second)

Unicast
6 to 4
2015 Data CDF (using 10ms resolution)

Cumulative Distribution of Relative Time Difference

- IPv6 is faster
- IPv6 is slower

Unicast

6 to 4

18% of samples unicast IPv6 is more than 1/100 sec faster than IPv4

24% of samples unicast IPv6 is more than 1/100 sec slower than IPv4
IPv6 is faster

IPv6 is slower

Unicast

6 to 4
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 70% 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 connection reliability currently sits at 0.2%

The base failure rate of Unicast V6 connection attempts at 1.8% of the total V6 unicast connections is not brilliant.
6to4 is still terrible!

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!

Questions?