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?

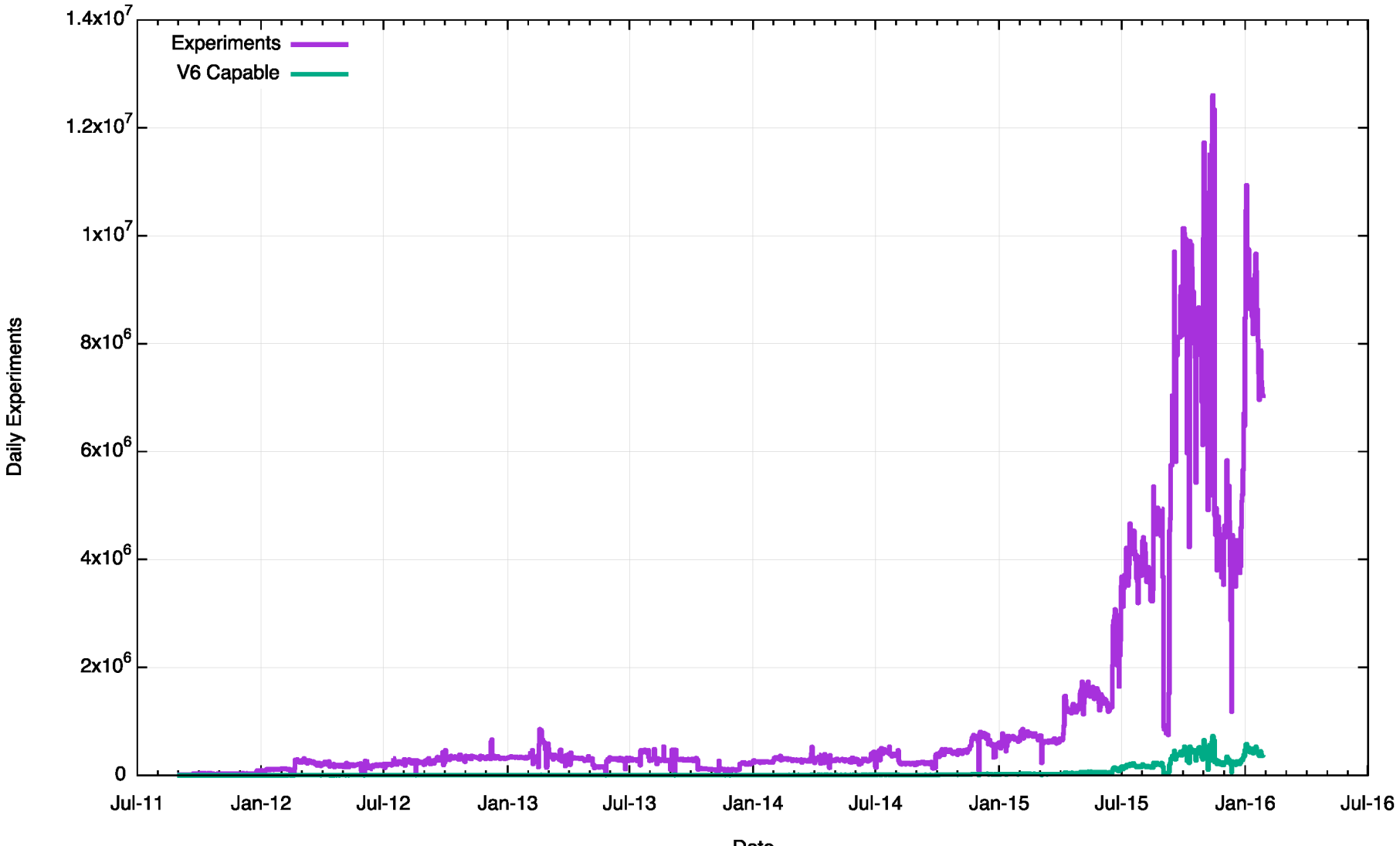
- How "fast" are IPv6 connections?

  is V6 slower than V4?

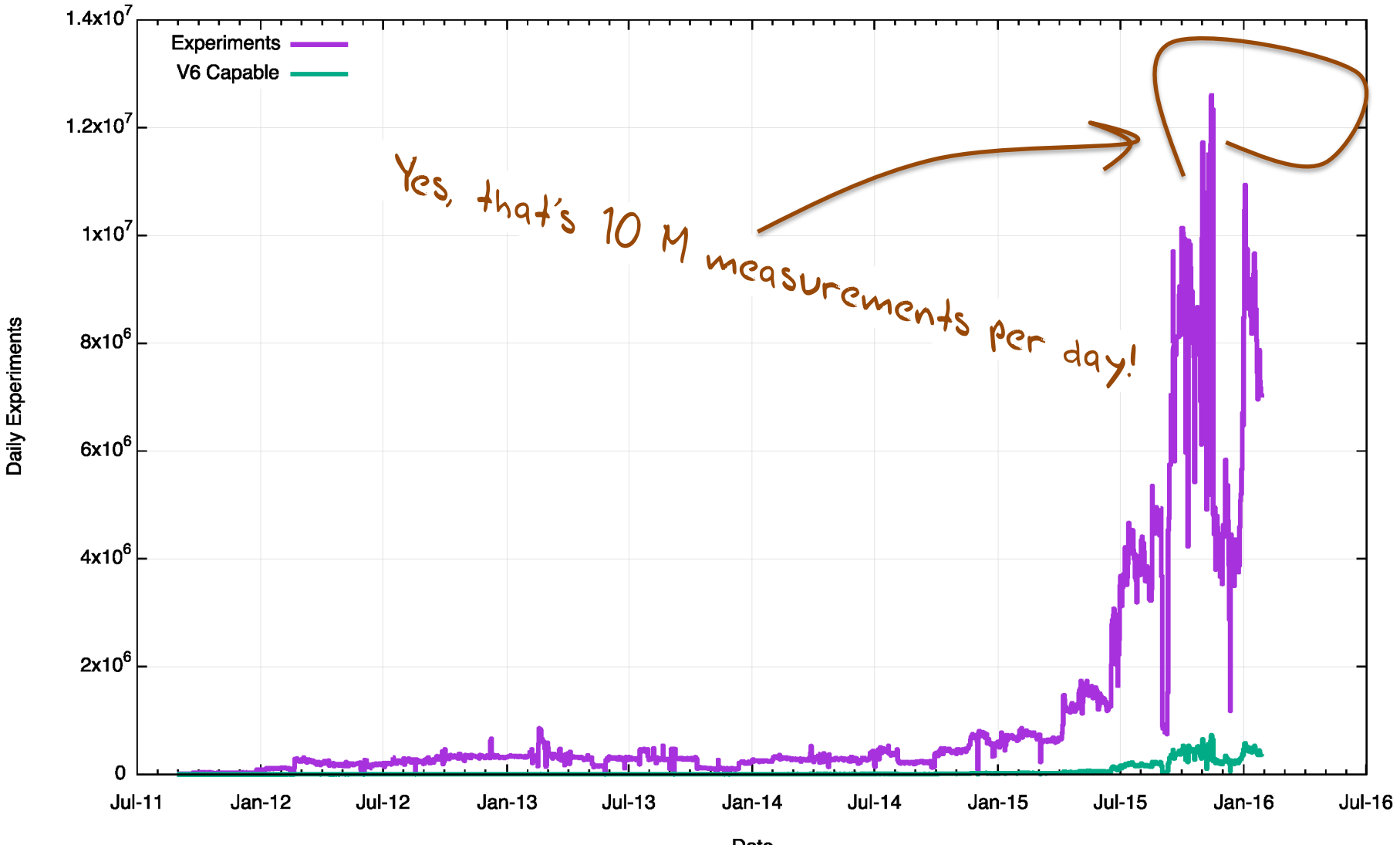
The Measurement Technique

- 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

Measurement Count



Measurement Count



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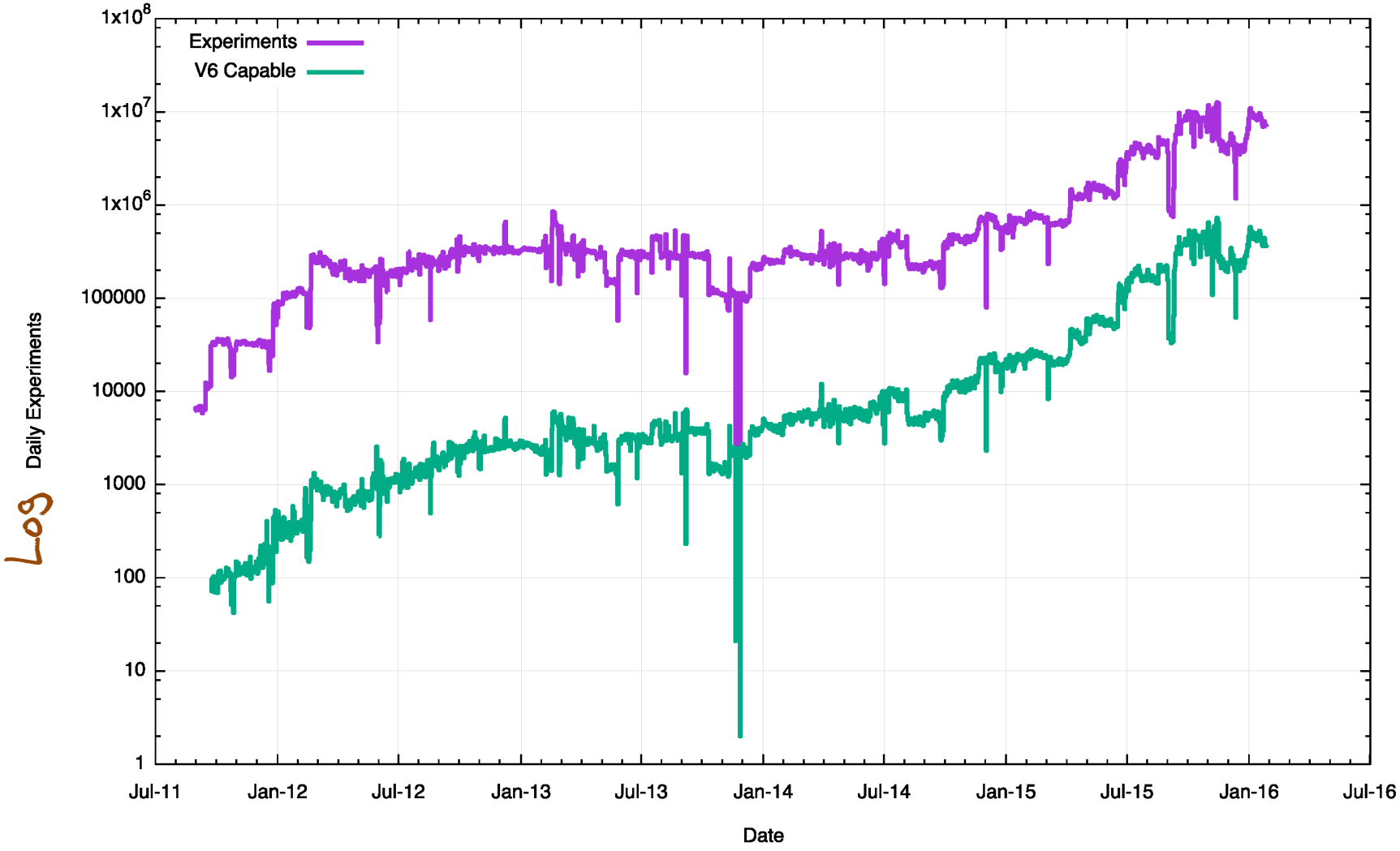

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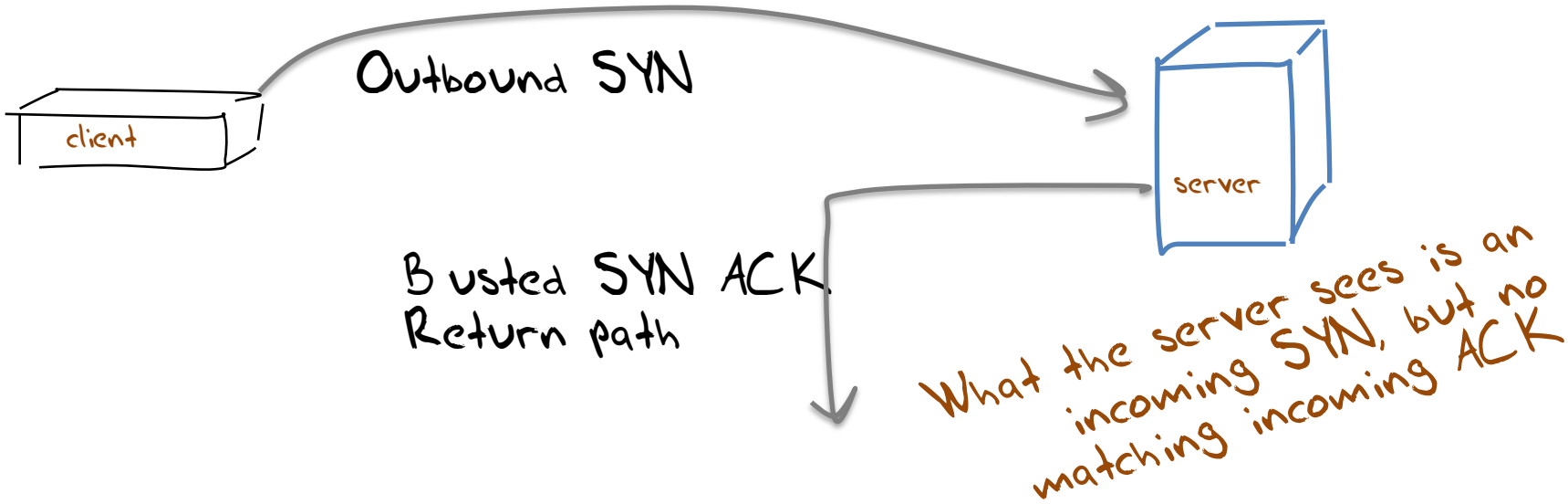
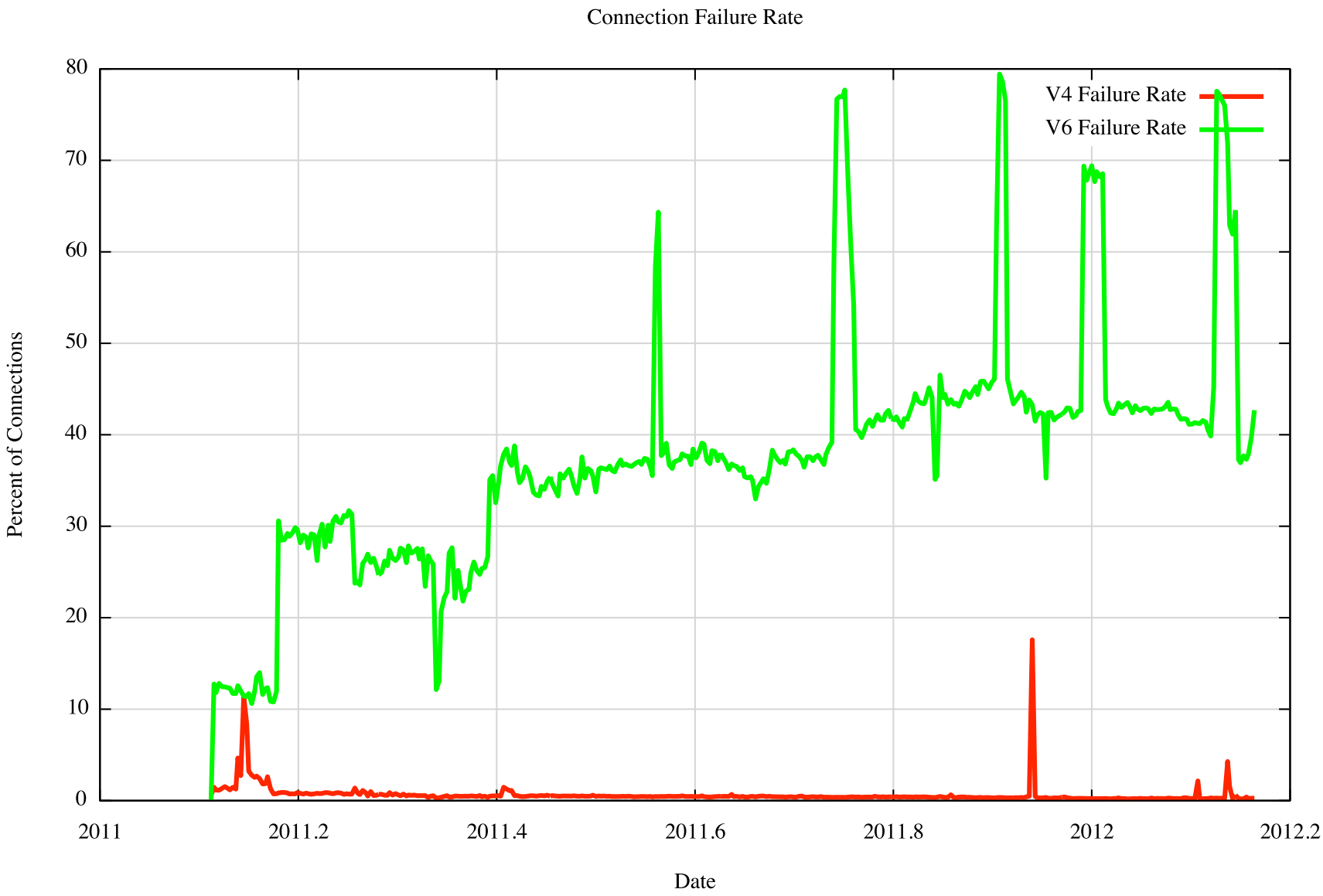
Connection Failure



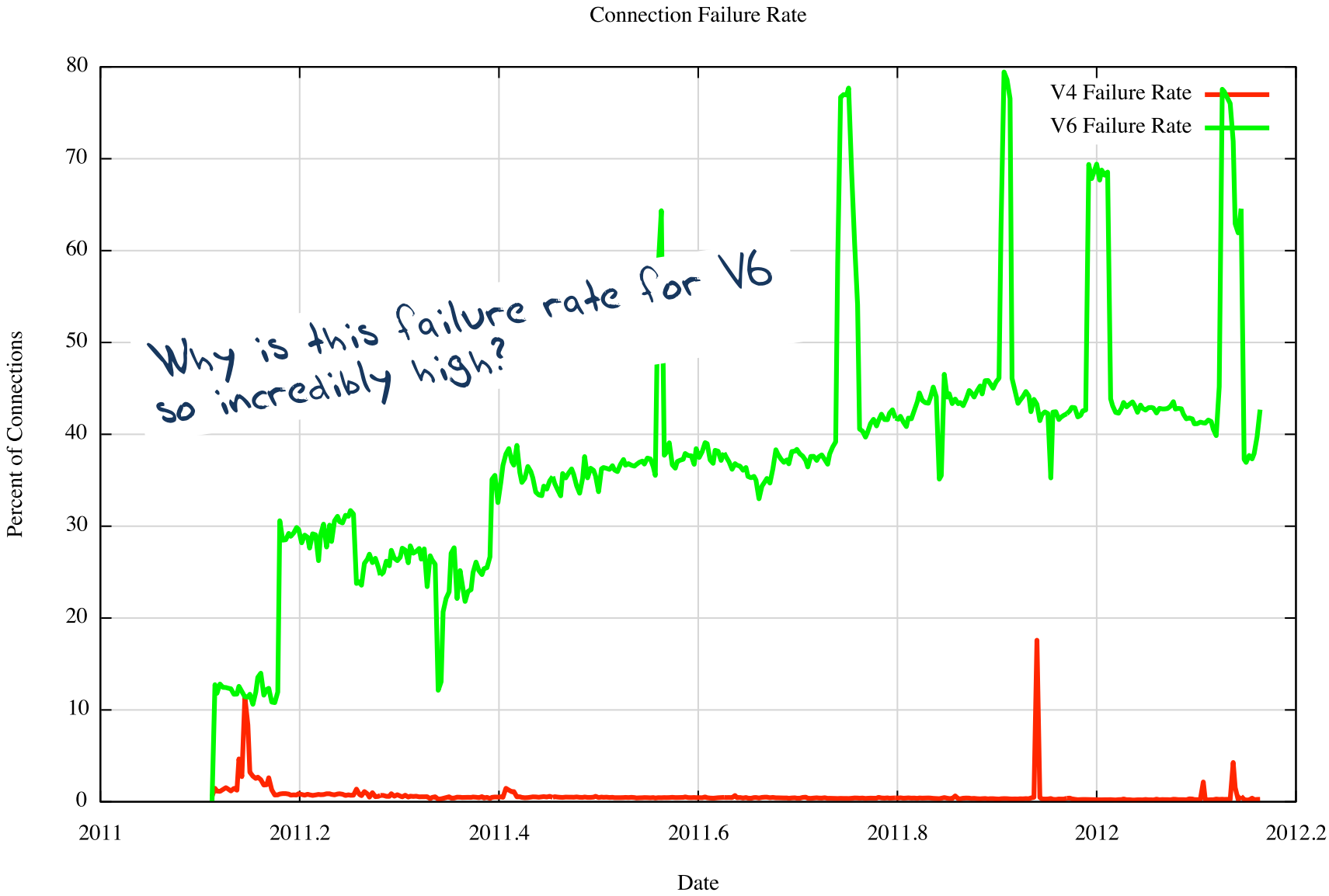
Compare two data sets

- 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 2015/2016
  - Missing comparative IPv4 data for the period September – October ☹

2011 - Measuring Failure

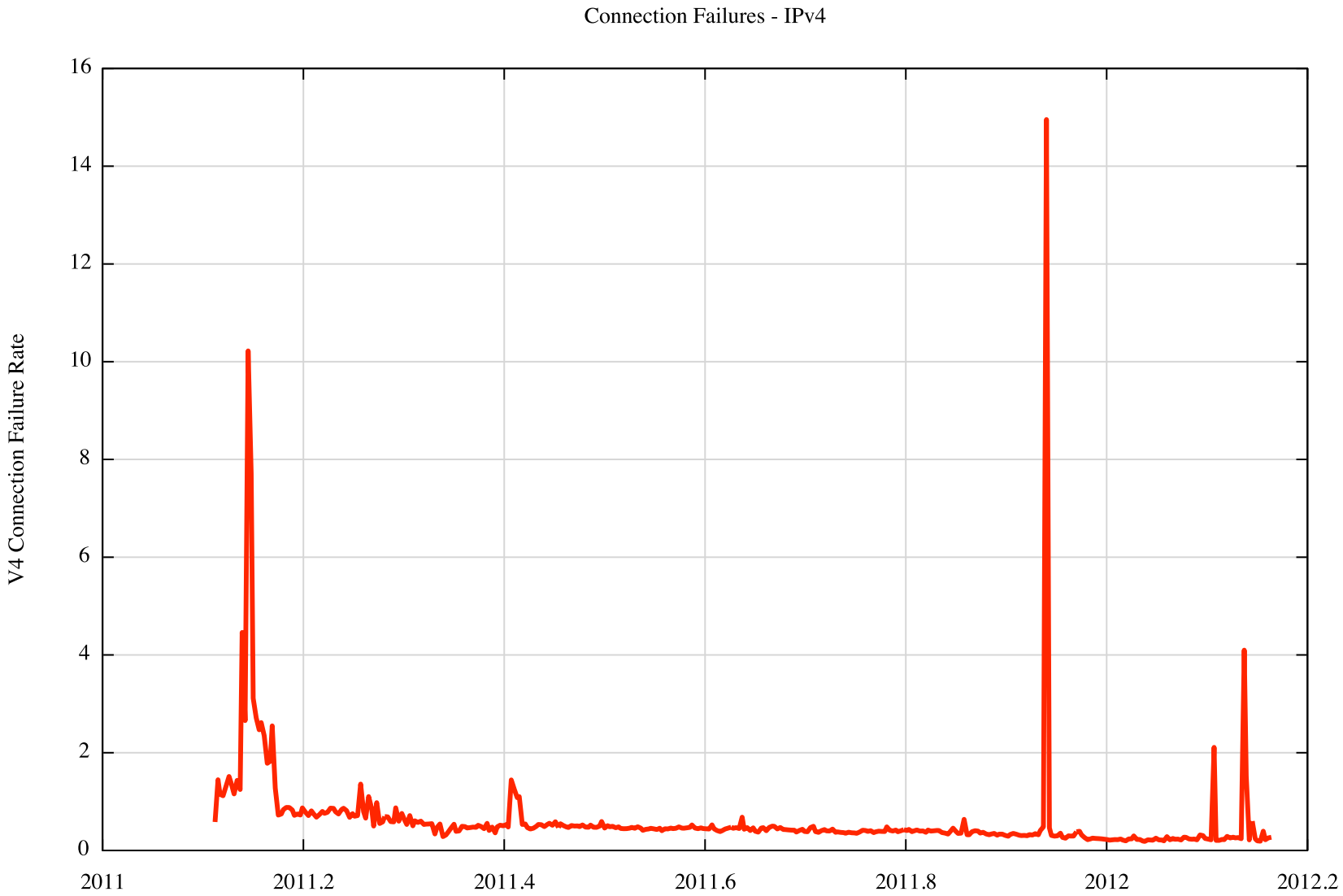


2011 - Relative Connection Failure Rates



2011 - Relative Connection Failure Rates

What is going on with IPv4?

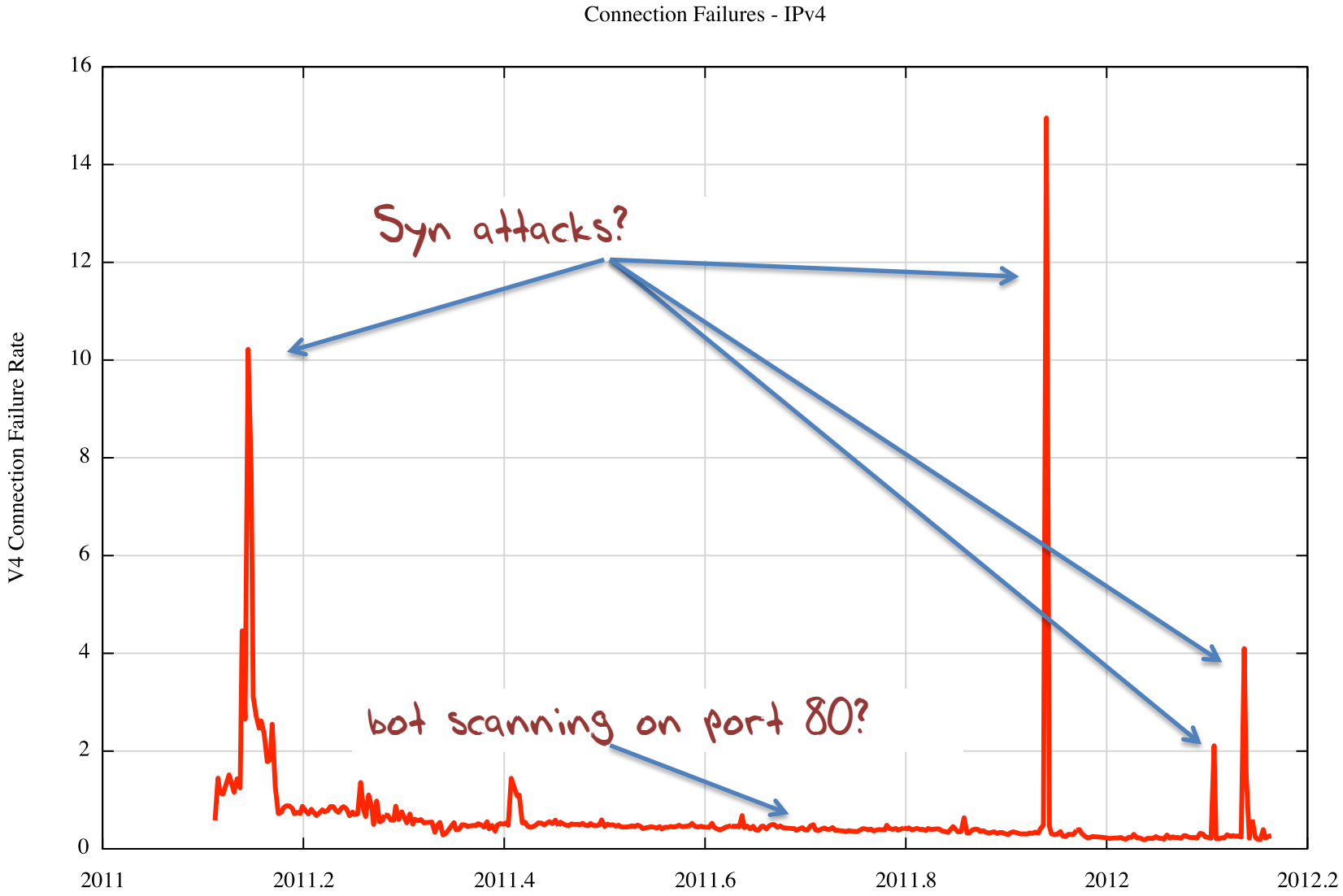


What is going on with IPv4?

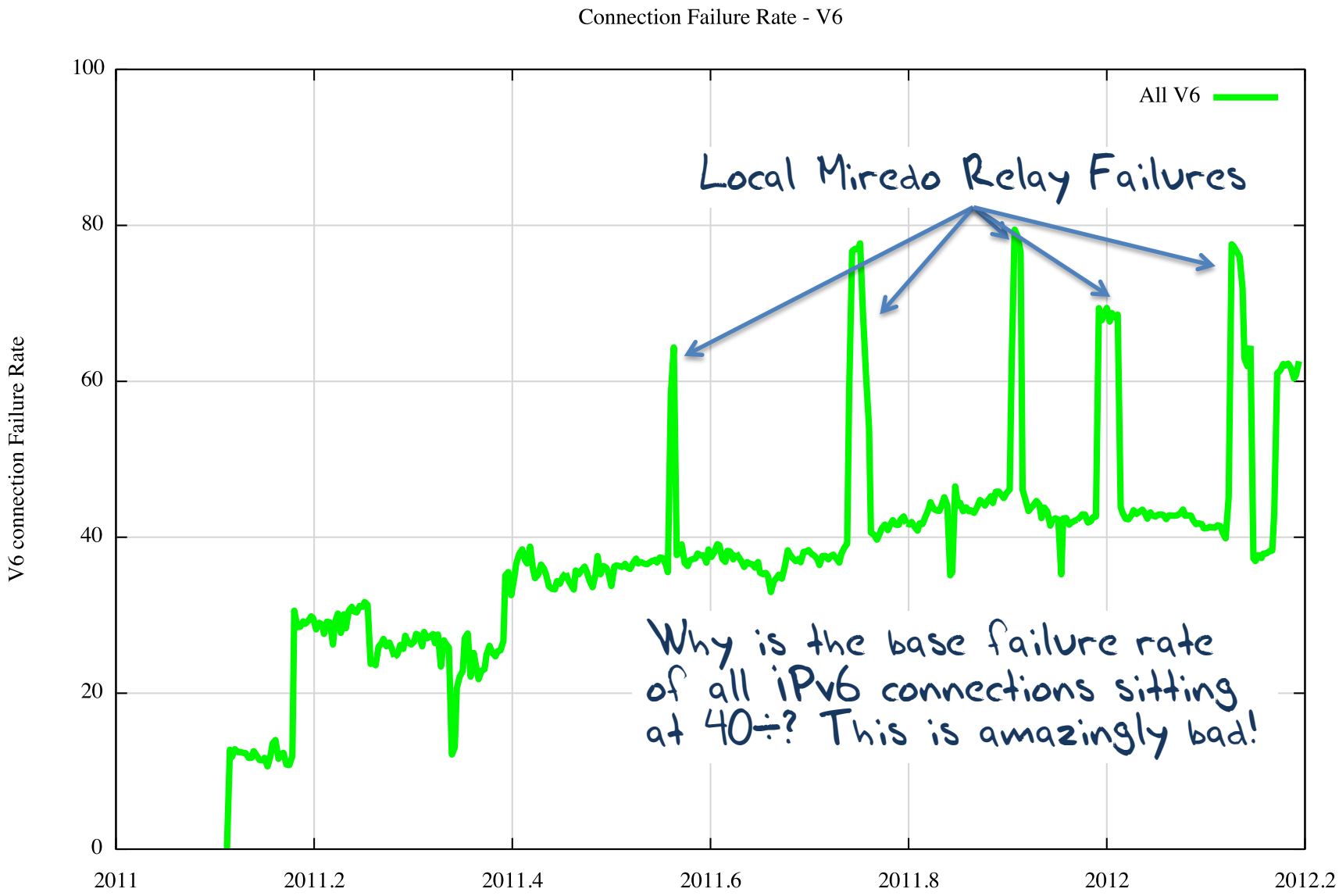
The failure rate for V4 decreases as the volume of experiments increases – which implies that the number of "naked SYNs" being sent to the servers is not related to the number of tests being performed.

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 bots doing all-of-address scanning on port 80

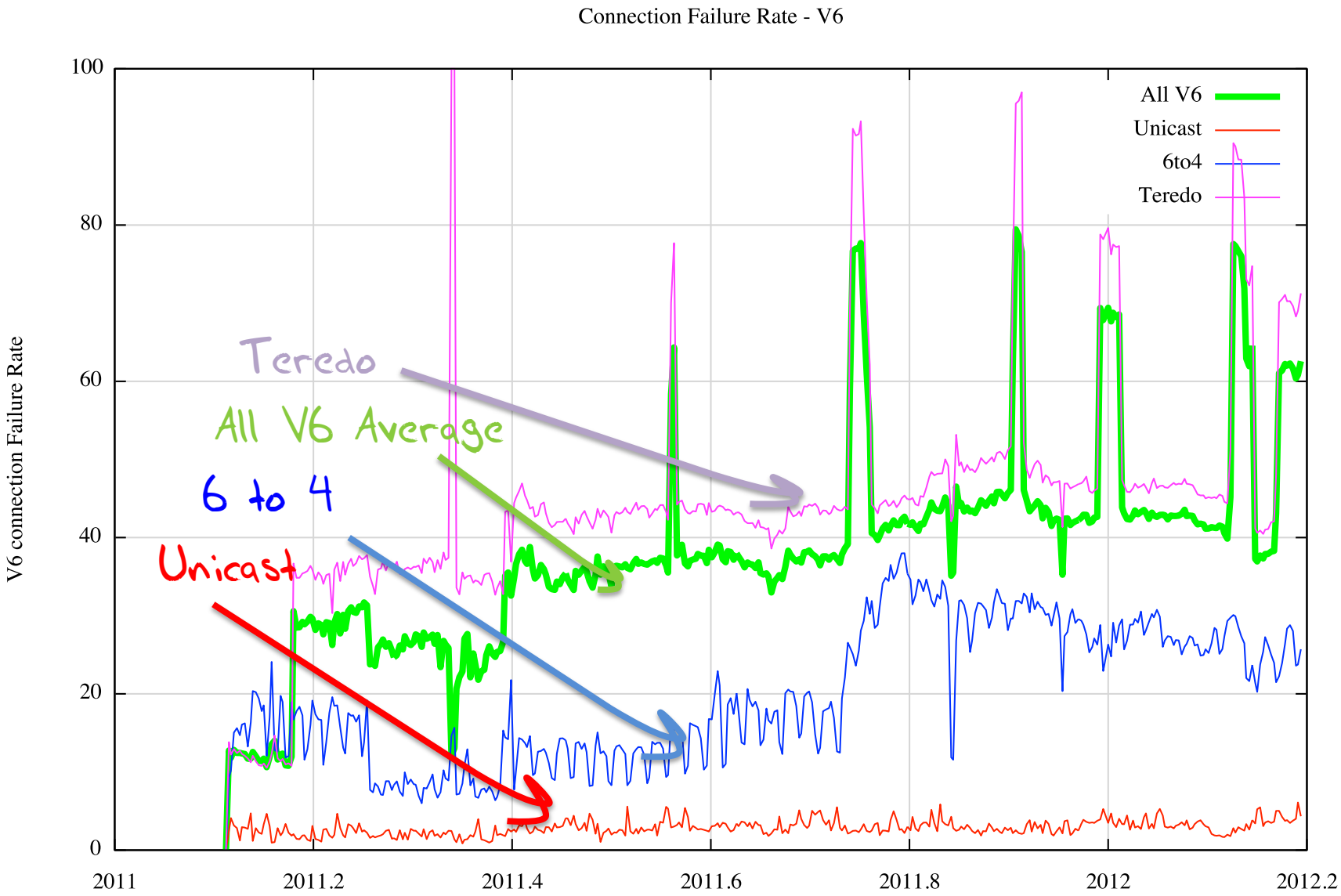
What is going on with IPv4?



What about IPv6?



V6 Failure Rate by Address Type



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!

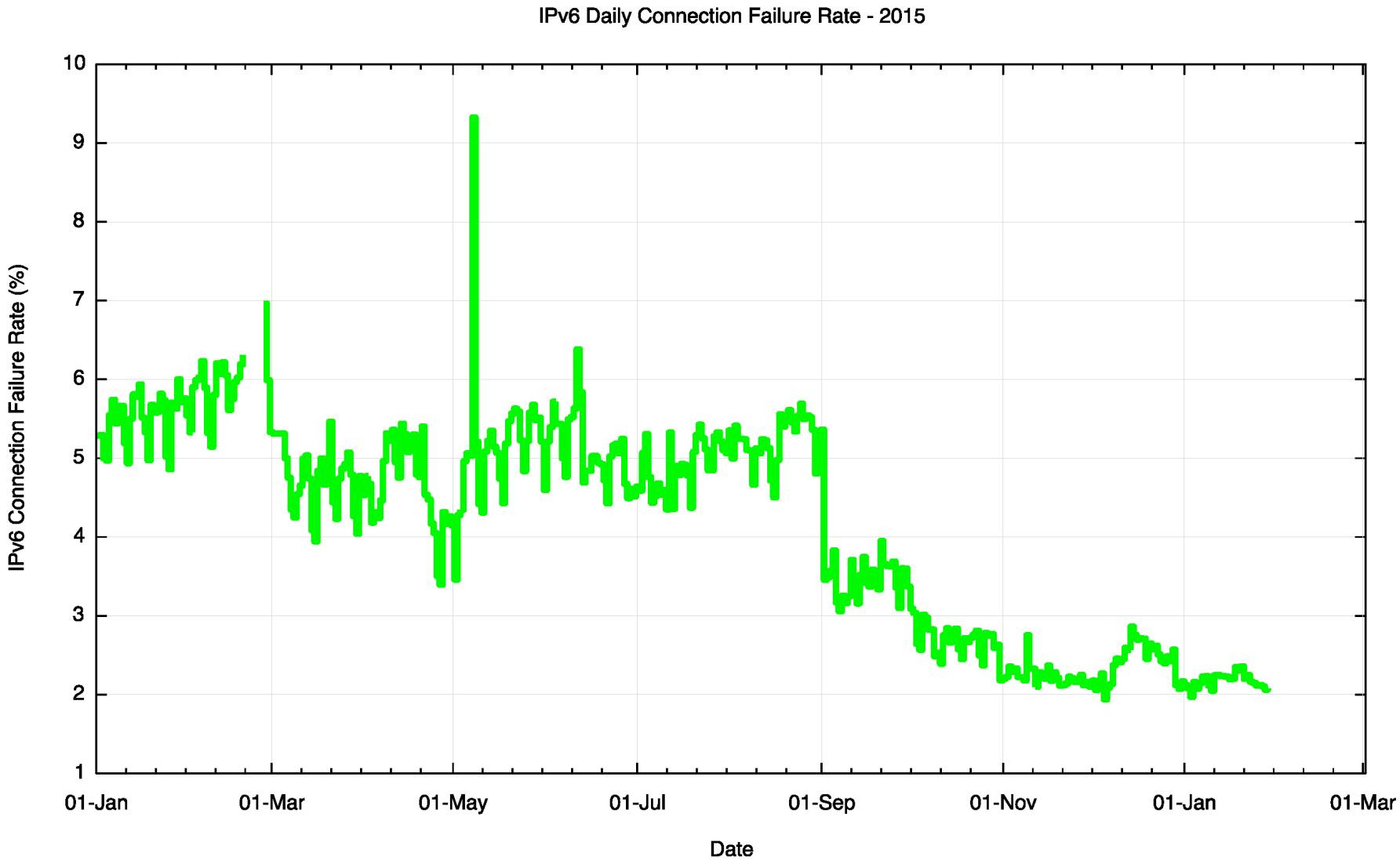
Data Set 2: Connection Failure in 2015/2016

January 2015– January 2016

37,292,489 IPv6 endpoints

1,289,699 Failure rate (3.46%)

Daily IPv6 Failures



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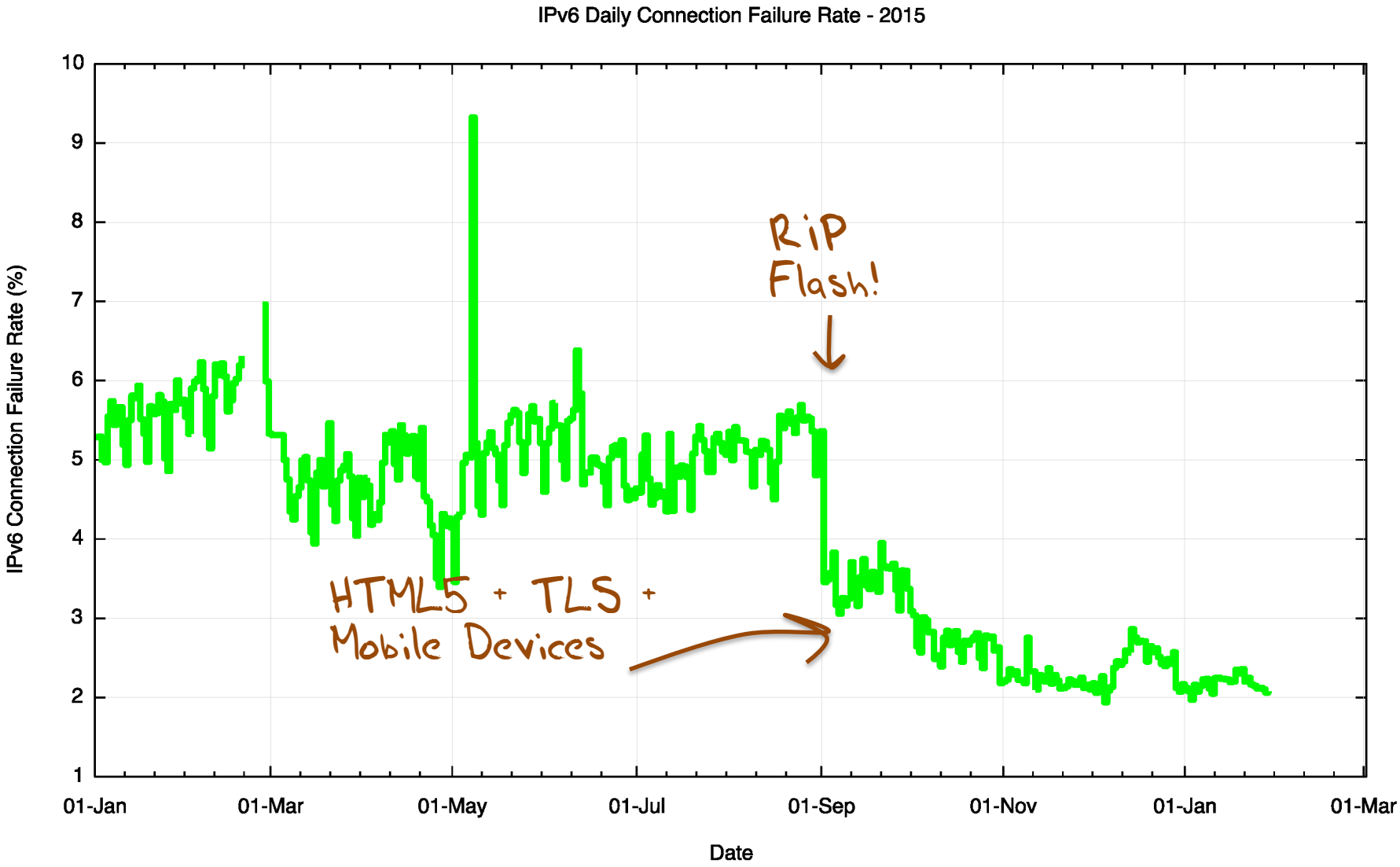


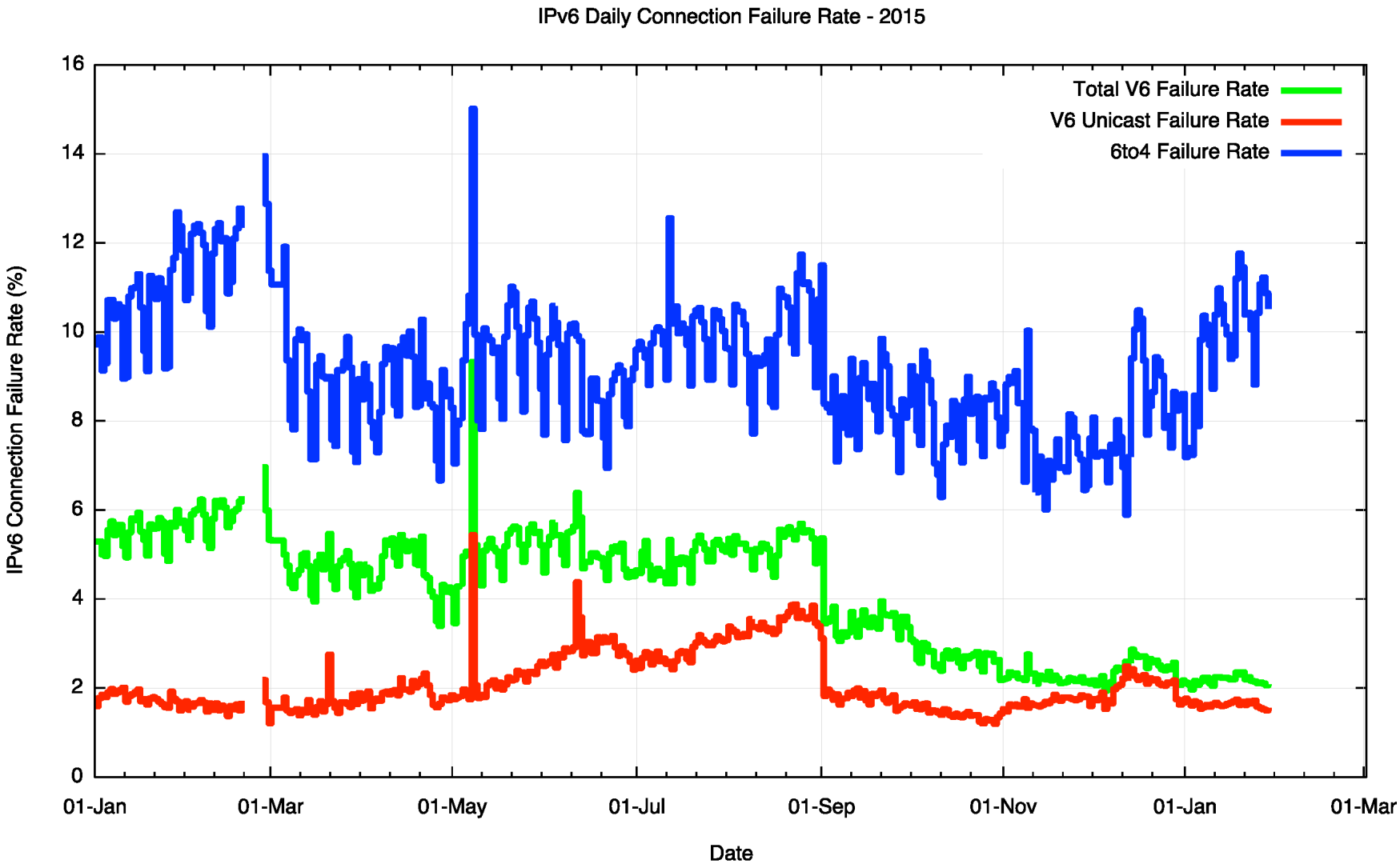
6to4

7,498,506 6to4 endpoints

- 20% of all IPv6 used 6to4
- 9% failure rate within the set of 6to4 connections

This is still very high!

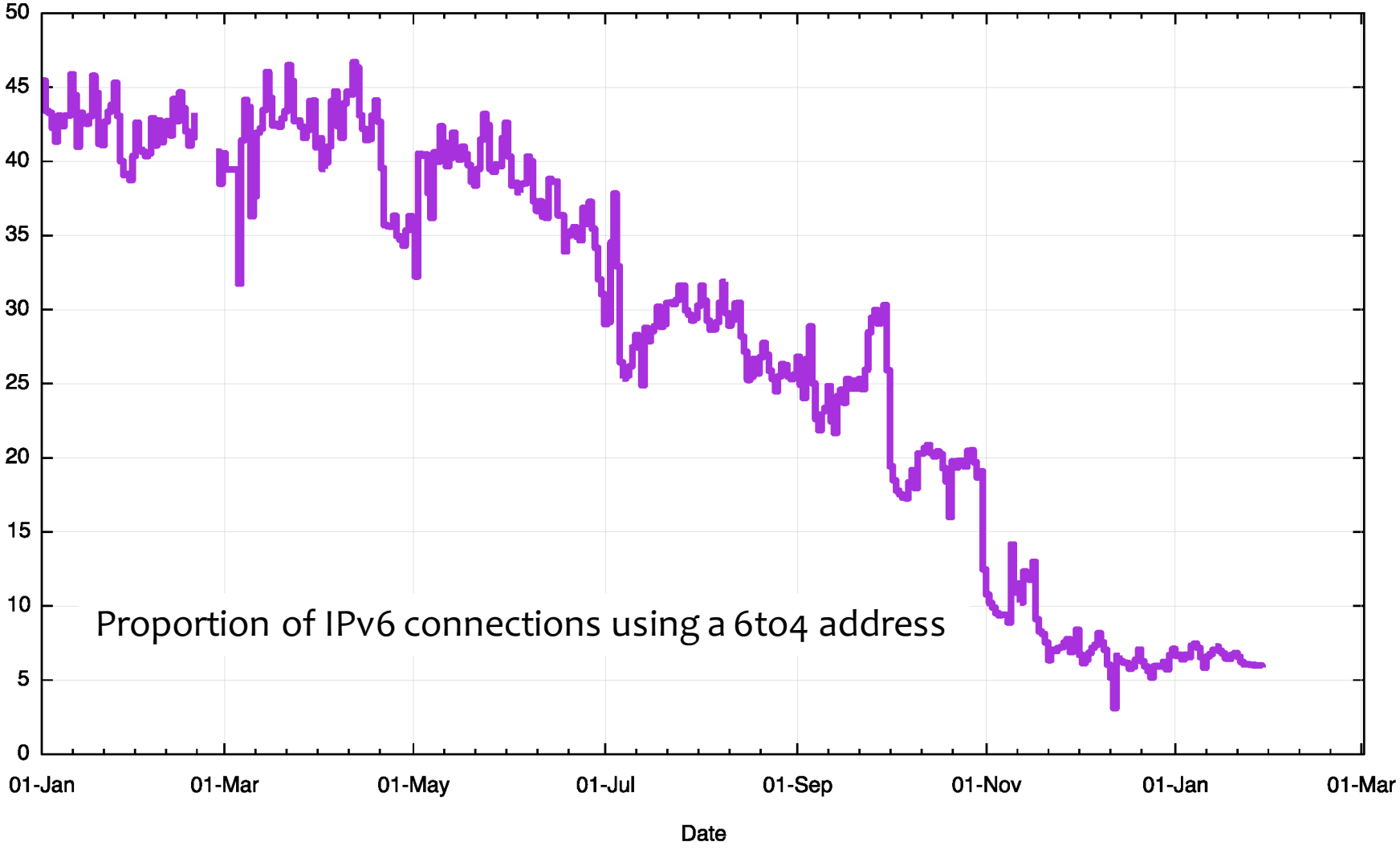
Daily IPv6 Failures



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%

Killing off 6to4



IPv6 Failures - Sep 2015 - Jan 2016

20,872,173 unique IPv6 Addresses

464,344 failing IPv6 addresses

142,362 6to4 addresses

138 teredo addresses

68 fe80:: local scope addresses

834 unallocated addresses

1,244 unannounced addresses

319,698 addresses from unicast allocated routed space

216,620 unique /64s

Origin AS's with High IPv6 Failure Rates

AS	Failure Rate	Samples	AS Name
AS13679	97.33%	374	Centros Culturales de Mexico, A.C.,MX
AS201986	93.69%	222	ARPINET Arpinet LLC,AM
AS17660	65.14%	1,374	DRUKNET-AS DrukNet ISP,BT
AS10349	60.29%	763	TULANE - Tulane University,US
AS21107	46.97%	692	BLICNET-AS Blicnet d.o.o.,BA
AS20880	42.65%	762	TELECOLUMBUS Tele Columbus AG,DE
AS12779	36.70%	109	ITGATE IT.Gate S.p.A.,IT
AS46261	35.64%	101	QUICKPACKET - QuickPacket, LLC,US
AS9329	35.29%	119	SLTINT-AS-AP Sri Lanka Telecom Internet,LK
AS52888	27.92%	265	UNIVERSIDADE FEDERAL DE SAO CARLOS,BR
AS30036	27.55%	60,228	MEDIACOM-ENTERPRISE-BUSINESS - Mediacom Communications Corp,US
AS45920	25.77%	163	SKYMESH-AS-AP SkyMesh Pty Ltd,AU
AS210	25.04%	571	WEST-NET-WEST - Utah Education Network,US
AS28343	24.57%	985	TPA TELECOMUNICACOES LTDA,BR
AS7477	21.72%	488	TEREDONN-AS-AP SkyMesh Pty Ltd,AU
AS24173	21.48%	256	NETNAM-AS-AP Netnam Company,VN
AS28580	21.48%	1,341	CILNET Comunicacao e Informatica LTDA.,BR
AS32329	20.63%	126	MONKEYBRAINS - Monkey Brains,US
AS17451	19.35%	248	BIZNET-AS-AP BIZNET NETWORKS,ID
AS5707	19.35%	155	UTHSC-H - The University of Texas Health Science Center at Houston,US

Origin AS's with Zero Failure Rates

AS3676	0.00%	2,149	UIOWA-AS - University of Iowa,US
AS55536	0.00%	1,548	PSWITCH-HK PACSWITCH GLOBAL IP NETWORK,HK
AS57026	0.00%	1,188	CHEB-AS JSC "ER-Telecom Holding",RU
AS133414	0.00%	1,179	FOXTEL-AS-AP Foxtel Management Pty Ltd,AU
AS18144	0.00%	1,179	AS-ENECOM Energia Communications,Inc.,JP
AS196705	0.00%	936	ARDINVEST Ardinvest LTD,UA
AS21191	0.00%	816	ASN-SEVERTTK Closed Joint Stock Company TransTeleCom,RU
AS1239	0.00%	734	SPRINTLINK - Sprint,US
AS56420	0.00%	717	RYAZAN-AS JSC "ER-Telecom Holding",RU
AS33070	0.00%	656	RMH-14 - Rackspace Hosting,US
AS51819	0.00%	651	YAR-AS JSC "ER-Telecom Holding",RU
AS27357	0.00%	625	RACKSPACE - Rackspace Hosting,US
AS7233	0.00%	623	YAHOO-US - Yahoo,US
AS20130	0.00%	606	DEPAUL - Depaul University,US
AS49048	0.00%	604	TVER-AS JSC "ER-Telecom Holding",RU
AS25513	0.00%	481	ASN-MGTS-USPD OJS Moscow city telephone network,RU
AS53264	0.00%	426	CDC-LMB1 - Continuum Data Centers, LLC.,US
AS29854	0.00%	392	WESTHOST - WestHost, Inc.,US
AS13238	0.00%	391	YANDEX Yandex LLC,RU
AS10359	0.00%	372	EPICSYS - Epic Systems Corporation,US

Ranked by iPv6 measurement count

What about IPv4 Connection Failures?

2011: failure rate 0.2%

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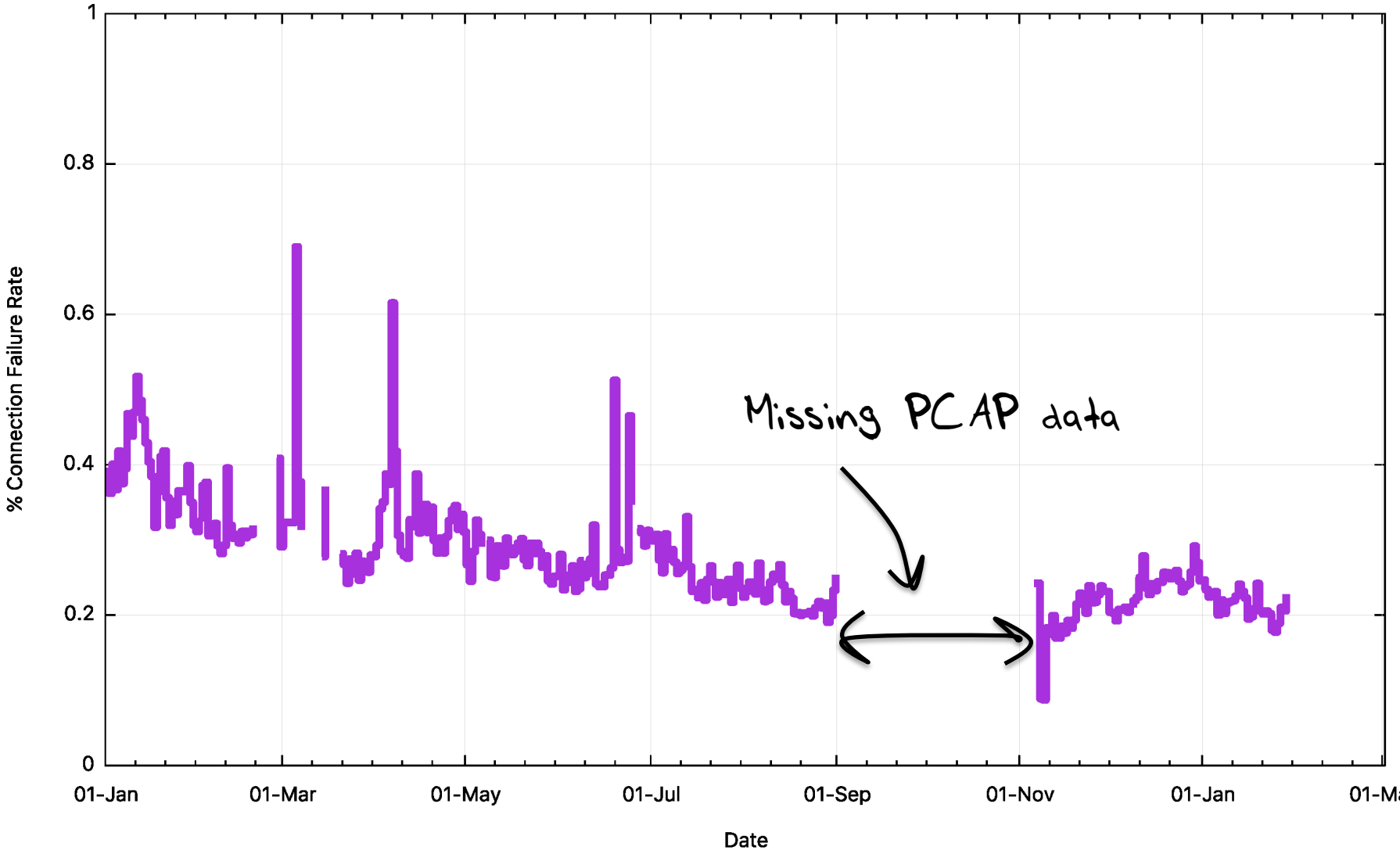
2011: failure rate 0.2%

2015:

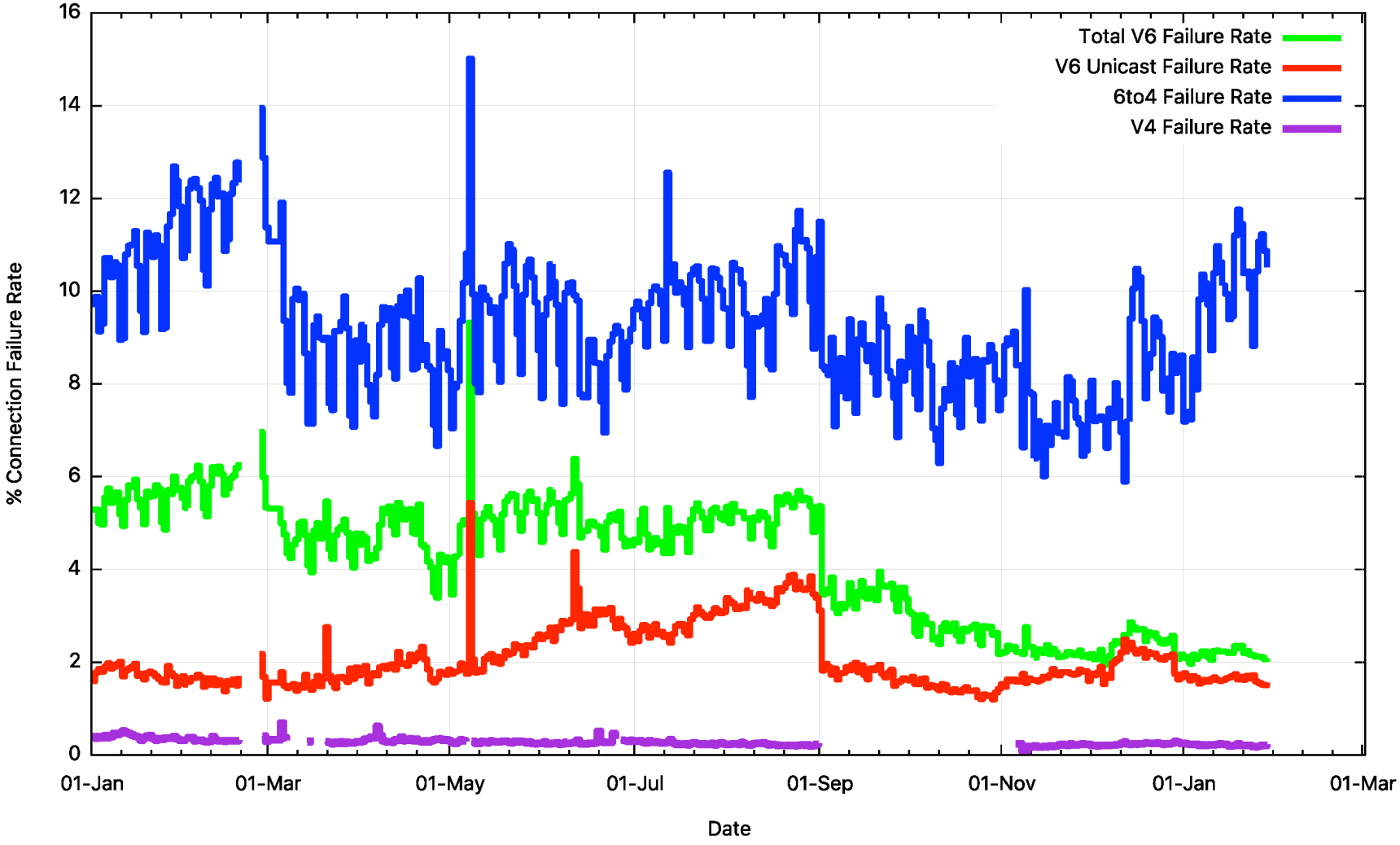
446,414,857 IPv4 endpoints

1,166,332Connection Failures (0.26%)

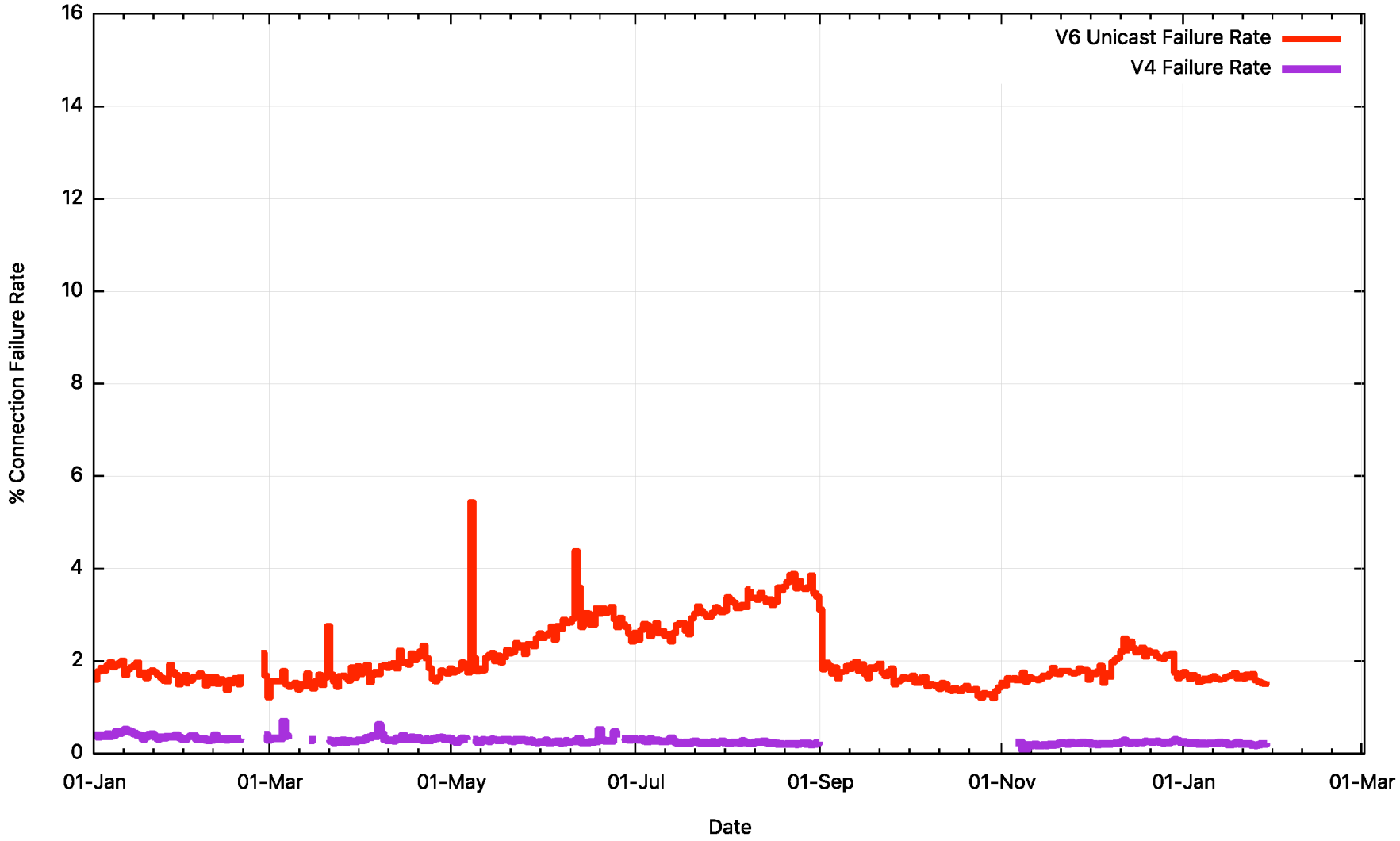
IPv4 Connection Failure



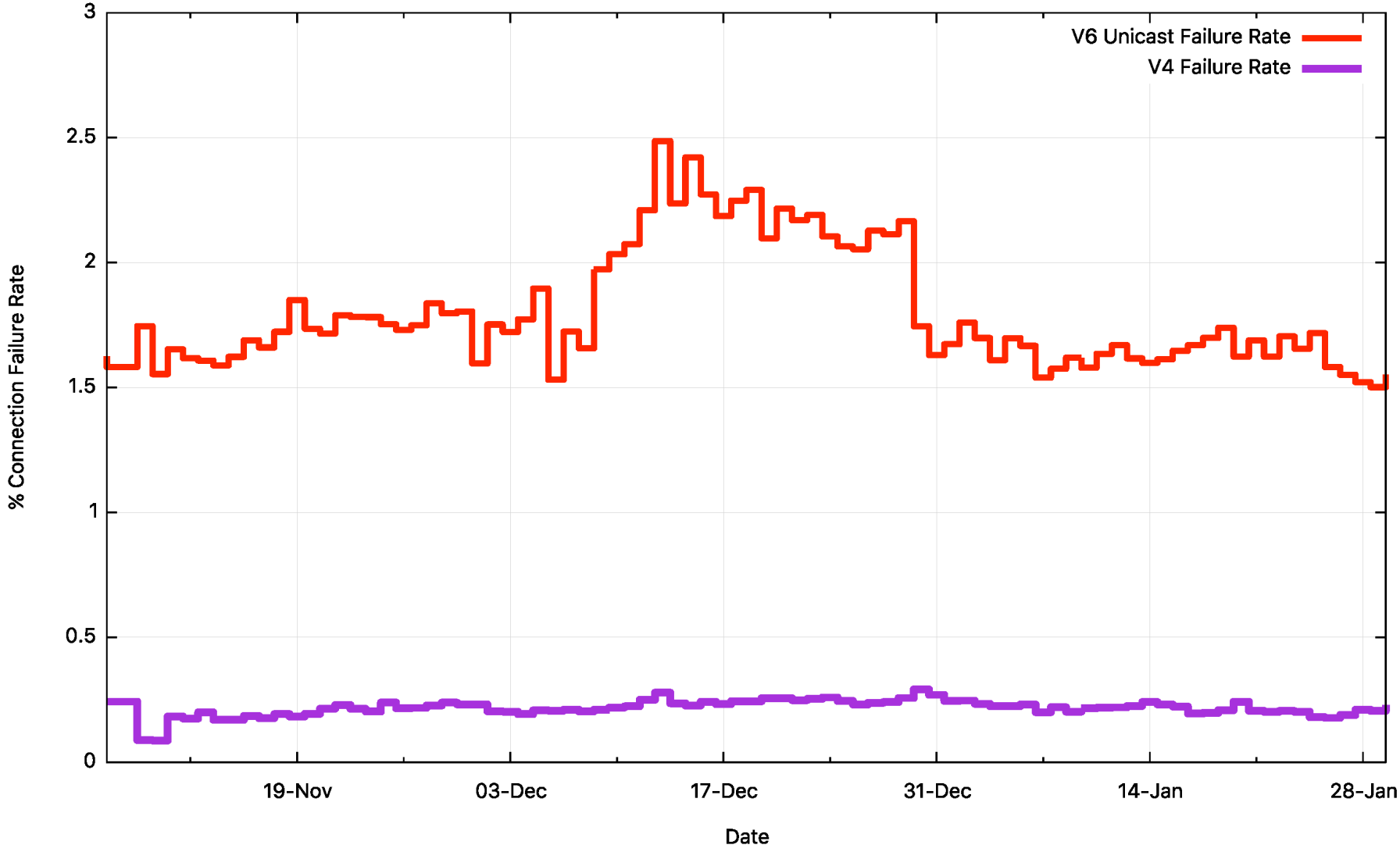
Comparison


Total V6 Failure Rate
V6 Unicast Failure Rate
6to4 Failure Rate
V4 Failure Rate
% Connection Failure Rate
16
14
12
10
8
6
4
2
0
01-Jan
01-Mar
01-May
01-Jul
01-Sep
01-Nov
01-Jan
01-Mar
Date

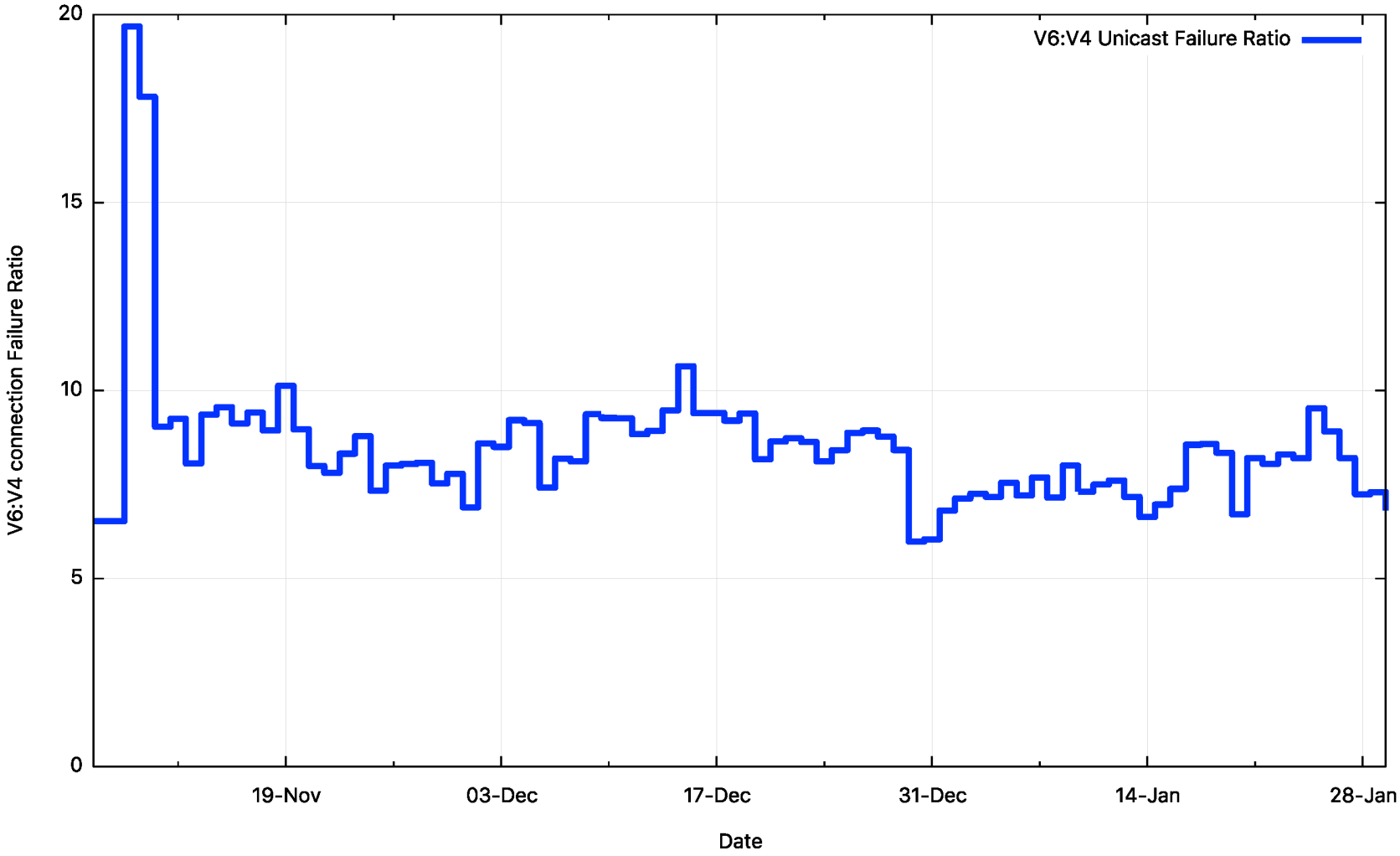
Comparison: Unicast



Comparison: Unicast



Comparison Ratio: Unicast



It's still not good!

IPv6 Unicast Failure rate: 1.6% (falling)

IPv4 Failure rate: 0.2% (steady)

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 S~~I~~YNs!

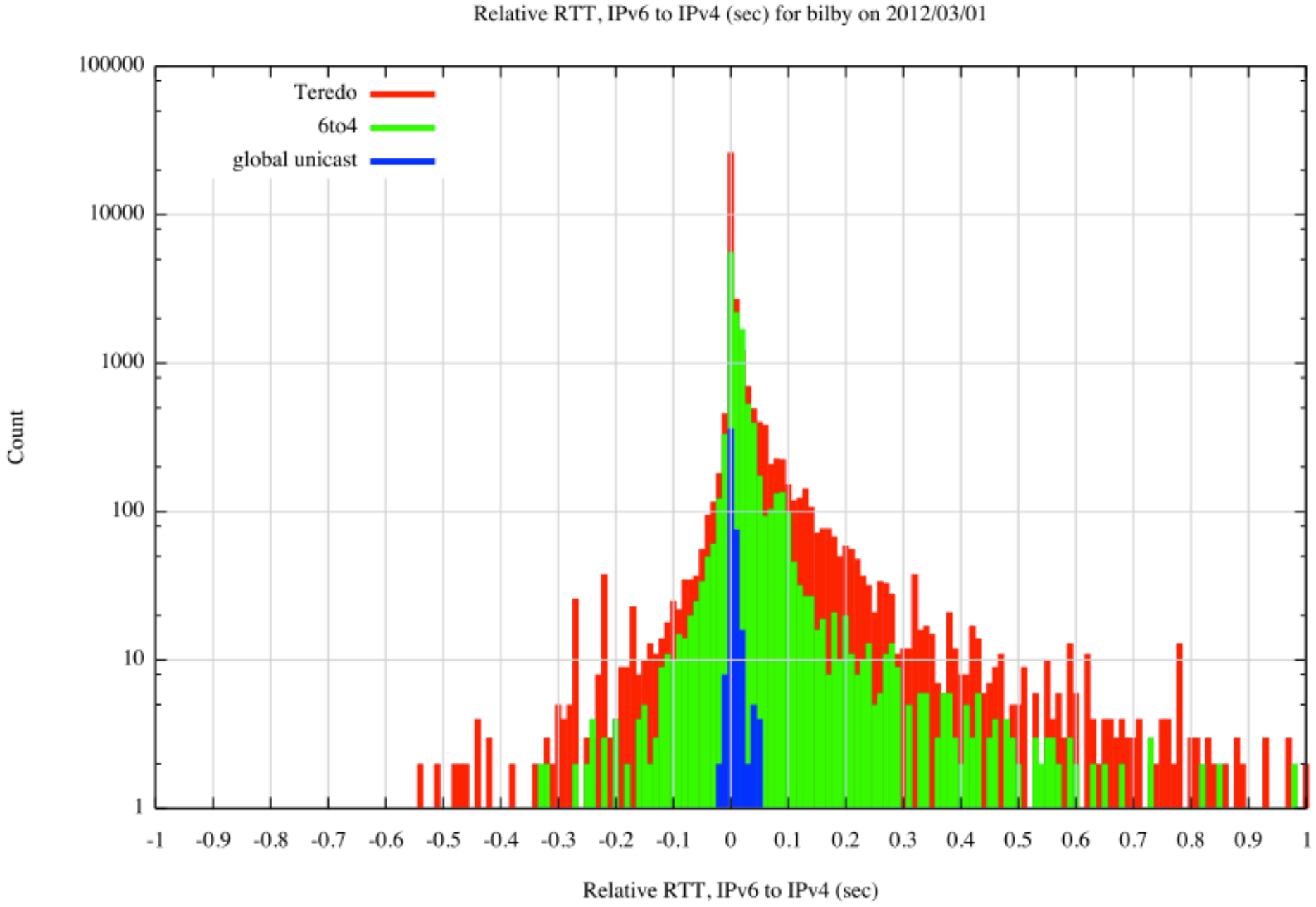
Why SYNs?

- 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

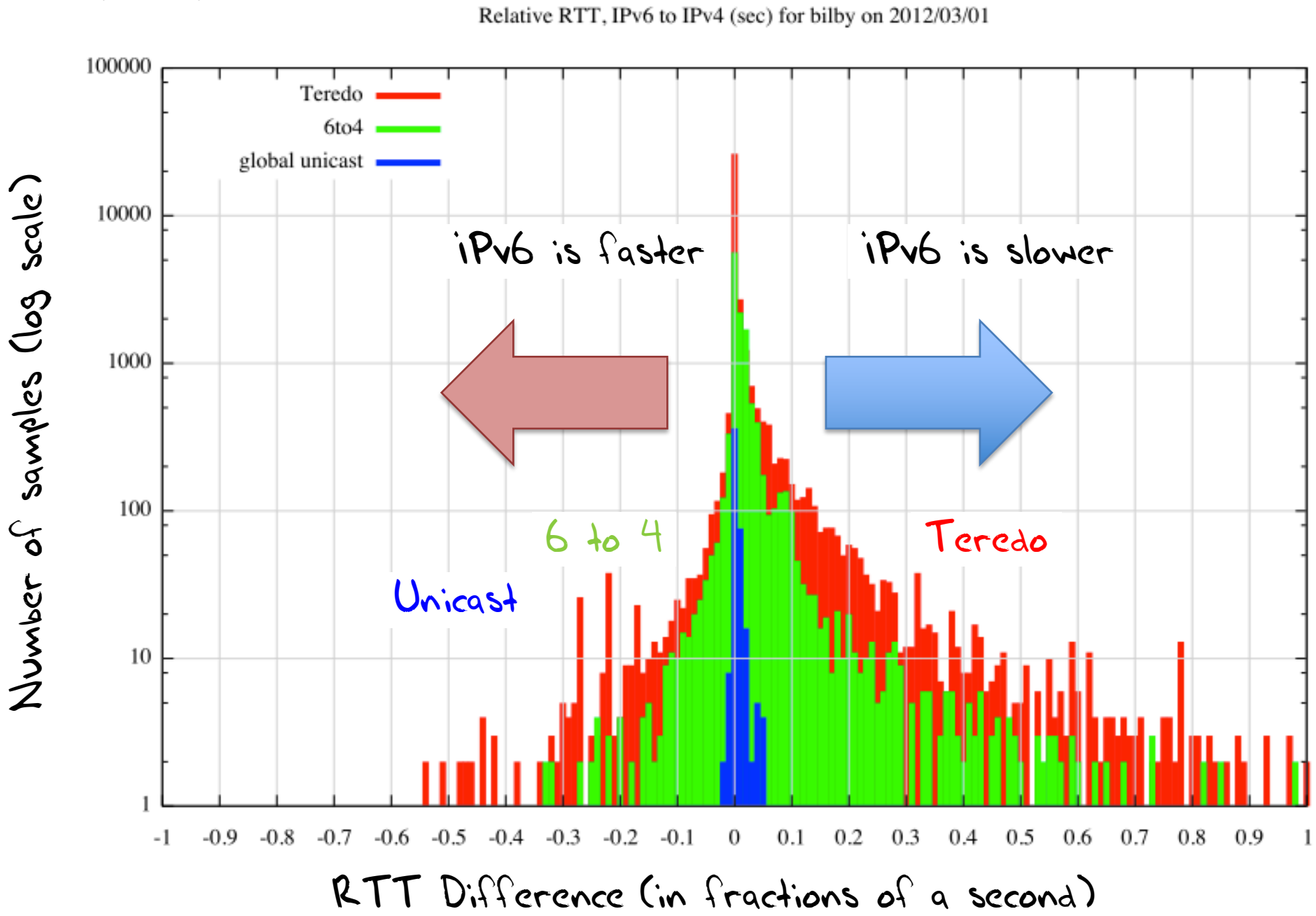
Generating a comparative RTT profile

- 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
  - Plot the difference in RTT in buckets

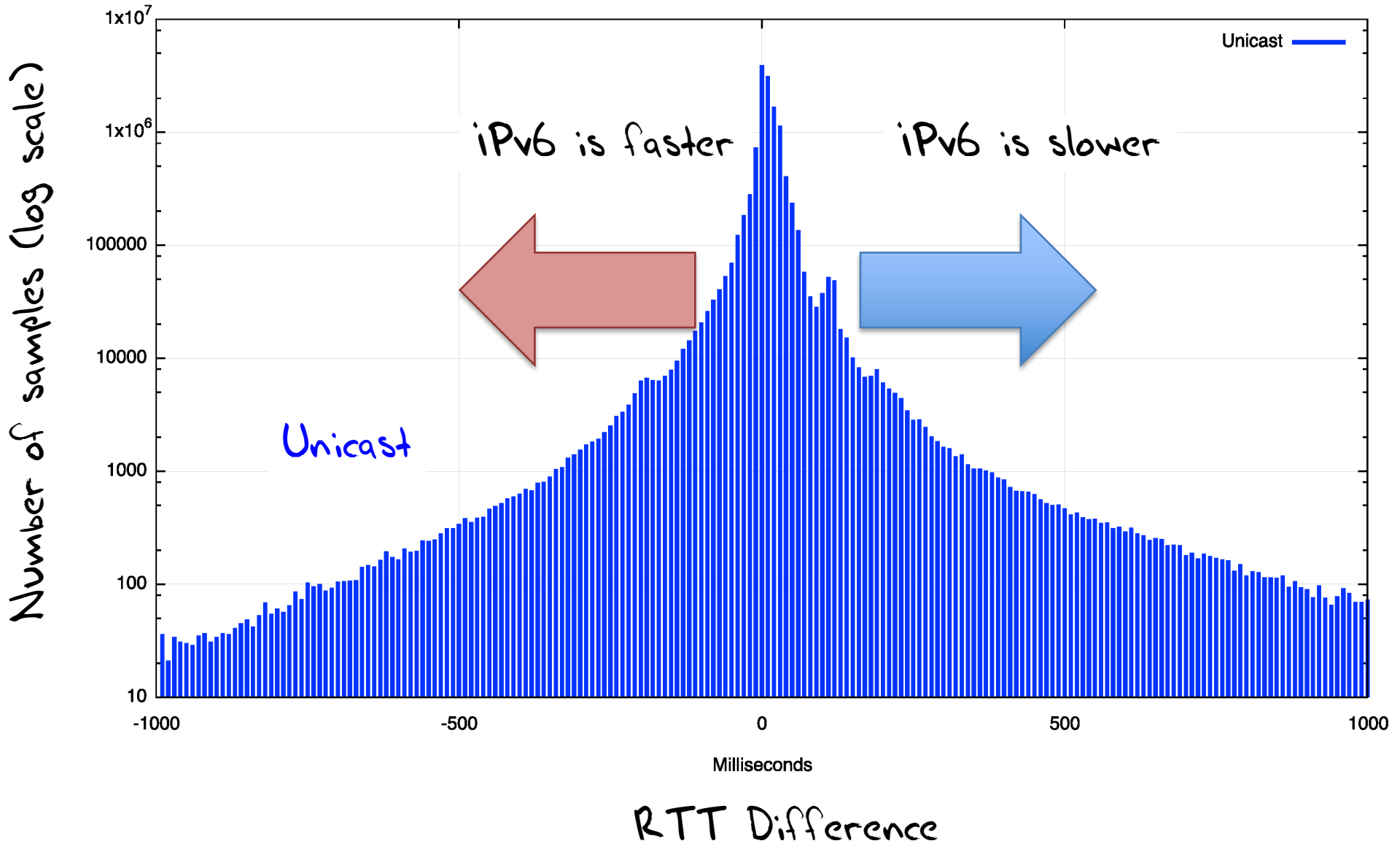
2012 Data


Relative RTT, IPv6 to IPv4 (sec) for bilby on 2012/03/01
Teredo
6to4
global unicast
Count
100000
10000
1000
100
10
1
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Relative RTT, IPv6 to IPv4 (sec)

2012 Data


Relative RTT, IPv6 to IPv4 (sec) for bilby on 2012/03/01
Teredo
6to4
global unicast
IPv6 is faster
IPv6 is slower
6 to 4
Teredo
Unicast
Number of samples (log scale)
100000
10000
1000
100
10
1
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
RTT Difference (in fractions of a second)

December 2015/January 2016



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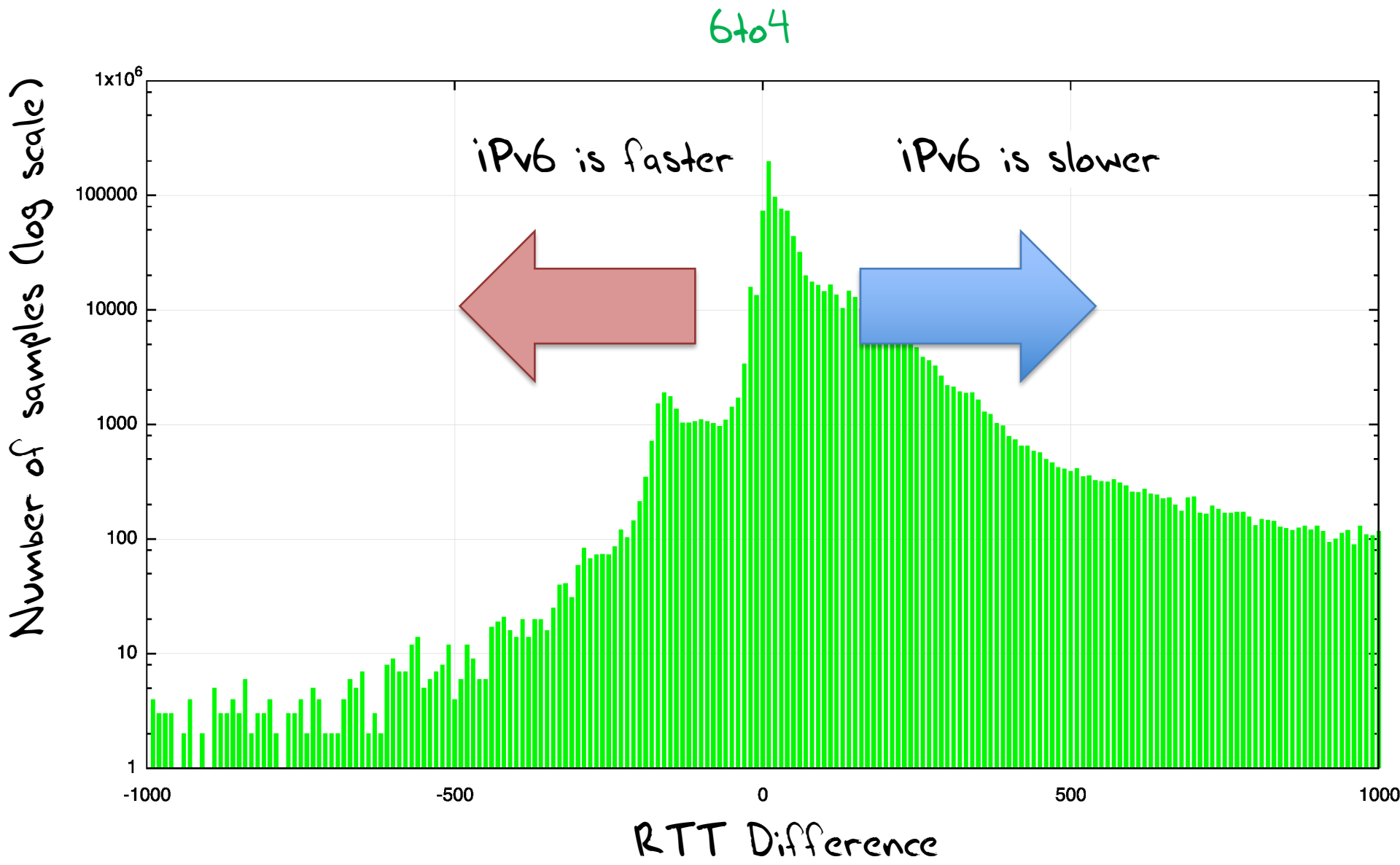

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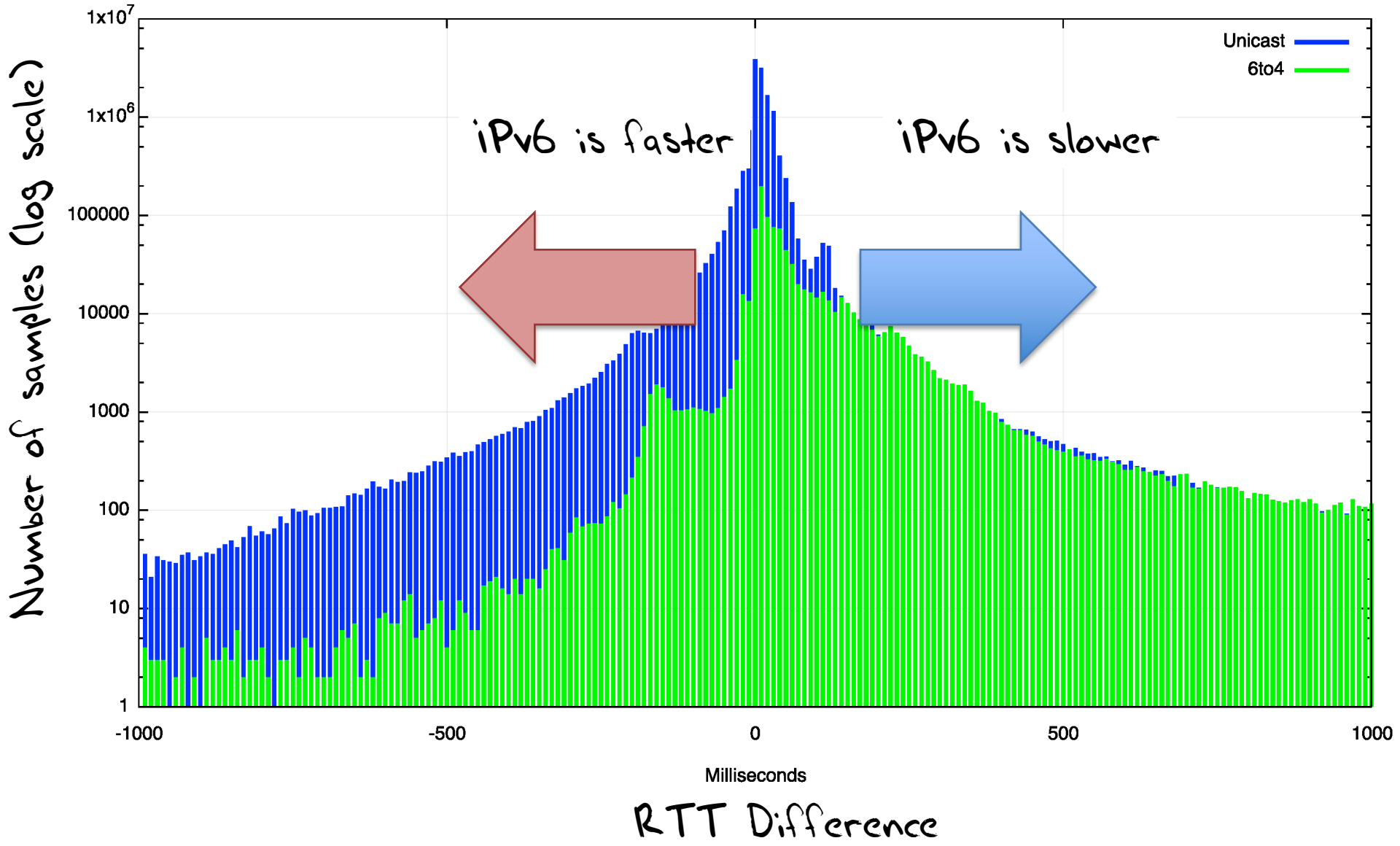
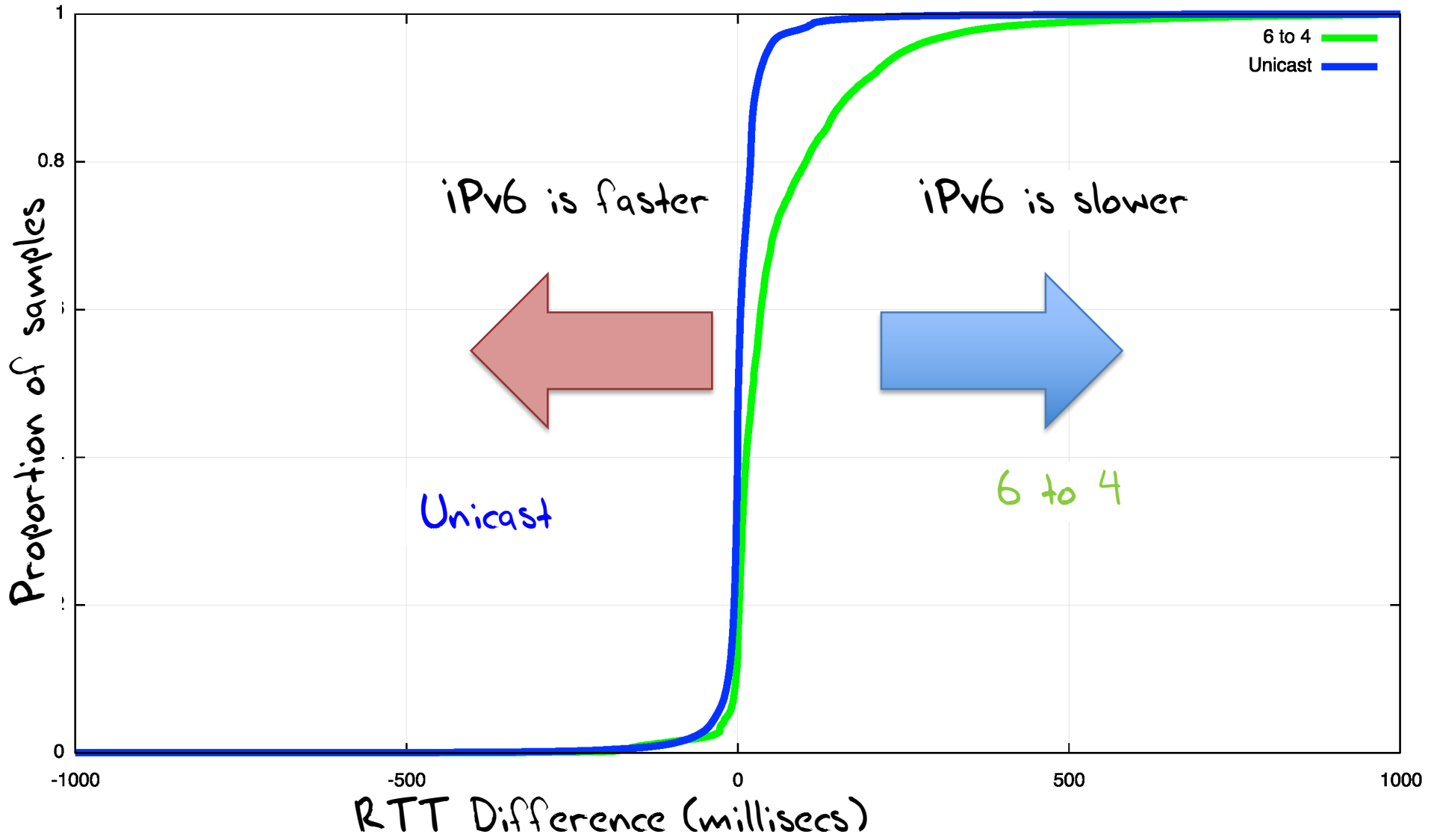


2015/6 RTT Data CDF



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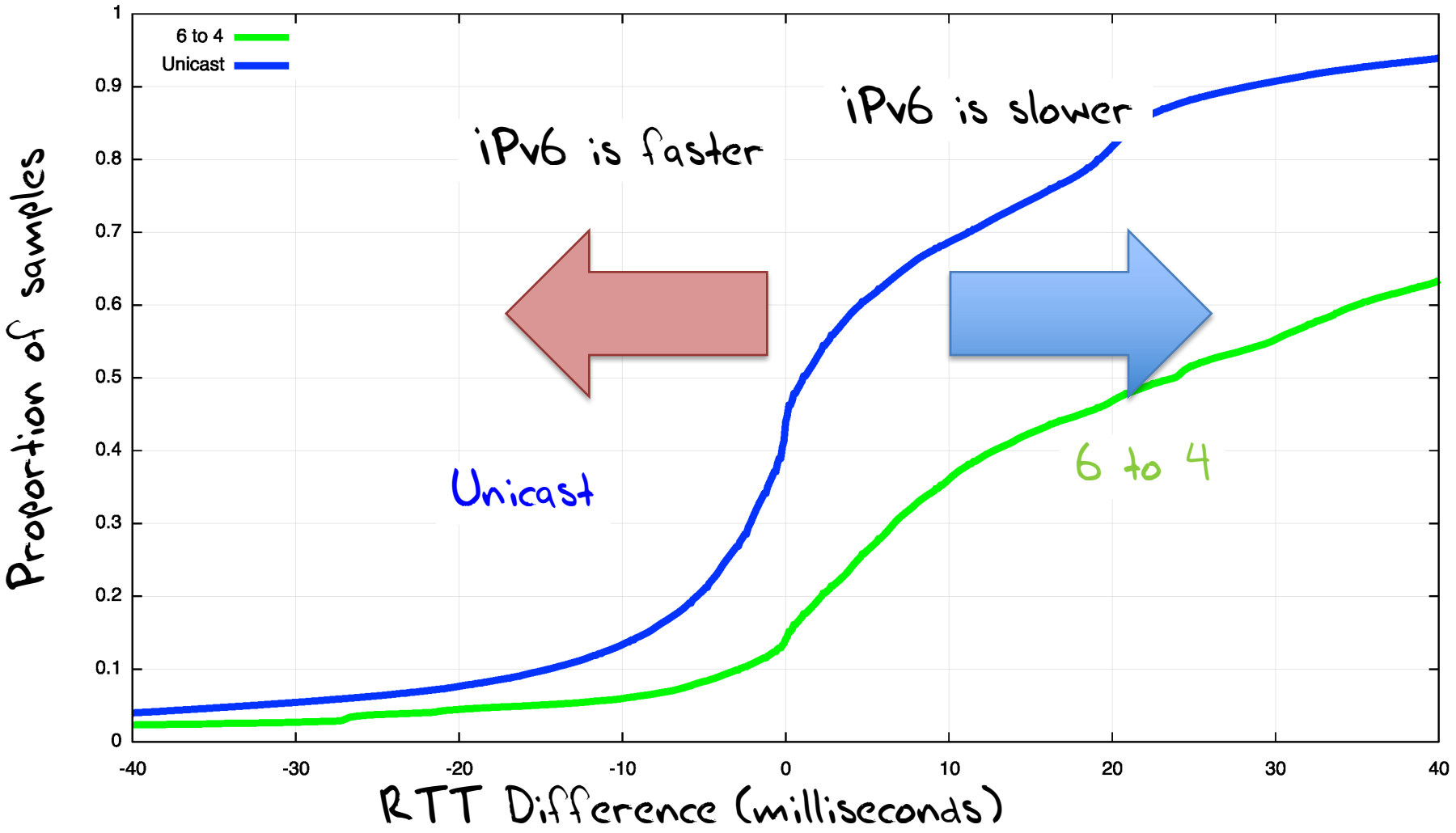
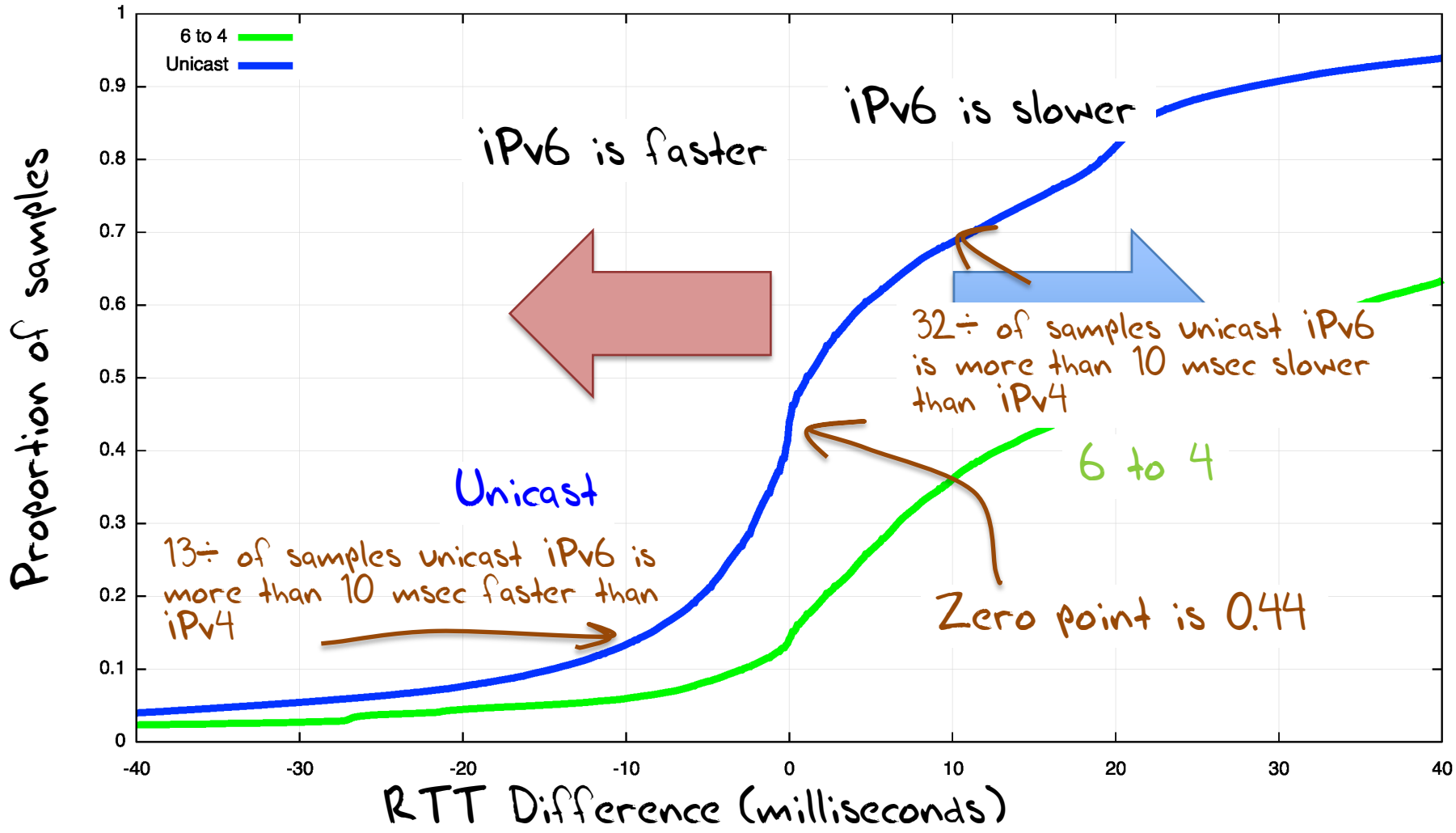


2015/6 RTT Data CDF



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 65% 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?