IPv6 Performance Measurement

February 2020

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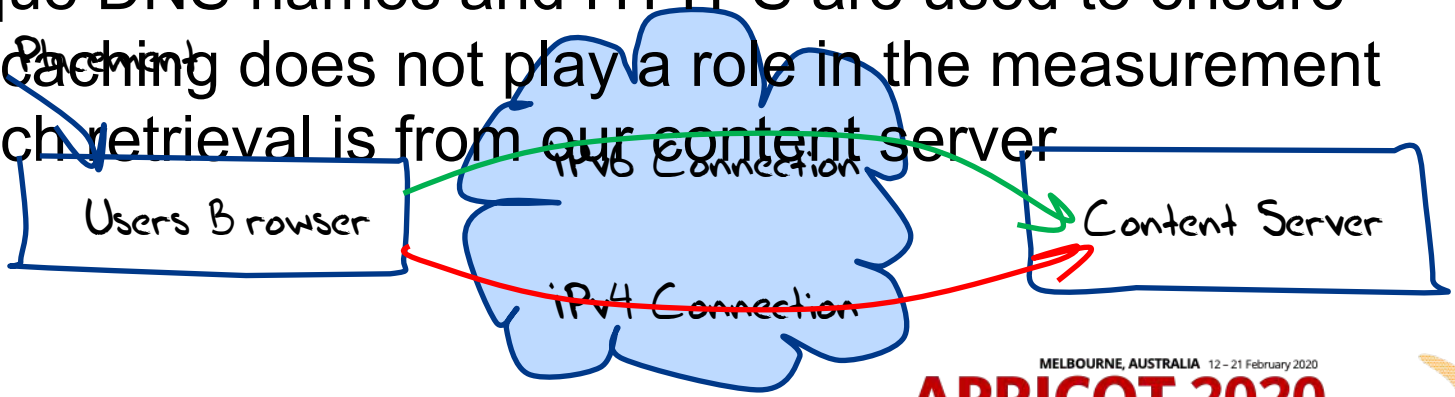
APNIC

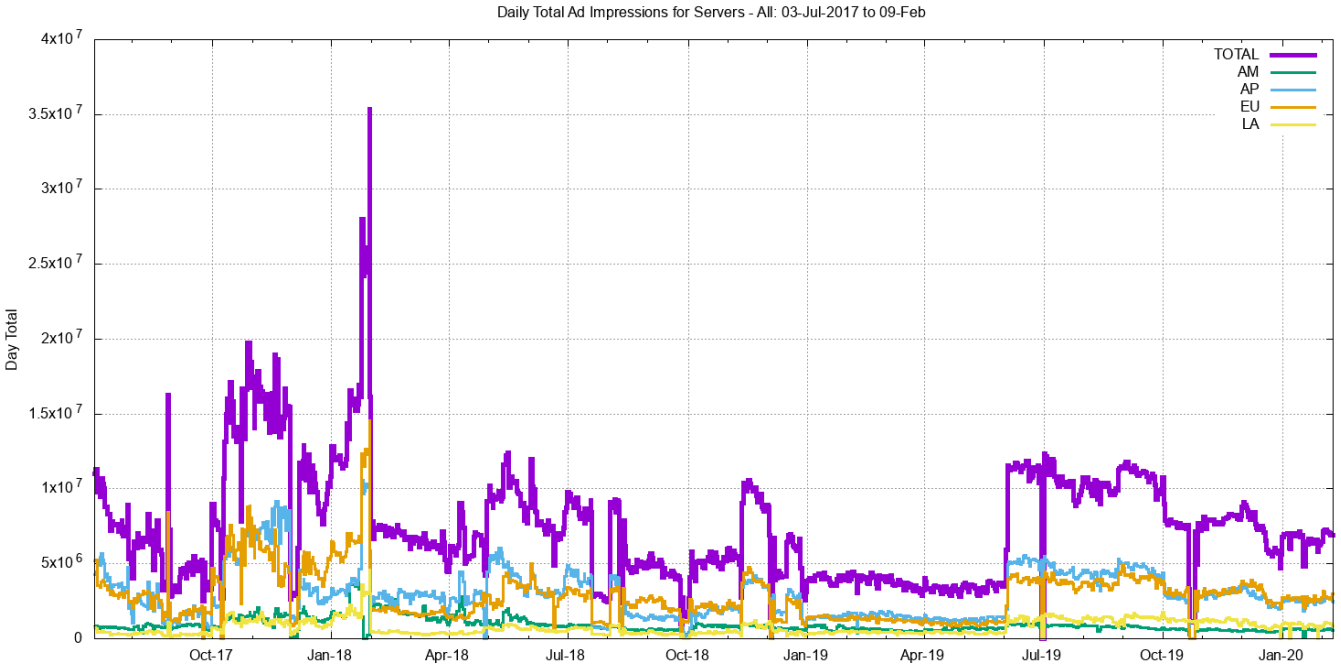
The Measurement

The endpoint that runs the experiment attempts to retrieve two URLs from the same remote server – one using IPv4 and the other using IPv6

– Unique DNS names and HTTPS are used to ensure that caching does not play a role in the measurement – each retrieval is from our content server



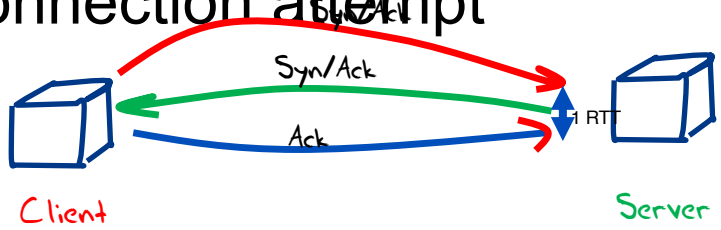
Measurement Volume



Ad Impressions per day for the period 2017 - 2020

The Measurement

- We perform full packet capture at the server
- Data analysis
  - We look at the SYN/ACK exchange at the start of the TCP session
  - A received SYN with no subsequent ACK is interpreted as a failed connection attempt



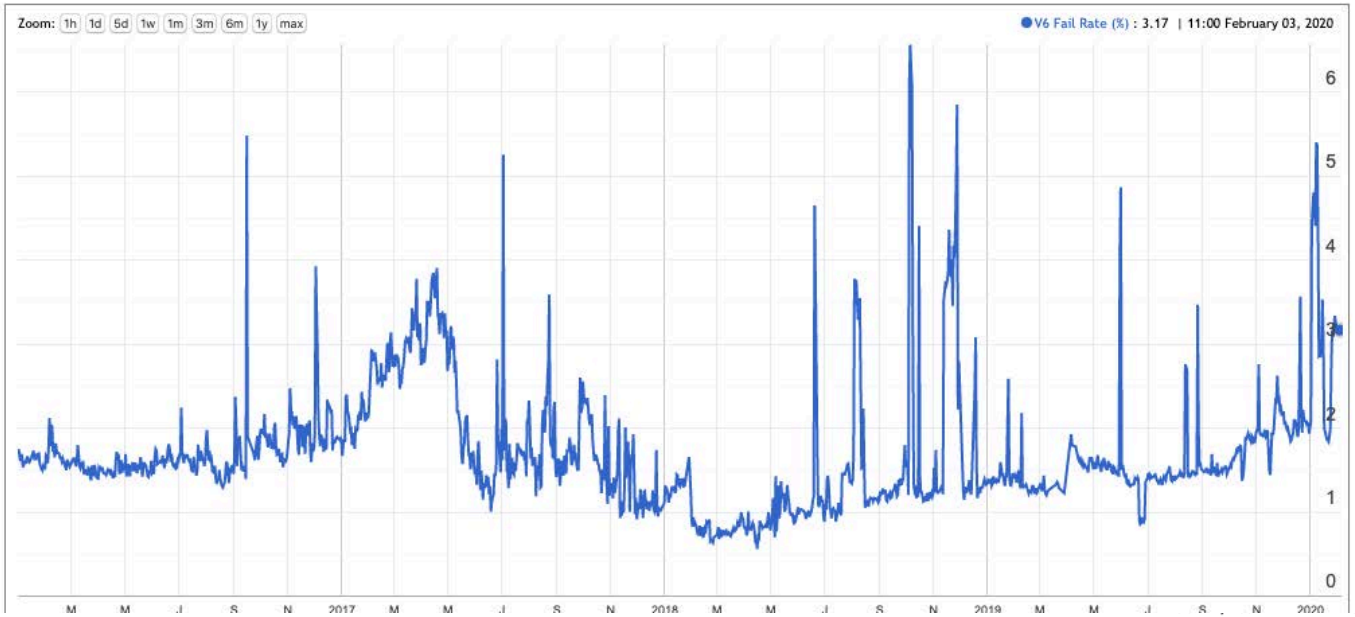
Analysis - Reliability

Why measure SYN handshake failure?

- In a dual stack environment many of the most widely used apps (browsers) use Happy Eyeballs to decide which protocol to select
- Happy Eyeballs bases its decision on the first protocol to complete a TCP SYN handshake
- So TCP handshake failure will strongly influence this decision

IPv6 TCP Connection Failure

Average V6 Connection Failure Rate for World (XA)



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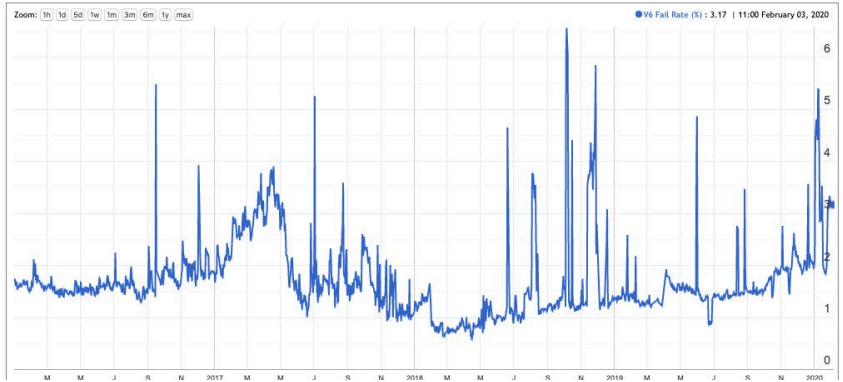

The global failure rate of some 2-3% is getting worse! As the IPv6 network is growing, its performance in terms of reliability is getting worse

What we are seeing is most likely a failure to deliver an IPv6 packet from the server to the endpoint

Possible reasons:

- Endpoint using an unreachable IPv6 address
- End site firewalls
- ??

IPv6 TCP Connection Failure

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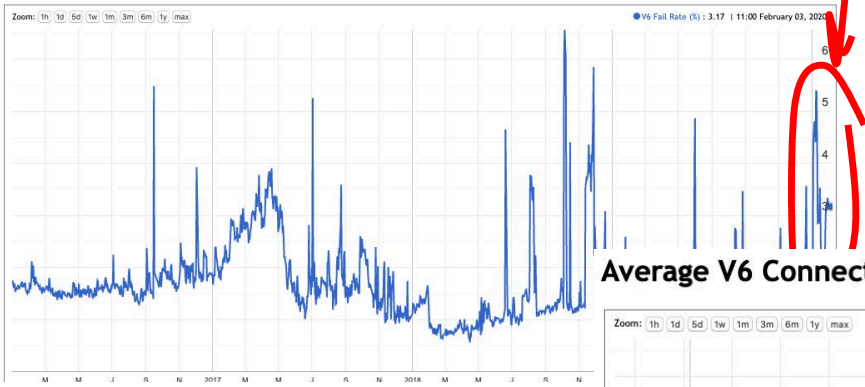
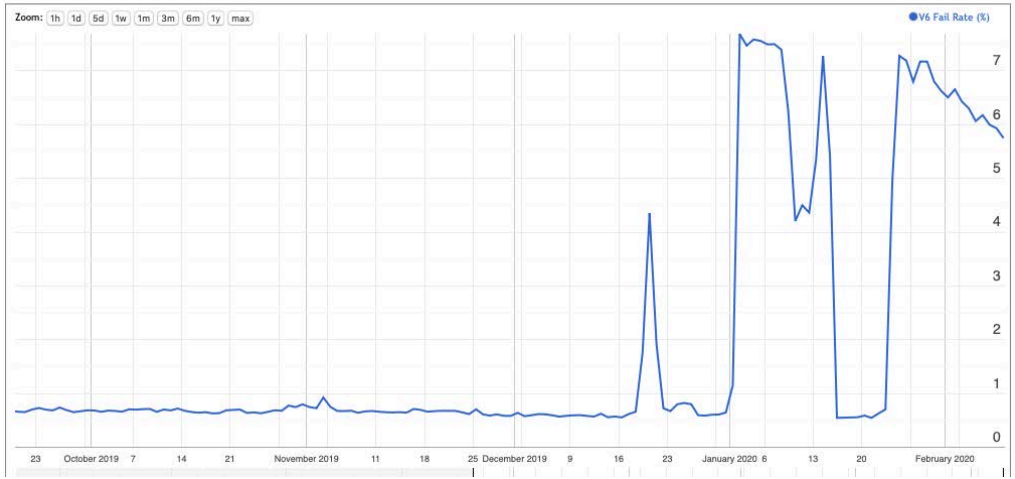


There have been some recent high noise periods

This is due to IPv6 routing instability in the North American network – parts of the IPv6 routing table appear to have been dropped for some destinations

Average V6 Connection Failure Rate for Northern America (XQ)



IPv6 TCP Connection Failure

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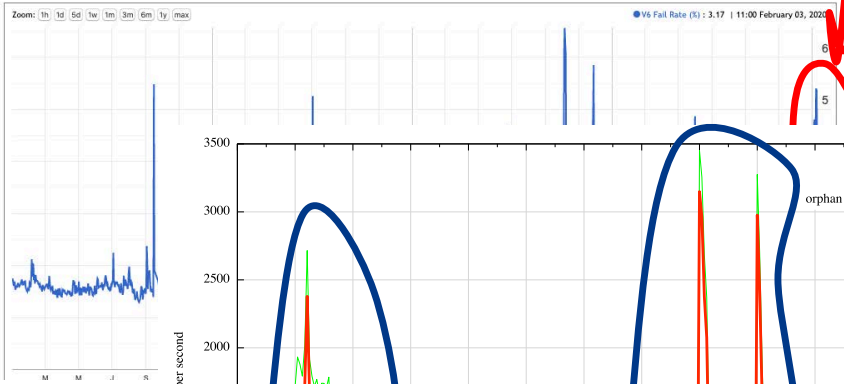

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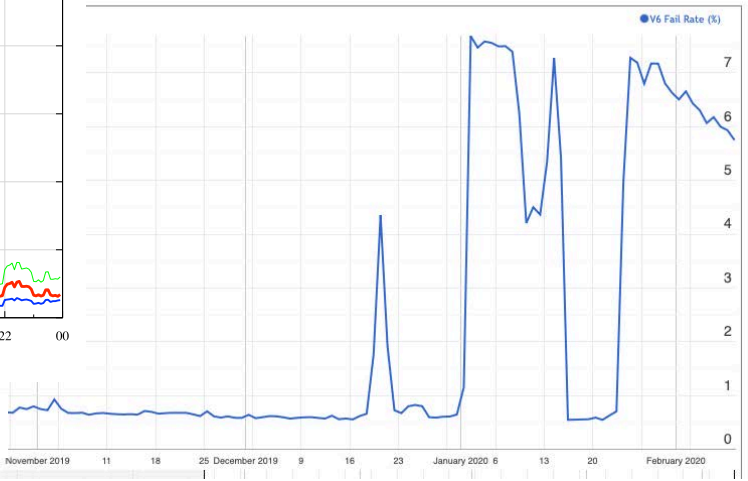
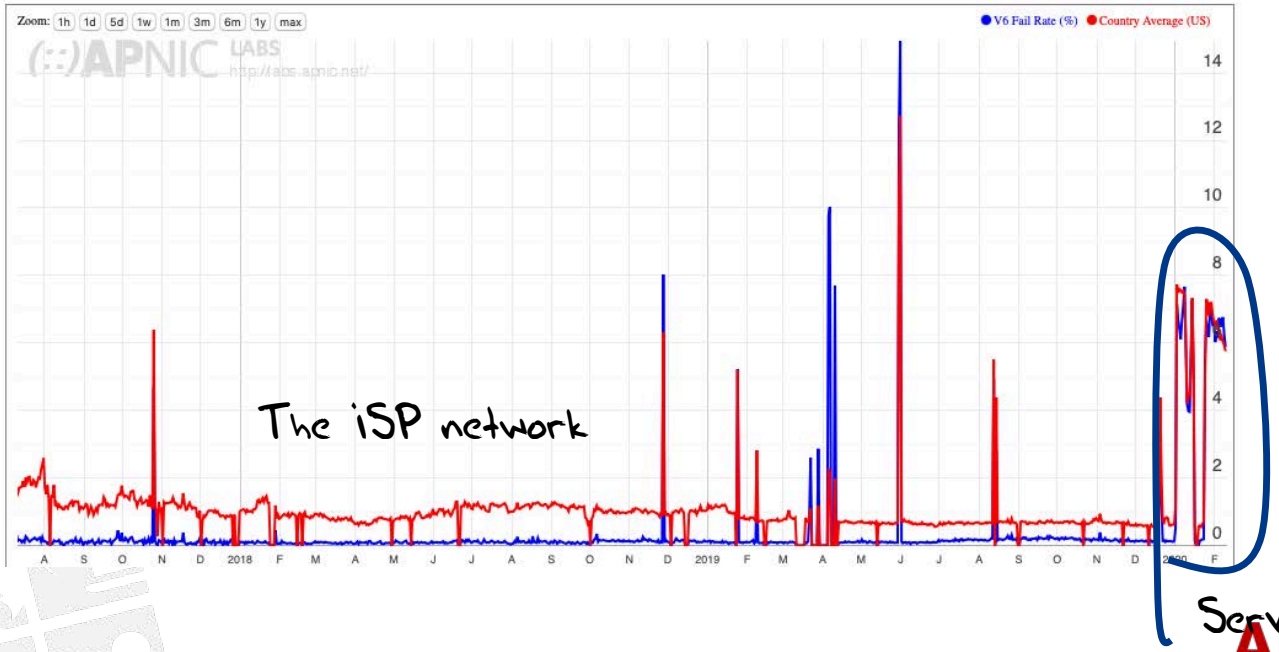


iPv6 instability over 24 hours

The Good

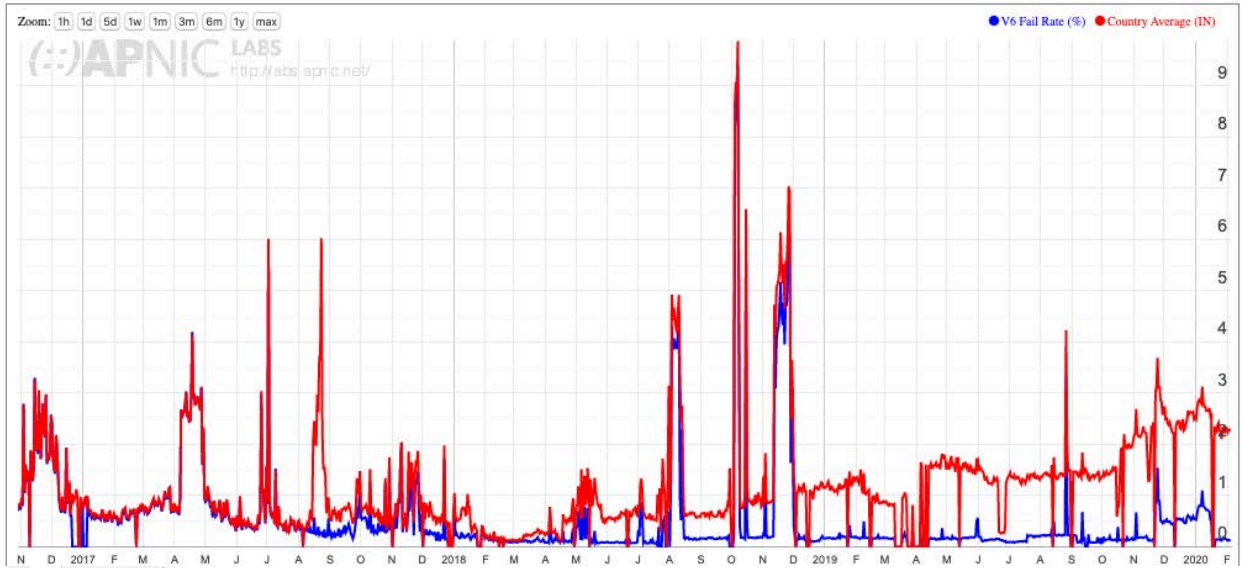
V6 Connection Failure Rate for AS21928: T-MOBILE-AS21928, United States of America (US)



This 464XLAT mobile network (T-Mobile) has remarkably small failure rates – the endpoints are connected via native IPv6 and as this is a mobile network there is only a small amount of customer-operated filtering middleware

The Good

V6 Connection Failure Rate for AS55836: RELIANCEJIO-IN Reliance Jio Infocomm Limited, India (IN)



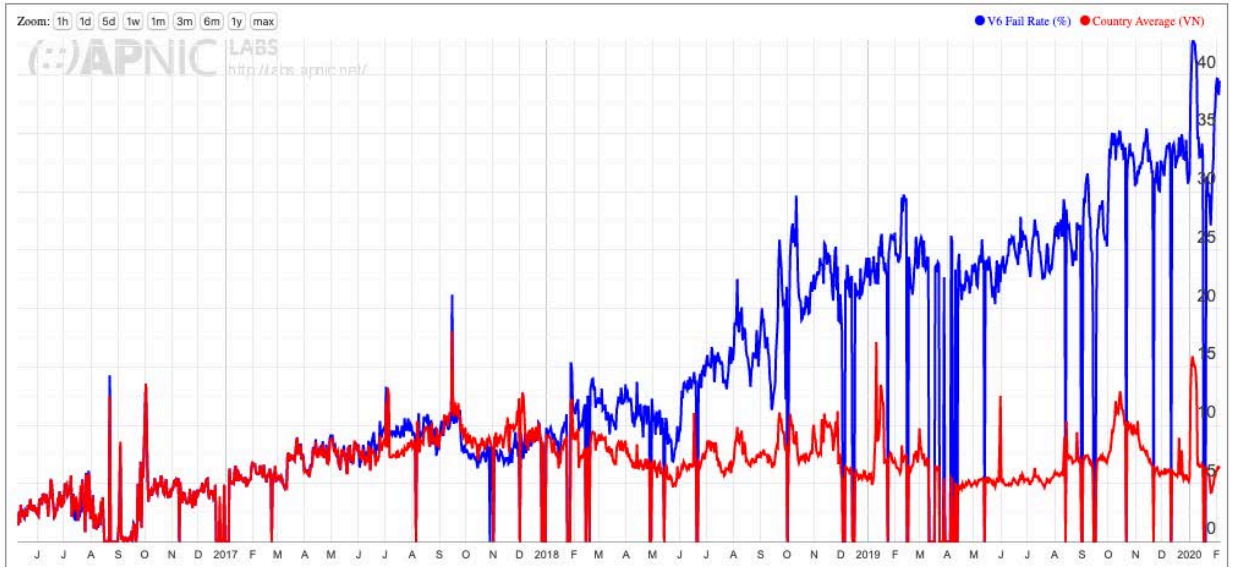
Similar story in India with Reliance JIO – the endpoints are connected via native IPv6 and as this is a mobile network there is only a small amount of customer-operated filtering middleware

464XLAT Performance

- These networks operate in a “native” IPv6 mode
- IPv6 connections to a server require no network processing and no client handling

The not quite so good

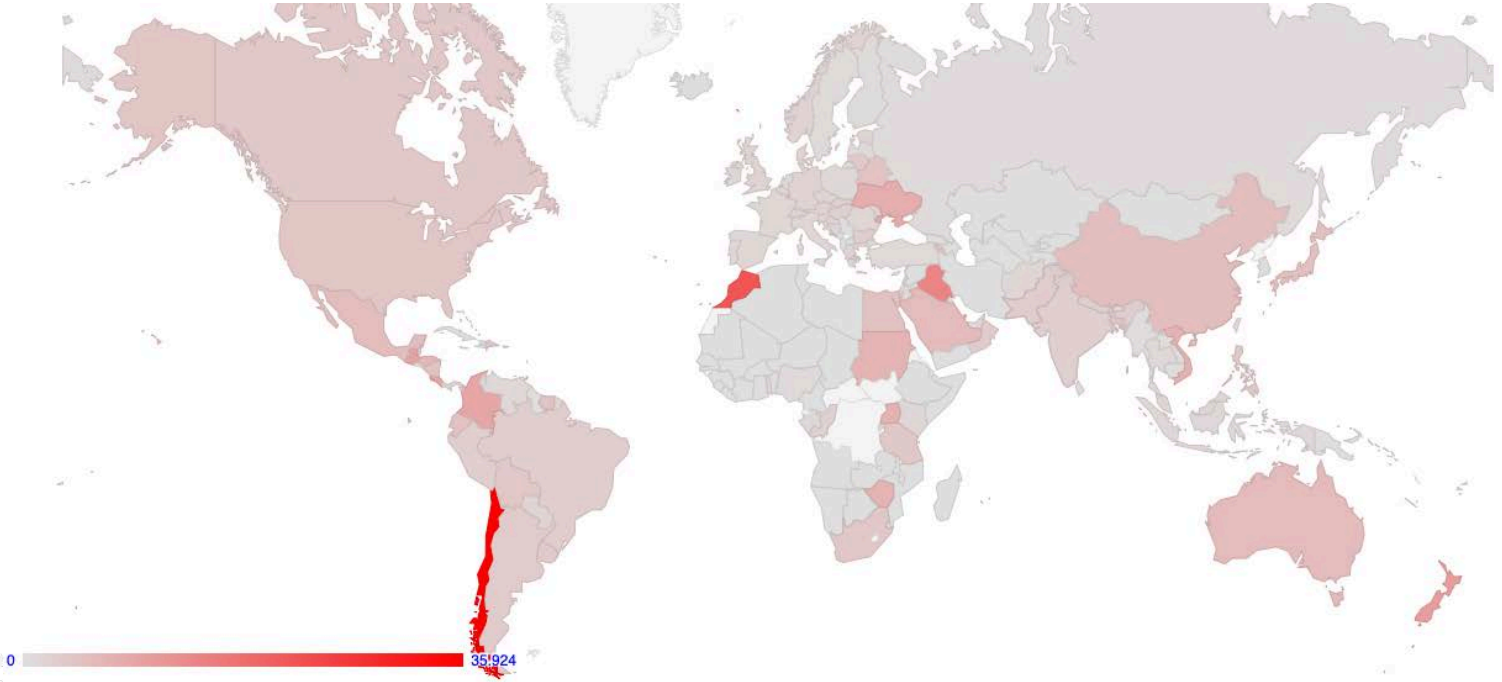
V6 Connection Failure Rate for AS18403: FPT-AS-AP The Corporation for Financing & Promoting Technology, Vietnam (VN)



January 2020 Stats

Code	Country	Avg RTT Diff (V6-V4)	Samples	Avg V6 Fail Rate	V6 Fails	V6 Samples	Dual Stack	Dual Stack (300ms)	V6 Use Rate
CL	Chile, South America, Americas	2.34 ms	708	33.14%	395	1,192	86.72%	90.25%	0.12%
CR	Costa Rica, Central America, Americas	-4.64 ms	219	13.27%	41	309	79.00%	85.39%	0.14%
MA	Morocco, Northern Africa, Africa	-24.73 ms	54	11.67%	7	60	90.74%	100.00%	0.01%
CO	Colombia, South America, Americas	7.67 ms	47,310	11.29%	8,084	71,578	48.54%	98.34%	2.57%
IQ	Iraq, Western Asia, Asia	-4.82 ms	36	11.11%	4	36	100.00%	100.00%	0.00%
FO	Faeroe Islands, Northern Europe, Europe	-11.23 ms	135	10.70%	20	187	80.74%	99.26%	6.36%
NZ	New Zealand, Australia and New Zealand, Oceania	-32.56 ms	17,722	10.64%	2,651	24,907	68.45%	87.08%	24.84%
GT	Guatemala, Central America, Americas	1.64 ms	22,598	10.27%	3,254	31,697	31.93%	99.19%	11.30%
SD	Sudan, Northern Africa, Africa	15.58 ms	33	10.00%	5	50	57.58%	100.00%	0.04%
UA	Ukraine, Eastern Europe, Europe	-2.11 ms	5,436	8.64%	557	6,447	65.18%	95.81%	0.24%
UG	Uganda, Eastern Africa, Africa	-4.81 ms	112	7.64%	11	144	33.04%	94.64%	0.17%
AM	Armenia, Western Asia, Asia	-6.88 ms	6,520	7.43%	664	8,941	66.26%	99.17%	7.13%
QA	Qatar, Western Asia, Asia	120.15 ms	46	7.02%	4	57	13.04%	97.83%	0.03%
ZW	Zimbabwe, Eastern Africa, Africa	-13.01 ms	4,058	7.00%	390	5,575	75.18%	89.35%	10.47%
VN	Vietnam, South-Eastern Asia, Asia	-6.35 ms	999,609	6.74%	90,799	1,346,562	46.72%	98.45%	42.74%
SX	Sint Maarten (Dutch part), Caribbean, Americas	-53.84 ms	15	6.45%	22	341	53.33%	100.00%	0.47%
TT	Trinidad and Tobago, Caribbean, Americas	-32.94 ms	15,603	6.33%	1,243	19,627	89.08%	99.15%	22.72%
MX	Mexico, Central America, Americas	-33.72 ms	1,104,014	6.11%	90,783	1,485,825	81.91%	99.03%	32.69%
SA	Saudi Arabia, Western Asia, Asia	-20.90 ms	124,098	5.64%	9,697	171,984	89.34%	98.03%	13.39%
CN	China, Eastern Asia, Asia	82.75 ms	474,004	5.45%	38,838	713,271	42.07%	84.75%	16.36%
EG	Egypt, Northern Africa, Africa	-39.85 ms	136,429	5.36%	9,799	182,723	82.36%	99.07%	11.14%
BY	Belarus, Eastern Europe, Europe	-1.54 ms	91	5.32%	5	94	40.66%	95.60%	0.02%

The Bigger Picture of IPv6 Connection Failure



Comment

- For many end-users their IPv6 service looks pretty broken
  - The combination of Dual Stack and Happy Eyeballs masks the problem so that the user does not experience a degraded service
  - But this only will work while Dual Stack is around
- Other ISPs have managed to do a much better job, such as in the India, Iceland, Australia and Korea and the IPv6 connection failure rates are close to experimental noise levels

Transition Technologies

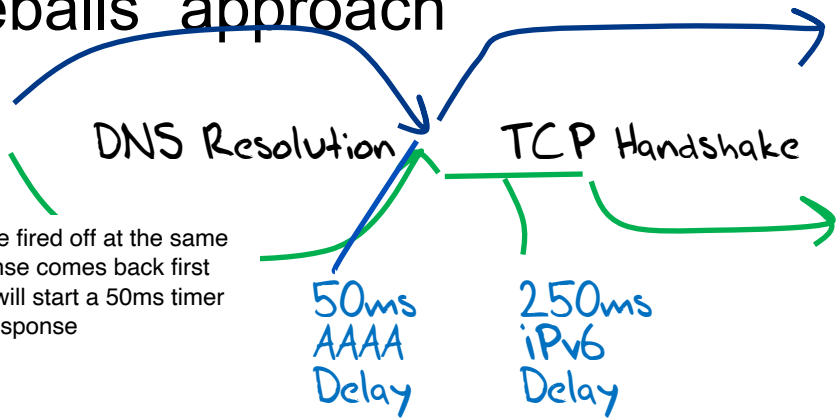
- Stateful transition technologies that involve protocol translation show higher levels of instability
- Translation technologies that require orchestration of DNS and network state are also more unstable

Dual Stack is NOT the Goal

- Despite all the grim predictions that IPv4 will be around for a long time to come, the aim of this transition is NOT to make Dual Stack work optimally
- The goal is to automatically transition the network to operate over IPv6
- The way to achieve this is for client systems to prefer to use IPv6 whenever it can

Happy Eyeballs

- An unconditional preference for IPv6 can lead to some very poor user experience instances
  - Linux uses a 108 second connection timer, for example
- Applications (particularly browsers) have used a “Happy Eyeballs” approach



DNS A and AAAA are fired off at the same time – if the A response comes back first then the application will start a 50ms timer to wait for a AAAA response

A TCP session will be started in IPv6 if there is a IPv6 address record. If the handshake is not completed within 250 ms then an IPv4 TCP session is also fired off

Tuning IPv6 for Happy Eyeballs

- When connecting to a remote dual stack service, the Routing Path selection for IPv6 should be similar to IPv4
- Where there are path deviations, the path discrepancy should be contained

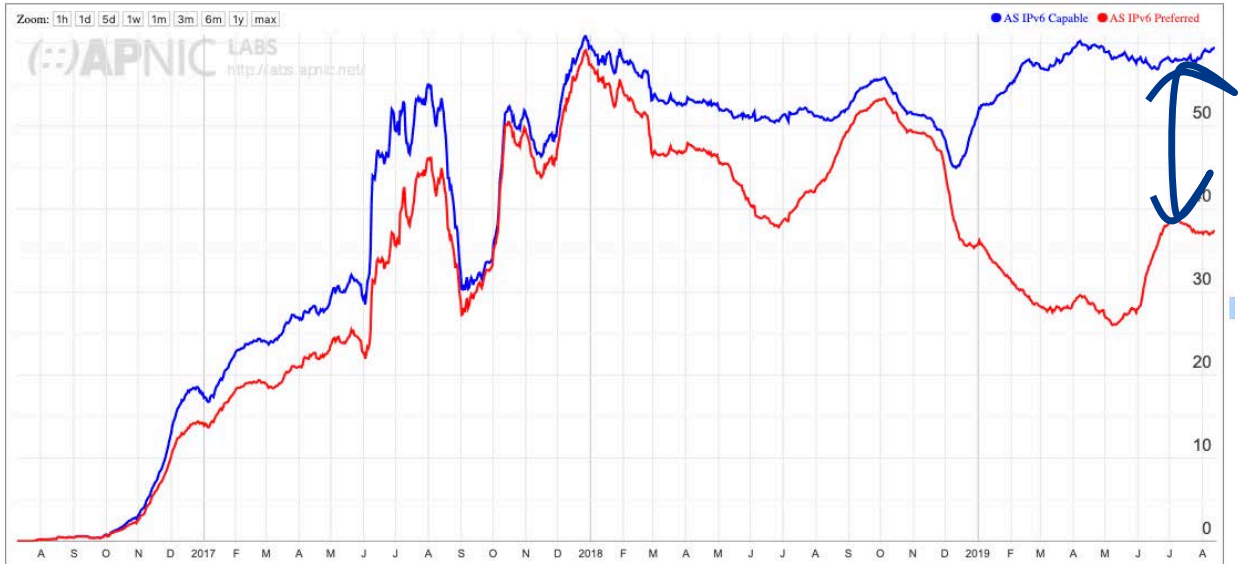
- This is not always the case…

India, late 2016

Use of IPv6 for India (IN)

Vodaphone New Zealand - 2019

IPv6 Per-Country Deployment for AS9500: VODAFONE-TRANSIT-AS
Vodafone NZ Ltd., New Zealand (NZ)



Sometimes it's the DNS!

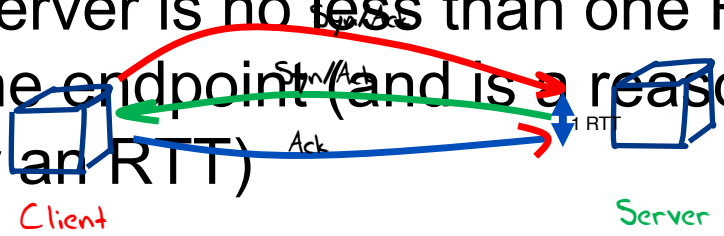
- Happy Eyeballs assumes that the time to resolve an A and a AAAA record are within 50 msecs of each other
- The client generates a query for the A record and a second query for a AAAA record at the same time
- The recursive resolver does not necessarily process the two requests in parallel:
  - A QNAME minimisation resolver may use A queries to walk the DNS hierarchy
  - A DNS-based content filter may use A queries to determine the outcome

3 Suggestions to Assist IPv6 Robustness

- Avoid stateful IPv6 -> IPv4 transition mechanisms if possible – if you can operate IPv6 in native mode all the better!
- Avoid using IPv6-in-IPv4 encapsulations
  - Not only are tunnels unstable, but the reduced IPv6 MTU may cause problems with extension header based packet discard
- Keep IPv4 and IPv6 paths congruent if possible
  - Yes, this can be really challenging for multi-homed

Speed Measurement

- We perform full packet capture at the server
- Data analysis
  - We look at the SYN/ACK exchange at the start of the TCP session
  - The time between receipt of the SYN and the subsequent ACK at the server is no less than one RTT between the server and the endpoint (and is a reasonable first order substitute for an RTT)

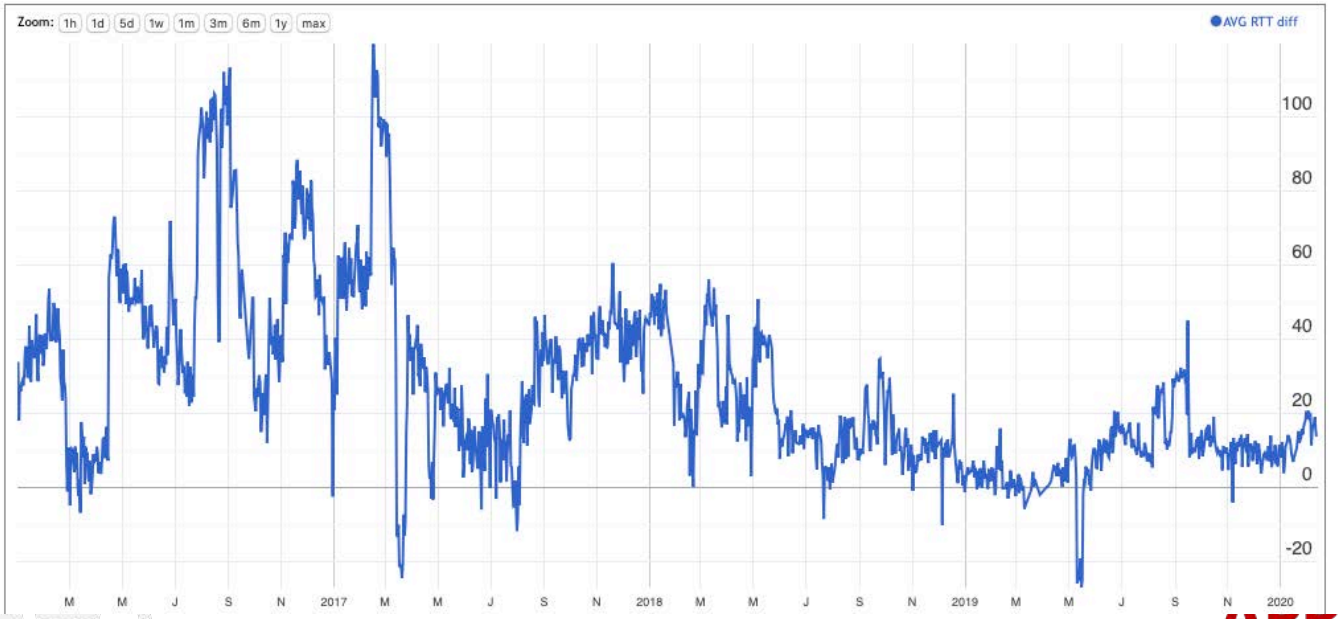


Analysis - Speed

- Why measure only the handshake delay? Why not measure a larger data transfer?
- Because in the end host and the server the same TCP version is used on top of IPv4 and IPv6
  - If the end to end paths are the same in IPv4 and IPv6 we would see precisely the same session throughput
- RTT and packet loss probability determine session throughput
  - In this experiment we use the RTT as in indicator of path

Worldwide RTT Diff Performance

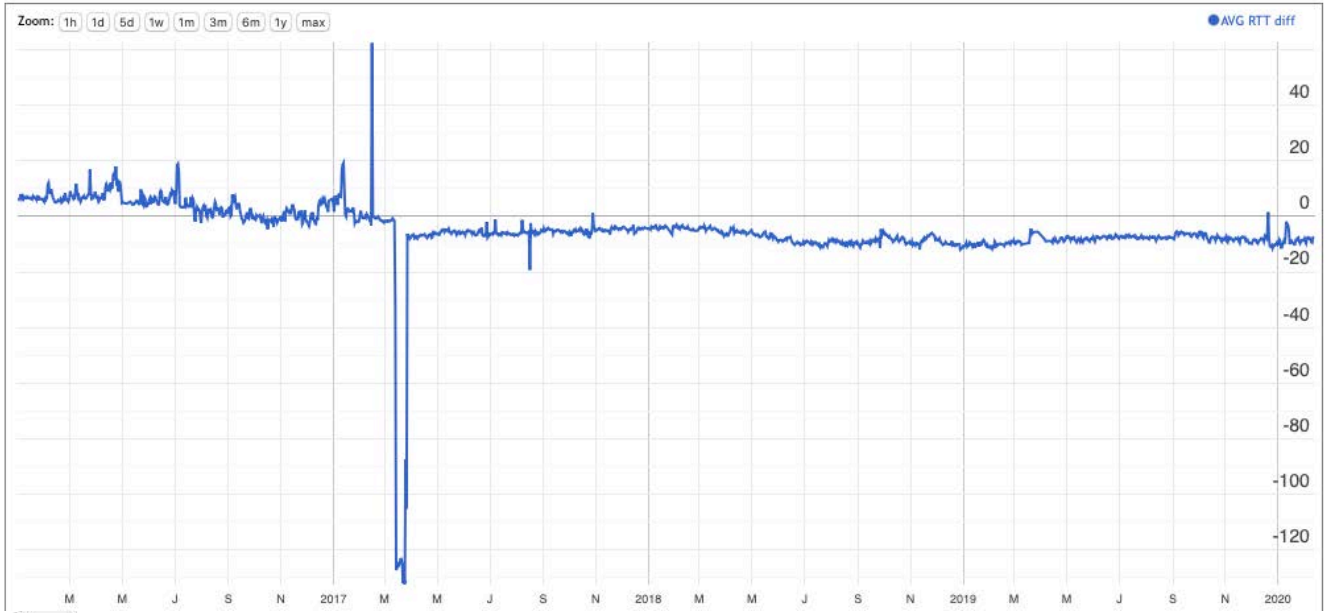
Average RTT Difference (ms) (V6 - V4) for World (XA)



IPv4 is consistently faster than IPv6 on average

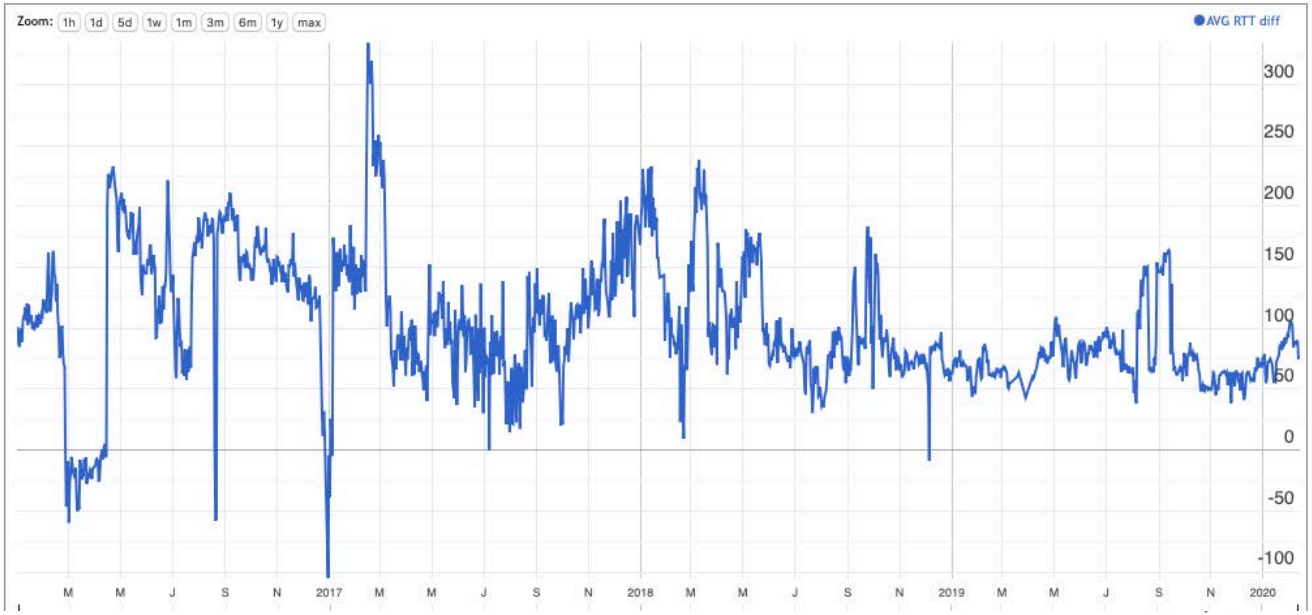
US IPv6 Network

Average RTT Difference (ms) (V6 - V4) for United States of America (US)

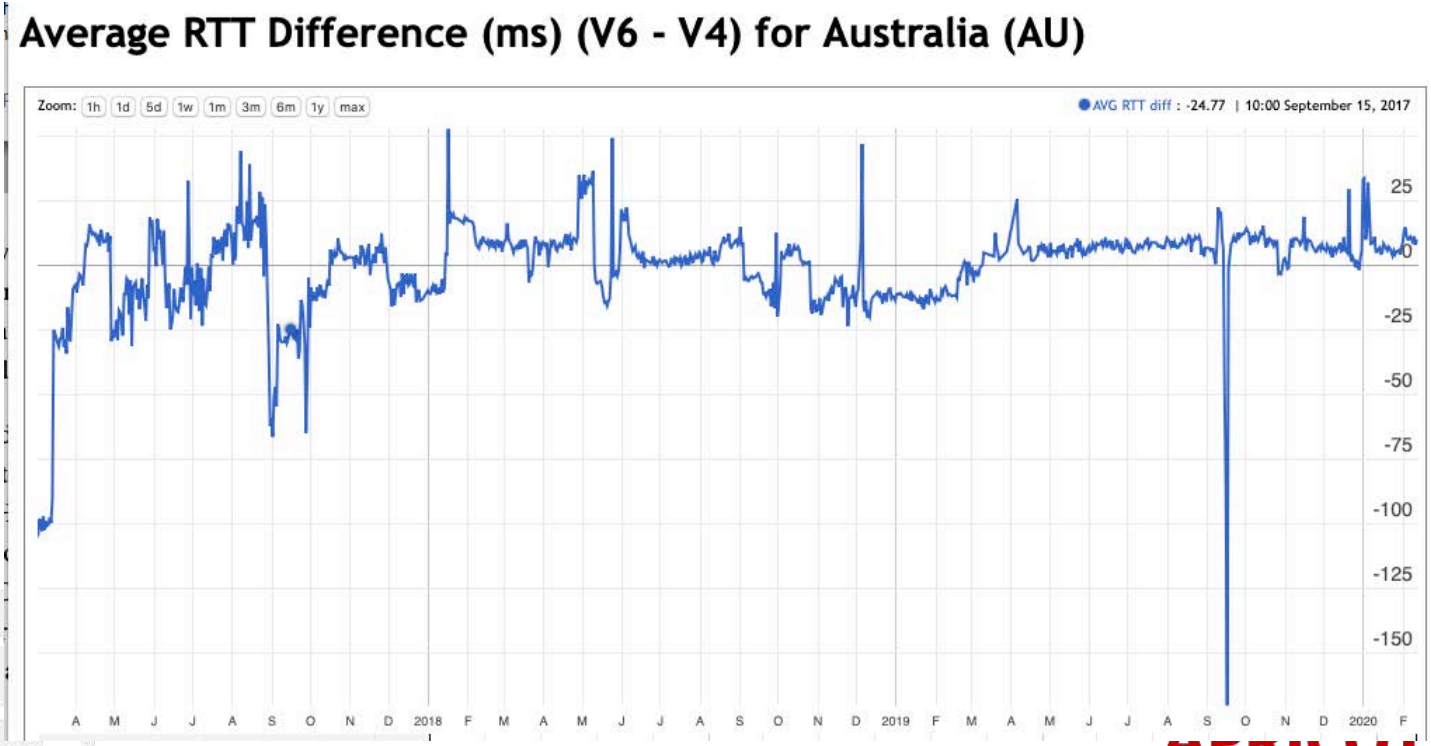


China's IPv6 Network

Average RTT Difference (ms) (V6 - V4) for China (CN)



Australia's IPv6 Network

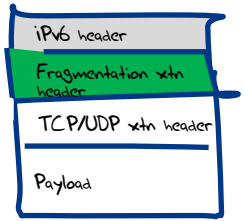


This is a localised measurement

- This is the result of millions of endpoints heading to one of 4 measurement points
  - If IPv4 and IPv6 paths are aligned then the RTT diff would be close to zero
  - Any deviation points to some form of asymmetric routing issues
  - And whether IPv6 is faster or slower than IPv4 is less important than the fact that they are different
- But the observation that they are different with respect to a

But that's not all…

- IPv6 used a new approach to extension headers, including packet fragmentation by inserting them between the IPv6 header and the transport header



- Which means that hardware will have to spend cycles to hunt for a transport header

- Or it can just drop the packet…

2017 Measurement

V6, the DNS and Fragmented UDP

Total number of tests: 10,851,323

Failure Rate in receiving a large response: 4,064,356

IPv6 Fragmentation Failure Rate: **38%**

This measurement test involved sending a fragmented UDP packet to recursive resolvers

2017 Measurement

What about TCP and Fragmentation?

1,961,561 distinct IPv6 end point addresses

434,971 failed to receive Fragmented IPv6 packets

22% failure rate

This measurement test involved sending a fragmented TCP packet to browser endpoints

What can we say?

- There are ongoing issues with IPv6 reliability in many parts of the world
  - This appears to relate to local security policies at the client edge of the network
  - We can expect most of this to improve over time by itself

What can we say?

- But there are also very serious issues with Path MTU management and handling of IPv6 extension headers
  - This is a more challenging issue that will probably not just clean itself up over time
  - Should we just avoid IPv6 extension headers?
  - Or try to clean up the IPv6 switching infrastructure?

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Thanks!


25 YEARS
2020
APRICOT
APNIC 49
MELBOURNE
AUSTRALIA
12 – 21 February 2020
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