IPv6 Reliability Measurements

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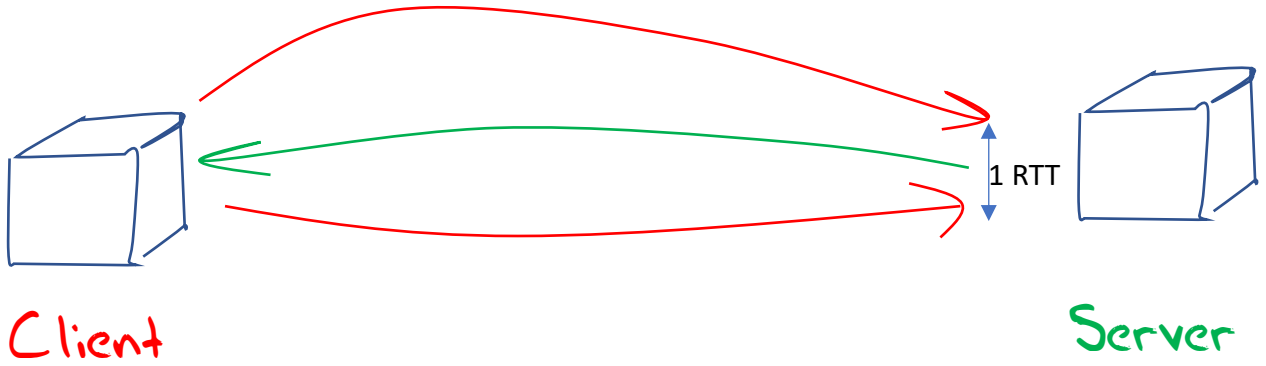
APNIC

The Measurement

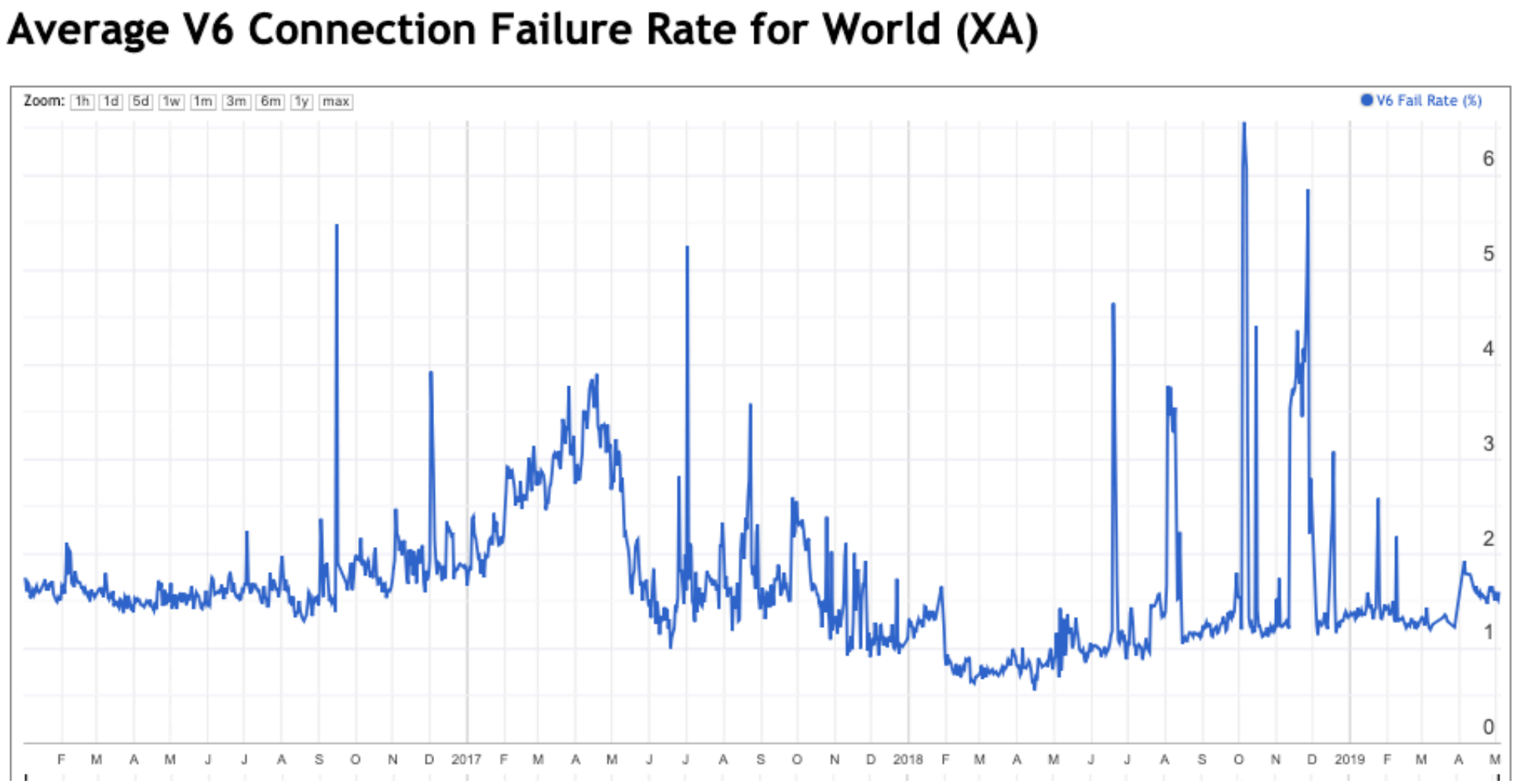
- The endpoint retrieves two URLs from the same remote server – one using IPv4 and the other using IPv6
  - Unique DNS names and TLS are used to ensure that caching does not play a role in the measurement
- We perform full packet capture at the server

Analysis

- We look at the SYN/ACK exchange at the start of the TLS 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)
- A received SYN with no subsequent ACK is interpreted as a failed connection attempt

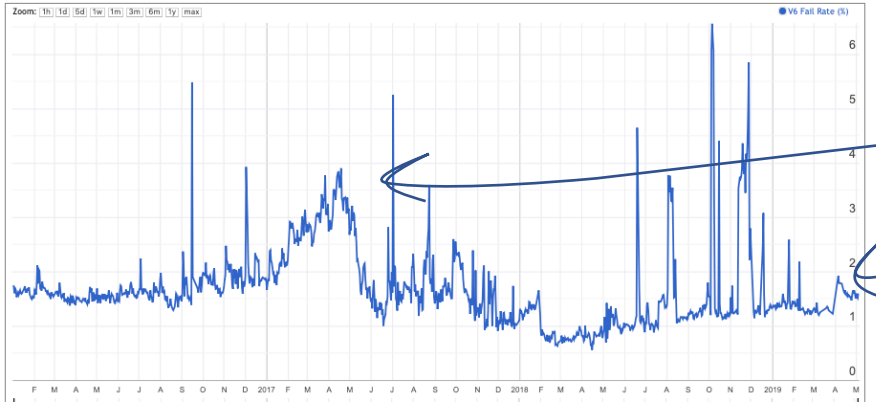


IPv6 TCP Connection Failure



IPv6 TCP Connection Failure

Average V6 Connection Failure Rate for World (XA)



The global failure rate of some 1.4% is better than earlier data (4% failure in early 2017), but its still bad

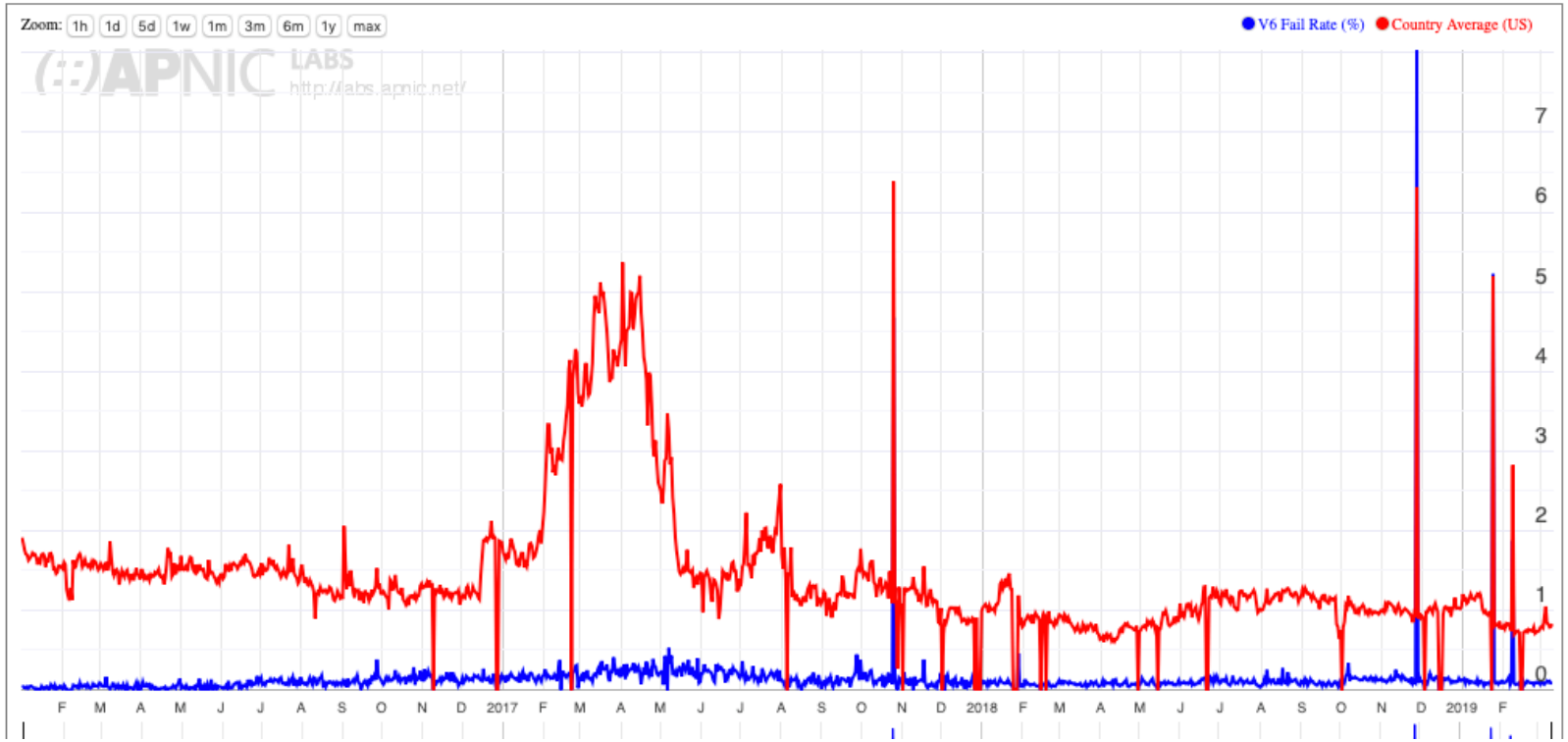
We cannot detect failure in attempting to deliver a packet from the client to the server – what we see as “failure” is a failure to deliver an IPv6 packet from the server to the client

Possible reasons:

- Endpoint using an unreachable IPv6 address
- End site firewalls and filters
- Transition mechanism failure

The Good

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



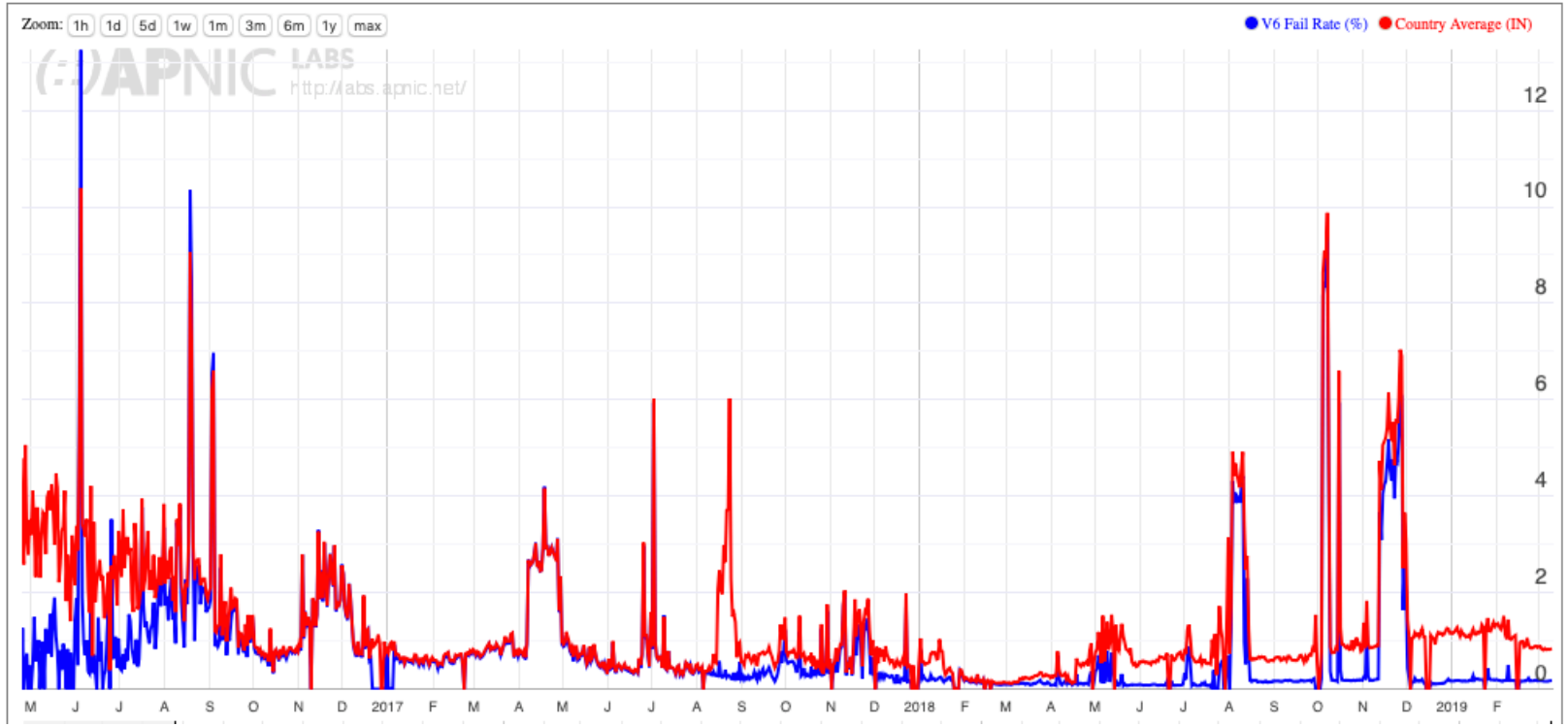
This 464XLAT mobile network (T-Mobile) has remarkably small failure rates – the endpoints are connected via native IPv6 and as this is a mobile network there is only a small amount of customer-operated filtering middleware

464XLAT Performance

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

The Good

V6 Connection Failure Rate for AS55836: RELIANCEJIO-IN Reliance Jio 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

The Bad

Average V6 Connection Failure Rate for Vietnam (VN)

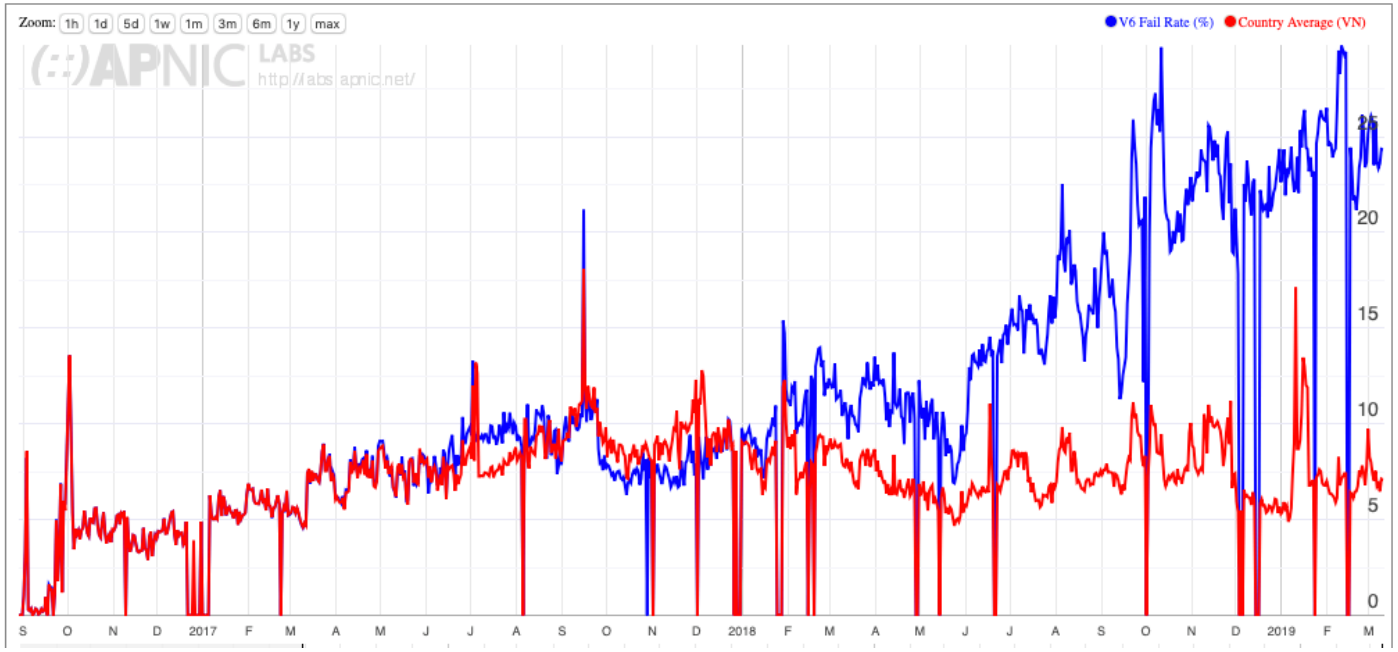
Seriously?

A 6%-10% IPv6 connection failure rate is bad enough

A sustained failure rate for over 2 years seems worse!

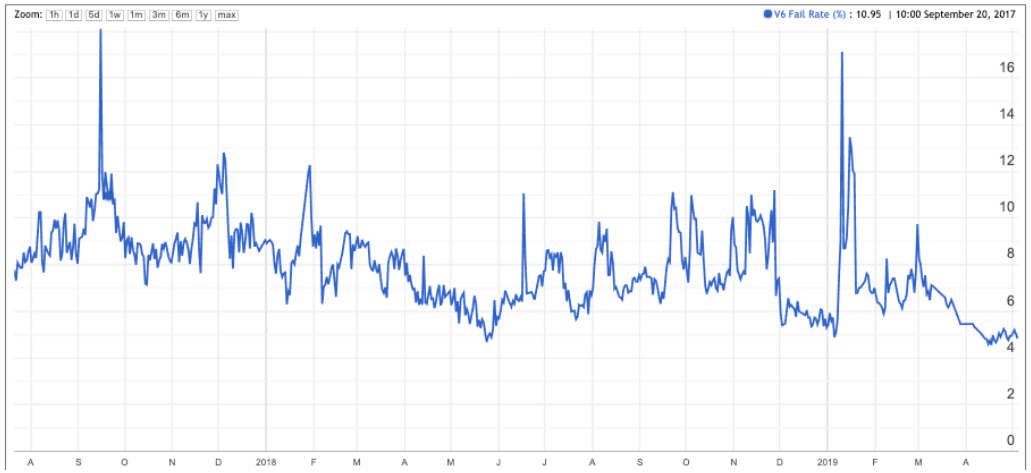
The Appalling!

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



High IPv6 Failure Levels

Average V6 Connection Failure Rate for Vietnam (VN)



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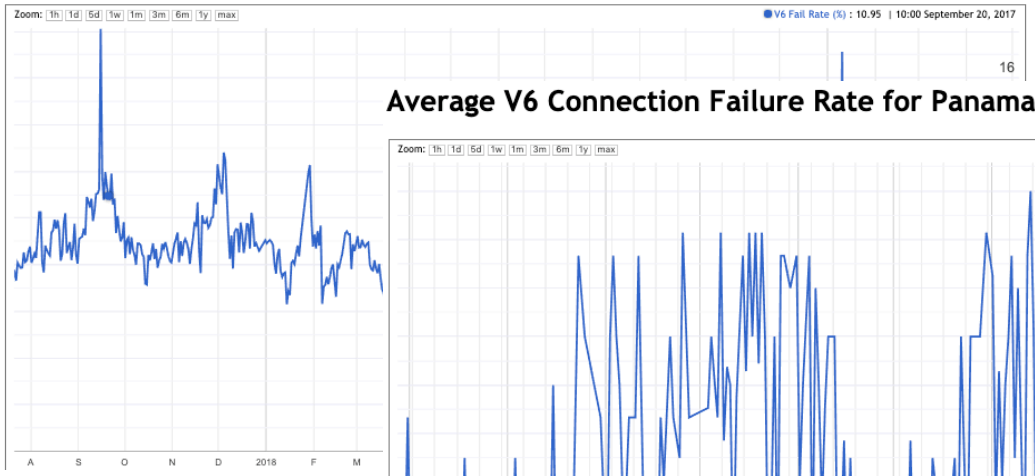
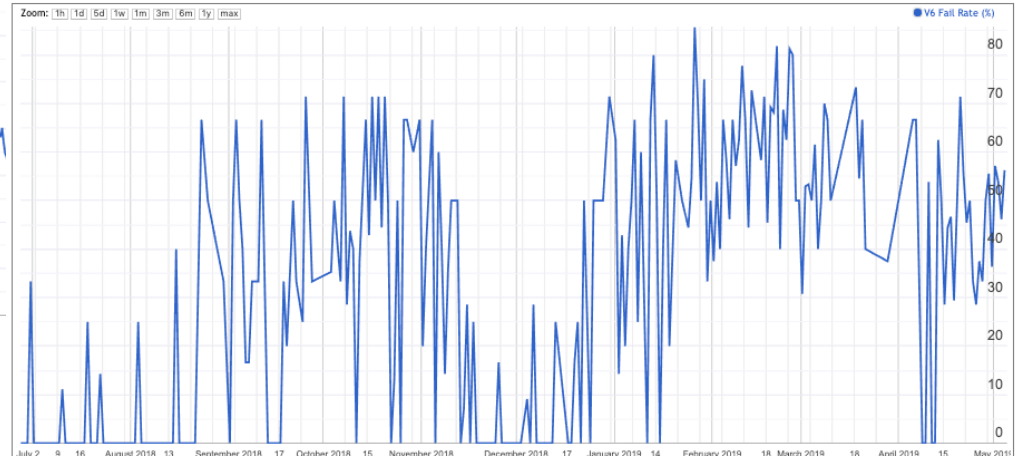


Average V6 Connection Failure Rate for Panama (PA)



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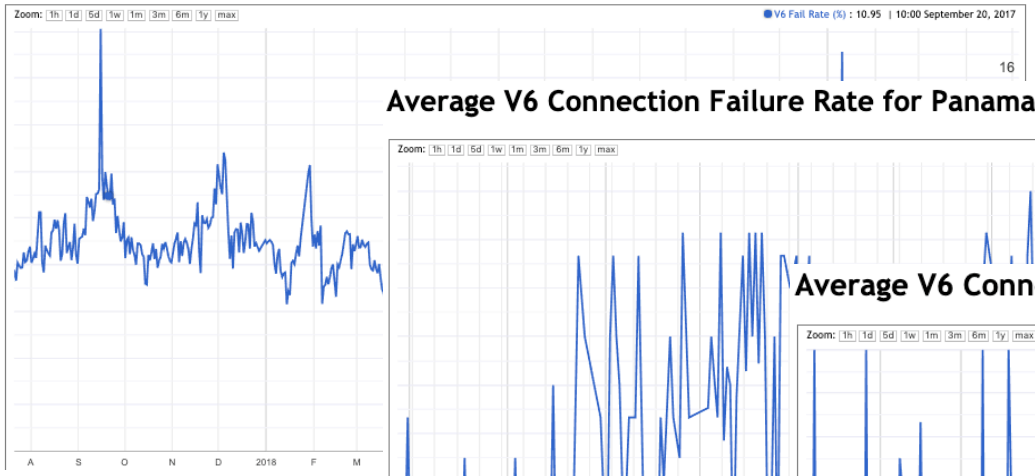

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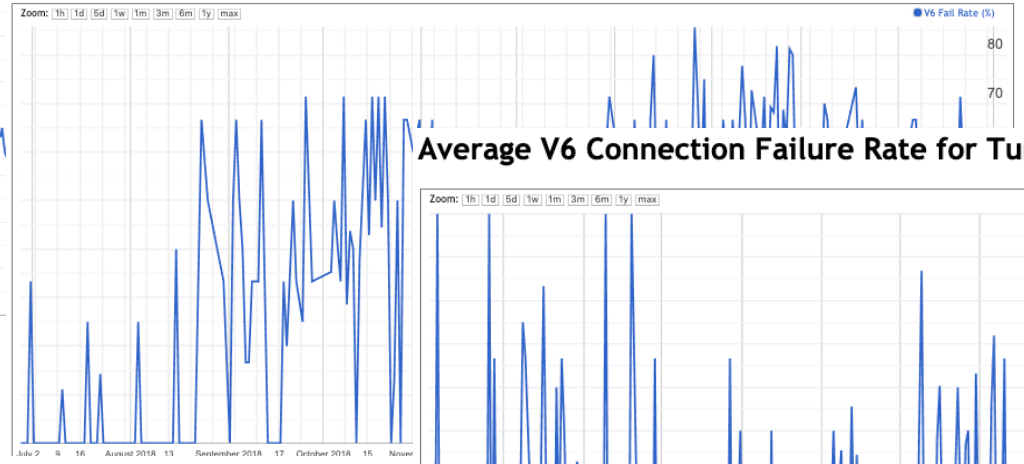
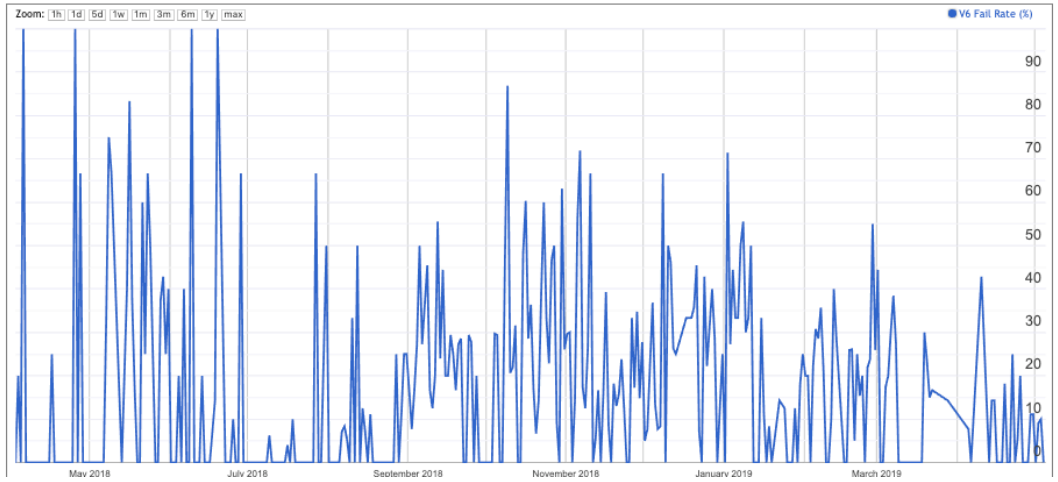


Average V6 Connection Failure Rate for Turkey (TR)



High IPv6 Failure Levels

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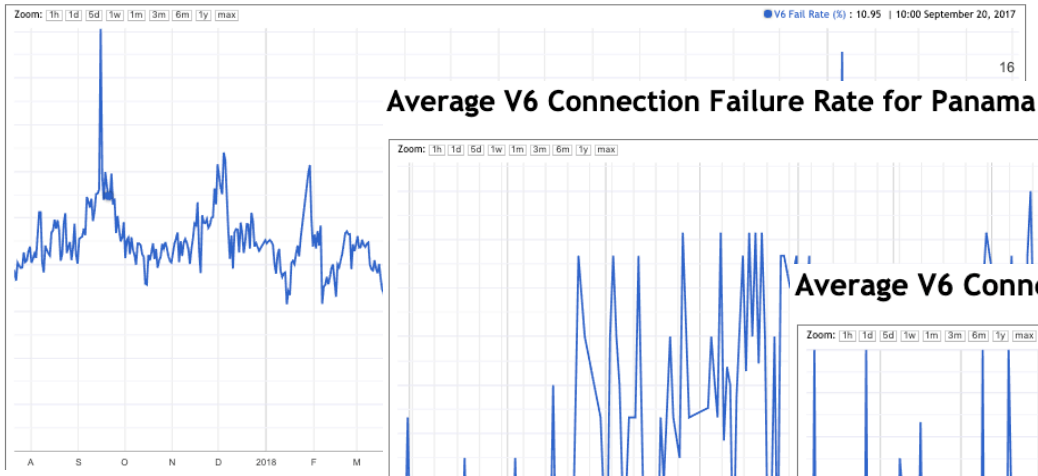

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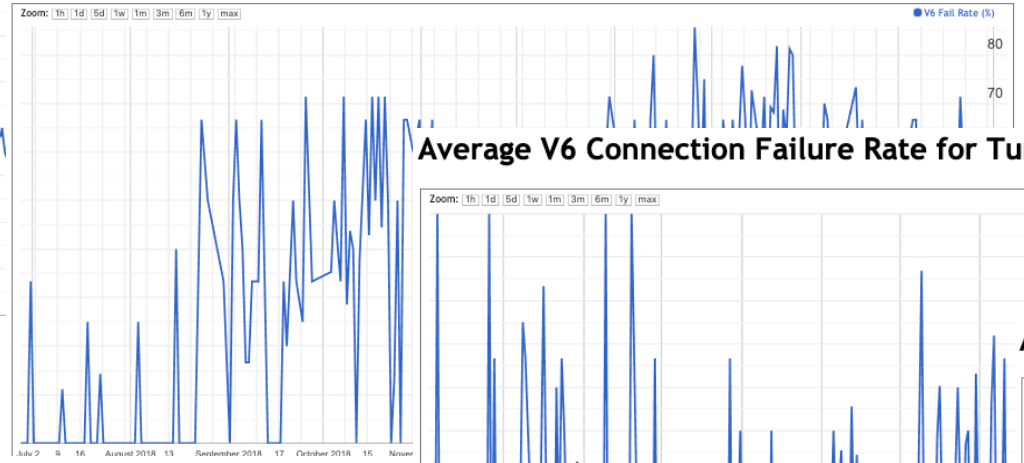

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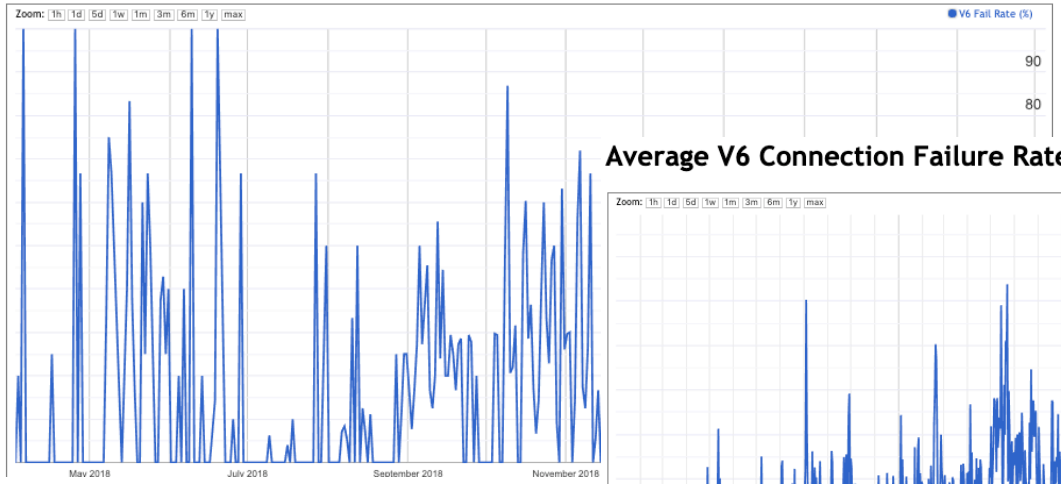
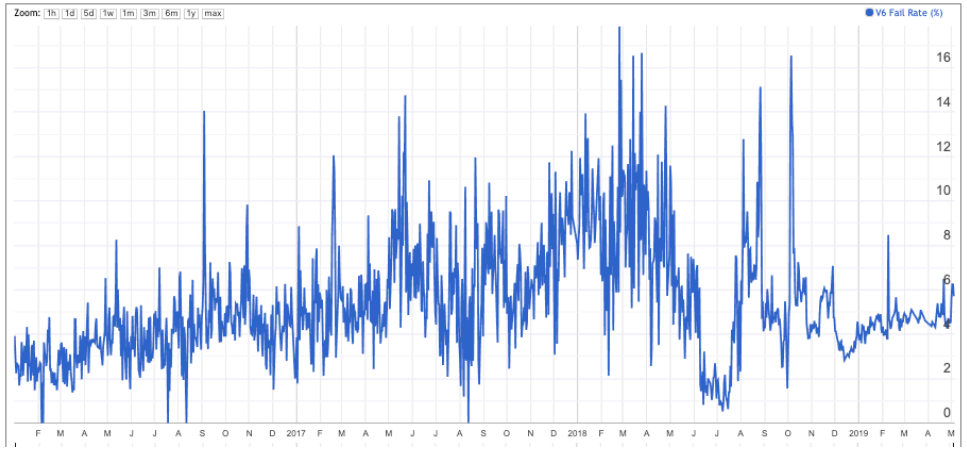


Average V6 Connection Failure Rate for China (CN)



Comment

- For many end users in Vietnam, Panama, Morocco, Turkey, Venezuela, China and Bangladesh 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 United States, Sweden, Thailand and Korea and the IPv6 connection failure rates are close to experimental noise levels
- What's happening in the second set of countries and ISPs that is NOT happening in the first set?

Transition Technologies

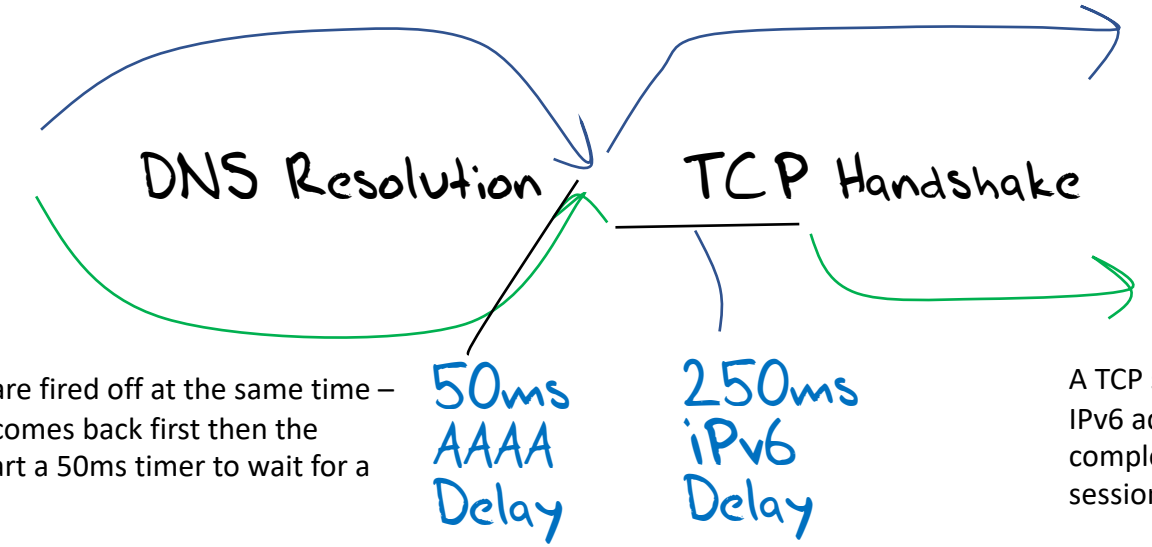
- Stateful transition technologies that involve protocol translation show higher levels of instability
- Translation technologies that require orchestration of DNS and network state are also more unstable

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

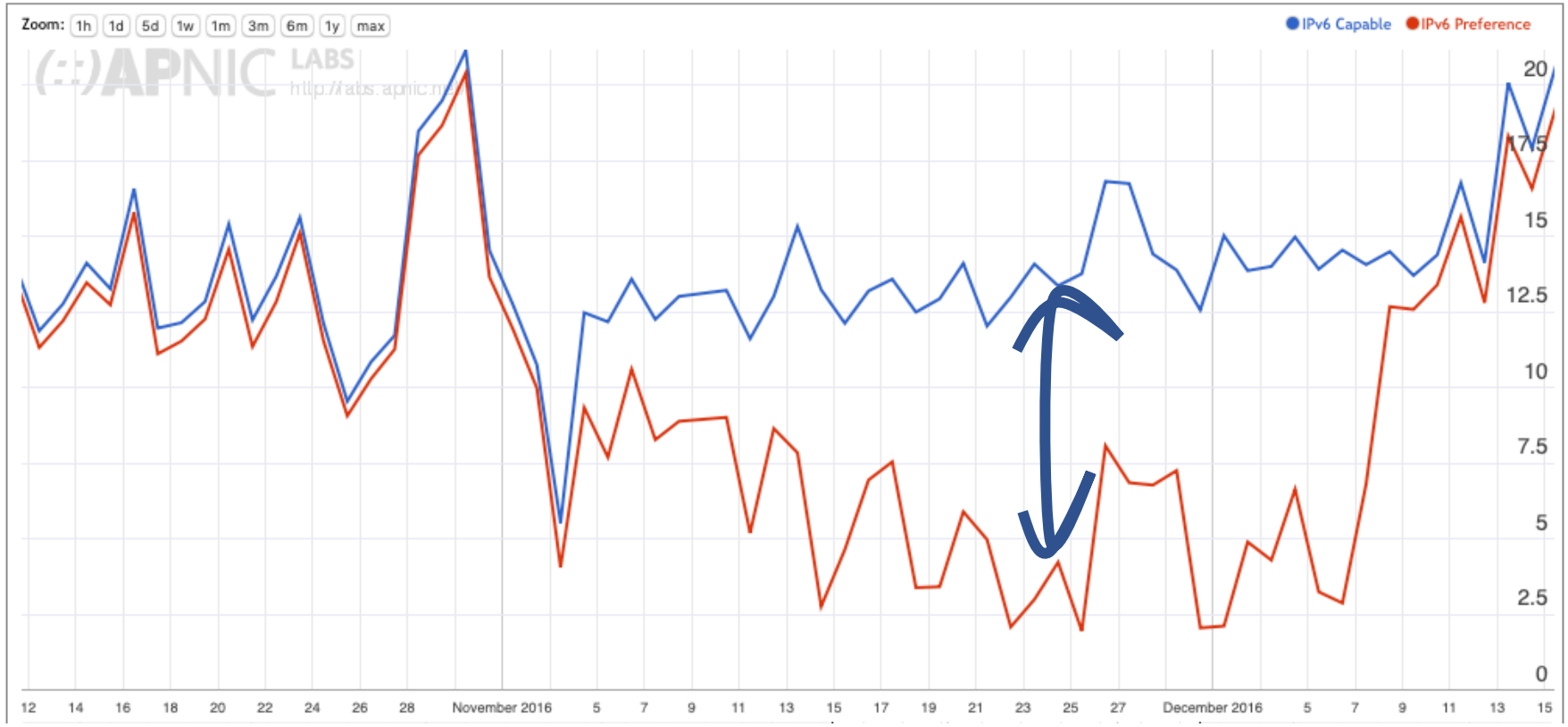
A TCP session will be started in IPv6 if there is a IPv6 address record. If the handshake is not completed within 250 ms then an IPv4 TCP session is also fired off

Tuning IPv6 for Happy Eyeballs

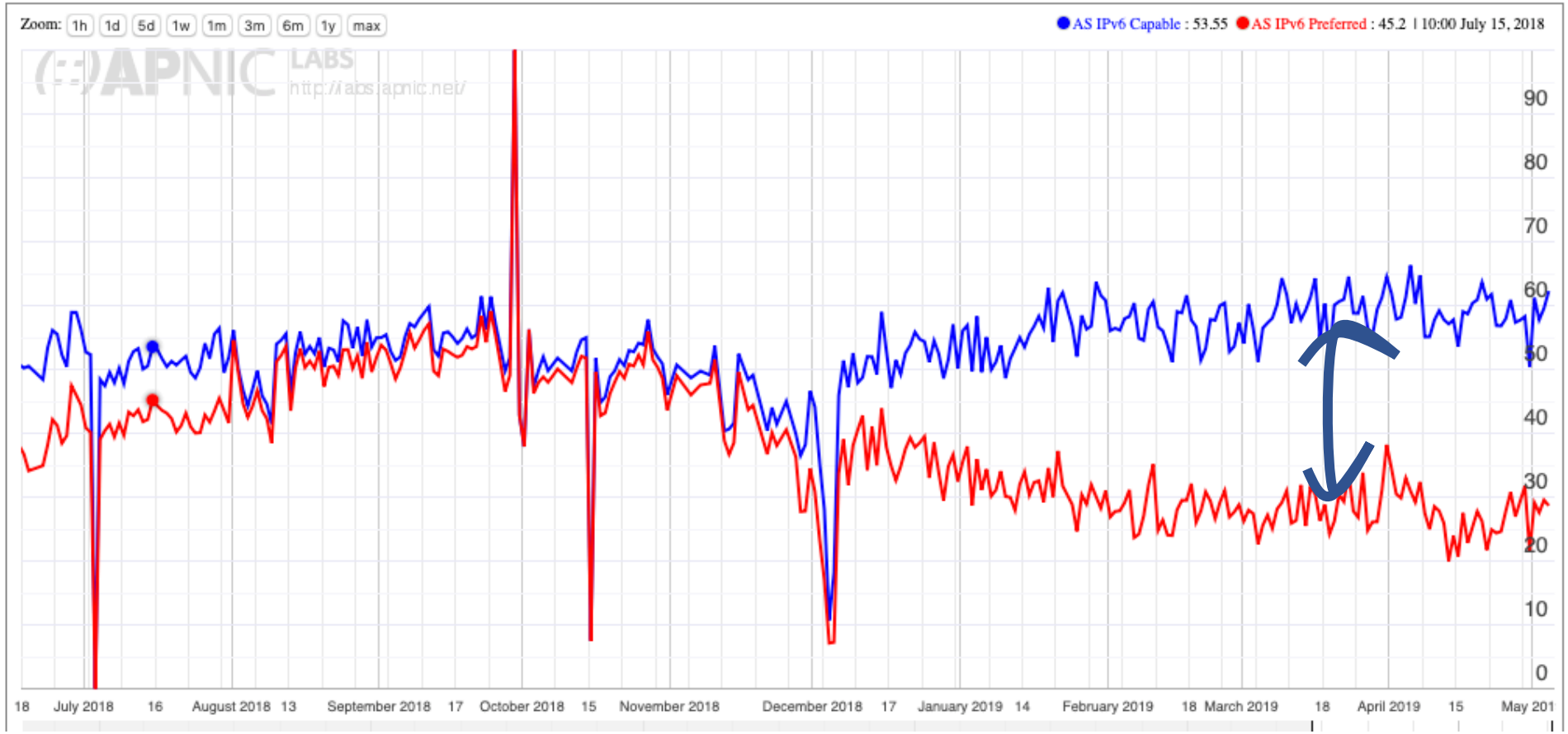
- When connecting to a remote dual stack service, the Routing Path selection for IPv6 should be similar to IPv4
- Where there are path deviations, the path discrepancy should be contained

- This is not always the case…

India, late 2016



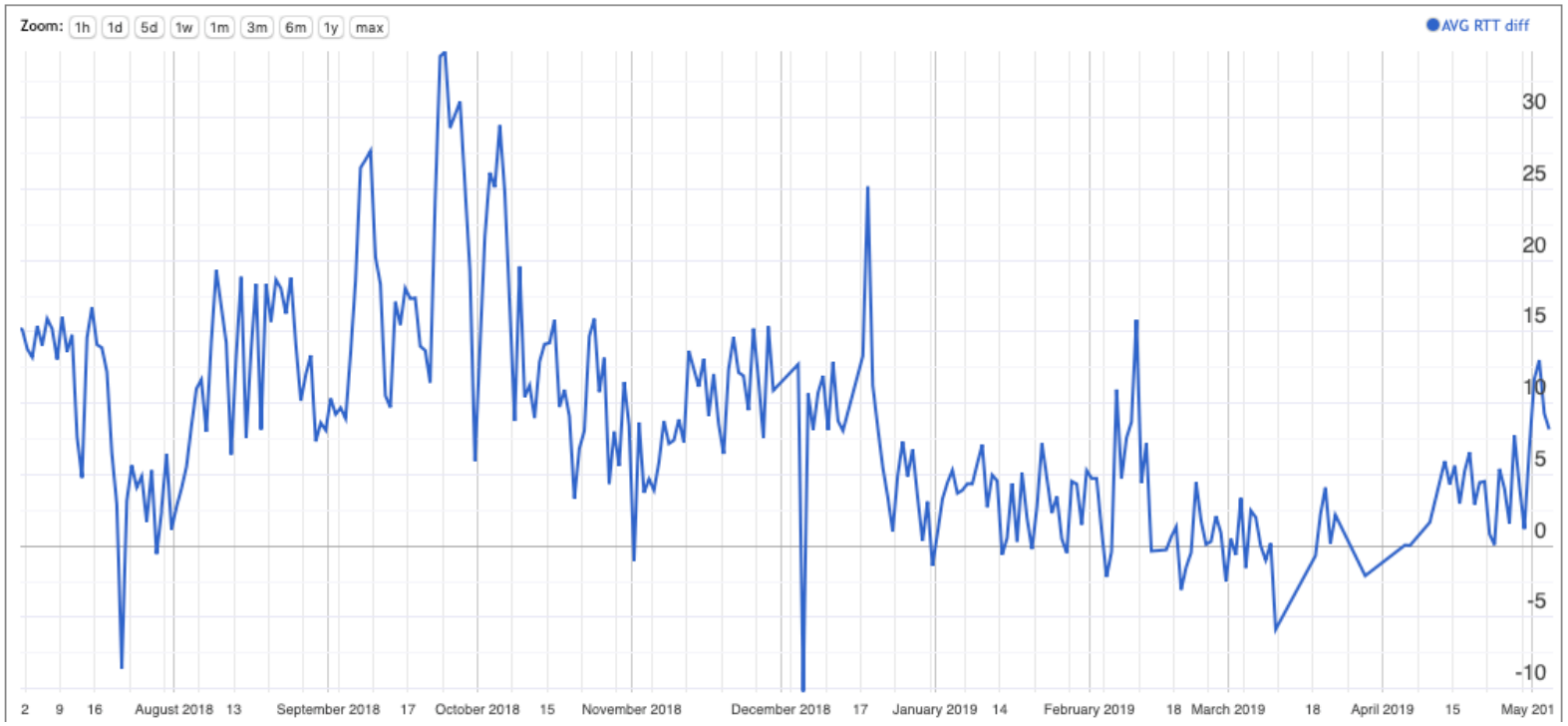
Vodaphone New Zealand - 2019



AS9500

Worldwide Performance

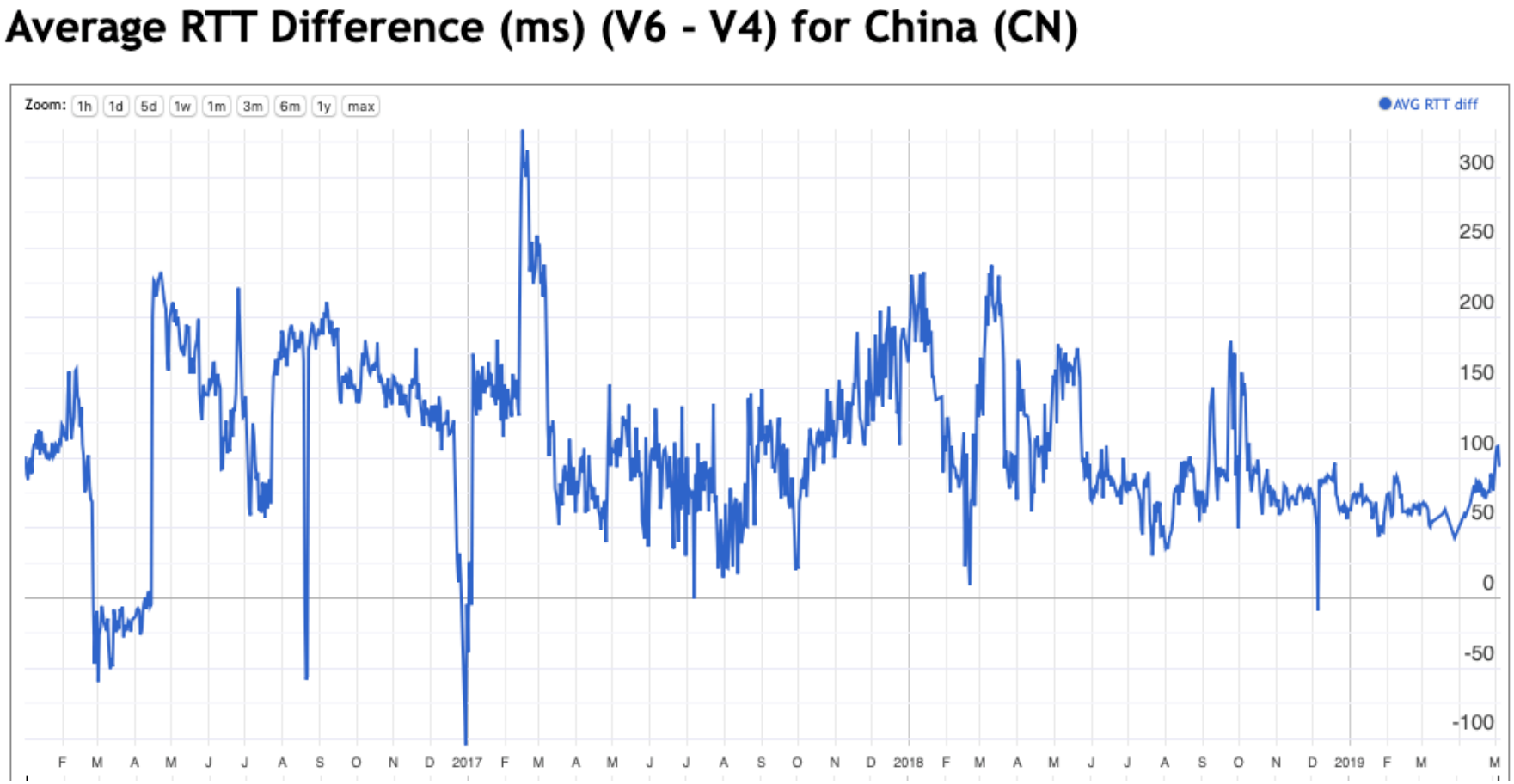
Average RTT Difference (ms) (V6 - V4) for World (XA)



Across the sample set the RTT for IPv4 is on average ~7ms faster than IPv6

This is not a major cause for concern

China's IPv6 Network

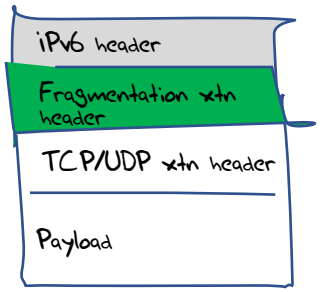


3 Suggestions to Assist IPv6 Robustness

- 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 networks, but try to use transit and peer arrangements that are dual stack

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
- But there are also very serious issues with Path MTU management and handling of IPv6 extension headers
  - This is a more challenging issue
  - Should we just avoid IPv6 extension headers?
  - Or try to clean up the IPv6 switching infrastructure?

Thanks!