IPv6 Deployment Update
(Where are we now?)

25 Nov 2019|IPv6 Summit, Tokyo

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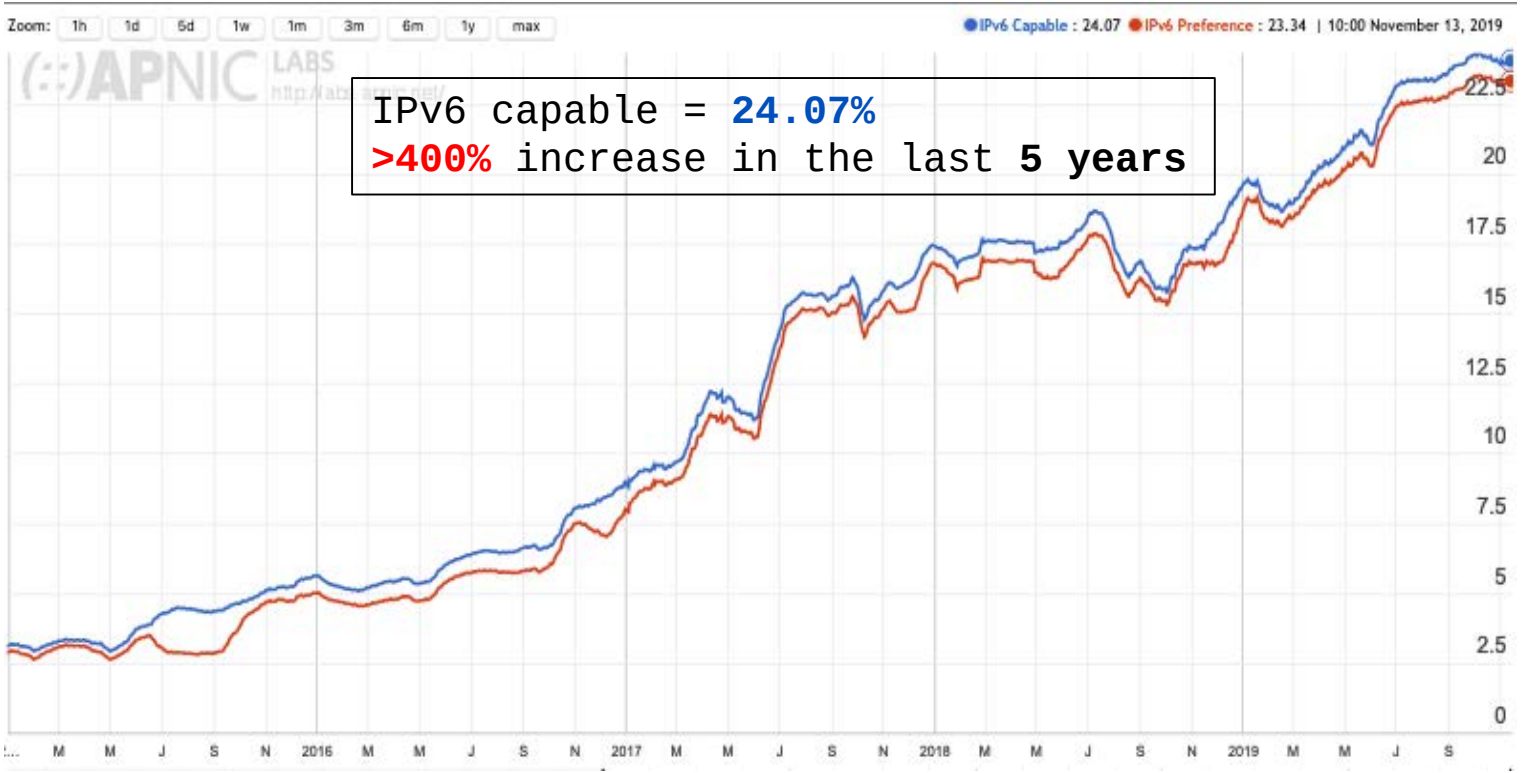
IPv6 Measurement

- Uses scripted online advertisement
  - Over **12M** measurements/day!!
- The ad-script fetches three URLs
  - IPv6 only URL, Dual-stack URL, IPv4 only URL
- If the device can fetch:
  - IPv6 URLs (*native/dual-stack*) over IPv6, deemed *IPv6 capable*
  - dual-stack URL over IPv6, deemed to *prefer IPv6*
    - RFC8305 (Happy Eyeballs) bias?

IPv6 end user Readiness



https://stats.labs.apnic.net/ipv6/

IPv6 Table - World

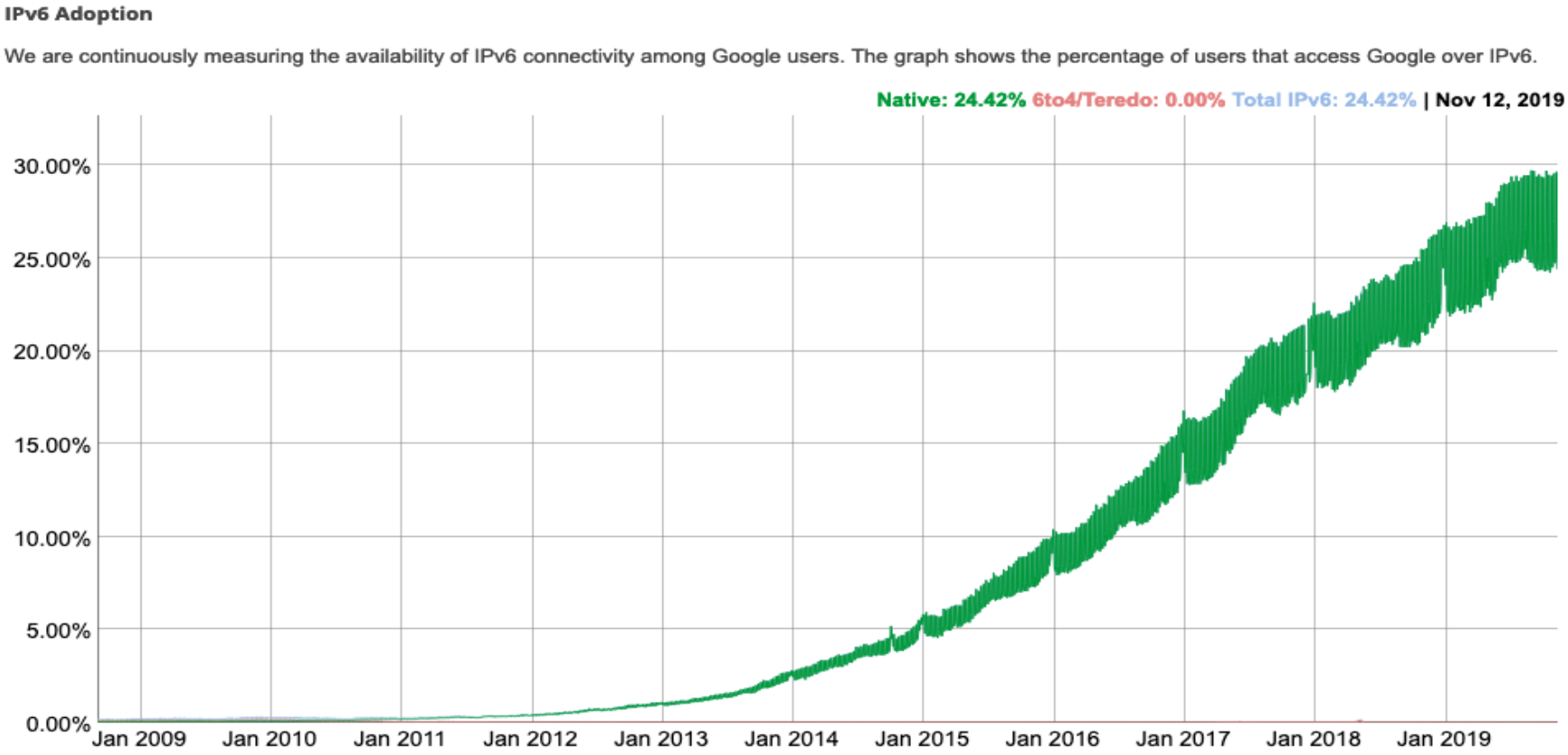
Economy	IPv6 capable (%)
India	63.79
Belgium	57.74
United States	56.74
Taiwan	45.29
Malaysia	45.07
Greece	44.17
Germany	40.96
France	38.21
Vietnam	38.14
Luxembourg	36.45
Japan	35.52
Switzerland	33.89

Economy	IPv6 capable (%)
Finland	32.93
Portugal	32.28
Uruguay	32.10
United Kingdom	31.82
Brazil	31.45
Mexico	30.87
Norway	29.64
Thailand	28.74
Canada	26.10
Sri Lanka	25.36
Hungary	25.20
UAE	24.95

Economy	IPv6 capable (%)
Estonia	24.94
New Zealand	23.37
Australia	23.27
Trinidad & Tobago	22.45
Netherlands	21.22
Ireland	20.62
Peru	19.83
South Korea	16.09
Romania	15.82
China	15.32
Ecuador	15.29

https://stats.labs.apnic.net/ipv6/ (15 Nov 2019)

IPv6 in Action - Google



https://www.google.com/intl/en/ipv6/statistics.html

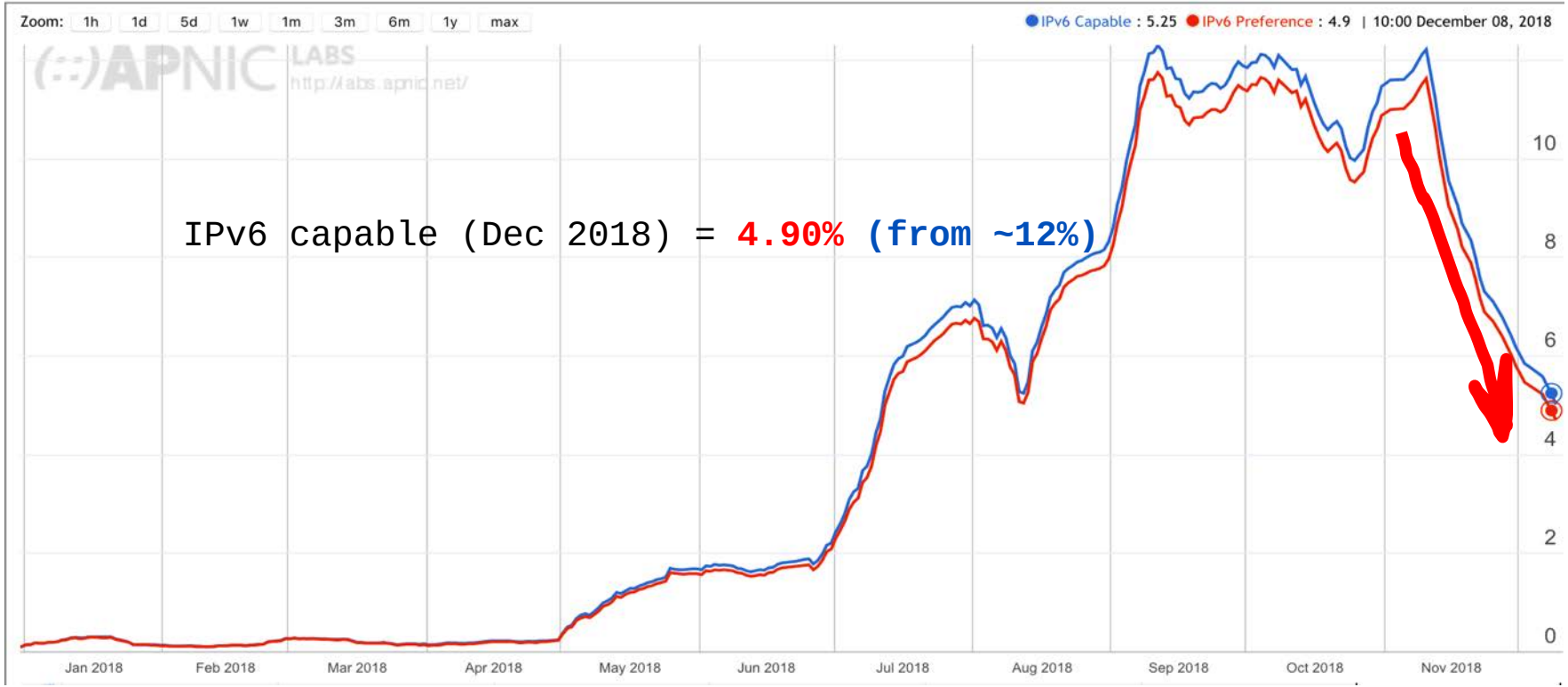
IPv6 in Action - Facebook

https://www.facebook.com/ipv6/

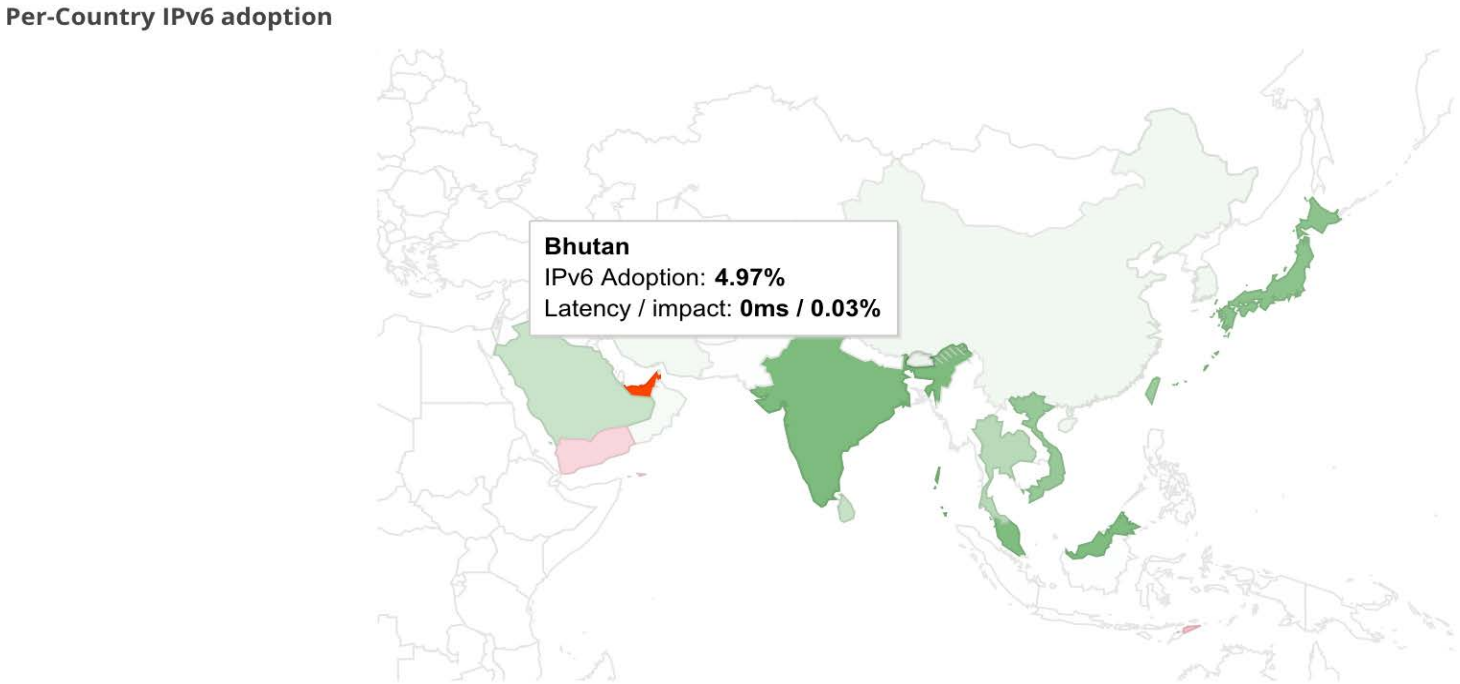
What about Asia-Pacific?

Economy	IPv6 capable (%)
India	**63.81**
Taiwan	**45.23**
Malaysia	**45.11**
Vietnam	**38.20**
Japan	35.54
Thailand	**28.75**
Sri Lanka	**25.23**
New Zealand	**23.38**
Australia	**23.29**
South Korea	16.08
Singapore	13.51
Myanmar	8.78
Bhutan	**7.57**

Something Interesting - BT

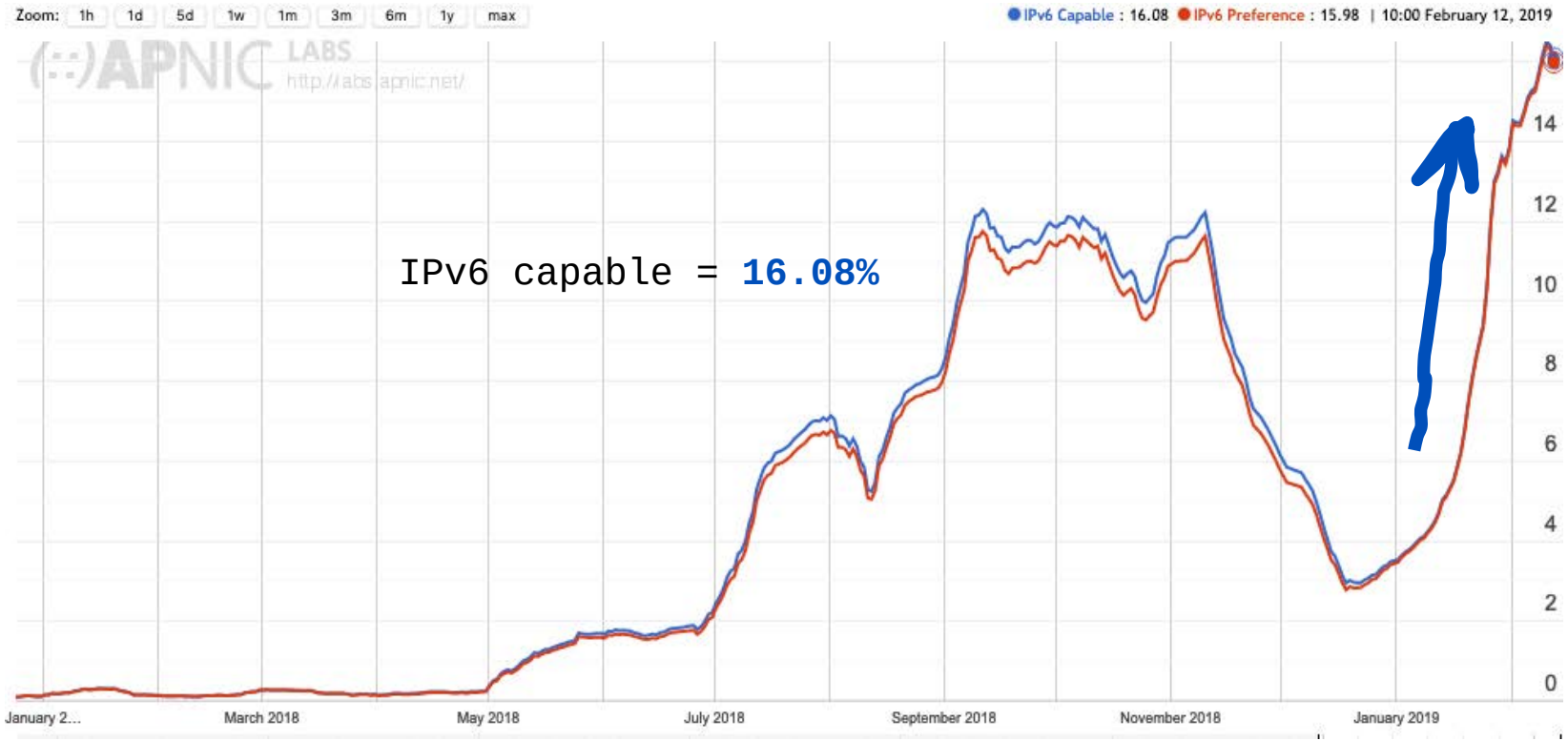


Google's view - BT

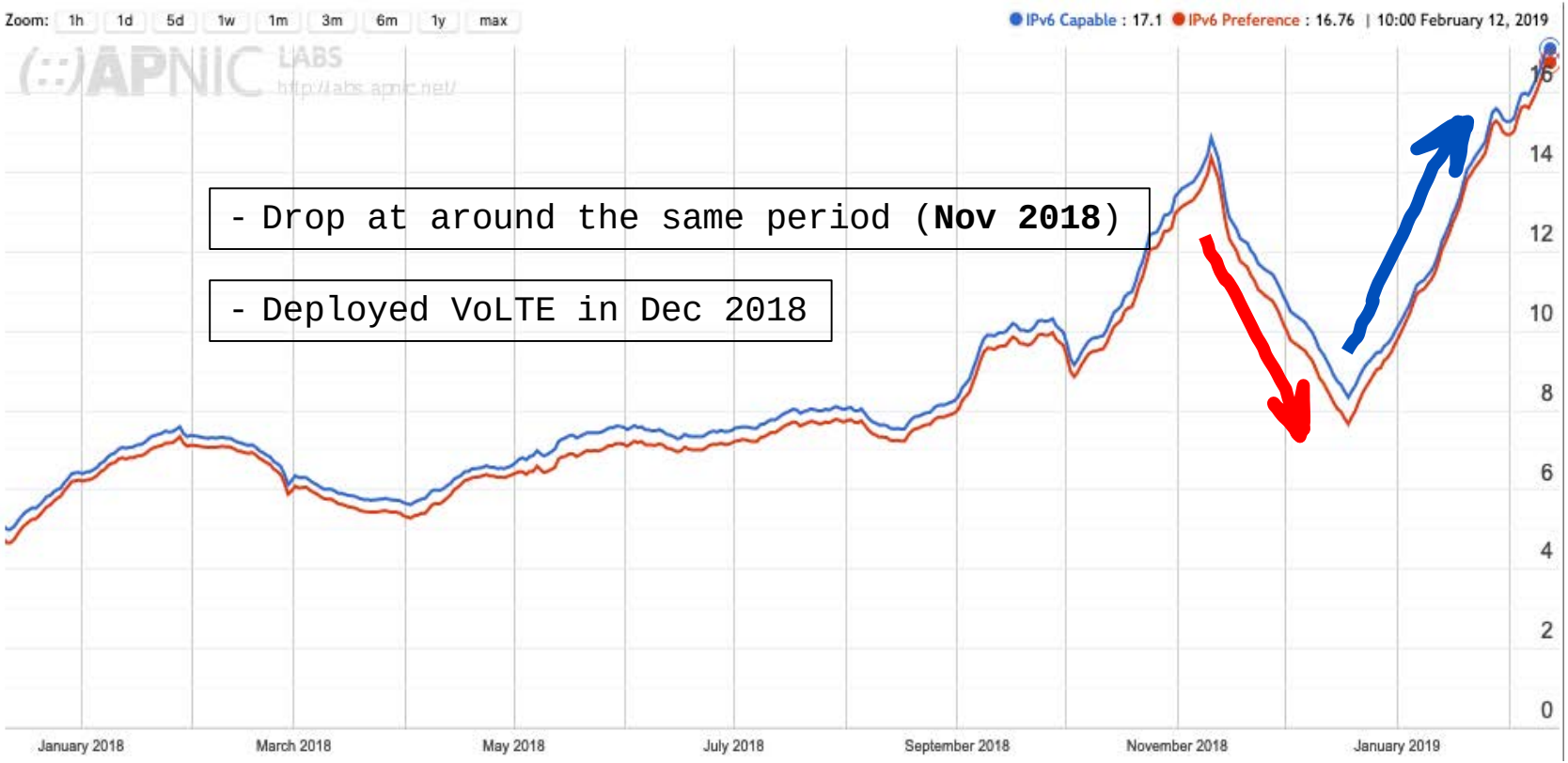


https://www.google.com/intl/en/ipv6/statistics.html#tab=per-country-ipv6-adoption

After the fix - BT



Coincidence - LK?



IPv6 - Who is in control?

- The true driver for IPv6 adoption - Mobile Internet!
- However, born and raised on NAT!
  - Still heavily based on CG-NAT

IPv6 in Action: Mobile Networks

Carrier	Economy	Deployment
Verizon Wireless	USA	Dual-stack (2011)
T-Mobile	USA	464XLAT (2012)
Telekom Malaysia	Malaysia	Dual-stack (2013)
SK Telecom	Korea	464XLAT (2014)
Telstra	Australia	464XLAT (2016)
Reliance Jio	India	**Dual-stack (2016)**
Dialog Axiata	Sri Lanka	**Dual-stack (2016)**
AIS	Thailand	**Dual-stack (2017)**
Bhutan Telecom	Bhutan	**Dual-stack (2018)**
Chungwa Telecom	Taiwan	**Dual-stack (2018)**

Dual-stack preference?

Our migration strategy was to allow existing users to make graceful switch to IPv6…

Users did not experience any issues, as they could still access the Internet via IPv4..

To help customers migrate from IPv4 to IPv6 in a seamless manner…

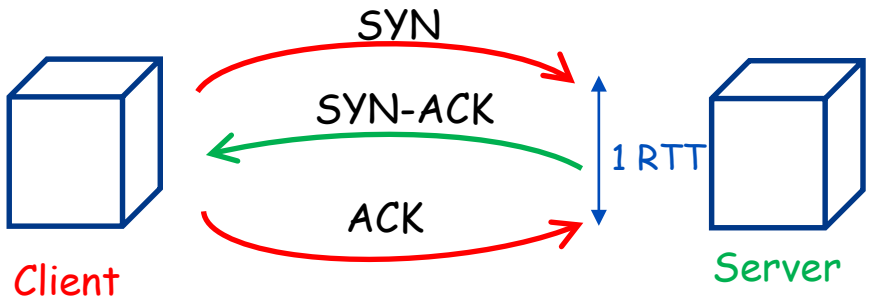
You need to consider redundancy/fallback, and ease of network maintenance….

IPv6 - Mobile Devices

- 464XLAT:
  - Android (4.3 - Jelly Bean)
  - Windows Phone (8.1+)
- IPv6-only:
  - iOS
    - since iOS 9 (*supported on WiFi for a long time)*
    - since June 2016, apps in App Store must support IPv6 https://developer.apple.com/support/ipv6/
- DHCPv6:
  - Windows
  - iOS
- Dual-stack:
  - KaiOS
    - Jio/Nokia 8110 feature handsets
  - iOS
    - reports for dual-stack since 11.3 (through carrier update)

IPv6 Performance - Analysis

- We look at TCP (3-way) handshake
  - A received SYN with no subsequent ACK is interpreted as a failed connection attempt
  - The time between the receipt of the SYN and the subsequent ACK at the server is interpreted as the RTT (*not implicit RTT*)

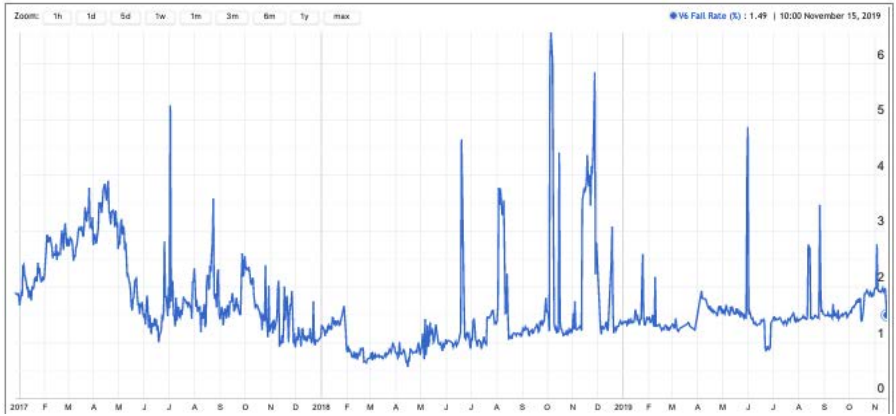


IPv6 Performance

- Is IPv6 as reliable (robust) as IPv4?
  - Do all TCP connection attempts succeed?
    - Failure ~ no ACK for a received SYN

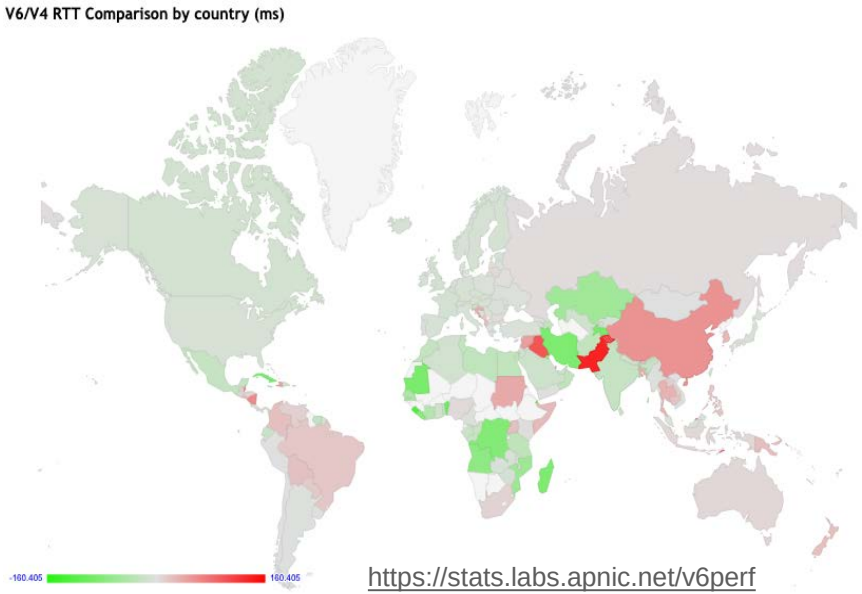
- Global IPv6 failure rate
  1.4% ☹
  - End point filters/firewalls?
    - Not allowing inbound IPv6 or
    - ICMPv6 (PTB) filtered? PMTUD failure?
  - End points on unreachable IPv6 address?

Average V6 Connection Failure Rate for World (XA)



IPv6 Performance

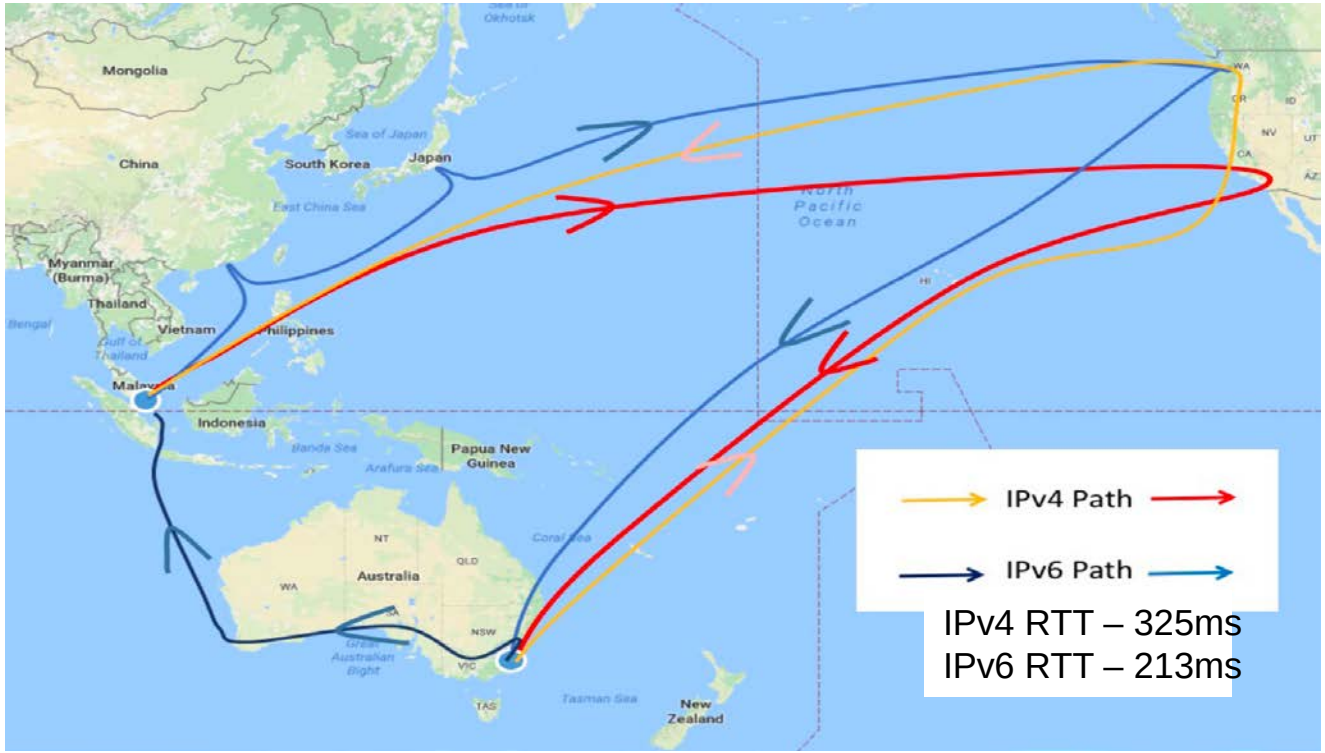
- Is IPv6 as fast as IPv4?
  - Comparison of RTT
    - time since SYN and subsequent ACK



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

- IPv6 appears faster
  - Africa, Europe, and the Americas
  - CG-NAT/NAT boxes?
- IPv4 seems faster
  - Asia & Oceania
  - Different routing paths for IPv4 and IPv6?

IPv6 Performance & Routing Path



https://labs.apnic.net/?p=850

Closer to home – Routing Path

tashi-2.local (0.0.0.0) Fri Nov 22 17:45:39 2019

Keys: Help Display mode Restart statistics Order of fields quit

	Host	Packets Loss%	Snt	Pings Last	Avg	Best	Wrst	StDev
1.	192.168.0.1	72.2%	19	2.0	1.6	1.4	2.0	0.0
2.	niccrswa-vlan66.nic.ad.jp	61.1%	19	4.2	3.9	2.0	6.1	1.4
3.	nicfwc-vlan7.nic.ad.jp	72.2%	18	3.2	3.4	2.1	4.6	0.7
4.	dixcrswe-vlan6.nic.ad.jp	58.8%	18	3.1	10.5	2.8	42.3	14.2
5.	dix-iee.nic.ad.jp	72.2%	18	2.9	2.7	2.3	3.0	0.0
6.	as2518-2.ix.jpix.ad.jp	76.5%	18	3.1	2.9	2.7	3.1	0.0
7.	133.208.191.144	70.6%	18	3.4	4.5	3.1	9.3	2.7
8.	vocus1-10g.hkix.net	66.7%	18	57.1	56.8	56.6	57.1	0.0
9.	Te-0-1-0-2-1.cor02.syd04.nsw.VOCUS.net	64.7%	18	230.4	233.2	230.0	248.0	7.2
10.	BE-1.cor01.syd11.nsw.VOCUS.net.au	52.9%	18	232.8	233.0	232.8	233.7	0.0
11.	???							
12.	???							
13.	???							
14.	ten-1-2-0.bdr01.bne03.qld.VOCUS.net.au	58.8%	18	210.0	210.2	209.8	210.7	0.0
15.	asn131107.bdr01.bne03.qld.vocus.net.au	70.6%	18	210.7	210.6	210.4	210.8	0.0
16.	202.125.96.226	77.8%	18	210.8	210.7	210.2	211.0	0.0
17.	wiki.apnictraining.net	82.4%	18	232.7	232.9	232.7	233.2	0.0

tashi-2.local (::) Fri Nov 22 17:45:39 2019

Keys: Help Display mode Restart statistics Order of fields quit

	Host	Packets Loss%	Snt	Pings Last	Avg	Best	Wrst	StDev
1.	guest.nic.ad.jp	56.2%	17	1.4	1.5	1.1	2.1	0.0
2.	2001:dc2:1000:4fff::1	68.8%	17	2.8	2.9	2.1	4.6	0.7
3.	2001:dc2:1000:4001::1	64.7%	17	4.4	6.2	2.5	16.2	5.0
4.	dix-ied.nic.ad.jp	68.8%	17	3.4	3.2	2.8	3.4	0.0
5.	2001:dc2:1000::4	58.8%	17	3.2	4.8	2.9	14.8	4.4
6.	gigabitethernet2-8.core1.tyo1.he.net	75.0%	17	3.2	4.1	3.0	6.7	1.6
7.	100ge10-2.core1.hkg1.he.net	75.0%	17	59.1	53.6	51.3	59.1	3.7
8.	vocus.gigabitethernet4-9.core1.hkg1.he	70.6%	17	53.0	53.2	53.0	53.4	0.0
9.	Te-0-0-0-2-8.cor01.syd11.nsw.VOCUS.net	81.2%	17	182.4	182.4	182.0	182.7	0.0
10.	BE-1.cor02.syd04.nsw.VOCUS.net.au	58.8%	17	182.4	182.4	181.9	182.6	0.0
11.	???							
12.	???							
13.	cor01.bne03.qld.vocus.net.au	50.0%	17	182.2	182.8	181.9	186.1	1.3
14.	2402:7800:10:2::151	56.2%	16	182.4	194.8	182.0	204.7	11.9
15.	2402:7800:10:2::152	56.2%	16	204.3	204.4	203.9	204.9	0.0
16.	2001:df2:ee00:1::2	53.3%	16	182.3	182.5	182.0	183.0	0.0
17.	wiki.apnictraining.net	60.0%	16	181.8	192.6	181.6	244.8	25.6

Where are we now?

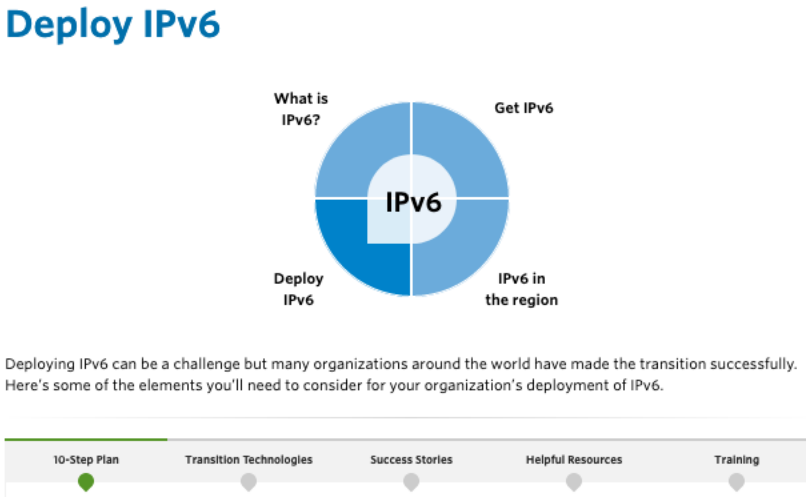
- Global IPv6 end-user readiness ~ 24%
- IPv6 deployments on the rise (across diverse economy profiles)
  - 63% of network operators in Asia-Pacific have IPv6 resources
- Observed trend of dual-stack in recent deployments

"IPv6 has emerged from the 'Innovators' and 'Early Adoption' stages of deployment, and is now in the 'Early Majority phase"

- ISOC State of IPv6 Deployment (2018)

How do we help?

- Track, measure, report
  - End-user readiness,
  - Performance analysis
- Operational trainings
  - Direct country assistance (Gov)
  - Standalone workshops
  - NOGs
- Technical Assistance
  - Remote or F2F



https://www.apnic.net/community/ipv6

どもありがとうございます！