A Longitudinal View of Dual-stacked Websites — Failures, Latency and Happy Eyeballs

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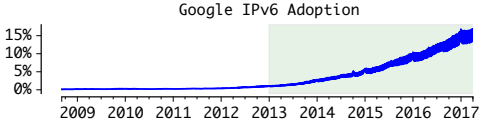
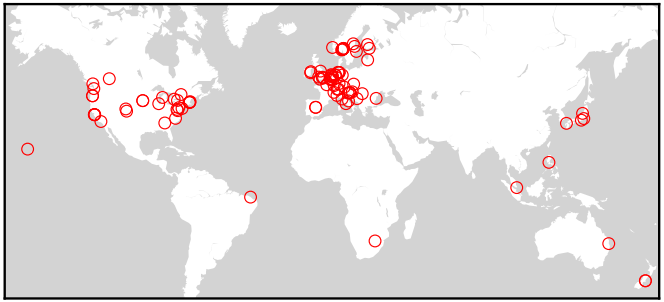
Motivation

- Literature focus *largely* on IPv6 adoption.
- Very little work on measuring IPv6 performance.
- This study *closes* the gap.



shaded region represents the duration of the longitudinal study.

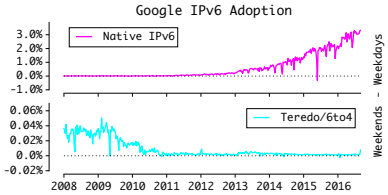


~100 dual-stacked SamKnows probes (~66 different origin ASes)

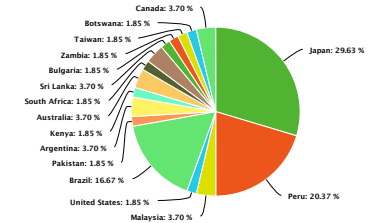
NETWORK TYPE	#
RESIDENTIAL	78
NREN / RESEARCH	10
BUSINESS / DATACENTER	08
OPERATOR LAB	04
IXP	01

RIR	#
RIPE	60
ARIN	29
APNIC	10
AFRINIC	01
LACNIC	01

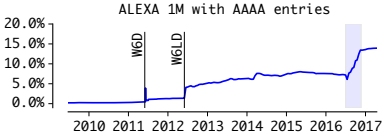
Motivation

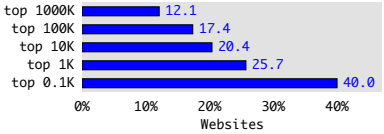


- The drift of IPv6 penetration is increasing.



- Prefixes blacklisted by Google over IPv6 (2017)





- Cloudflare Effect (shaded region)
- The dent created by Cloudflare > W6D (or W6LD).
- Cloudflare added AAAA entries for all websites [1].

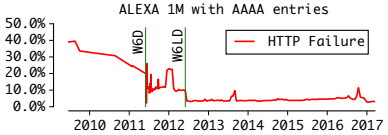
A CDN plays a *leading* role in technology adoption and shifting significant traffic overnight over IPv6.

Research Contribution

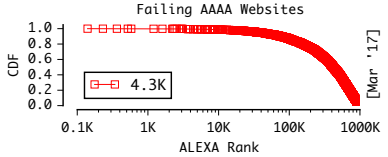
- Complete Failures
- Partial Failures
  - Failures silently exist; clients do not notice them due to IPv4 fallback.
  - Can websites with partial failures be deemed IPv6-ready?
  - Quantification of failures helpful for upcoming IPv6-only networks.
- Latency
- Happy Eyeballs

This is the first study to provide a longitudinal view (4 years) of failures and performance of dual-stacked websites.

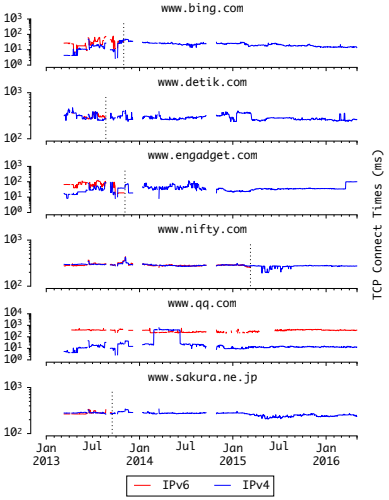
Complete Failures



- Failures reduced from 40% (2009) to 3% today.



- 88% failing websites rank > 100K.
- 1% rank < 10K, six websites rank < 300.



Metrics should account for *changes* in IPv6-readiness.

Complete Failures | WL6D websites

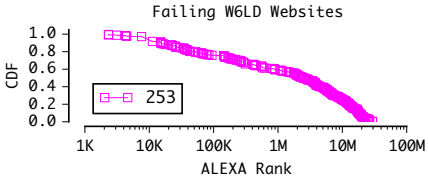
- ∼3K websites participated on the W6LD (2012).
- Promise to permanently enable production-ready IPv6 on the Internet.

W6LD websites –

- 8% (259) do not have A or AAAA entries in DNS.

W6LD websites (with A and AAAA entries) –

- 1% (36) TCP timeout over both AF.
- 8% (253) TCP timeout over IPv6.

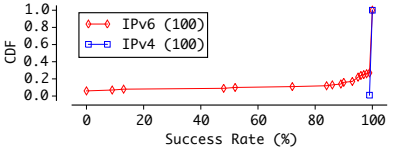


- 3% failing websites rank < 10K.
- 75% rank > 100K, 61% rank > 1M.

Partial Failures

ALEXA top 100 websites with AAAA entries.

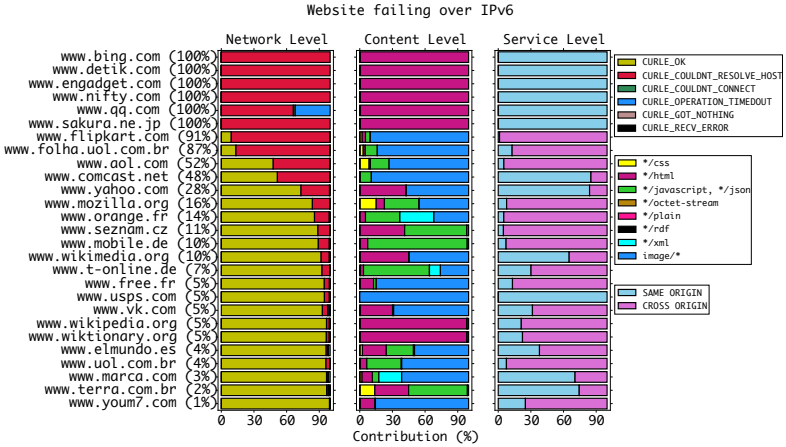
- 27% show some rate of failure over IPv6.
- 9% exhibit more than 50% failures over IPv6.



- Limiting to root webpage can lead to overestimation of IPv6 adoption numbers
- Unclear whether websites with partial failures can be deemed *IPv6-ready*
- ISOC now supporting [2] development of *tools* that identify such partial failures

#	Webpage	Success Rate (%) IPv6(↓)	Success Rate (%) IPv4	W6LD
01	www.bing.com	0	100	✓
02	www.detik.com	0	100	✓
03	www.engadget.com	0	100	✓
04	www.nifty.com	0	100	
05	www.qq.com	0	100	
06	www.sakura.ne.jp	0	100	
07	www.flipkart.com	09	99	✓
08	www.folha.uol.com.br	13	100	
09	www.aol.com	48	100	✓
10	www.comcast.net	52	100	✓
11	www.yahoo.com	72	100	✓
12	www.mozilla.org	84	100	✓
13	www.orange.fr	86	100	✓
14	www.seznam.cz	89	100	✓
15	www.mobile.de	90	100	✓
16	www.wikimedia.org	90	100	
17	www.t-online.de	93	100	✓
18	www.free.fr	95	100	
19	www.usps.com	95	100	
20	www.vk.com	95	100	✓
21	www.wikipedia.org	95	100	✓
22	www.wiktionary.org	95	100	
23	www.elmundo.es	96	100	✓
24	www.uol.com.br	96	100	✓
25	www.marca.com	97	100	✓
26	www.terra.com.br	98	100	✓
27	www.youm7.com	99	100	

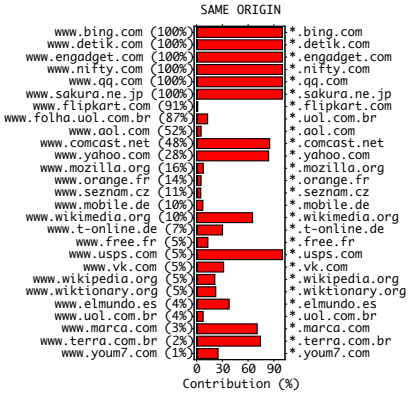
Partial Failures | Root Cause Analysis



- Failures due to DNS resolution error on `image/*`, `*/javascript`, `*/json` and `*/css` content.

- Failures *silently* exist; clients do not notice them due to IPv4 fallback.
- Identification of operational issues relevant for upcoming IPv6-only networks

Partial Failures | Root Cause Analysis

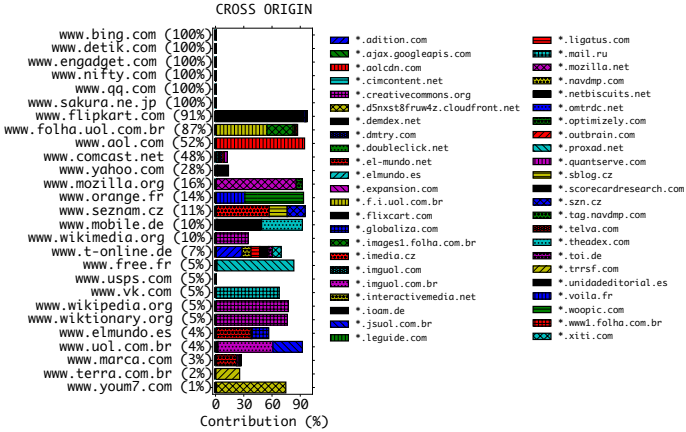


- 12% of websites have more than 50% webpage elements that belong to the same origin source and fail over IPv6.

- CDN infrastructure does not have IPv6 turned on by default for all same-origin webpage elements.

#	Webpage	Same Origin (↓)
01	www.bing.com	100%
02	www.detik.com	100%
03	www.engadget.com	100%
04	www.nifty.com	100%
05	www.usps.com	100%
06	www.qq.com	100%
07	www.sakura.ne.jp	100%
08	www.comcast.net	85%
09	www.yahoo.com	83%
10	www.terra.com.br	74%
11	www.marca.com	70%
12	www.wikimedia.org	65%
13	www.elmundo.es	37%
14	www.vk.com	31%
15	www.t-online.de	30%
16	www.youm7.com	24%
17	www.wiktionary.org	22%
18	www.wikipedia.org	22%
19	www.free.fr	13%
20	www.folha.uol.com.br	12%
21	www.mozilla.org	7%
22	www.uol.com.br	7%
23	www.mobile.de	7%
24	www.aol.com	5%
25	www.orange.fr	5%
26	www.seznam.cz	4%
27	www.flipkart.com	1%

Partial Failures | Root Cause Analysis



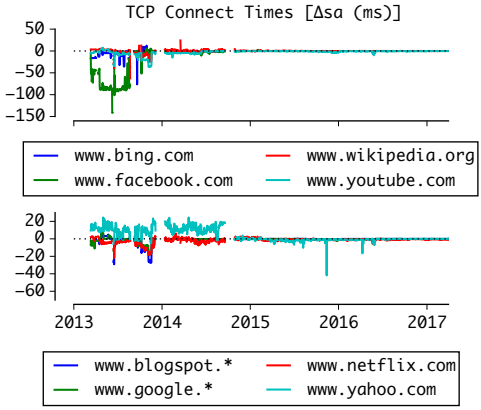
- Third-party advertisements (*.doubleclick.net)
- Analytics (*.scorecardresearch.com, *.quantserve.com)
- User-centric content (*.facebook.com, *.ajax.googleapis.com)
- Static content (*.wikimedia.org, *.creativecommons.org)

- Enabling IPv6 on few cross cross-origin sources (creativecommons.org, doubleclick.net) will help reduce partial failure of multiple websites.

Latency | Websites

$$\Delta s_a(u) = t_4(u) - t_6(u)$$

where $t(u)$ is the time taken to establish TCP connection to website u.

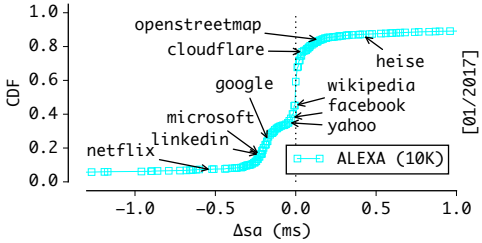


- ISPs in early stages of IPv6 deployment should ensure their CDN caches are dual-stacked.

- TCP connect times to popular websites over IPv6 have *considerably* improved over time.
- Inflated latency over IPv6 was due to *missing* content caches over IPv6

ALEXA top 10K websites (as of Jan 2017):

- 40% are *faster* over IPv6.
- 94% of the rest are at most 1 ms slower.
- 3% are at least 10 ms slower.
- 1% are at least 100 ms slower.

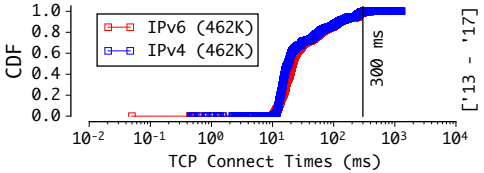


$$\Delta s_a(u) = t_4(u) - t_6(u)$$

- Relevant for content providers to get insights on how their service delivery compares over IPv6.

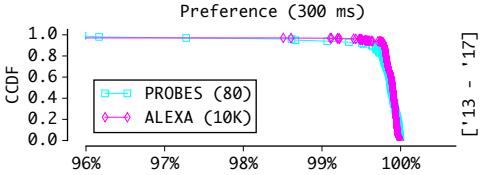
Happy Eyeballs

- Only ∼1% of samples above HE timer value > 300 ms



Websites where HE *prefers* IPv6 —

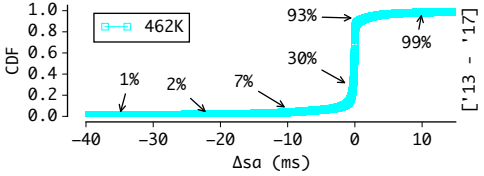
- A 300 ms HE timer value leaves 2% chance for IPv4.
- 99% of top 10K ALEXA prefer IPv6 98% of time.



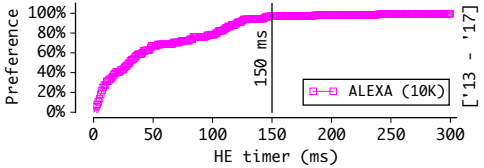
Happy Eyeballs

Samples where HE *prefers* IPv6 —

- HE prefers slower IPv6 connections 90% of the time.



- HE timer of 150 ms maintains same IPv6 preference levels.
- We get margin benefit of 10% because timer cuts early.



- RFC 6555 should have used 150 ms timer. Measurements should inform protocol engineering.
- Drive an RFC 6555 update with operational experience within the IETF.

This work would not have been possible without these amazing people —

■ Jürgen Schönwälder ■ Jörg Ott ■ Sam Crawford ■ Jamie Mason ■ Steffie Jacob Eravuchira ■ Philip Eardley ■ Trevor Burbridge ■ Andrea Soppera ■ Olivier Bonaventure ■ Dan Wing ■ Andrew Yourtchenko ■ Stephen Strowes ■ Eric Vyncke ■ Arthur Berger ■ Karen Davis ■ Fred Baker ■ Aiko Pras ■ Al Morton ■ Alex Buie ■ Alexandru Dumitru ■ Andrew Barnes ■ Antonio Prado ■ Antonio Querubin ■ Arash Naderpour ■ Bart Van Der Veer ■ Bayani Benjamin Lara ■ Bill Walker ■ Brandon Ross ■ Chiang Fong Lee ■ Chris Baker ■ Christian Kaufmann ■ Clinton Work ■ Daniel Karrenberg ■ Dario Ercole ■ Dustin Grant ■ Edi SUC ■ Edoardo Martelli ■ Egil-Andre Oelschlagel ■ Emile Aben ■ Erik Taraldsen ■ Espen Pederson ■ Faruk Sejdic ■ Filip De Turck ■ Frank Bulk ■ Fuminori Tany Tanizaki ■ Heinrich Stamerjohanns ■ Herman Hermansen ■ Hugo Slabbert ■ James Cutler ■ Jan Zorz ■ Jason Fesler ■ Jasper Rappard ■ Javier Henderson ■ Jens Hoffmann ■ Jesse Sowell ■ Joel Maslak ■ John Ioannidis ■ Jon Thompson ■ Jordi Palet ■ Josh Hoge ■ Juan Cerezo ■ Juan Cordero ■ Kawashima Masanobu ■ Kinga Lipskoch ■ Kris Lambrechts ■ Kristijan Lecnik ■ Krunal Shah ■ Lucas do Amaral Saboya ■ Luka Manojlovic ■ Marco Hogewoning ■ Marco Sommani ■ Marian Neagul ■ Martin Neitzel ■ Masaki Tagawa ■ Mat Ford ■ Mathew Newton ■ Matthieu Bouthors ■ Michael Carey ■ Michael Richardson ■ Michael Van Norman ■ Mikael Abrahamsson ■ Mike Taylor ■ Mircea Suciu ■ Nick Chettle ■ Nishal Goburdhan ■ Ole Troan ■ Owen DeLong ■ Pedro Tumusok ■ Per Olsson ■ Peter Bulckens ■ Philip Homburg ■ Philip Smith ■ Phillip Remaker ■ Radek Krejci ■ Richard Patterson ■ Robert Kisteleki ■ Ryan Rawdon ■ Saba Ahsan ■ Sergey Sarayev ■ Steinar Haug ■ Steve Bauer ■ Tero Marttila ■ Thibault Cholez ■ Thomas Schafer ■ Tim Chown ■ Tim Coote ■ Tim Martin ■ Tobias Oetiker ■ Torbjorn Eklov ■ Trond Hastad ■ Uros Gaber ■ Vesna Manojlovic ■ Vlad Ungureanu ■ Wouter de Vries ■ Yasuyuki Kaneko

Impact

- A Longitudinal View of Dual-Stacked Websites —
  - Failures [3] [CNSM '16]
  - Latency [4] and [NETWORKING '15]
  - Happy Eyeballs [5] [ANRW '16]

- Relevance:
  - Network operators in *early* stages of IPv6 deployment.
  - Content providers to see how their *service delivery* over IPv6 compares to IPv4.
  - Drive related *standards* work in the IETF.

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References

[1] "98.01% of sites on Cloudflare now use IPv6," https://blog.cloudflare.com/98-percent-ipv6, [Online; accessed 15-Apr-2017].

[2] "NAT64 Check," nat64check.ipv6-lab.net, [Accessed 15-Apr-2017].

[3] S. J. Eravuchira, V. Bajpai, J. Schönwälder, and S. Crawford, "Measuring Web Similarity from Dual-stacked Hosts," ser. Conference on Network and Service Management, 2016, pp. 181–187. [Online]. Available: http://dx.doi.org/10.1109/CNSM.2016.7818415

[4] V. Bajpai and J. Schönwälder, "IPv4 versus IPv6 - who connects faster?" ser. IFIP Networking Conference, 2015, pp. 1–9. [Online]. Available: http://dx.doi.org/10.1109/IFIPNetworking.2015.7145323

[5] ——, "Measuring the Effects of Happy Eyeballs," ser. Applied Networking Research Workshop, 2016. [Online]. Available: http://dl.acm.org/citation.cfm?id=2959429