Measuring IPv6 Performance

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Joint Work with

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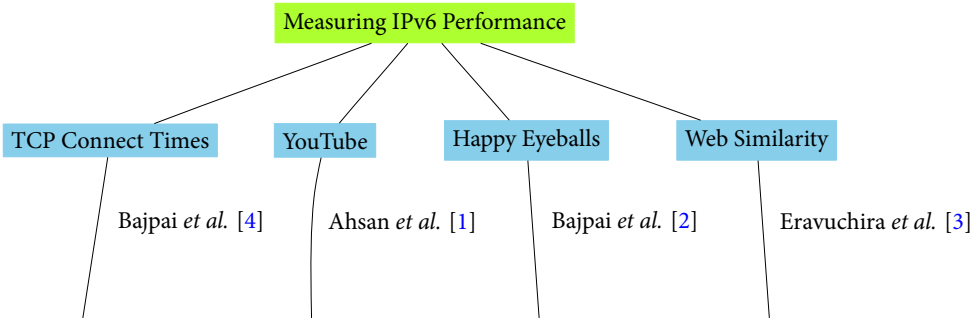
This research would not have been possible without these amazing people!

Overview



Overview | Motivation

- Literature has *largely* focussed on measuring IPv6 adoption [5, 6, 7] ('10 –'14).
  - Addressing
  - Naming
  - Routing
  - Reachability
- Very little work [8] on measuring performance of service delivery over IPv6.
- Largely due to lack of available content over IPv6.
- A number of *significant* events occured during the span of this dissertation.
  - IANA IPv4 Address Exhaustion [9]
  - World IPv6 Day '11 [10]
  - World IPv6 Launch Day '12 [11]
  - RIR IPv4 Address Exhaustion [9]

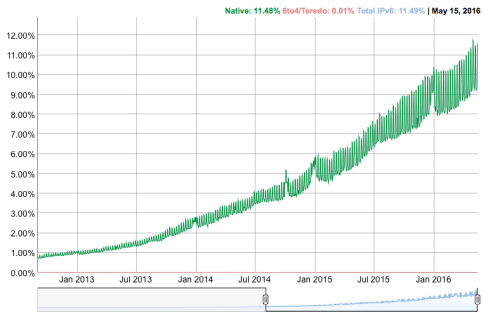
APNIC	Apr'11
RIPE	Sep'12
LACNIC	Jun'14
ARIN	Sep'15

Overview | Motivation

- Large IPv6 broadband rollouts[1] [4].
- Global IPv6 adoption [12].

09/2012 0.85%
11/2016 12.46%

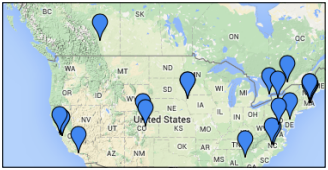
Belgium	47.38%
United States	30.12%
Switzerland	26.95%
Germany	26.61%



- This study *closes* the gap.
- It measures IPv6 performance of *operational* dual-stacked content delivery services.

[1] Comcast, Deutsche Telekom AG, AT&T, Verizon Wireless, T-Mobile USA

Overview | Measurement Trial

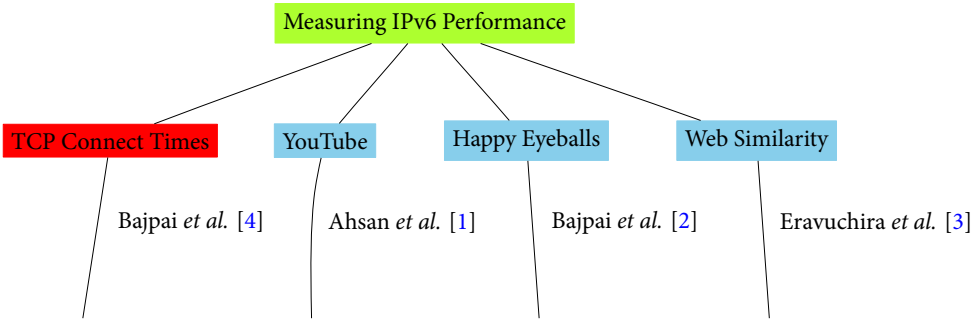


NETWORK TYPE	#
RESIDENTIAL	55
NREN / RESEARCH	11
BUSINESS / DATACENTER	09
OPERATOR LAB	04
IXP	01

RIR	#
RIPE	42
ARIN	29
APNIC	07
AFRINIC	01
LACNIC	01

We measure from 80 dual-stacked SamKnows [13] probes.

Overview | TCP Connect Times

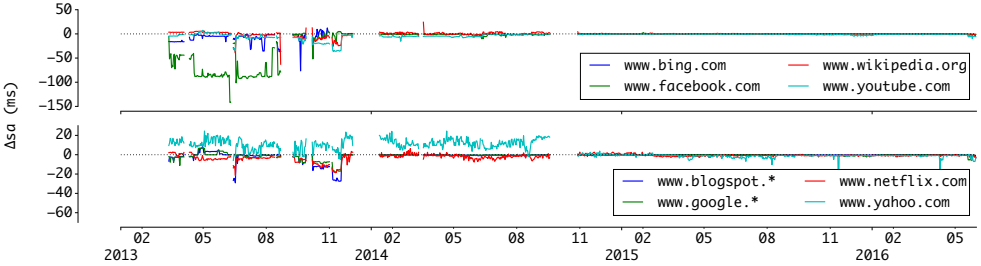


* entries are papers currently under review.

TCP Connect Times | Trends (2013 - 2016)

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

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

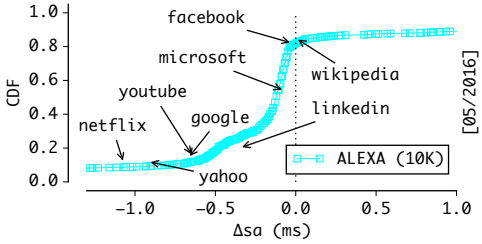


- TCP connect times to popular websites over IPv6 have *considerably* improved over time.

TCP Connect Times | Who connects faster?

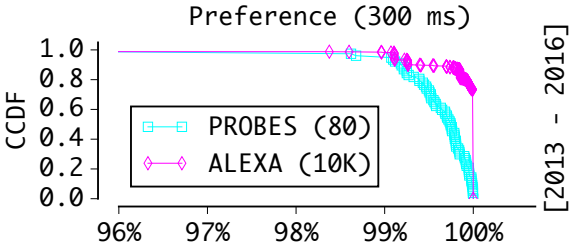
ALEXA top 10K websites (as of May 2016):

- 18% are *faster* over IPv6.
- 91% of the rest are at most 1 ms slower.
- 3% are at least 10 ms slower.
- 1% are at least 100 ms slower.



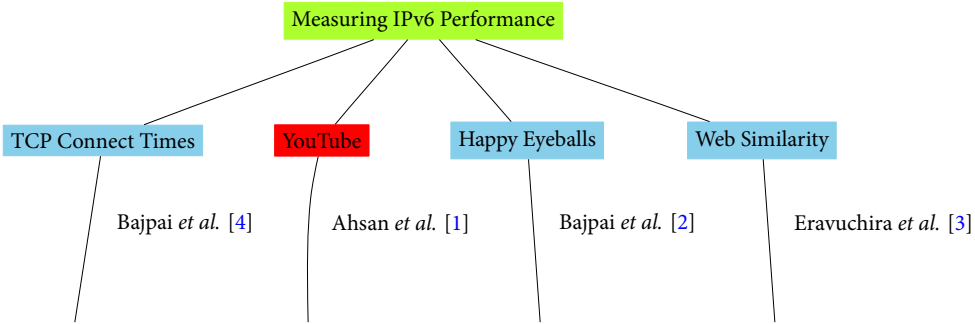
$$\Delta s_a(u) = t_4(u) - t_6(u)$$

TCP Connect Times | IPv6 Preference



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

Overview | Measuring YouTube



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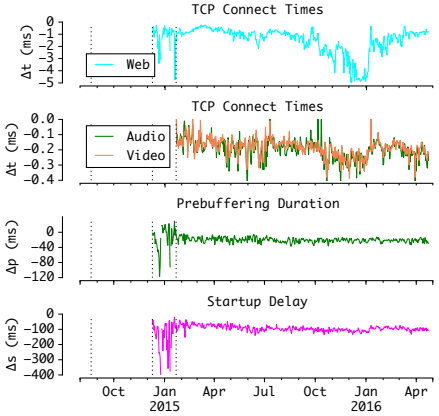
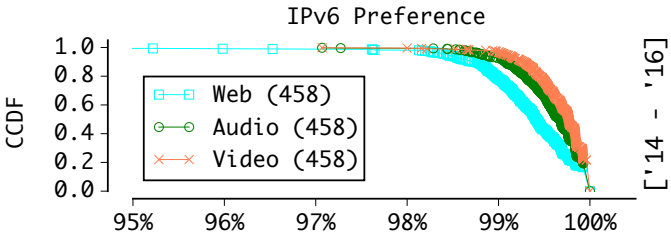
YouTube | Latency

- TCP connect times
  - < 1 ms slower over IPv6
  - Higher towards webpages
- Prebuffering durations
  - > 25 ms slower over IPv6
- Startup delay
  - > 100 ms slower over IPv6



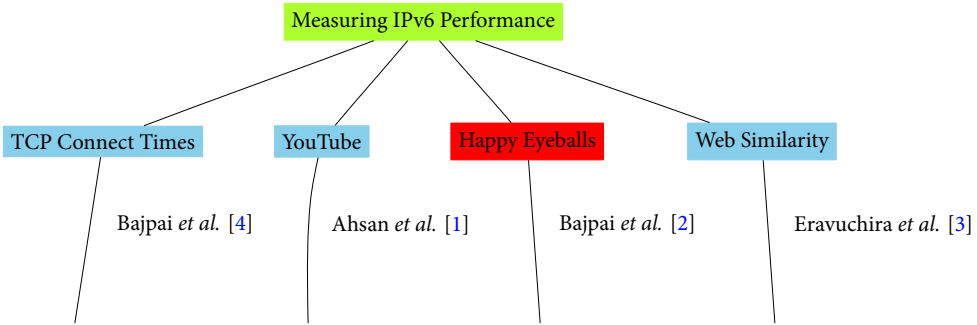
$$\Delta t(y) = tc_4(y) - tc_6(y)$$
$$\Delta p(y) = pd_4(y) - pd_6(y)$$
$$\Delta s(y) = sd_4(y) - sd_6(y)$$

Latency is consistently *higher* over IPv6.



- Media streams are *preferred* over IPv6 more than 97% of the time.

Overview | Measuring Effects of Happy Eyeballs



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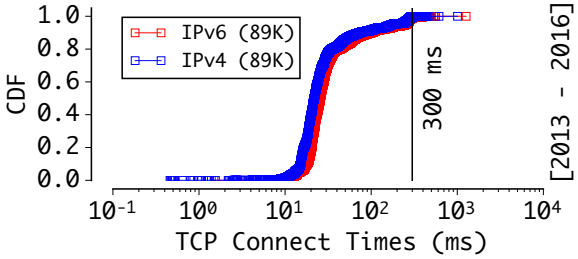
Happy Eyeballs | Preference

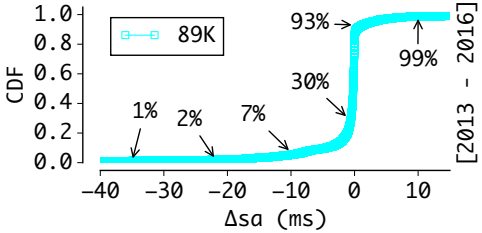


- Only ∼1% of samples above HE timer value > 300 ms

Happy Eyeballs | Slowness

Samples where HE *prefers* IPv6 —

- HE prefers slower IPv6 connections 90% of the time.
- Absolute difference is not that far apart from IPv4
  - 30% — at least 1 ms slower.
  - 7% — at least 10 ms slower.



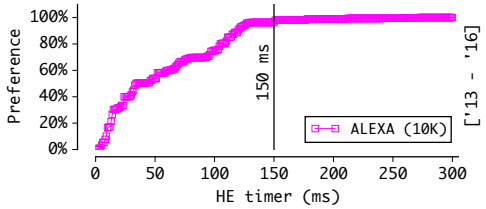
$$\Delta s_a(u) = t_4(u) - t_6(u)$$

$$\Delta s_r(u) = \frac{t_4(u) - t_6(u)}{t_4(u)}$$

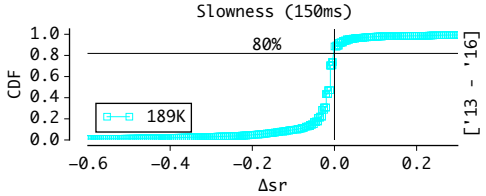
Can a lower HE timer provide same preference over IPv6 but not penalise IPv4 when it's faster?

Happy Eyeballs | Lowering HE Timer

- We control two[2] parameters and lower the HE timer value.
- Each data point is the 1th percentile preference towards ALEXA 10K websites.

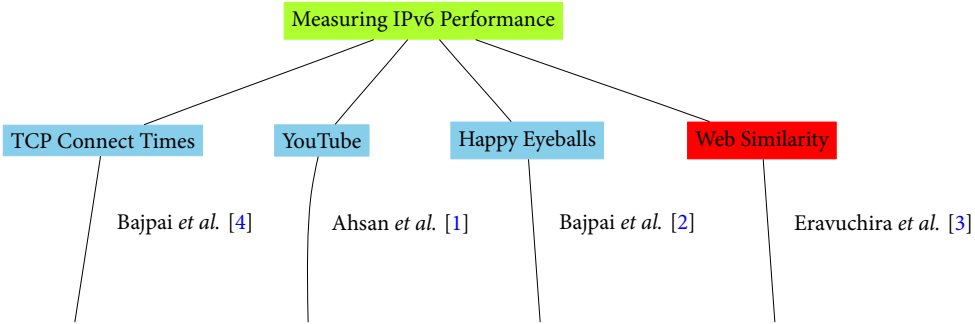


- Lowering to 150 ms retains preference levels over IPv6.
- We get margin benefit of 10% (18.9K) because timer cuts early.



[2] 99% ALEXA top 10K websites prefer IPv6 connections 98.6% of the time

Overview | Measuring Web Similarity

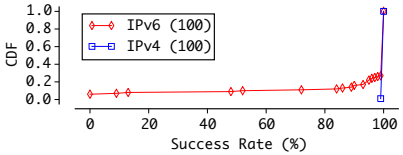


* entries are papers currently under review.

Web Similarity | Success Rate

Can we fetch all webpage elements over IPv6?

- 27% of websites show some rate of failure over IPv6.
- 9% exhibit more than 50% failures over IPv6.
- 6% show complete failure (0% success) over IPv6.



#	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	

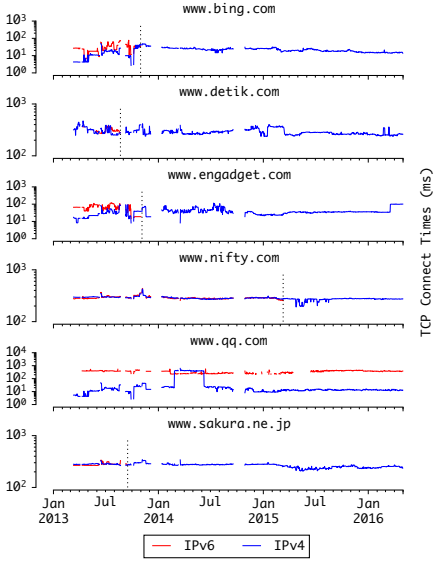
Web Similarity | Success Rate

ALEXA top 100 dual-stacked websites:

- 6% show complete failure over IPv6.

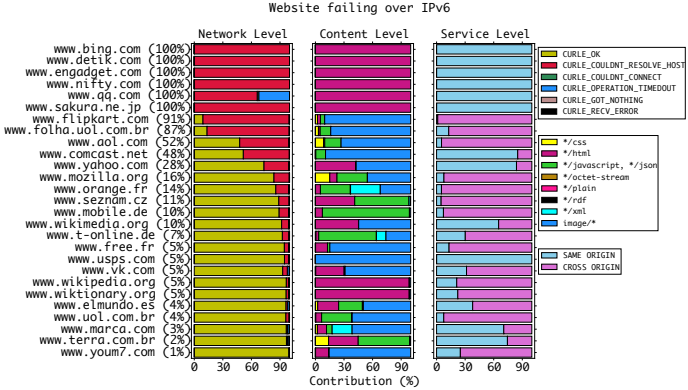
#	Webpage	Success Rate (%)		W6LD
		IPv6(↓)	IPv4	
01	www.bing.com	0	100	✓
02	www.detik.com	0	100	✓
03	www.engadget.com	0	100	✓
04	www.nifty.com	0	100	
05	www.qq.com	0	100	
06	www.sakura.ne.jp	0	100	

- Metrics that measure IPv6 adoption should account for *changes* in IPv6-readiness.



Web Similarity | Causality Analysis

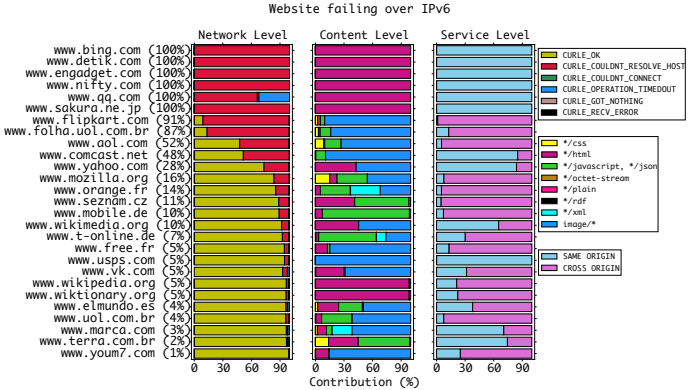
Where in the network does the failure occur?



- `CURLE_COULDNT_RESOLVE_HOST` is the major contributor to failure rates.
- AAAA entries missing for these webpage elements in the DNS.

Web Similarity | Causality Analysis

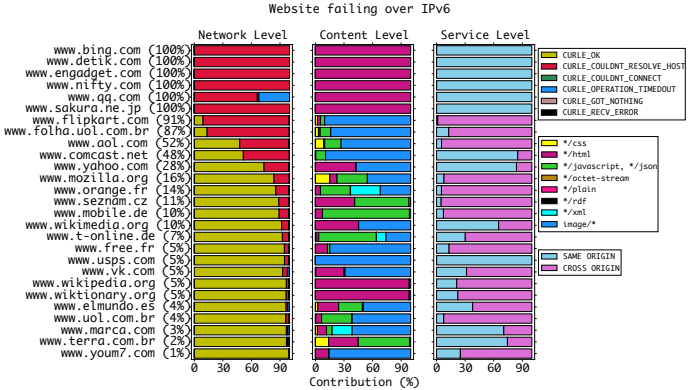
Which type of objects fail more than others?



- `image/*`, `*/javascript`, `*/json` and `*/css` content contribute to the majority of the failure over IPv6.

Web Similarity | Causality Analysis

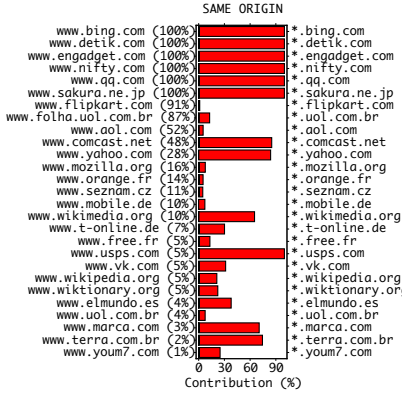
Where do the failing objects originate from?



- Both same and cross origin sources contribute to the failure of webpage elements over IPv6.

Web Similarity | Causality Analysis

What is failure contribution of same-origin sources?

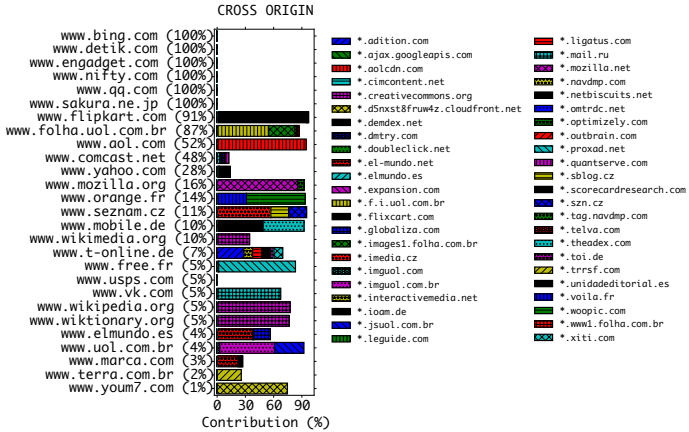


- 12% of websites have more than 50% webpage elements that belong to the same origin source and fail over IPv6.

#	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%

Web Similarity | Causality Analysis

What is failure contribution of cross-origin sources?



- Some of the cross-origin sources contribute to the failure of multiple websites.

Takeway

- ISPs should ensure CDN caches are dual-stacked form the very outset.
- ISPs should put latency as a first-class citizen.
- Measurements should be used to inform protocol-engineering.
- Metrics that measure IPv6 adoption should account for changes in IPv6-readiness.
- Limiting to root webpage can lead to overestimation of IPv6 adoption numbers.
- Let's deem a website IPv6-ready when there is no partial failure over IPv6.

Impact

- Measuring IPv6 Performance
  - Measuring TCP Connect Times [NETWORKING '15]
  - Measuring YouTube Performance [PAM '15]
  - Measuring Effects of Happy Eyeballs [ANRW '16]
  - Measuring Web Similarity [CNSM '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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