Understanding the Impact of Network Infrastructure Changes using Large Scale Measurement Platforms

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Survey on Internet Performance Measurement Platforms [1] [COMST '15]

Measuring IPv6 Performance

- Measuring Web Similarity [2] [CNSM '16]
- Measuring TCP Connect Times [3] [NETWORKING '15]
- Measuring YouTube Performance [4] [PAM '15]
- Measuring Effects of Happy Eyeballs [5] [ANRW '16]

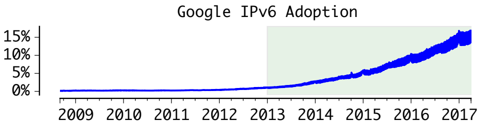
Measuring Access Network Performance

- RIPE Atlas Vantage Point Selection [6] [IM '17]
- Dissecting Last-mile Latency Characteristics [∗]
- Lessons Learned from using RIPE Atlas [7] [SIGCOMM CCR '15]

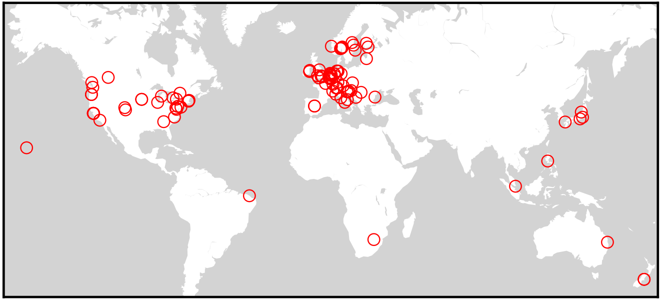
∗ entries are papers currently under review.

IPv6 Performance

- 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.

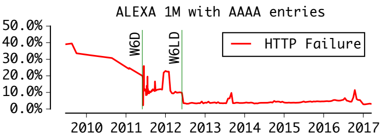


We measure from ∼100 dual-stacked SamKnows probes.

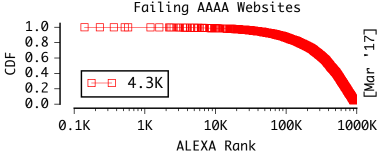
NETWORK TYPE	#
RESIDENTIAL	78
NREN / RESEARCH	10
BUSINESS / DATACENTER	08
OPERATOR LAB	04
IXP	01

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

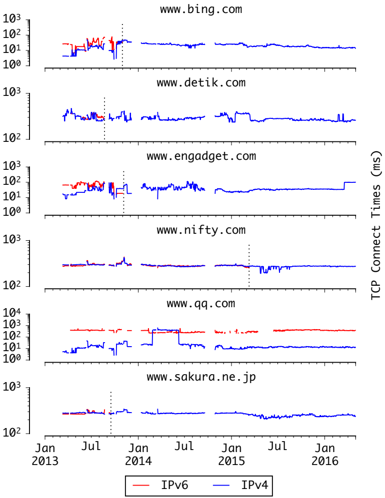
Complete Failures



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



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

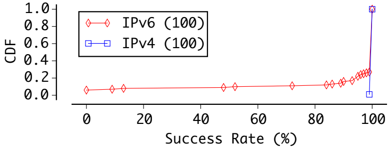


Metrics should account for *changes* in IPv6-readiness.

Partial Failures

ALEXA top 100 websites with AAAA entries.

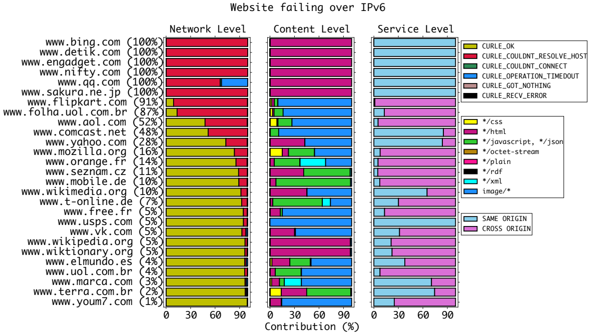
- 27% show some rate of failure over IPv6.
- 9% exhibit more than 50% failures over IPv6.



- 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 [8] development of *tools* that identify such partial failures

#	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	
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



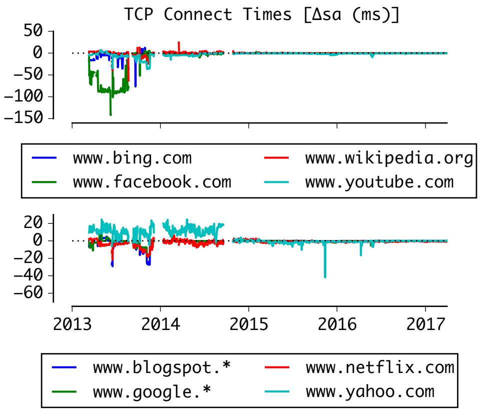
- Failures *silently* exist; clients do not notice them due to IPv4 fallback.
- Identification of operational issues relevant for upcoming IPv6-only networks

- Failures due to DNS resolution error on `image/*`, `*/javascript`, `*/json` and `*/css` content.
- 12% websites have more than 50% content that belongs to same-origin source and fails over IPv6,
- Content failing from cross-origin sources consists of analytics and third-party advertisements.

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.

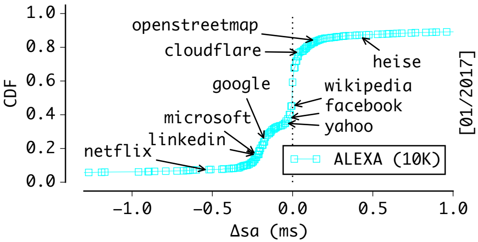


- ISPs in early stages of IPv6 deployment should ensure their CDN caches are dual-stacked.

- 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.



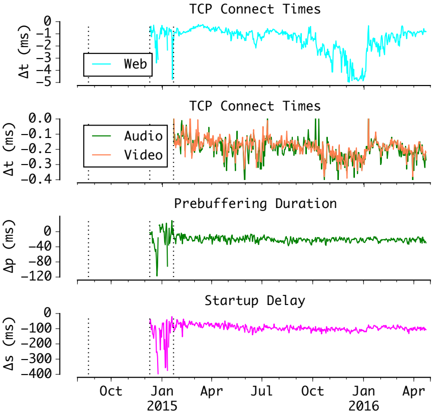
$$\Delta s_a(u) = t_4(u) - t_6(u)$$

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

YouTube

Latency is consistently *higher* over IPv6.

- 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

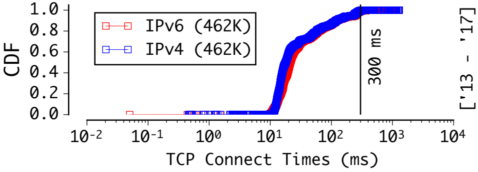


- ISPs should make their GGC nodes dual-stacked.

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

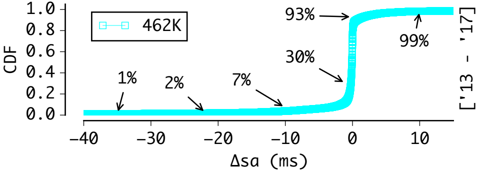
Happy Eyeballs

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



Samples where HE *prefers* IPv6 –

- HE prefers slower IPv6 connections 90% of the time.
- HE timer of 150 ms maintains same IPv6 preference levels.



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

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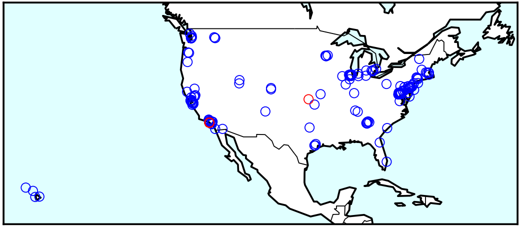
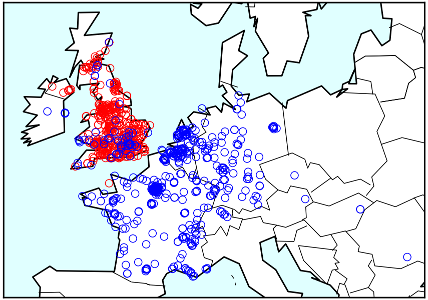
Last-mile Latency

- Latency becomes a critical factor [9] when downstream throughput > 16 Mb/s.
- Last-mile latency is a *major* contributor[9] to end-to-end latency.
- However, little is known [10, 11] about *characteristics* of last-mile latency.



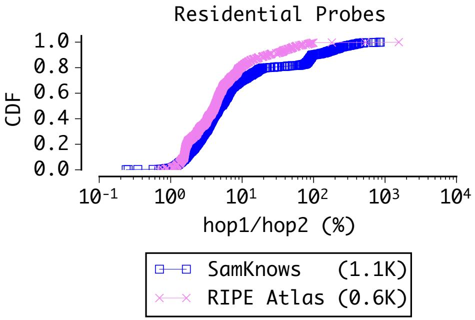


- 696 RIPE Atlas v3 residential probes (blue)
- 1245 SamKnows residential probes (red)

Methodology described to isolate residential probes useful for future broadband measurement *studies* using these platforms.

Last-mile Latency | Home Network Latency

The home network should not be accounted when measuring last-mile latency.

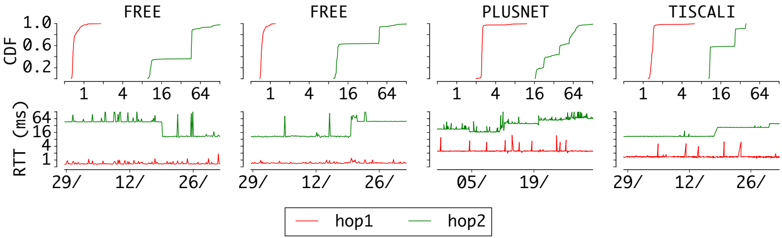


- *hop*1 > 10% of *hop*2 latency (∼19% probes).

Last-mile latency should be the difference between the *hop2* and *hop1* latency.

Last-mile Latency | Interleaving Depths

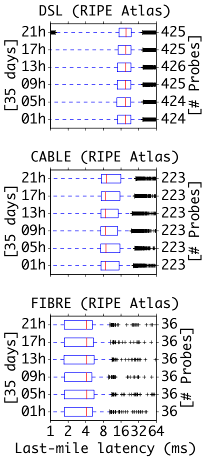
- DSL networks *not* only enable interleaving [11] but …
- …also employ *multiple* interleaving depth levels that *change* with time.



- Interleaving depths show a step-wise functional change.
- *hop*2 latency transitions correlate with corresponding timeseries.

Last-mile Latency | Time of Day Effects

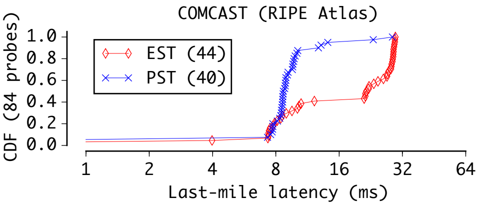
- Last-mile latencies are *stable* over time.
- Last-mile latencies do *not* exhibit diurnal load patterns.



- Simulation studies can now accurately *model* access links.
- CDN providers benefit from characteristics of the last-mile.
- Promotes ISPs to *cache* popular content close to the CPE.

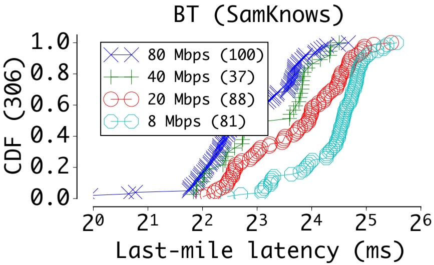
Last-mile Latency | Subscriber Location

- Not *all* cable deployments [10, 11] show last-mile latencies < DSL.



- Last-mile latencies:
  - can depend on *geographic location* of the subscriber.
  - are considerably different along US east (∼32 ms) and west (∼8 ms) coast.

Last-mile latencies *vary* by broadband speeds.



- Input for future *standards* (QUIC, TLS 1.3) work that targets operation in 0-RTT mode.

- ADSL2+ and VDSL with higher transmission rates help reduce interleaving delays.
- Last-mile latencies for VDSL < ADSL/ADSL2+

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

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