Measuring IPv6 Adoption

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Outline

1. Introduction

- State of the art: IPv4
  - Most widely-deployed networking protocol
  - reached its limits
  - exhausted address space

  → IPv6 was designed as solution

- Goals of the Paper:
  - Understand the adoption of IPv6
  - No widespread measurement available
  - Only single perspectives are available

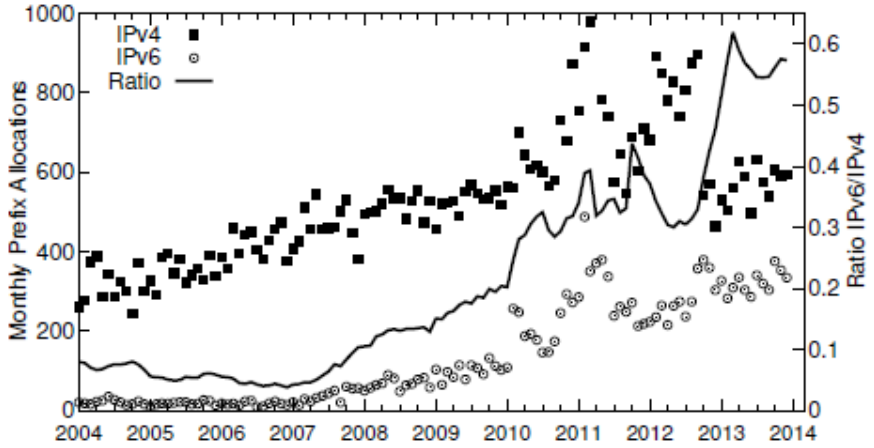
2. Measurement Metrics

		Prerequisite IP Functions				Operational Characteristics	
		Addressing	**Naming**	**Routing**	**End-to-End Reachability**	**Usage Profile**	**Performance**
Perspective	**Content Provider**		Nameserver Server Readiness		Server Readiness	Transition Technologies	
	Service Provider	Address Allocation Address Advertisement	Resolvers	Topology Address Advertisement		Traffic Volume Transition Technologies	Network RTT
	Content Consumer		Queries		Client Readiness	Application Mix Queries	

3. Datasets

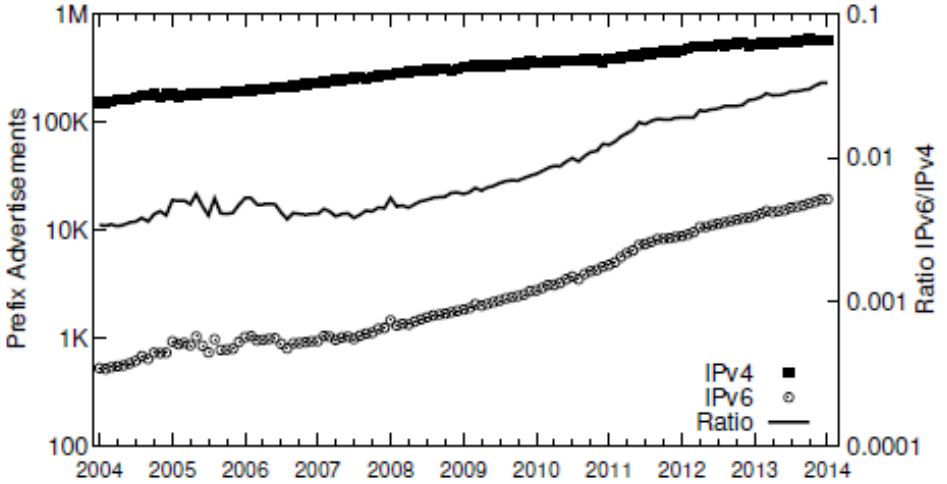
Dataset	Time Period	Recent Scale
RIR Address Allocation	Jan 2004 – Jan 2014	~18K allocation snapshots (5 daily)
Routing: Route Views	Jan 2004 – Jan 2014	45,271 BGP table snapshots
Routing: RIPE	Jan 2004 – Jan 2014	
Google IPv6 Client Adoption	Sep 2008 – Dec 2013	millions of daily global samples
Verisign TLD Zone Files	Apr 2007 – Jan 2014	daily snapshots of 2.5 million A+AAAA glue records
CAIDA Ark Performance Data	Dec 2008 – Dec 2013	~10 million IPs probed daily
Arbor Networks ISP Traffic Data	Mar 2010 – Dec 2013	~33-50% of global Internet traffic;
Verisign TLD Packets: IPv4	Jun 2011 – Dec 2013	~ 4.5Bn queries
Verisign TLD Packets: IPv6	Jun 2011 – Dec 2013	647M queries
Alexa Top Host Probing	Apr 2011 – Dec 2013	10,000 servers probed twice/month

4.1. Addressing

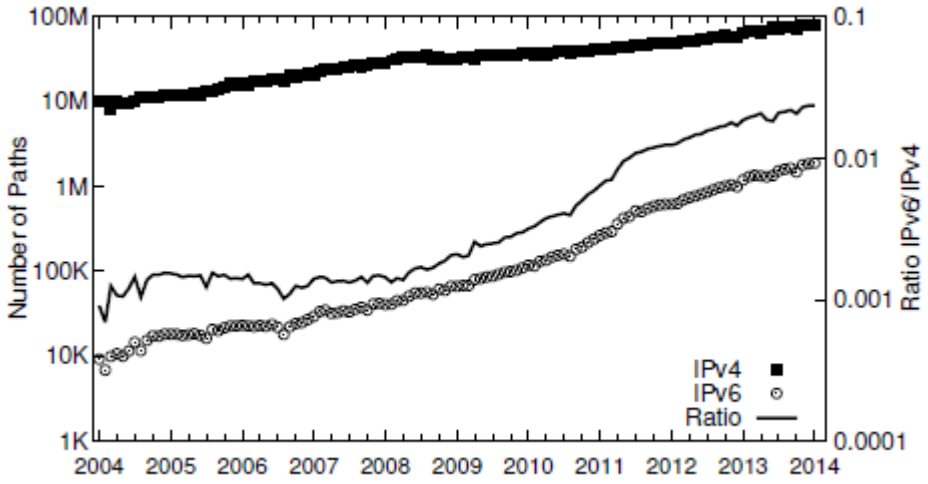


Total IPv4 Prefixes: 136k

Total IPv6 Prefixes 18k

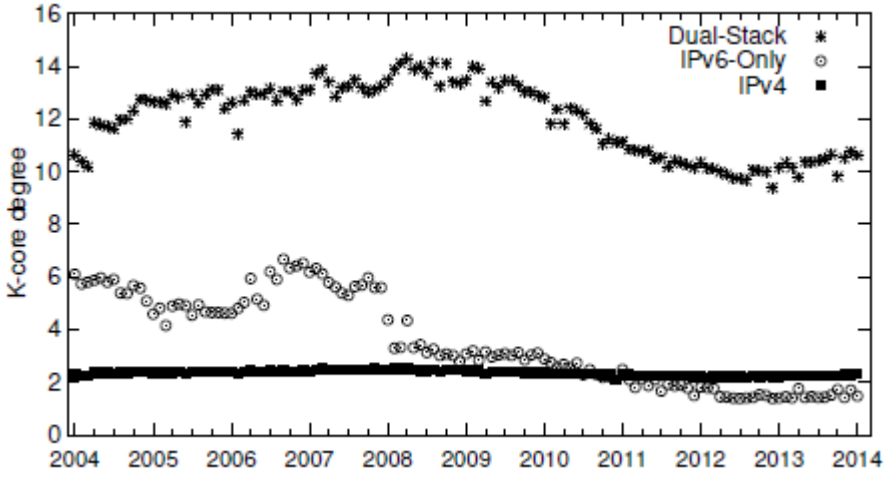


4.2 Topology

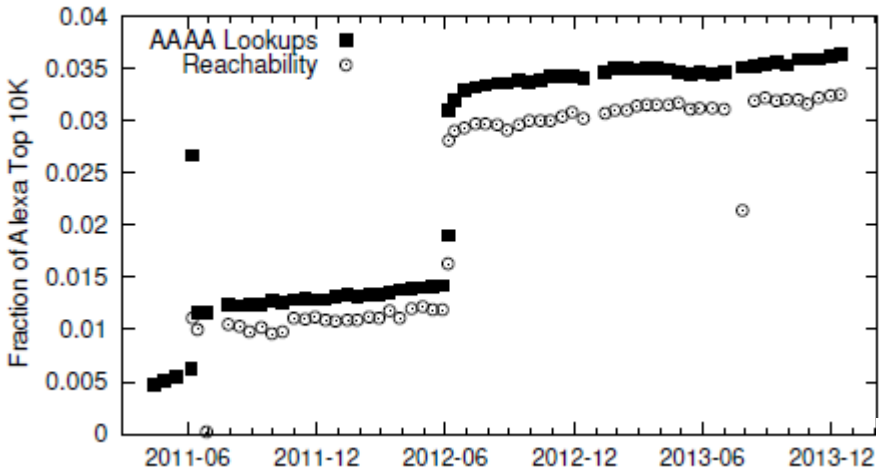


- Visible unique AS-paths
- Mainly top tier provider
- Peer to peer between low level provider missing

- k-core: maximal subgraph in which every node has at least degree k
- K-core degree N: belongs to the N-core but not the (N+1)-core



4.3 End-to-End Readiness

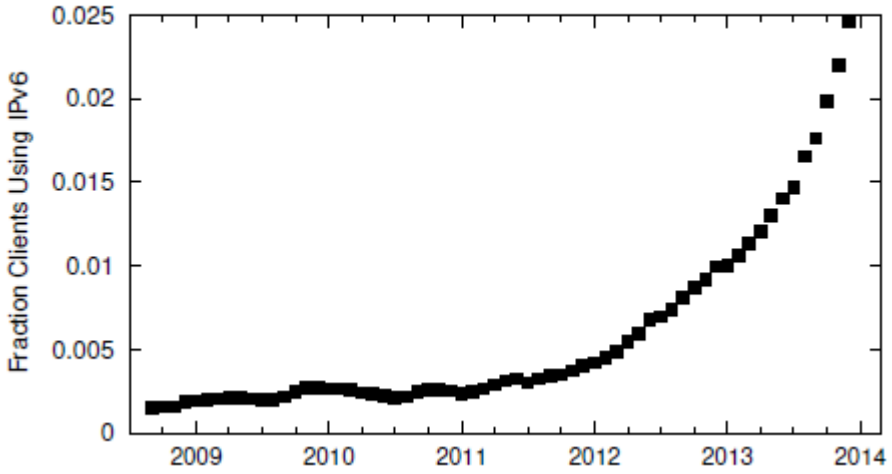


Content Provider

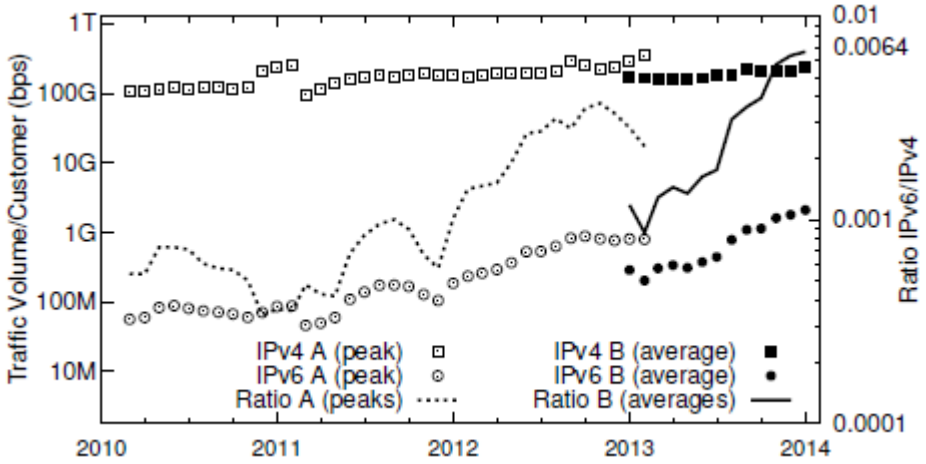
- 2011 World IPv6 Day
- 2012 World IPv6 Launch Day

Content Consumer

- Based on Google Dataset
- JavaScript applet
- Connections from users to Google



4.4 IPv6 Usage Profile

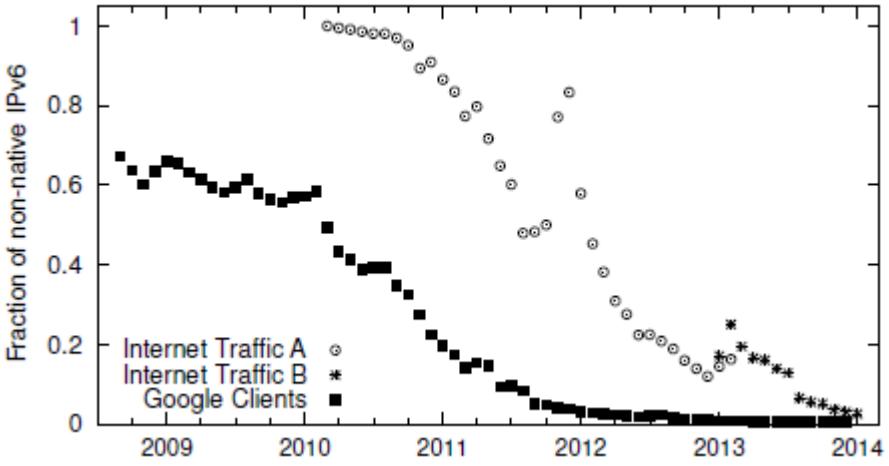


Traffic Volume

- Dataset A: 12 providers
- Dataset B: 260 providers

Transition Technologies

- Tunneling to connect IPv6 “islands”
  - E.g. Teredo



4.4 IPv6 Usage Profile: Application Mix

Application	Dec 2010	Apr/May 2011	Apr/May 2012		Apr-Dec 2013	
	IPv6	IPv6	IPv6	IPv4	IPv6	IPv4
HTTP	5.61	11.81	63.04	62.40	82.56	60.61
HTTPS	0.15	0.88	0.39	3.91	12.66	8.59
DNS	4.75	9.11	4.09	0.14	0.33	0.22
SSH	0.56	3.73	2.65	0.11	0.27	0.20
Rsync	20.78	5.11	2.65	0.00	0.13	0.00
NNTP	27.65	5.84	1.03	0.13	0.00	0.25
RTMP	0.00	0.05	0.11	2.39	0.00	2.74
Other TCP	-	-	18.72	3.20	1.66	4.08
Other UDP	-	-	1.73	11.90	0.27	2.82
Non-TCP/UDP	-	-	4.94	14.10	2.11	20.21

5. Conclusion and Limitations

- Detailed taxonomy to measure and compare IPv6 adaption
- Main results:
  - IPv6 is growing
  - IPv6 utilization has shifted
  - Geographic adoptions differ

- Limitations:
  - Mainly data from high level ISP
  - Most of the data from US/Europe
  - Social, behavioral and economic factors missing

References

[1] Jakub Czyz, Mark Allman, Jing Zhang, Scott Iekel-Johnson, Eric Osterweil, and Michael Bailey. 2014. Measuring IPv6 adoption. In *Proceedings of the 2014 ACM conference on SIGCOMM* (SIGCOMM '14). ACM, New York, NY, USA, 87-98. DOI: https://doi.org/10.1145/2619239.2626295