Measuring and Modeling the Adoption of IPv6

Amogh Dhamdhere, Matthew Luckie, Bradley Huffaker, kc claffy (CAIDA/UCSD)
Ahmed Elmokashfi (Simula Research)
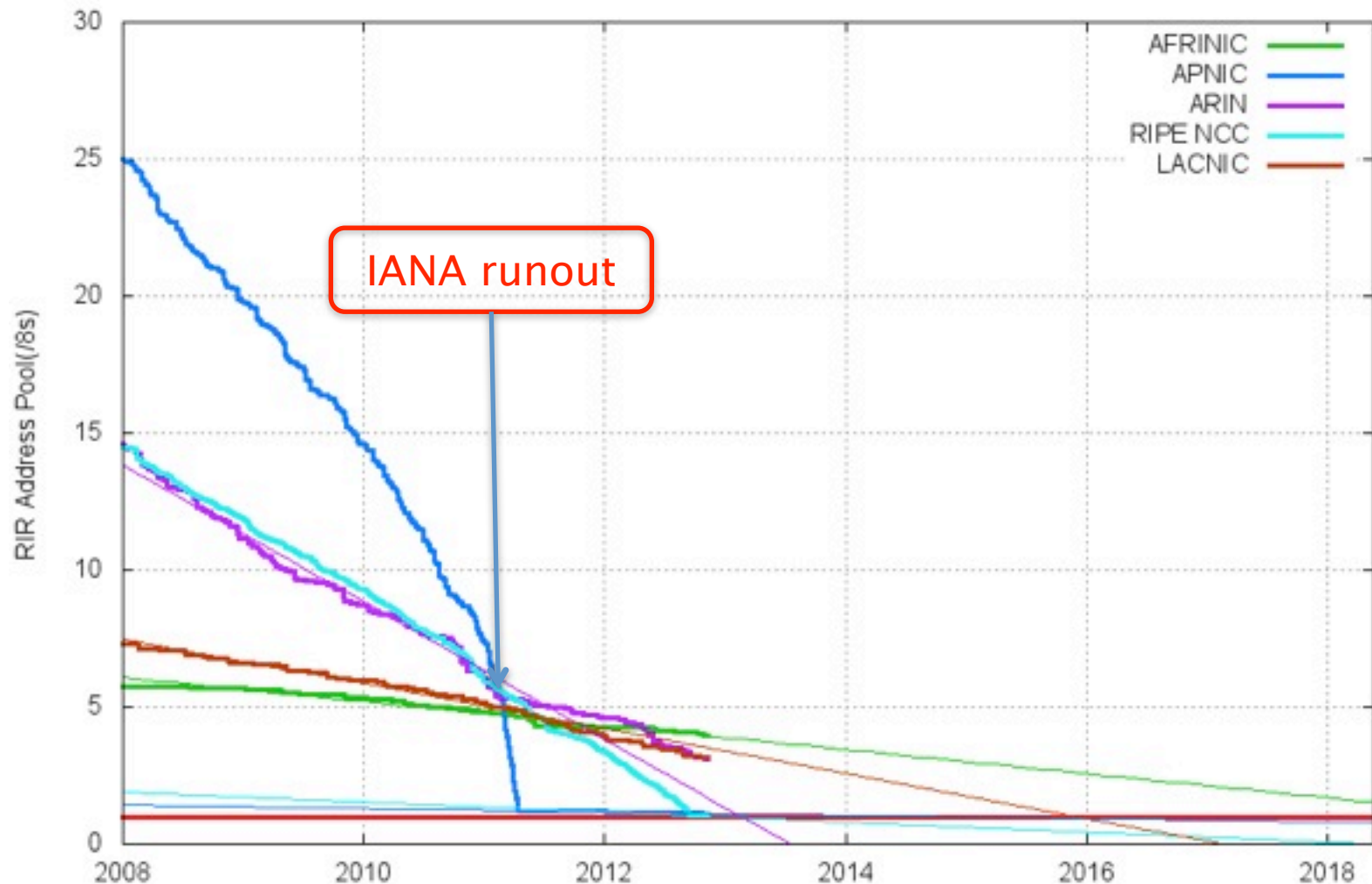Emile Aben (RIPE NCC)

When will we run out of IPv4

- IANA ran out of IPv4 addresses in 2011
- Regional Registries (RIRs) are rationing; will soon run out too
- Address trading ramping up (see Curran's NANOG56 talk)

Source: http://www.potaroo.net/tools/ipv4/index.html

IPv6

- Address runout anticipated back in 1990s
- The "new" (15 years old) IPv6 was standardized in the late 90s
- IPv6 provides much more address space than our foreseeable addressing needs
- Operating systems and network hardware have supported IPv6 for many years now
- Core transit providers also mostly announcing IPv6 routes

Sunday, January 13, 13

So, What's the Problem?

- Just use IPv6, right?
- The issue: IPv6 is not backwards compatible with IPv4
- Hosts with an IPv4 address cannot directly communicate with hosts with IPv6 addresses
- IPv6 configuration, management and troubleshooting still not well understood
- Many costs, no tangible benefit!

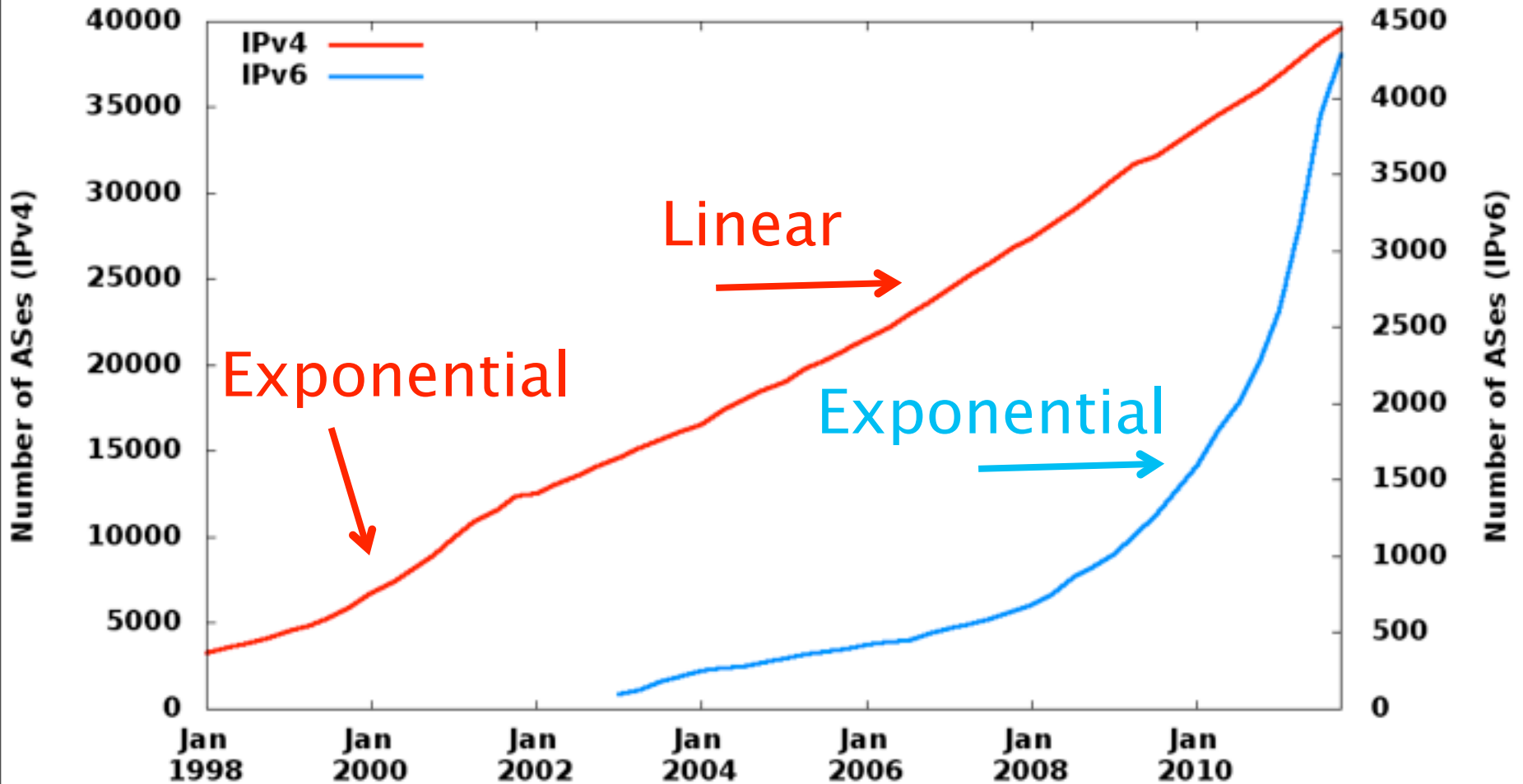# Two Endgame Scenarios

- IPv6 gets deployed!
  - Existing measurement techniques and data will be ineffective
- IPv6 languishes
  - A world of large-scale NATs and poor performance
- We don't have a good idea which scenario will happen
  - Insufficient (but some) data about IPv6 deployment, performance, traffic

Growth of IPv[4|6]
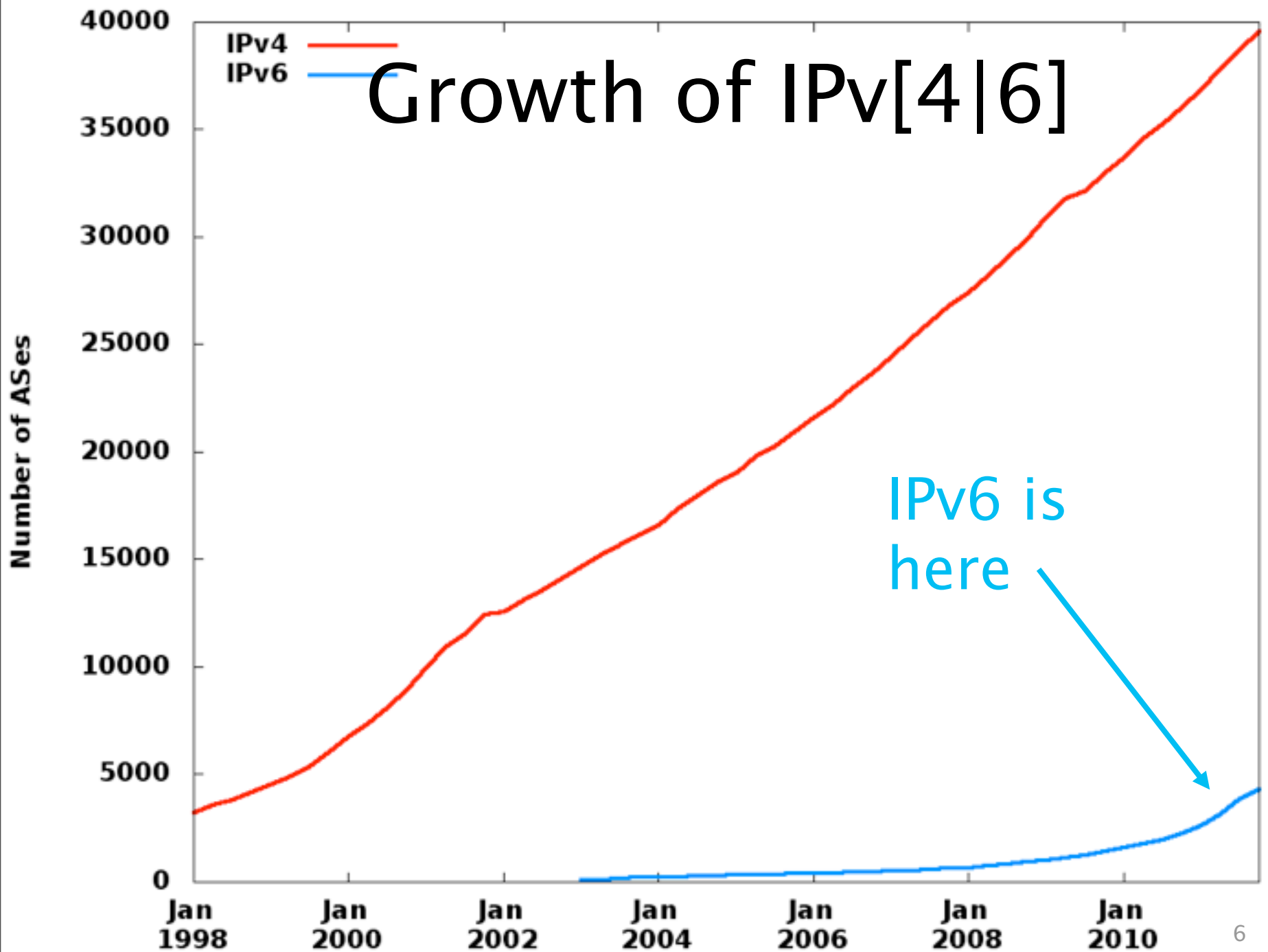
IPv6 growth: we need to zoom in..

- The IPv6 topology grows exponentially while the IPv4 topology now grows linearly

Digging deeper

- Exponential growth of IPv6 is encouraging
  - shift from a "toy" network to production?
- Which geographical regions and network types contribute most of the growth?
- Is the business mix in IPv6 converging to that in IPv4?
- Is IPv6 performance comparable to IPv4 performance?

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  - Could be much larger w/o deploying new infrastructure
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- some of these results recently cited by *http://arstechnica.com/business/2013/01/ipv6-takes-one-step-forward-ipv4-two-steps-back-in-2012/*

Measurement Data

- Topology snapshots+updates from BGP routing datasets from 1998–present
  - Routeviews and RIPE
- Annotated AS topology with business relationships on each link (Gao)
  - TODO: Integrate CAIDA's algorithm (2013)

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- Web page downloads & AS paths to dual-stack webservers in Alexa 1M (performance)

10

Growth trends by RIR region

11
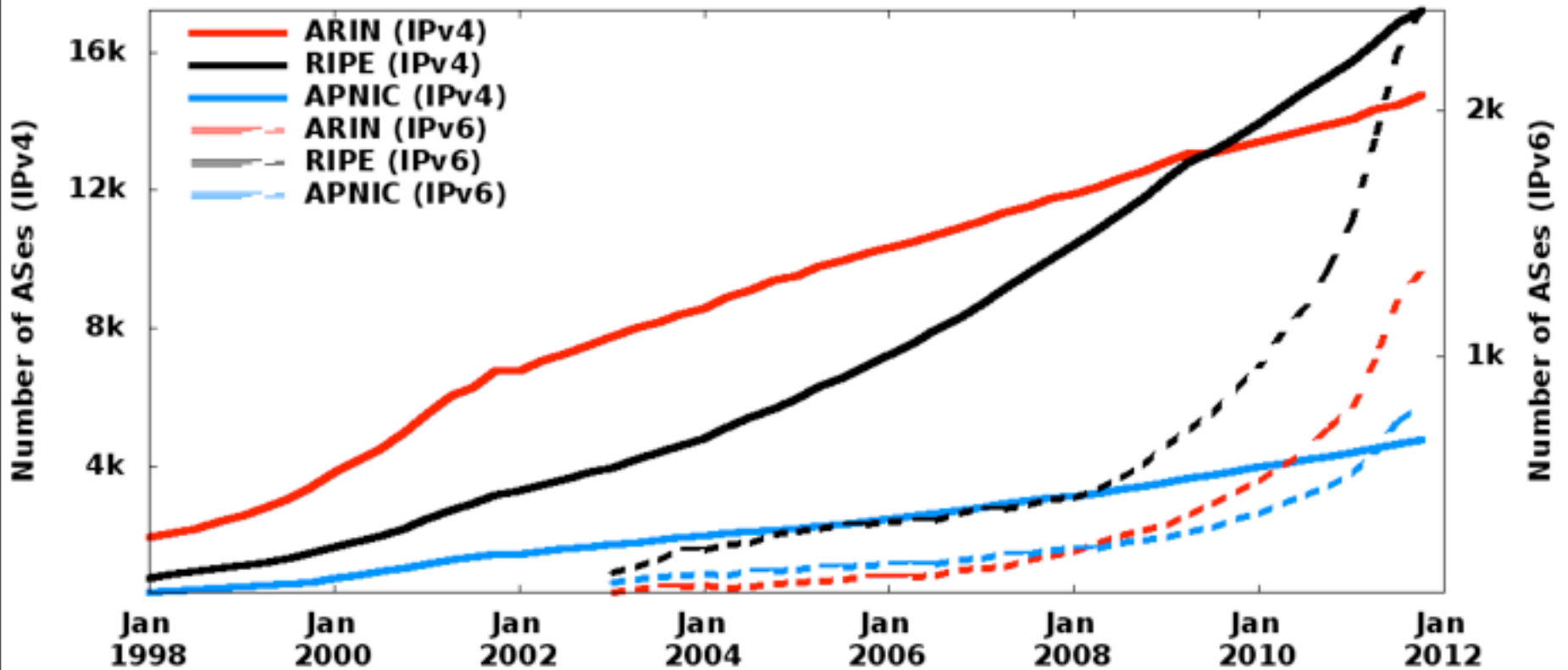
Growth trends by RIR region

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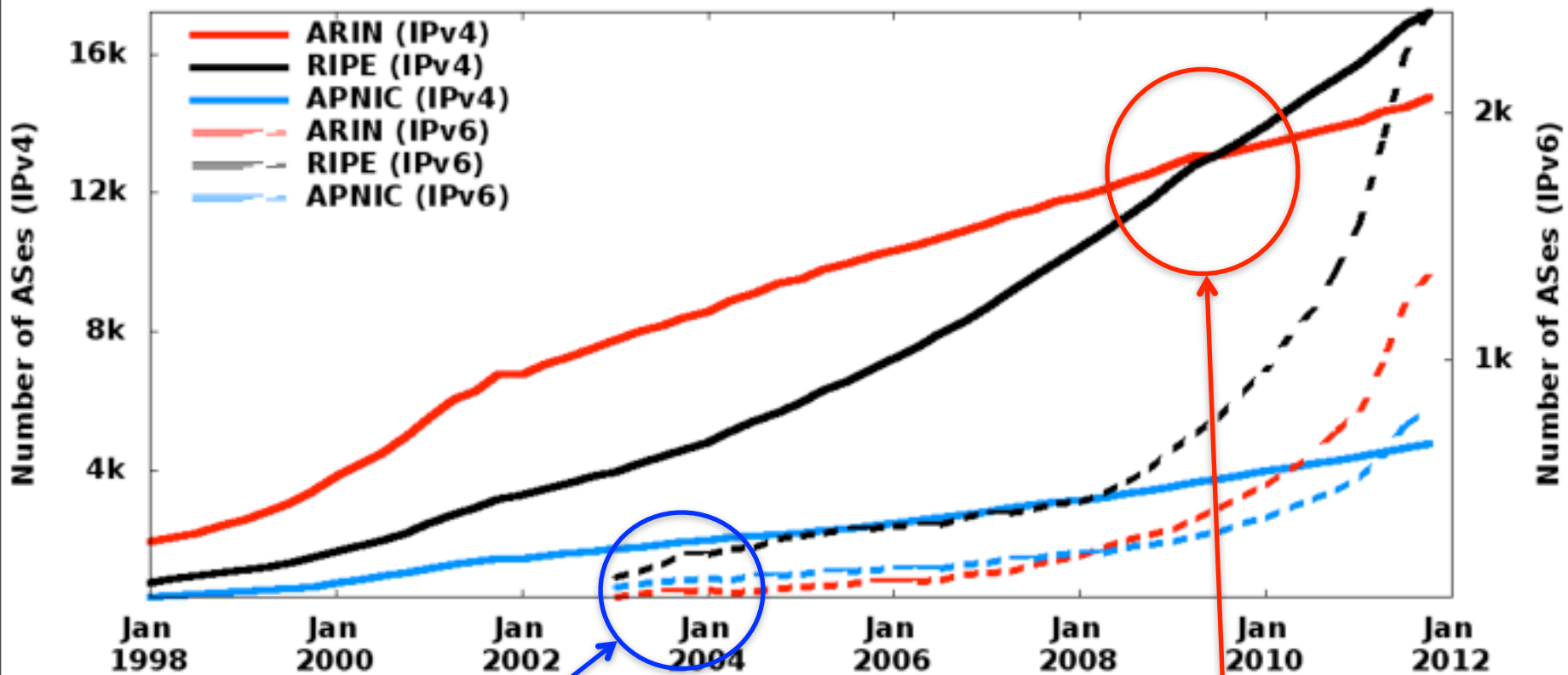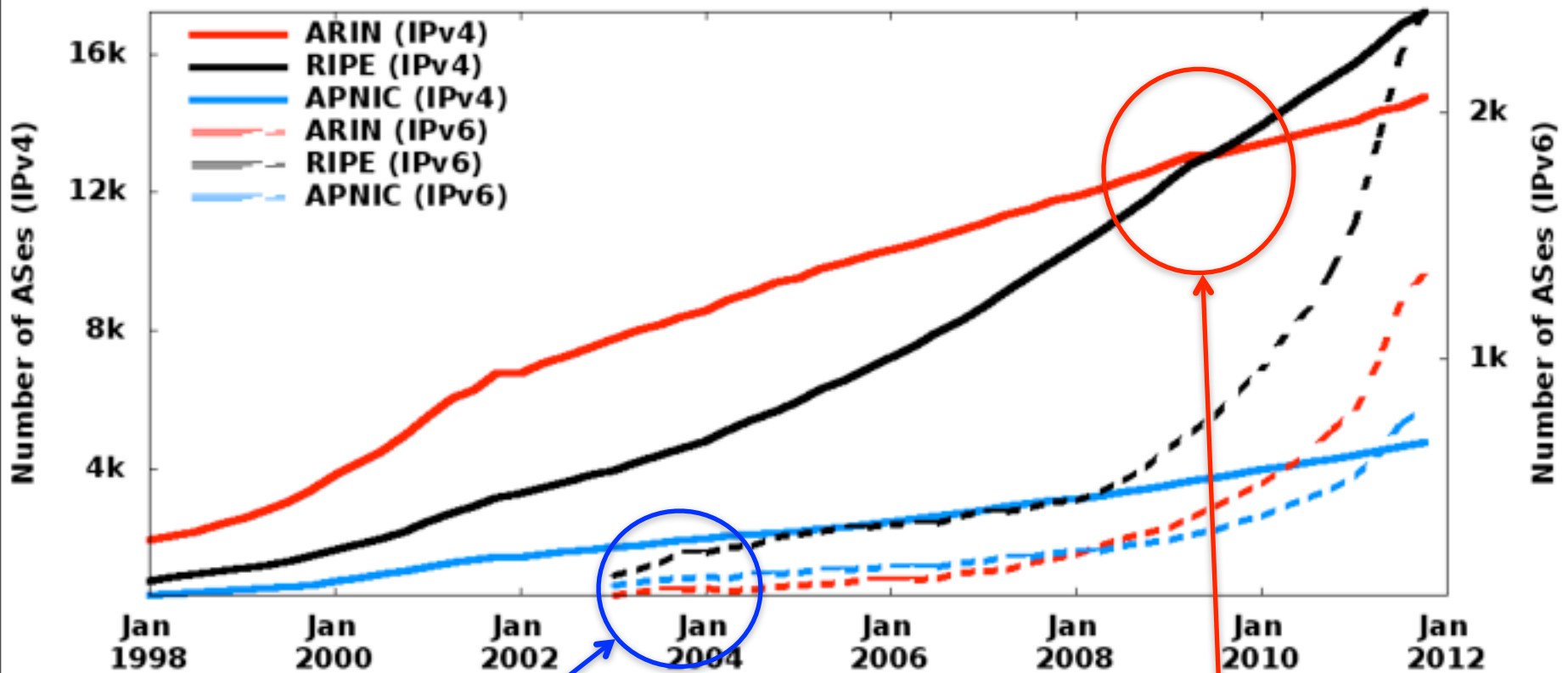
IPv6: RIPE region was always ahead of ARIN

IPv4: More ASes in RIPE region than ARIN since 2009

ARIN region is lagging in IPv6 deployment

11

AS Business Types

A. Dhamdhere, C. Dovrolis. *Twelve Years in the Evolution of the Internet Ecosystem.* IEEE/ACM Transactions on Networking, vol. 19, no. 5

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AS Business Types

Large Transit Provider (LTP)

Small Transit Provider (STP)

p2p

p2c

A. Dhamdhere, C. Dovrolis. *Twelve Years in the Evolution of the Internet Ecosystem*. IEEE/ACM Transactions on Networking, vol. 19, no. 5

12

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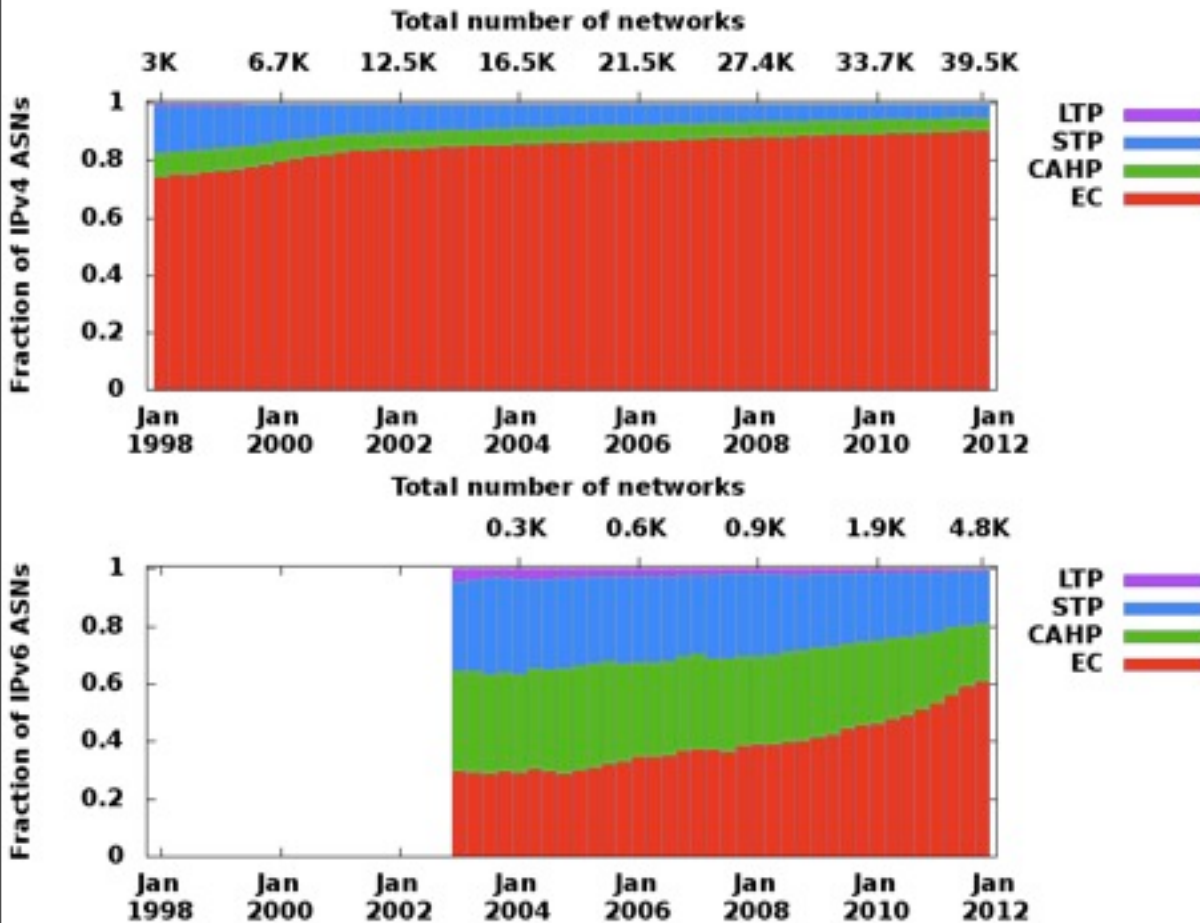
Evolution of the business mix

Hypothesis: As IPv6 matures, the business mix should become similar to that in IPv4

13

Evolution of the business mix

IPv4 network is dominated by ECs

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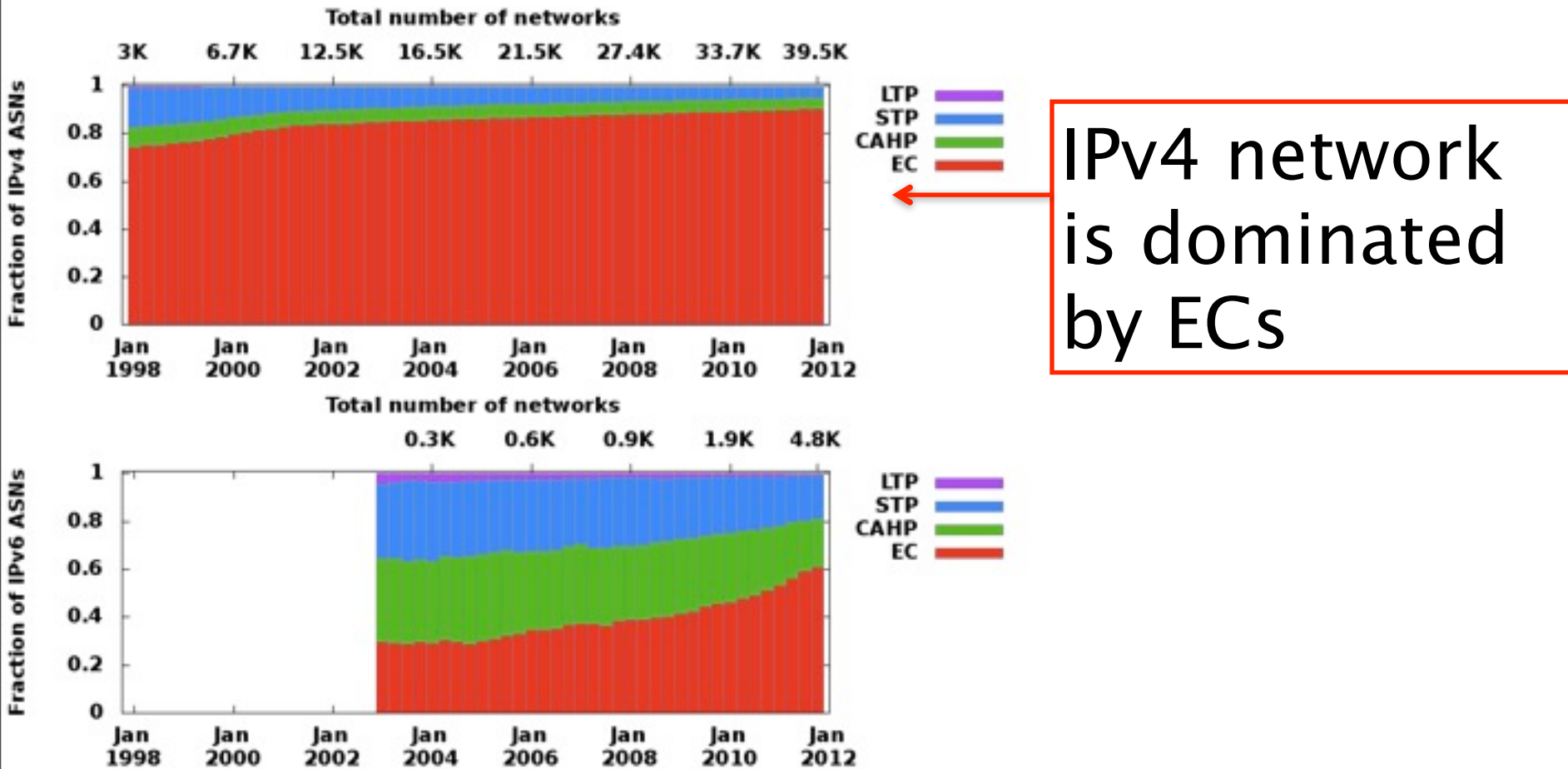
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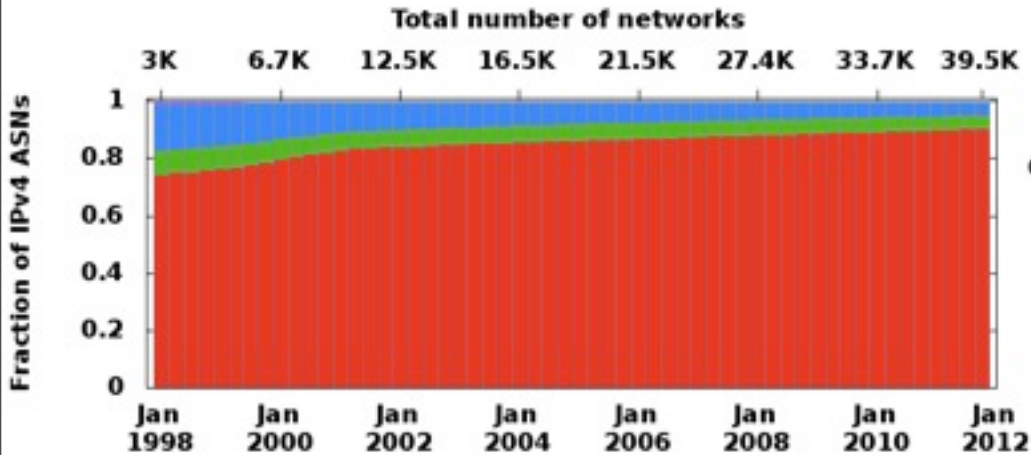
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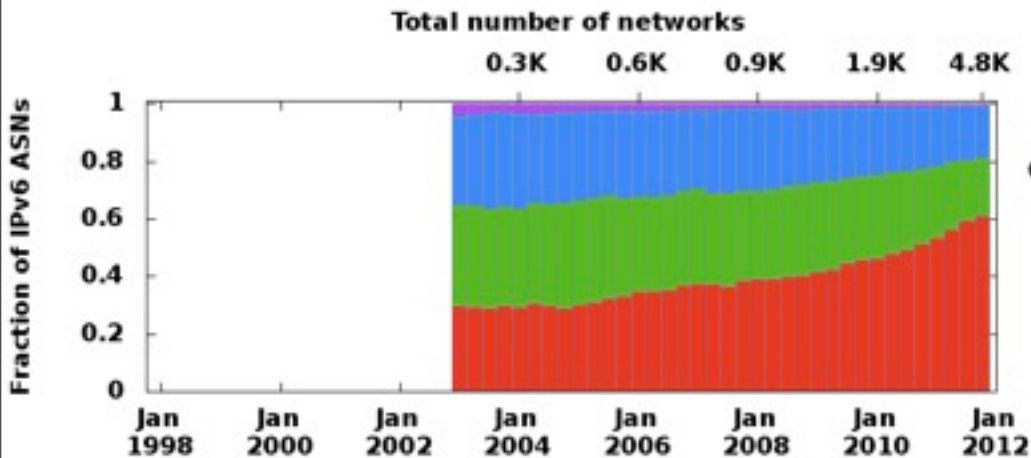
Lower fraction of ECs in IPv6

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IPv6 deployment at the edges is lagging

13

IPv4 and IPv6 topology convergence

Classification: business type
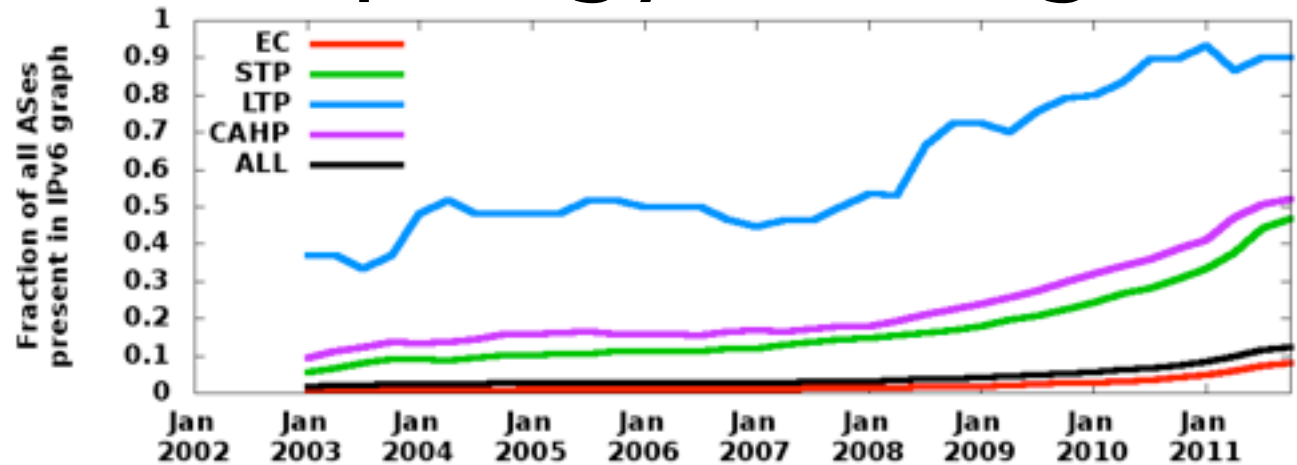
Classification: geographical region
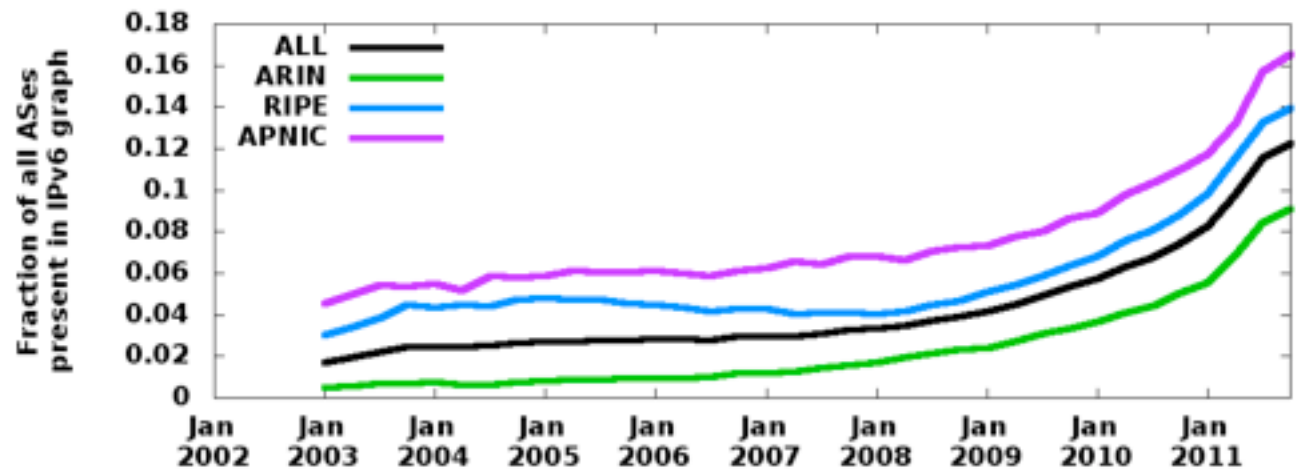
- Transit providers and content providers are mostly present in the IPv6 graph, ECs are lagging
- APNIC and RIPE lead ARIN in IPv6 presence
- IPv6 convergence is not uniform across business types and geographical regions

14

IPv4 and IPv6 topology convergence
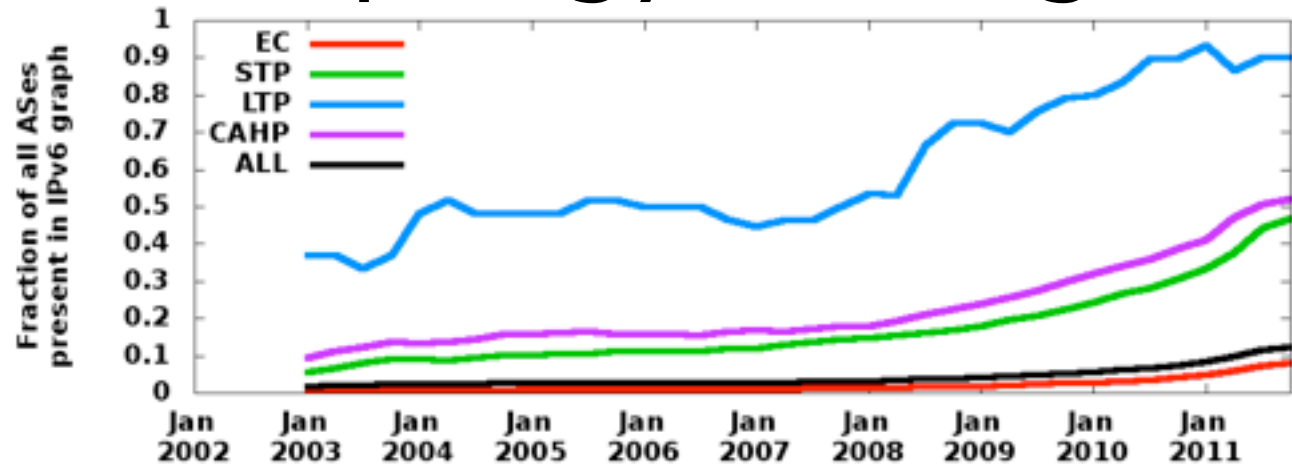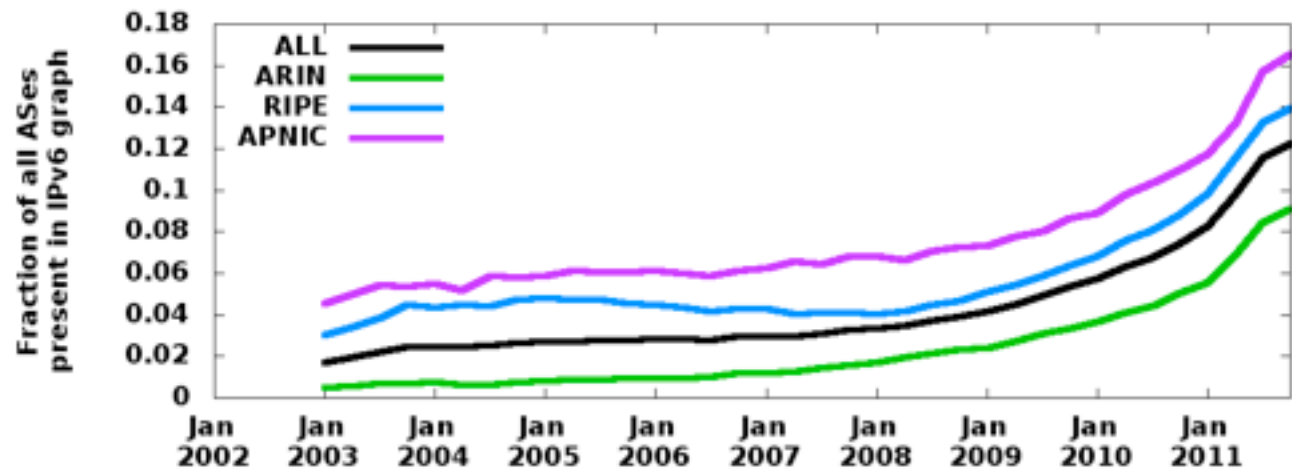
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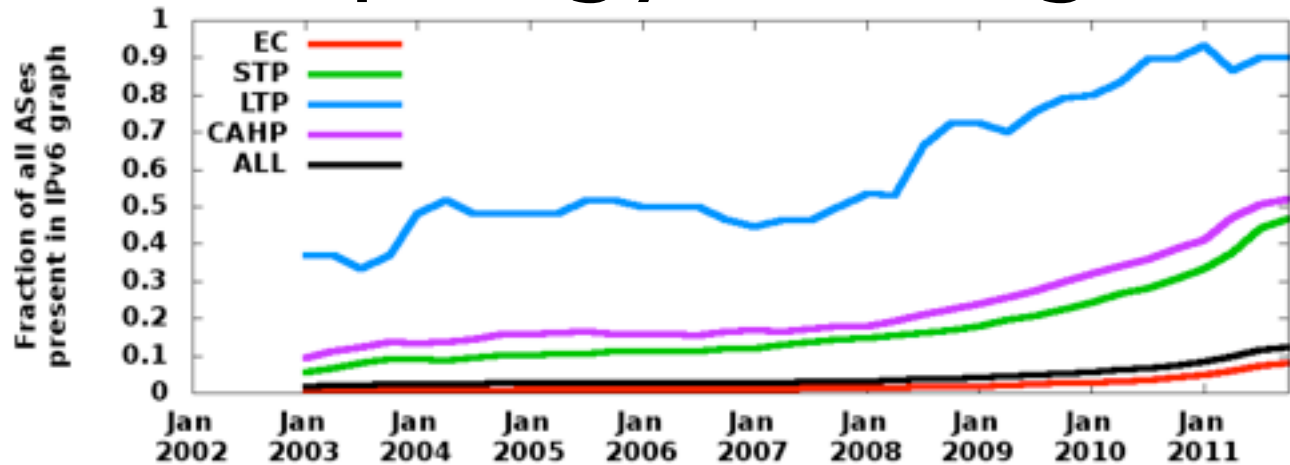
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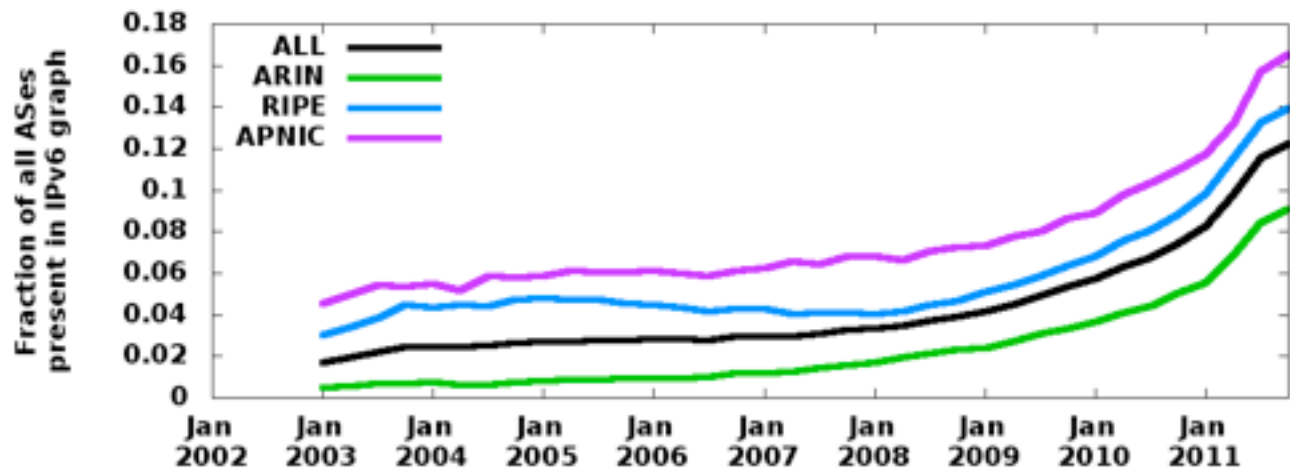
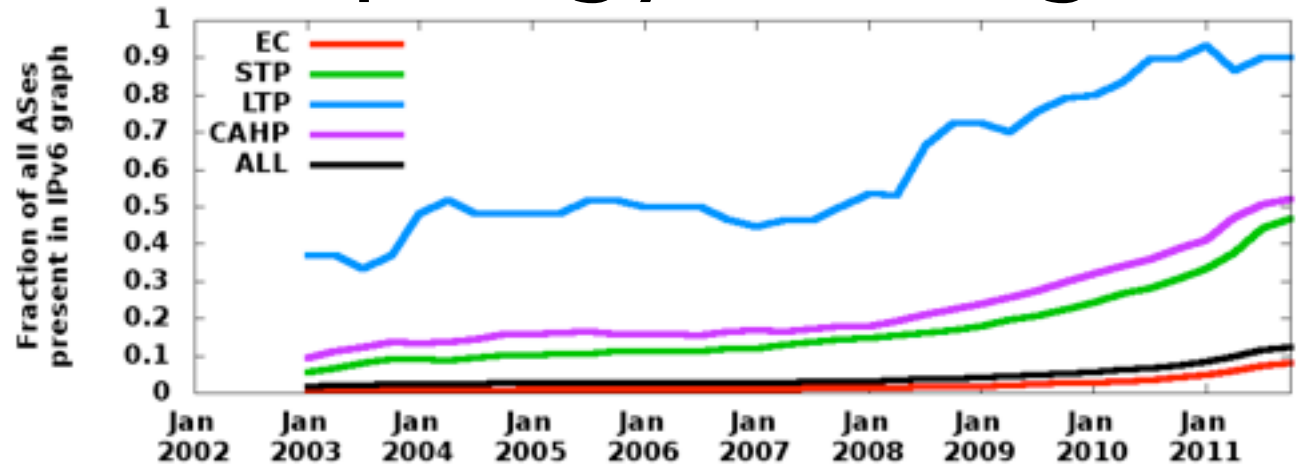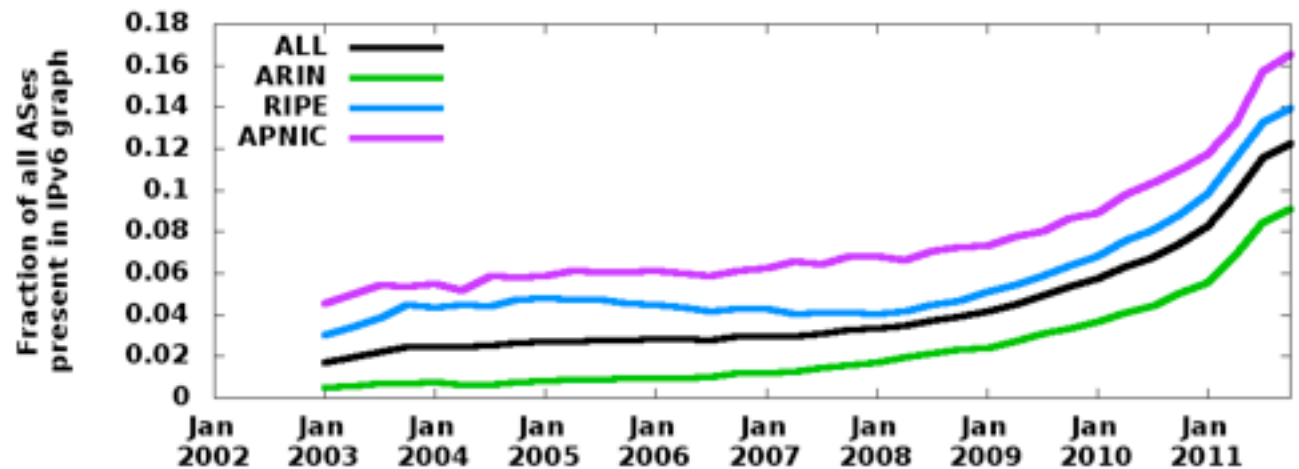# IPv4 and IPv6 topology convergence

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IPv4 and IPv6 topology convergence

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Classification: geographical region

Structure of AS-level paths

- Hypothesis: As IPv6 matures, routing paths in IPv4 and IPv6 should become similar over time

- Measured AS-level paths from 7 vantage points towards dual-stacked origin ASes

- Focused on the fraction of identical IPv4 and IPv6 paths from each VP

15

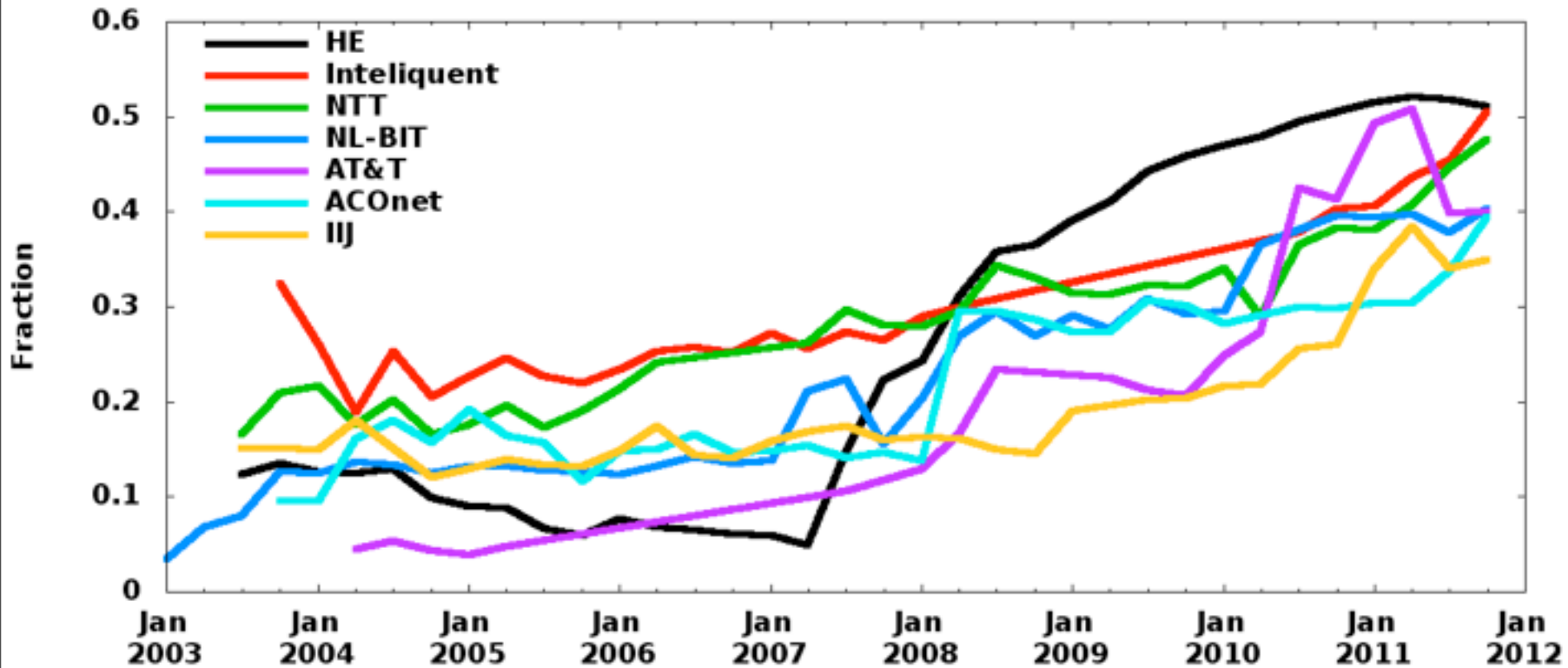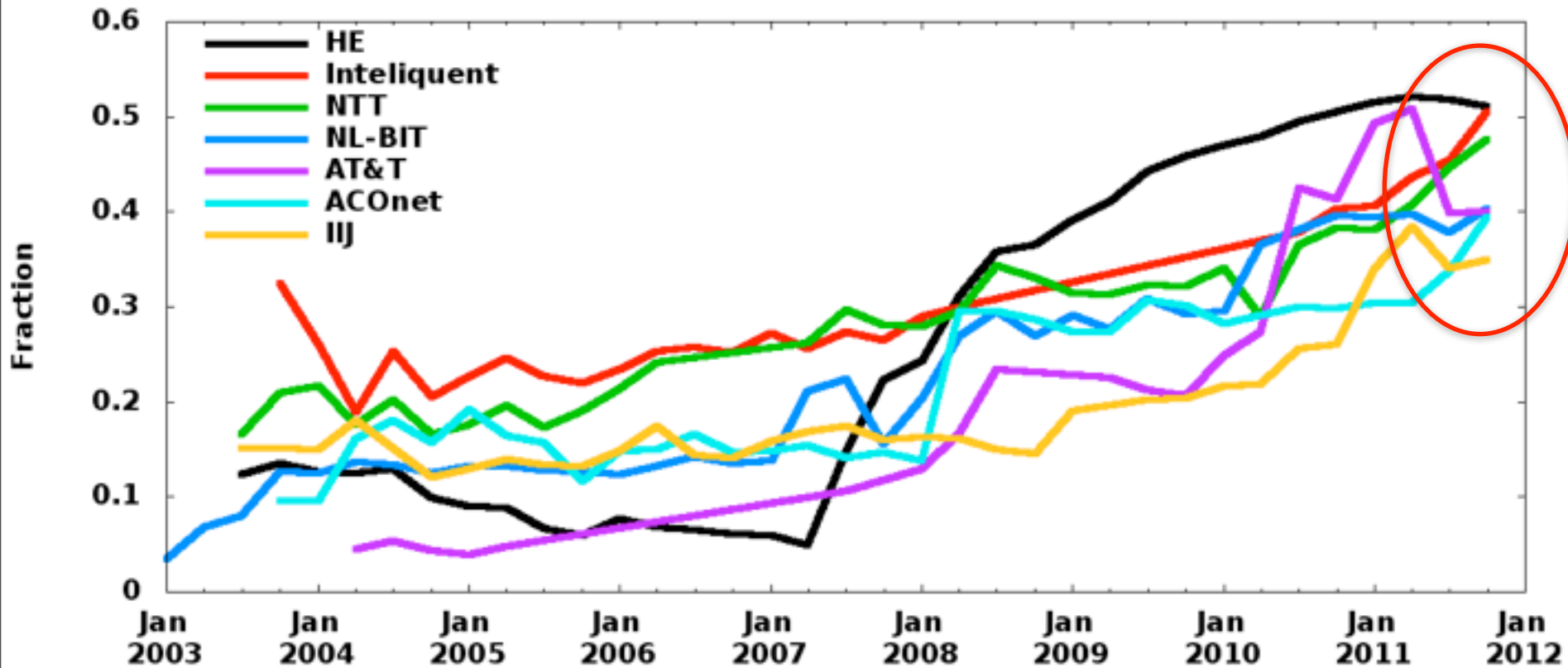# Identical AS−level paths
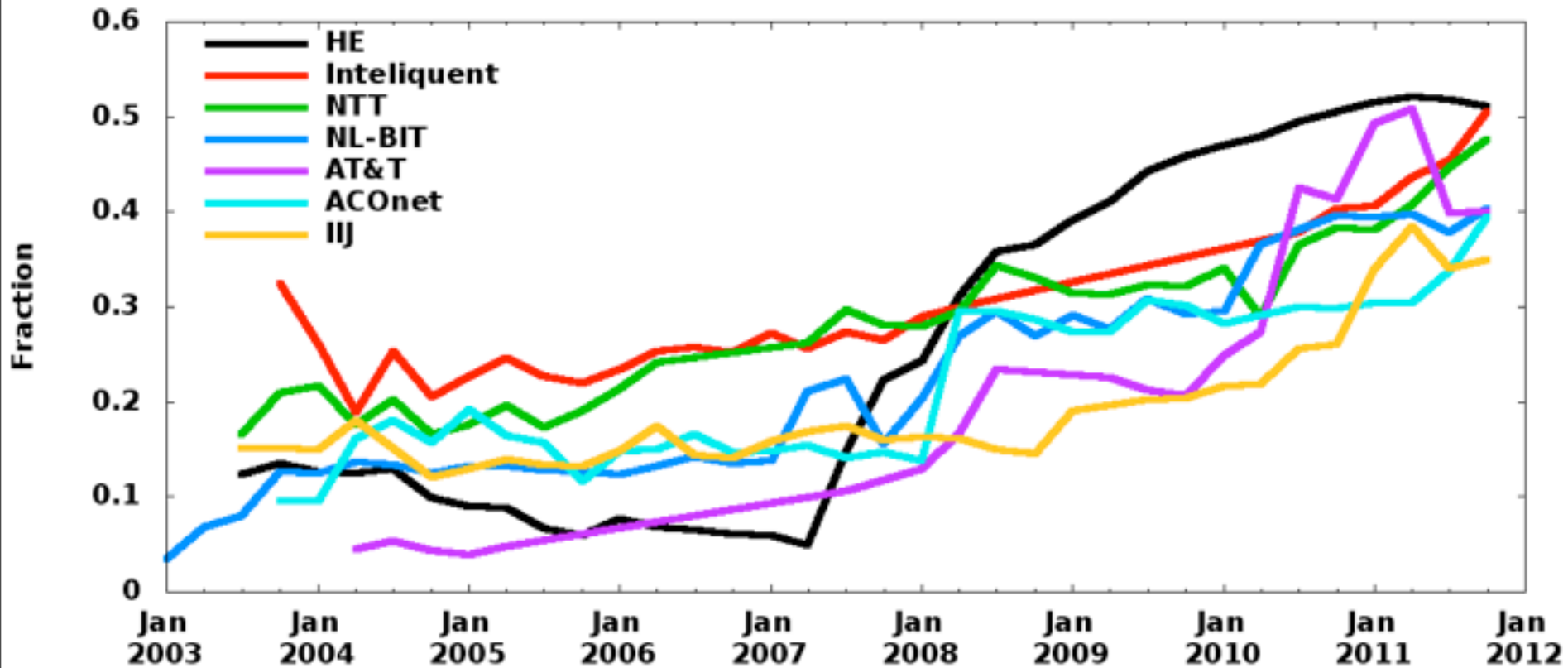
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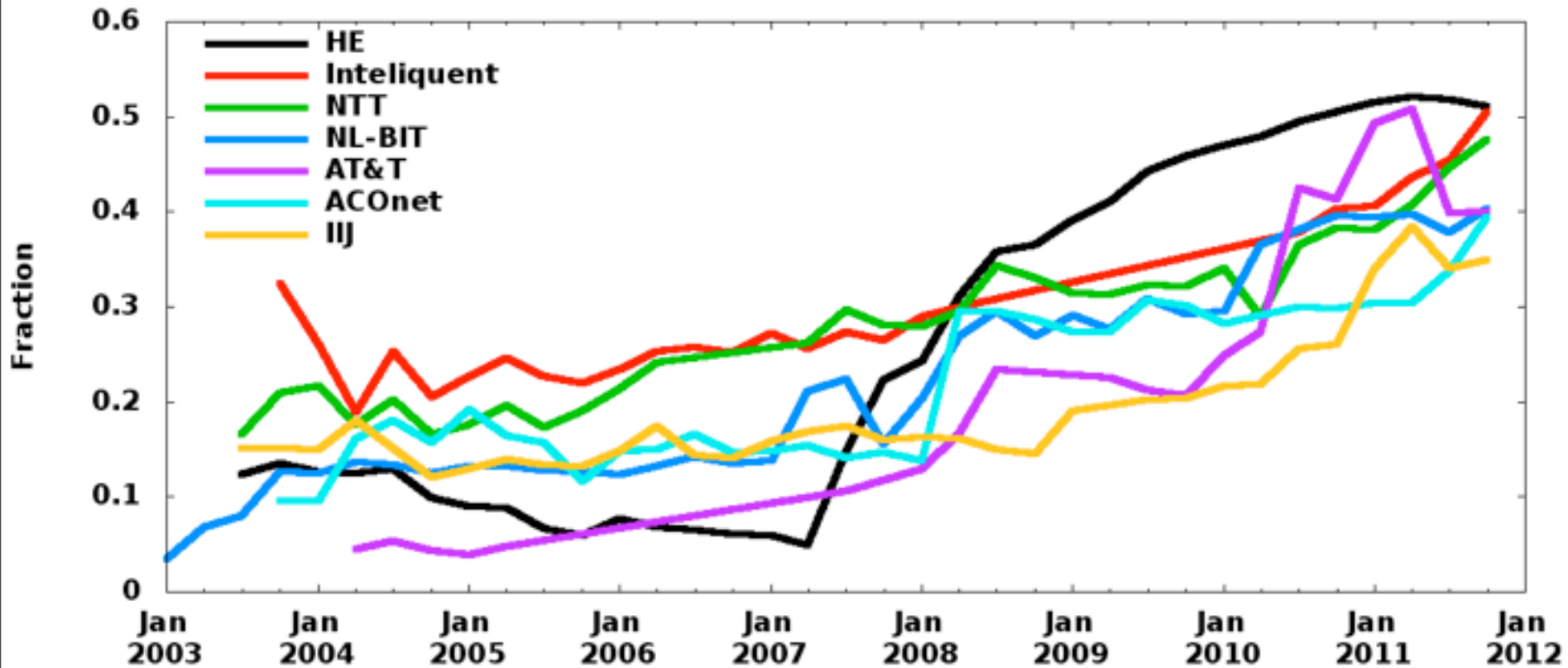
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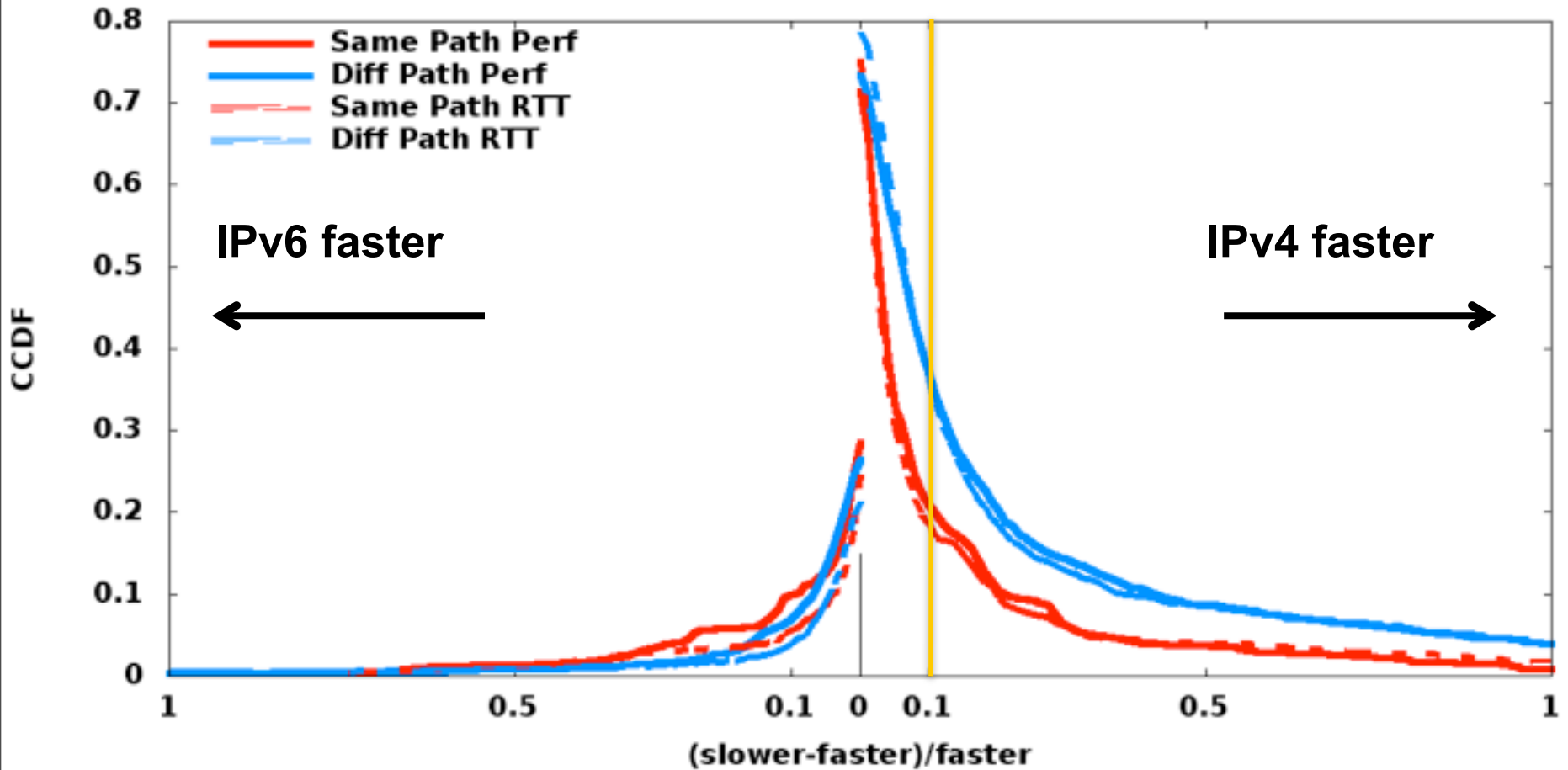
The IPv6 network is maturing, but slowly

Comparing IPv4 & IPv6 performance

- Poor performance over IPv6 is likely to inhibit the adoption of IPv6

- How often is performance over IPv6 similar to that over IPv4?

- Measurements from 5 dual-stacked vantage points (CAIDA Ark) to dual-stacked websites
  – Webpage download times
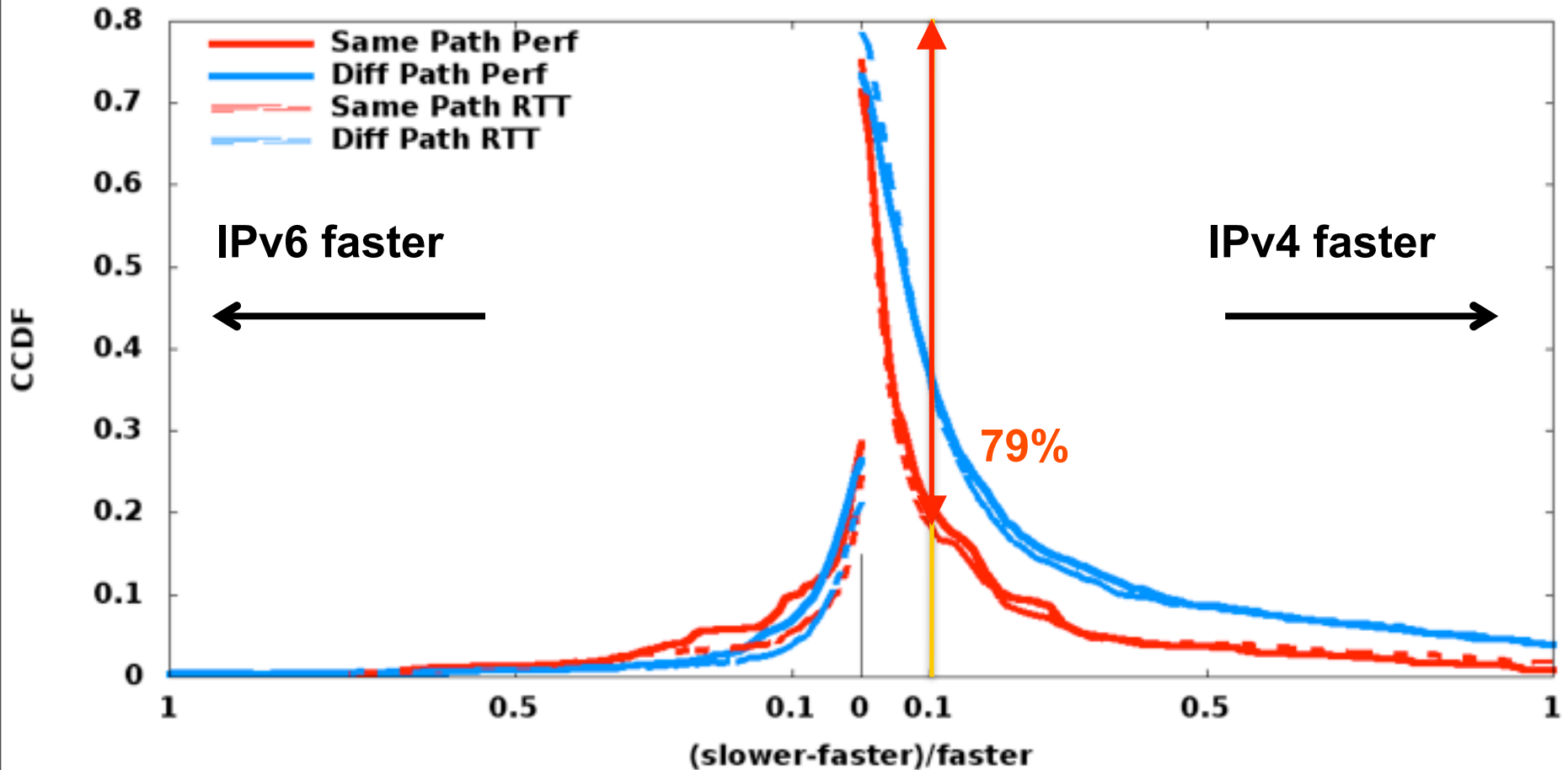 – AS paths to those websites (traceroute)
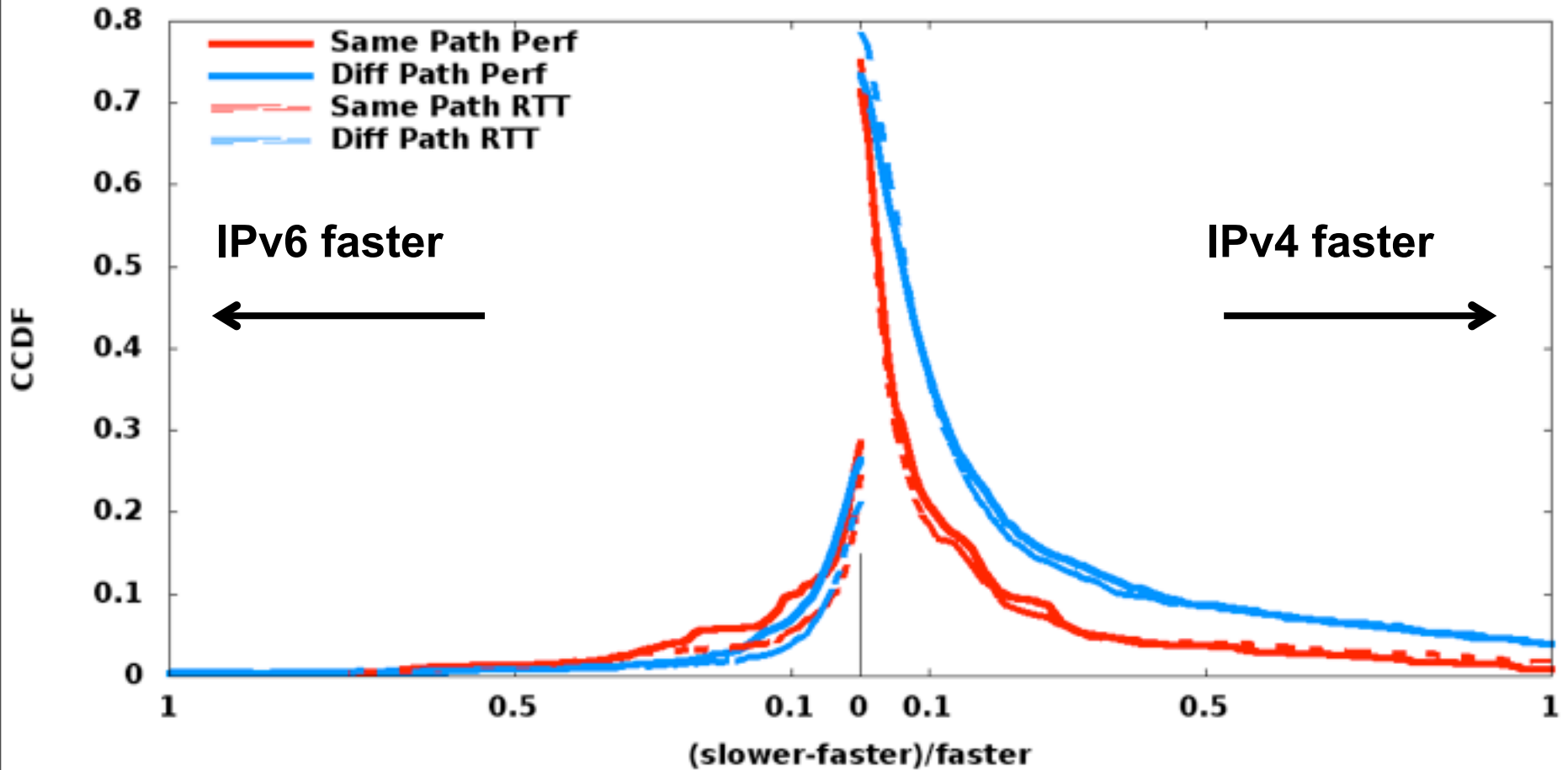
17

Performance: Webpage downloads
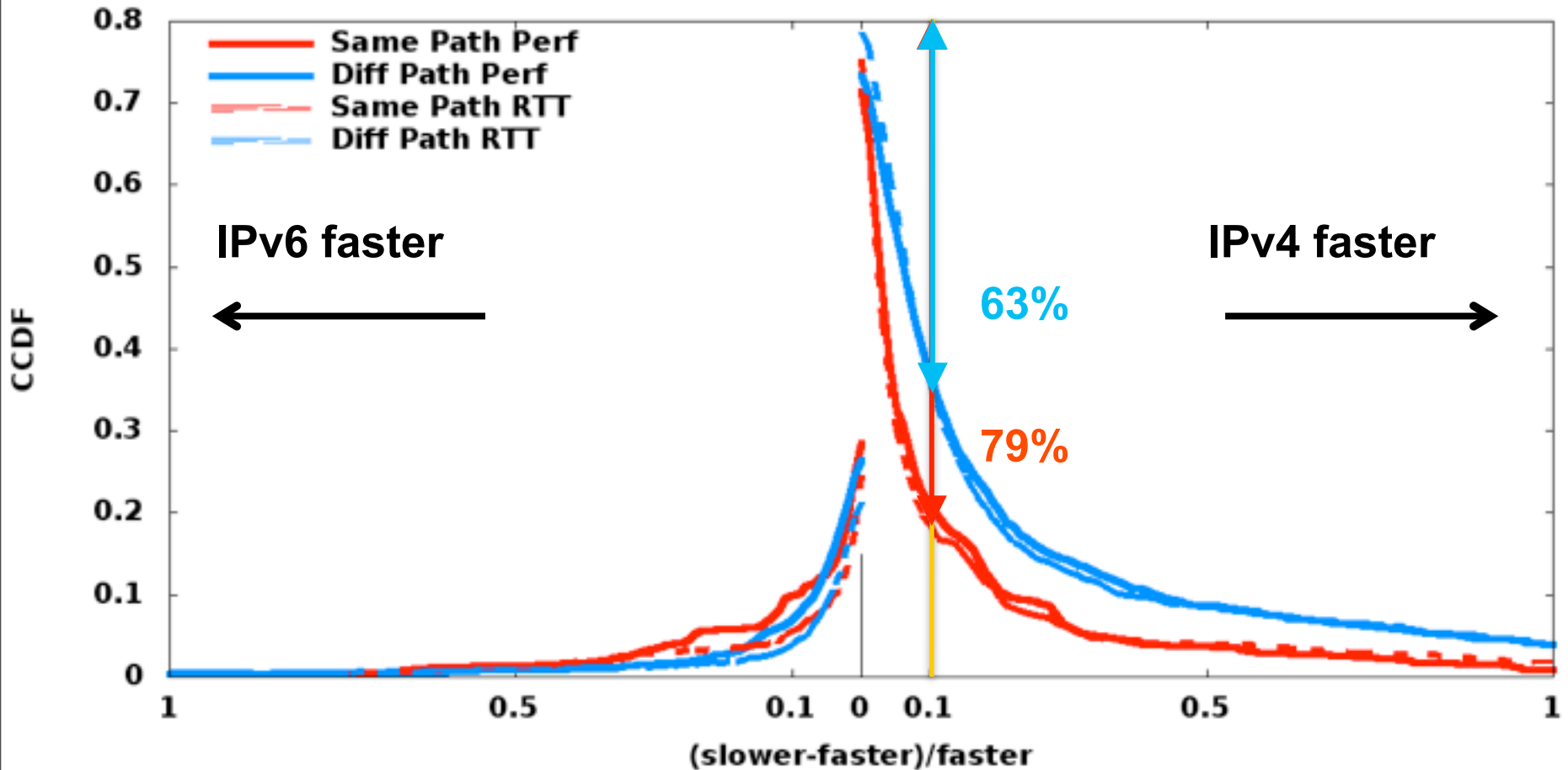
Performance: Webpage downloads

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- **79% of paths had IPv6 performance within 10% of IPv4 when AS paths were the same**

18

Performance: Webpage downloads

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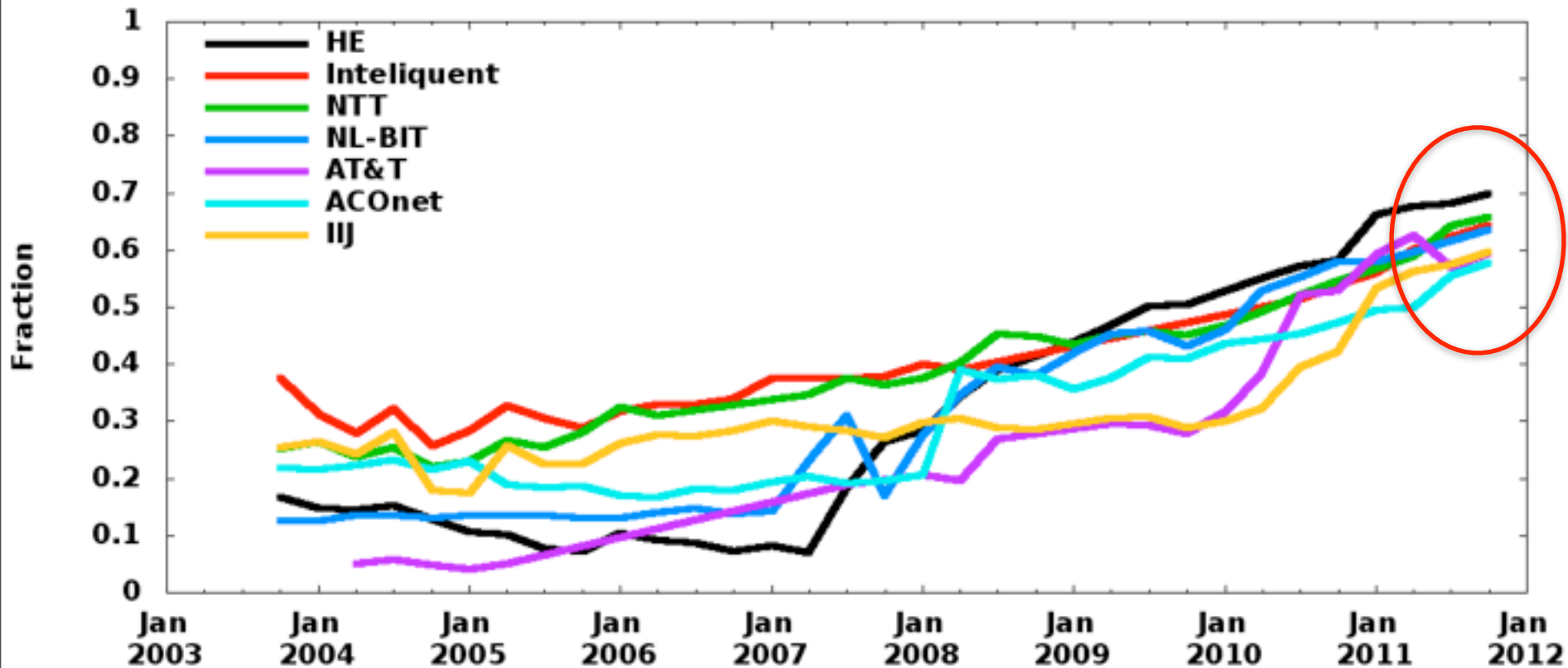- **Only 63% of paths had similar performance when AS paths differed**

Relation between performance and AS–level paths

- IPv6 performance is similar to IPv4 performance, if AS–level paths are the same
  - Key finding of M. Nikkhah, R. Guerin, Y. Lee, R. Woundy. *Assessing IPv6 through web access: a measurement study and its findings*. CoNEXT 2011.
- < 50% of AS paths from dual-stacked vantage points are currently the same in IPv4 and IPv6

- Increasing congruence between IPv4 and IPv6 topology will improve performance and thus deployment incentives

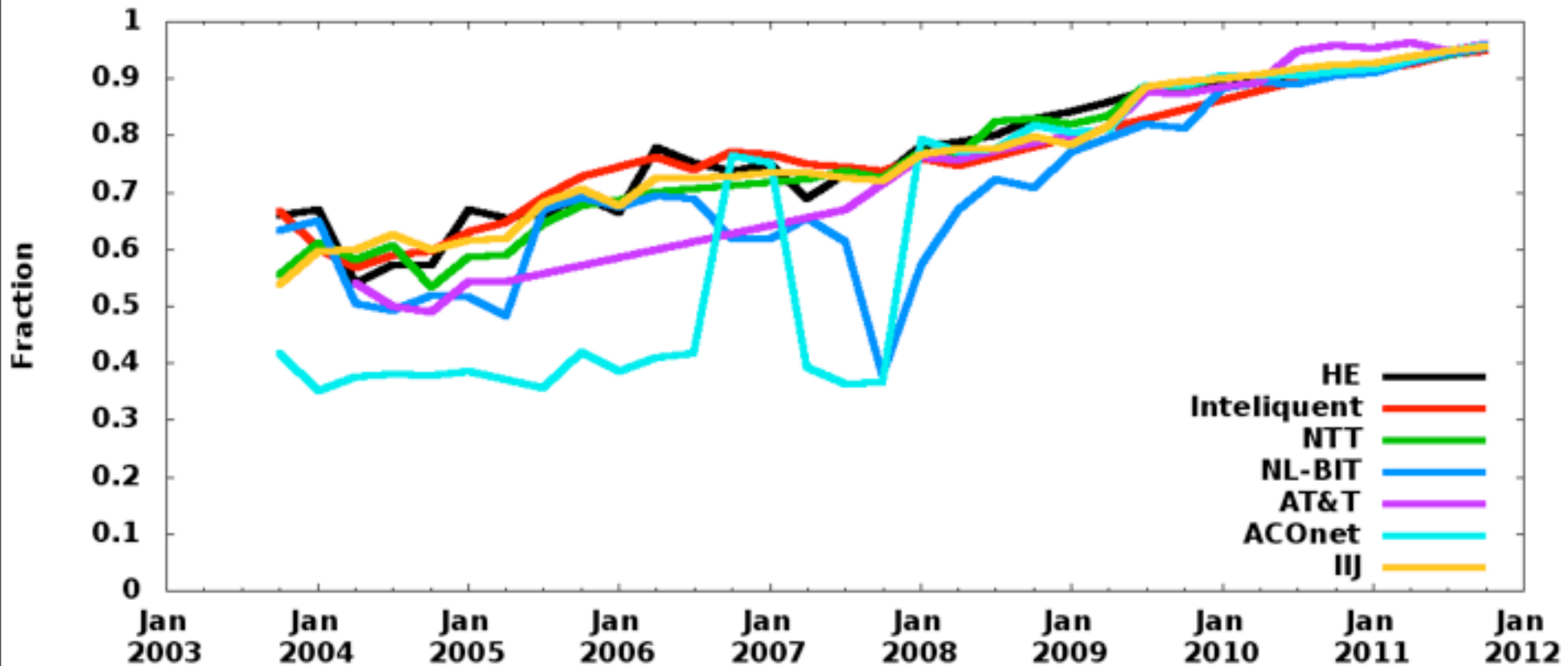# Potential AS–path congruence

Sunday, January 13, 13
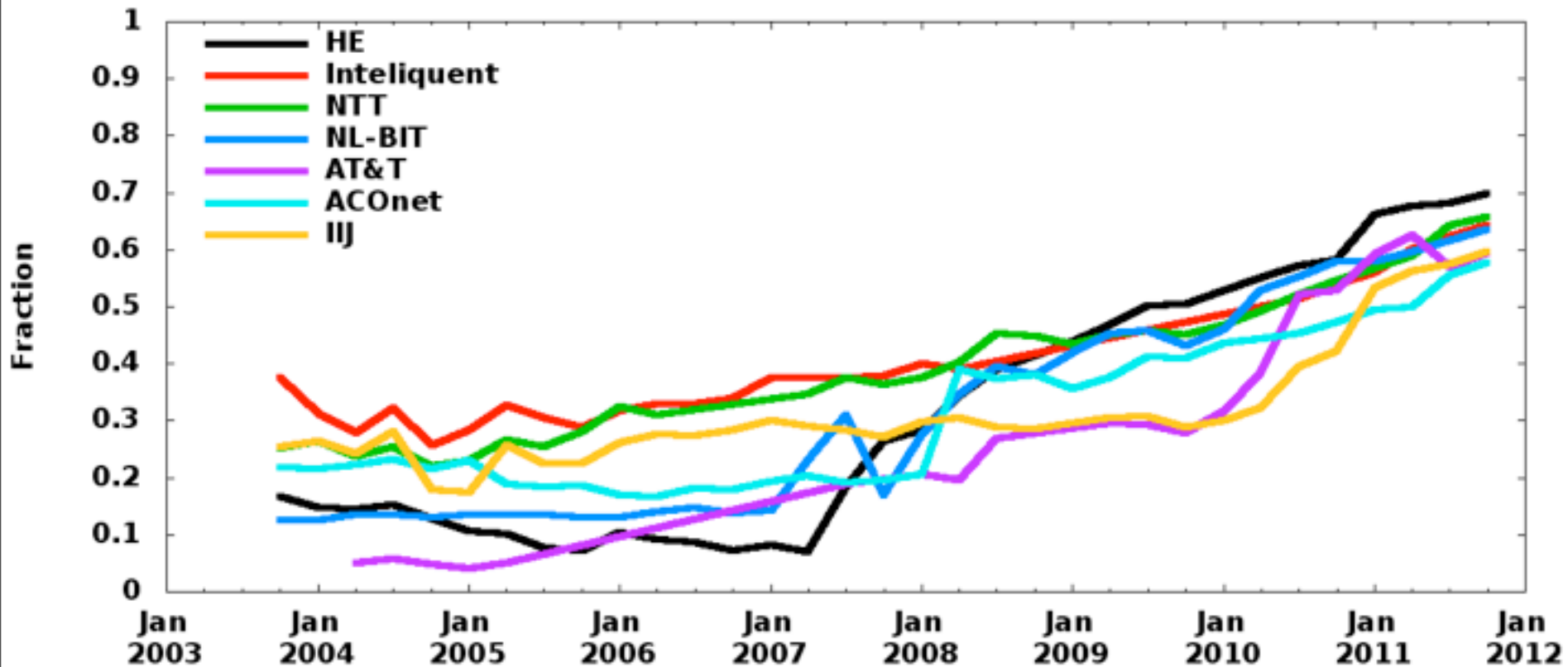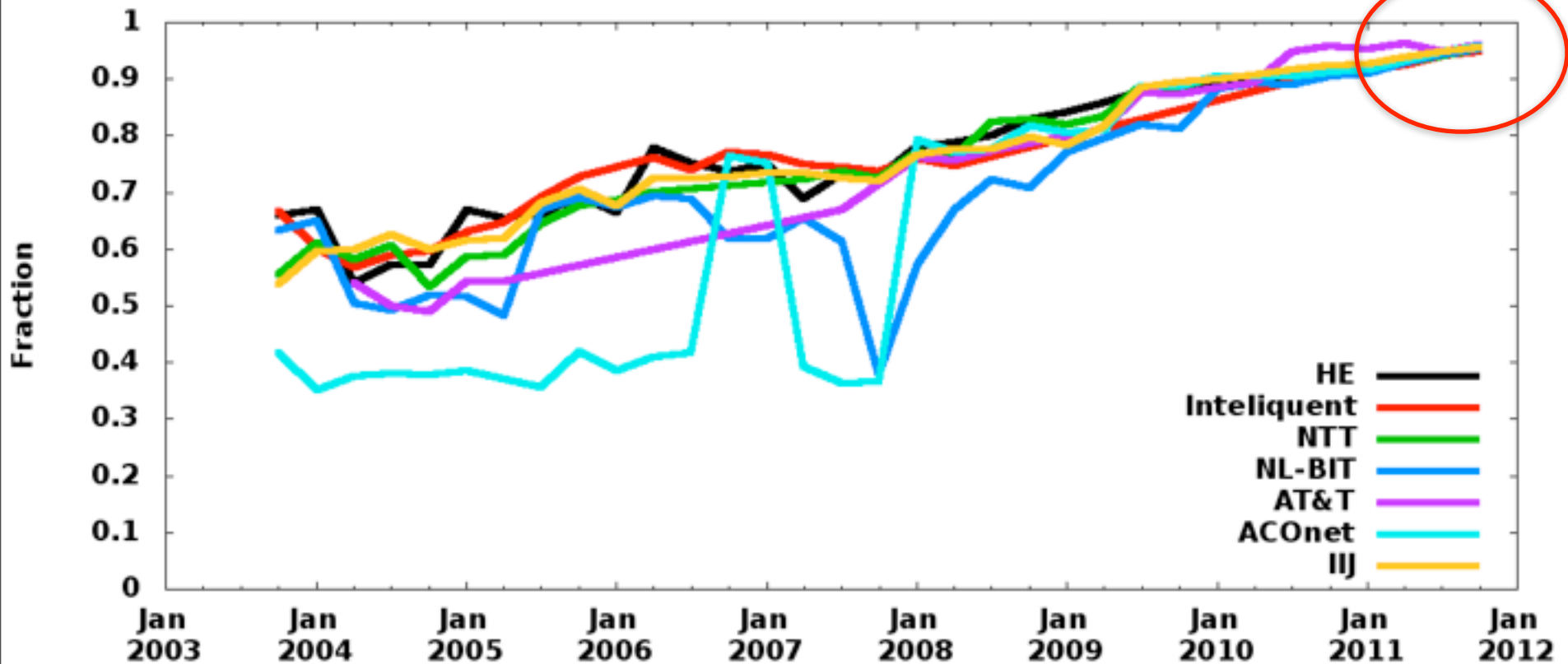
Potential AS-path congruence

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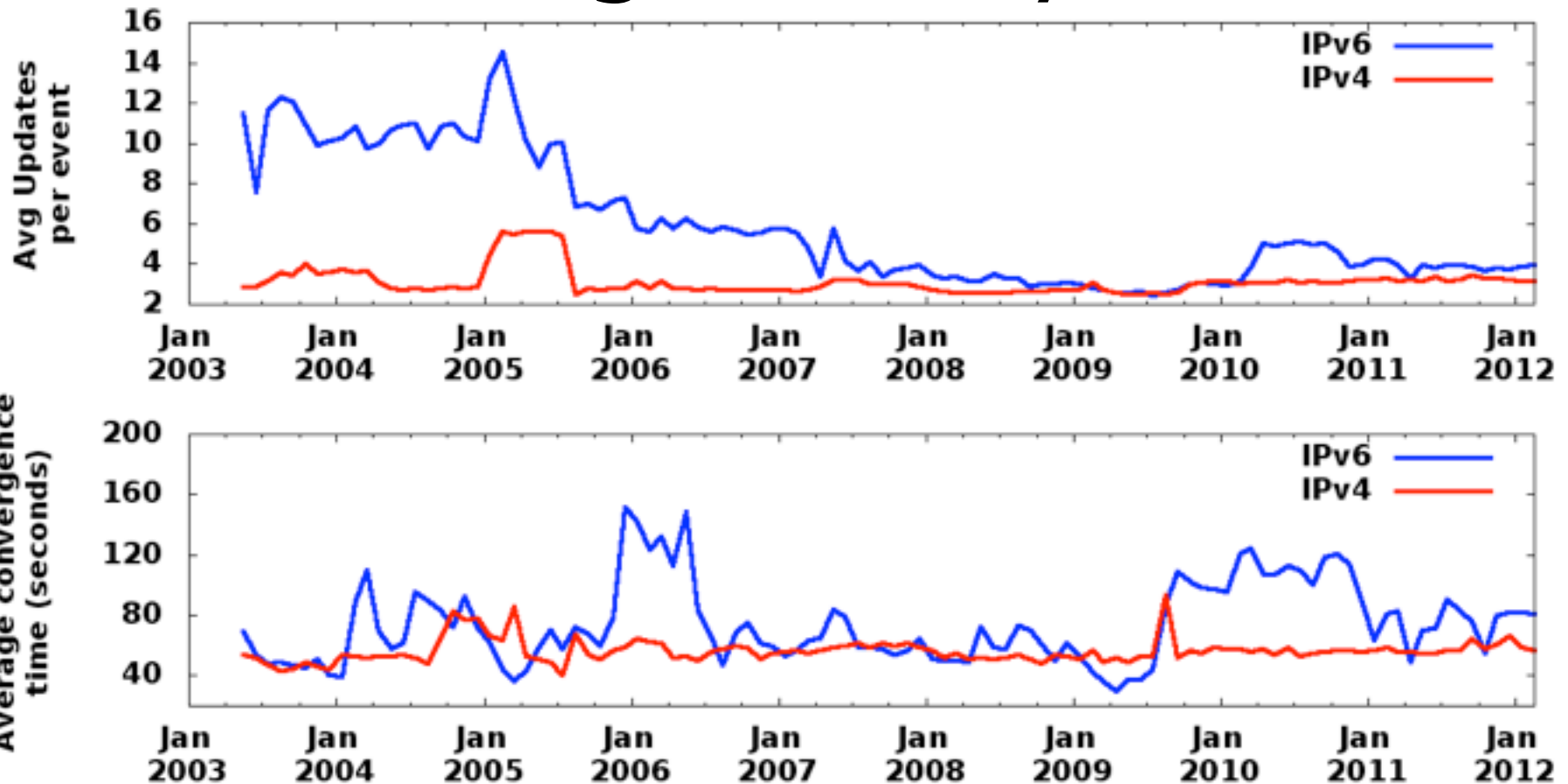
20

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- Based on ASes that are already in the IPv6 graph, more than 90% of paths could be identical

21

Routing Stability -- IIJ

- **Path exploration is similar in IPv4 and IPv6 since 2008**
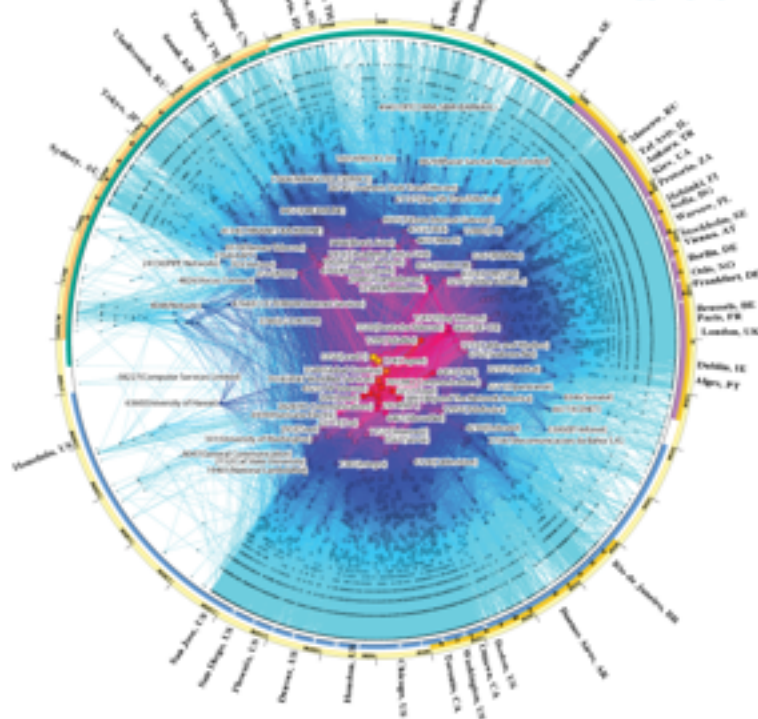- **Time to convergence peaks in IPv6 are due to single prefix events -- convergence time is otherwise similar**

Summary of findings

- The IPv6 network is maturing…albeit slowly and non-uniformly
- The "core" of the network (transit providers) are mostly doing well with IPv6 deployment
- The edge (enterprises and access providers) is lagging
- IPv6 deployment is faster in Europe and Asia-Pacific regions, North America is lagging
- IPv4 and IPv6 paths could potentially be 90% similar, without deploying any additional infrastructure
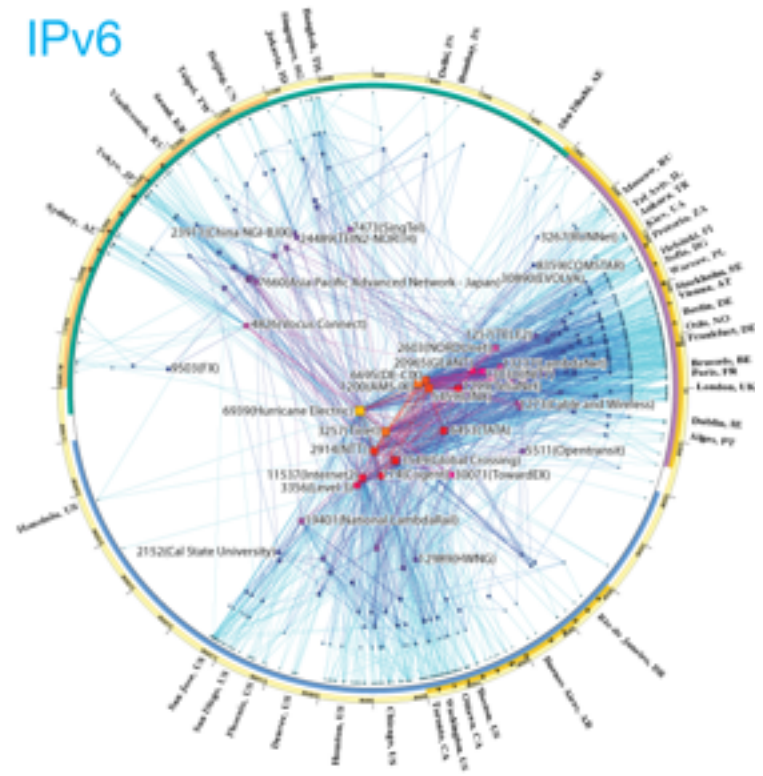
23

CAIDA's IPv4 & IPv6 AS Core
AS-level INTERNET GRAPH
Archipelago August 2010

IPv4

IPv6

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thanks! questions?

kc@caida.org