Why does IP have Versions?
Why do I care?

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Agenda

- What do the version numbers mean?
- What are the well known versions?
- What happened to all the missing version numbers?
- What is the most popular Version?
- What is the current Version?
- What are the advantages of the current version?
- What You Can Do

Version Numbers

* Each version of IP has a separate Layer 2 Protocol Number assigned.
* Packets from one IP version cannot be understood by a host running exclusive a different IP version.
* e.g. A host which only knows IPv4 cannot usefully exchange packets directly with a host which only speaks IPv6.
* Why create these incompatibilities?

Well Known Versions

* IPv4 — Obsolete, but still most widely deployed version of IP. Full support for up to 3.2 billion unicast hosts globally. Poor support through address sharing for additional hosts.
* IPv6 — Current version of IP. Not yet as widely deployed as IPv4, but gaining ground rapidly in recent years. Defined more than 20 years ago.
* What about IPv1, IPv2, IPv3, IPv5?
* Is work being done on IPv7-9?

Missing Versions

- IPv1-IPv2
  - These were never really defined, but the protocol numbers were used for TCPv1 and TCPv2. The reason for this overlap is that prior to v3, TCP was being intended as the Layer3 and Layer4 replacement for NCP, so there wasn't yet a separate IP specification.
  - v1 defined in RFC675 December, 1974, V. Cerf, V. Dalal, C. Sunshine
  - v2 defined in IEN 5 March, 1977, V. Cerf

Missing Versions

- IPv3
  - First version where IP is separated from TCP (sort of, actually happened in Version 3.1)
    - TCP3 first documented in IEN21, January 1978, V. Cerf, J. Postel
  - RFC 750 shows historical IP header version numbers
  - IEN 26 and IEN 27 discuss changes to IP version 3 (TCP Version 3.1 and introduction of IP as Version 3)
  - Still not a completely clean separation.
  - Fixed boundary 8-bit network, 24-bit host address.
  - 32-bit port numbers — In the IP header, not the TCP header.

Missing Versions

* IPv5
  * Originally defined in RFC1190, known as “ST” Internet Stream Protocol
  * Provided a state-based QoS mechanism with distributed state maintained by every router in the “Stream Path”
  * Never widely adopted.
  * IPv5 assignment shows up in RFC1700.

Missing Versions

- IPv7, IPv8, IPv9
  - There were at least 4 competing protocol specifications to replace IPv4 under the “IPNG” banner.
  - The one that finally got chosen was IPv6 and represents somewhat of a synthesis of all 4. The initial working title was “SIP Simple Internet Protocol [RH6]”
  - IPv7 was known as “TP/IX: The Next Internet [RXU]”
  - IPv8 was known as “PIP — The P Internet Protocol [PXF]”
  - IPv9 was known as “TUBA — Tcp & Udp with Big Addresses [RXC]”

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What is the most popular version?

- IPv4 is by far the most popular version ever deployed.
  - Obsolete for at least 10 years
  - Still the most widely used protocol
  - Support for up to 3.2 billion unique unicast hosts
  - Completely dysfunctional for the modern internet
    - Limited Address Space
    - Address Sharing
    - Issues with Routing Table Size, TE, etc.
    - NAT inconvenient at best, harmful at worst
    - CGN — All the problems of NAT squared

Current Version

- IPv6 is the current recommended standard Internet Protocol Version
  - Support for more than 340 undecillion total hosts
  - Support for at least 42 undecillion unicast host addresses (2000::/3)
  - Support for more than 151 Sextillion /48 end sites (within 2000::/3)
  - Support for dynamic Network Address distribution through DHCP (DHCP-PD)

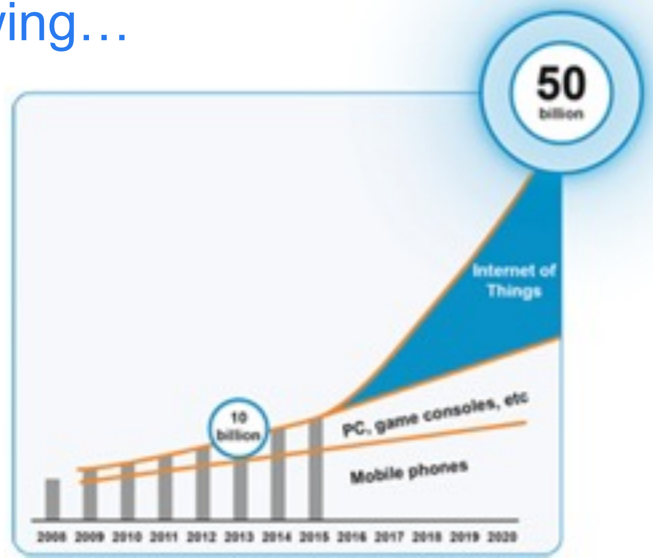
Current Version (cont'd)

* IPv6
  * Simple math:
    * 7 Billion people currently on earth
    * Each one can receive at least 21,587,961,064,546 end-site / 48s before we use up 2000::/3
    * At least 5 more /3s completely reserved could be used for additional unicast if needed.
    * 0::/3 and e000::/3 are partially used by special purpose addresses (::/0 unknown/default, ::1/128 loopback, fe80::/10 link-local addresses, fd00::/7 ULA, ff00::/8 multicast, etc.)

Only 4 billion IPv4 addresses…

and most regional registries are exhausted…
but 7+ billion people…
with 10+ billion devices and growing…

What could go wrong?



IPv6 brings us 10^{38} possible addresses

(Enough to give 50 million addresses to every bacteria on Earth!)

A record – DNS record holding an IPv4 address

AAAA record – DNS record holding an IPv6 address

Dual Stacked – Available over both IPv4 and IPv6

- For clients, having both IPv4 and IPv6 connectivity
- For servers, having both A and AAAA DNS records

NAT – Network Address Translation

- **NAT64** for gatewaying from IPv6 to IPv4
- **NAT44** between private and public IPv4 address space

Photo: Xinhua News

IPv6 goes direct, access to legacy IPv4 resources via constrained NATs

- Top mobile and broadband ISPs rapidly deploying IPv6
  - Over 55% of US mobile clients will use IPv6 to access content!
- IPv6 has faster page load times (at least on mobile in the US)
  - Per separate studies by Akamai, Facebook, and LinkedIn
- Apple app store now enforces that apps work in IPv6-only environments
  - NAT64+DNS64 in IPv6-only mobile networks allows content to remain IPv4-only, but with worse performance
- IPv6 is getting used to solve business problems
  - Comcast switching X1 set-top-box to IPv6-only
  - App partners will need to dual-stack content

What's Taking So Long?

(we only started in the 1990's…)

- ☑ OS support
- ☑ Client software support
- ☑ Infrastructure/backbone support

Small issues remain

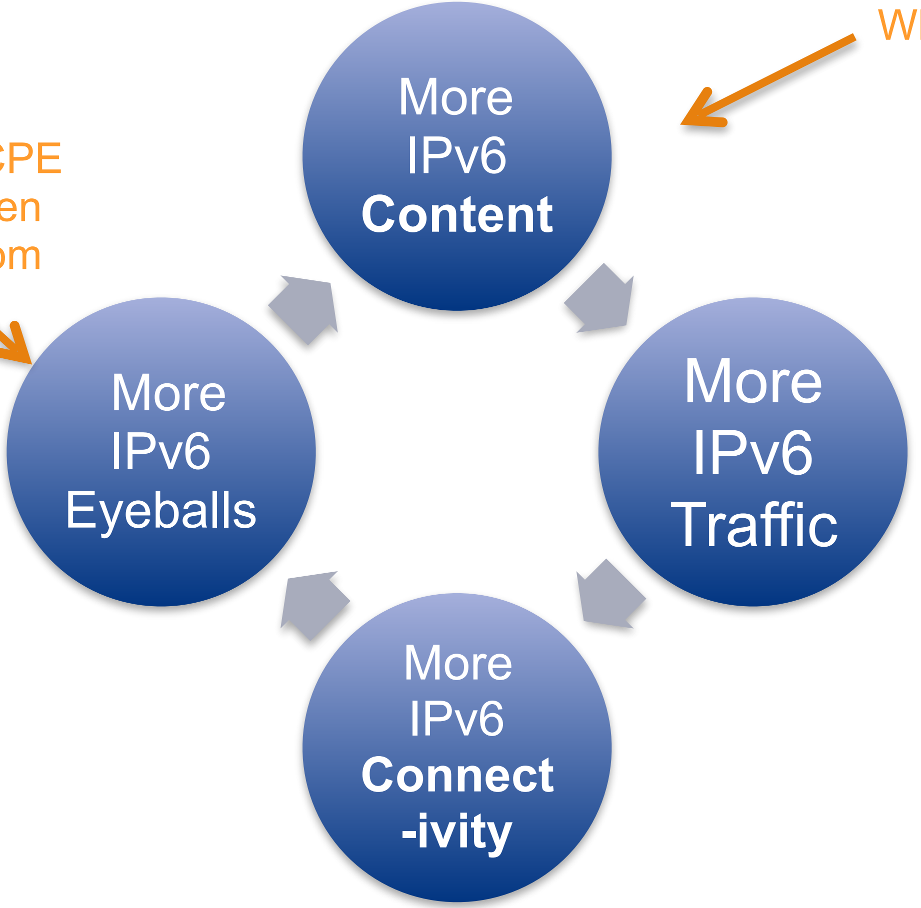
- ☑ Content availability
- ☑ End-user connectivity
- ☑ End-user CPE device support

Making solid progress

Virtuous cycle

What you can help with!

Make sure your CPE Supports and then demand IPv6 from your ISP



IPv6 Adoption Status

(or “why should I care?”)

Over **500 million** client IPv6 addresses per day
… from over five thousand client networks

Nearly **3 billion** IPv6 addresses per week

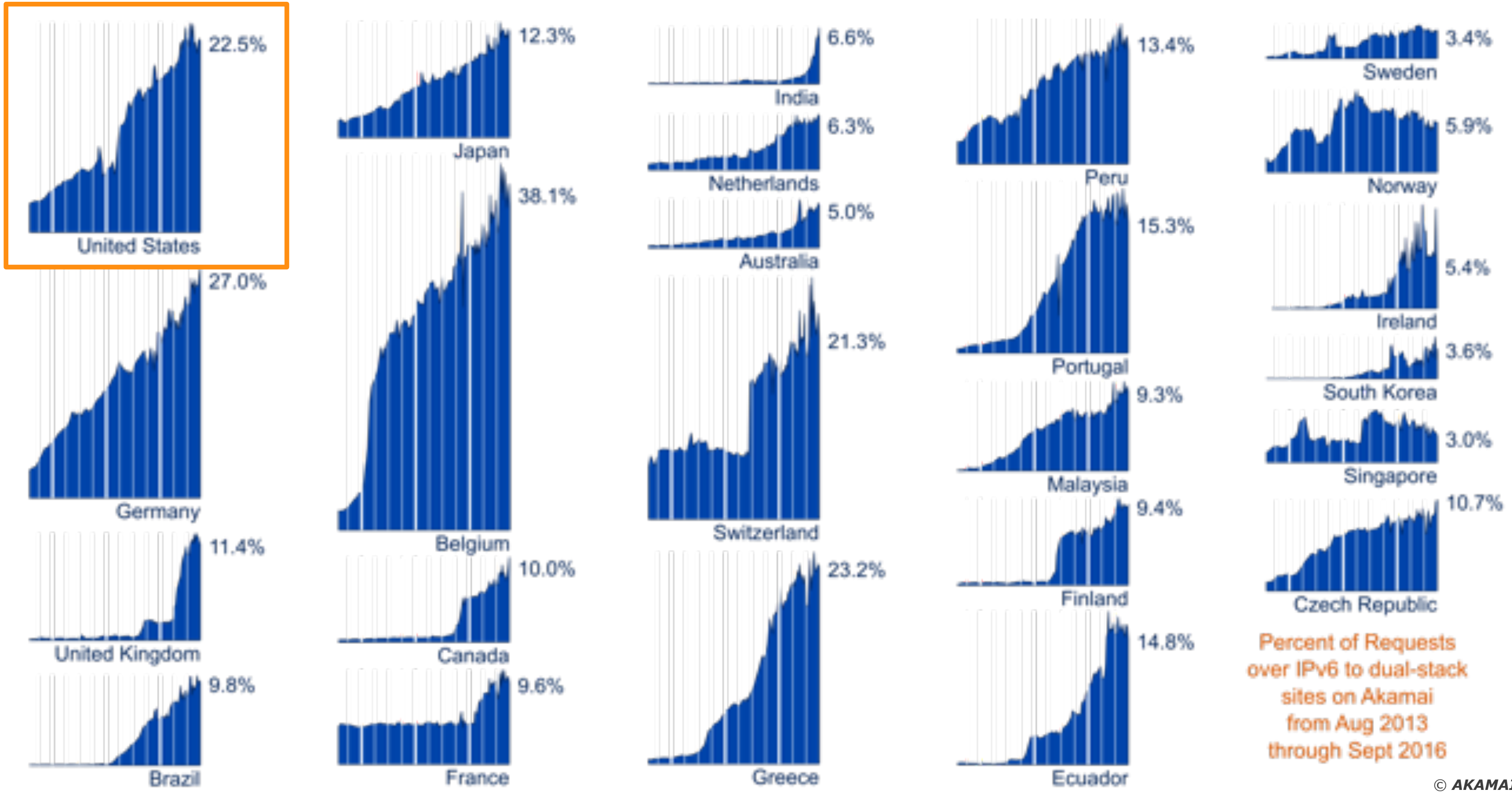
Over **10 billion** IPv6 addresses per month

- Robust/mature IPv6 support in most recent operating systems
- Some embedded devices and custom client software lag behind
- Anecdotes for IPv6 preference from leading devices:
  - iOS on top-4 US mobile networks: 43%
  - *And looks likely to climb rapidly with iOS 10 upgrades*
  - Android on top-4 US mobile networks: 75%
  - Windows 10 browsers in home broadband networks:
  - 54% in Comcast, 71% in AT&T Broadband, 81% in BSkyB, 38% in DT
  - 28% across entire United States

- Analyze HTTP(S) requests to dual-stack hosts on Akamai
  - Subset of representative traffic for a 24-hour period
  - Analysis set exceeds 200 billion HTTP(S) requests per day
  - Compare IPv6 requests to total requests across dimensions
  - Includes data from thousands of host names

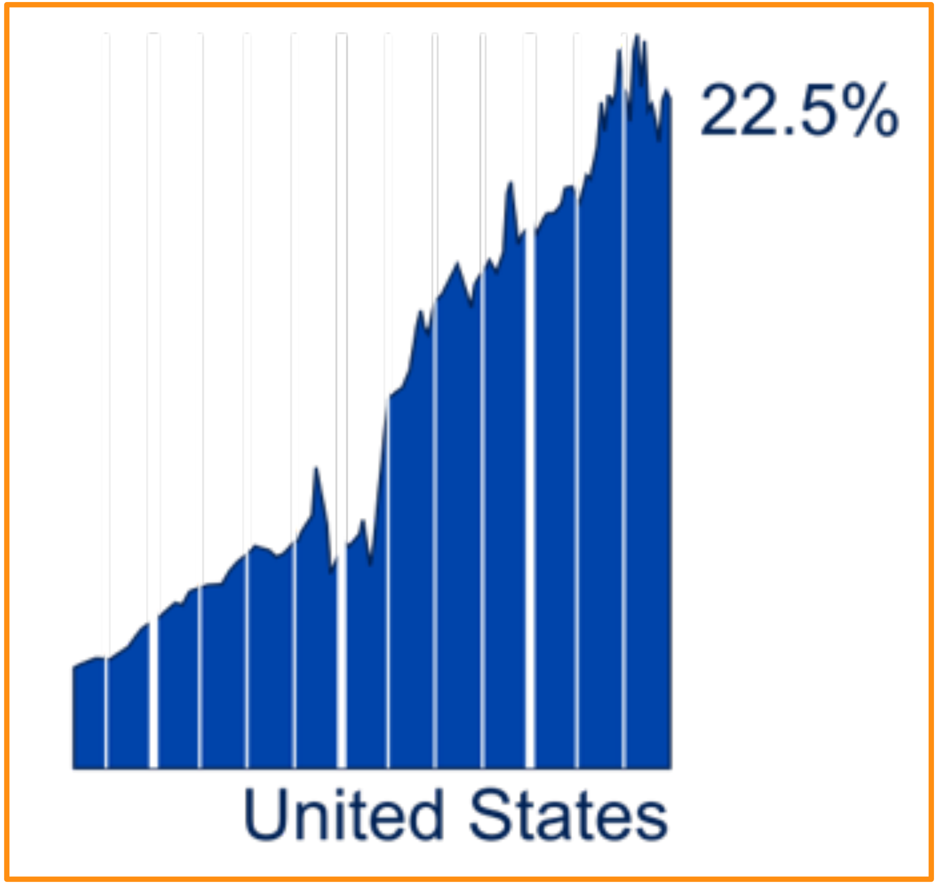
- Caveats:
  - Different content provider audiences skew global measurements
  - Some sample bias (e.g., faster users may make more requests)
  - Different metrics (hits, bytes, users, IPs) yield different results

Leading Countries: three years of IPv6 growth



Percent of Requests over IPv6 to dual-stack sites on Akamai from Aug 2013 through Sept 2016

Leading Countries: three years of IPv6 growth



Leading U.S. end-user networks: 3 years of IPv6 growth

Percent of Requests over IPv6
to dual-stack sites on Akamai
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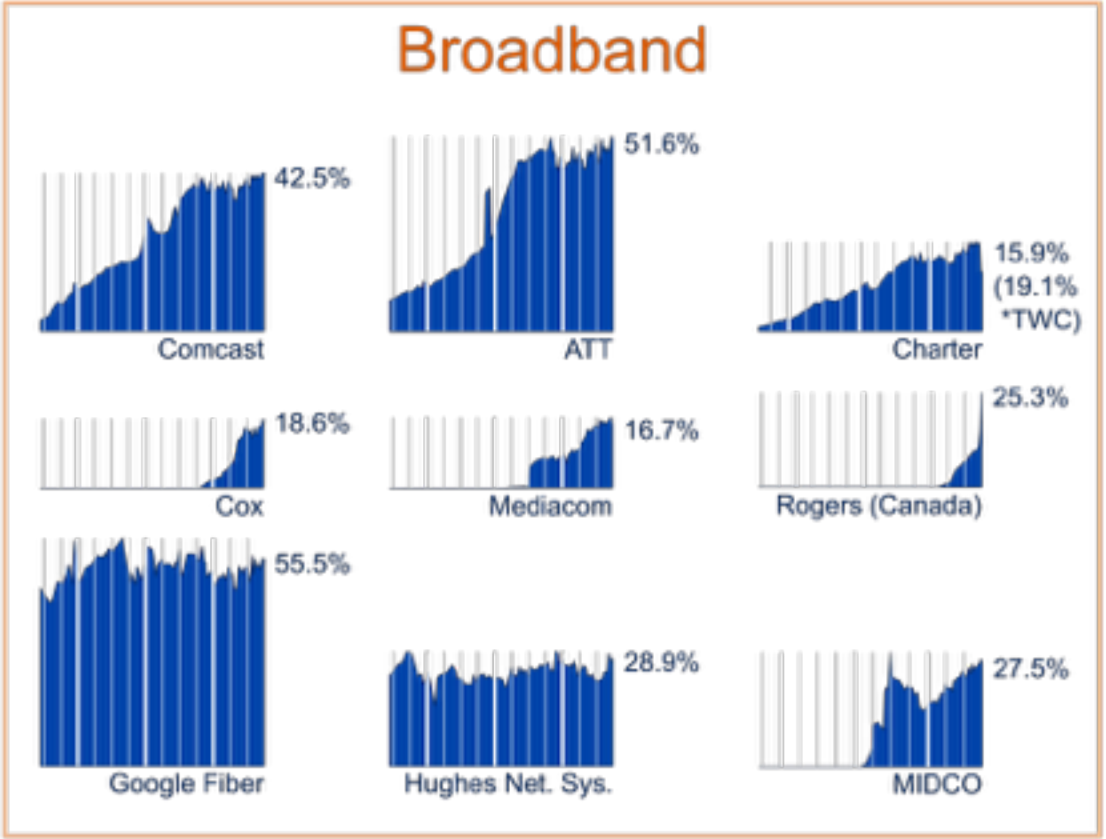
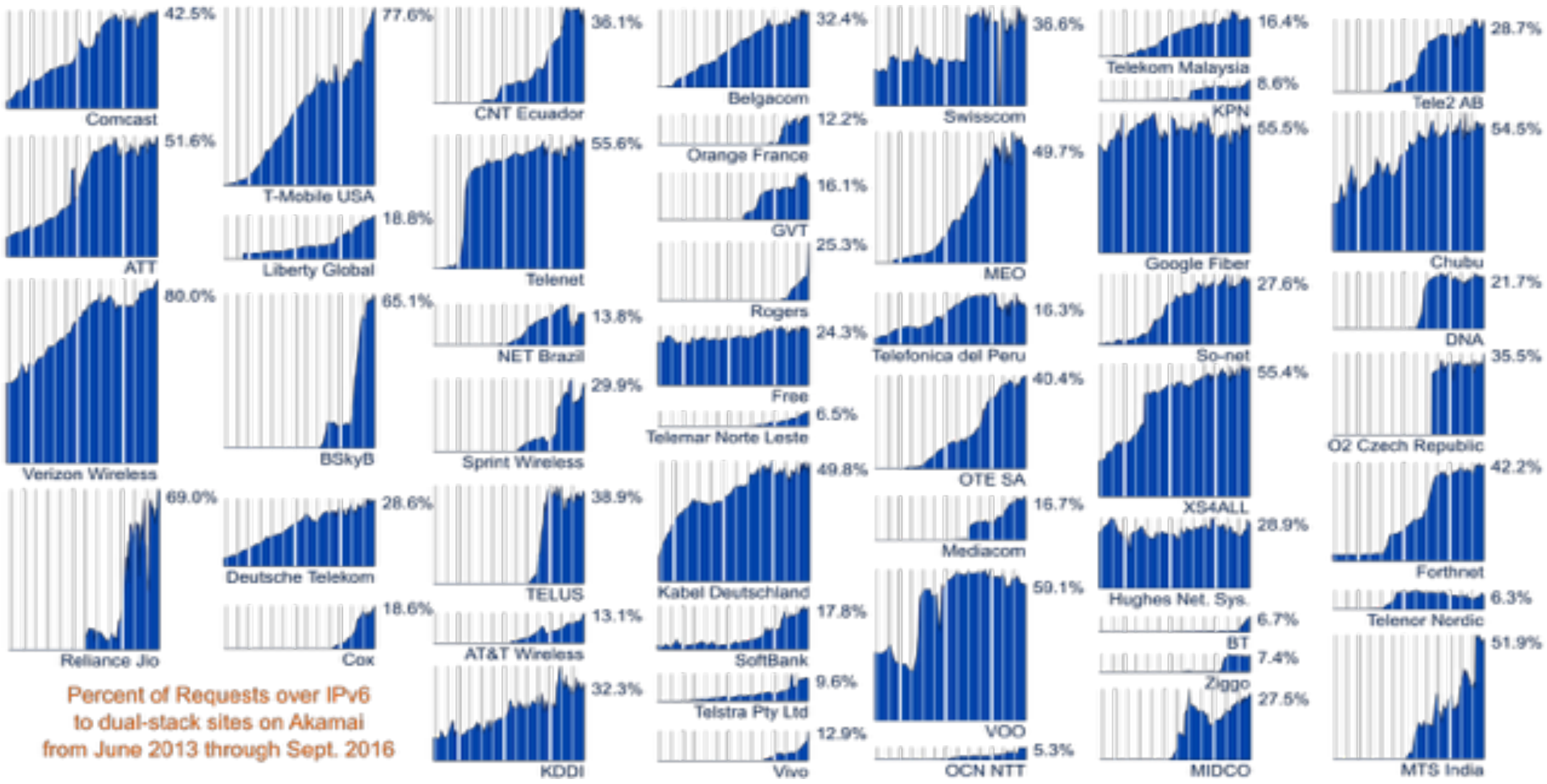


Leading global networks: 3 years of IPv6 growth



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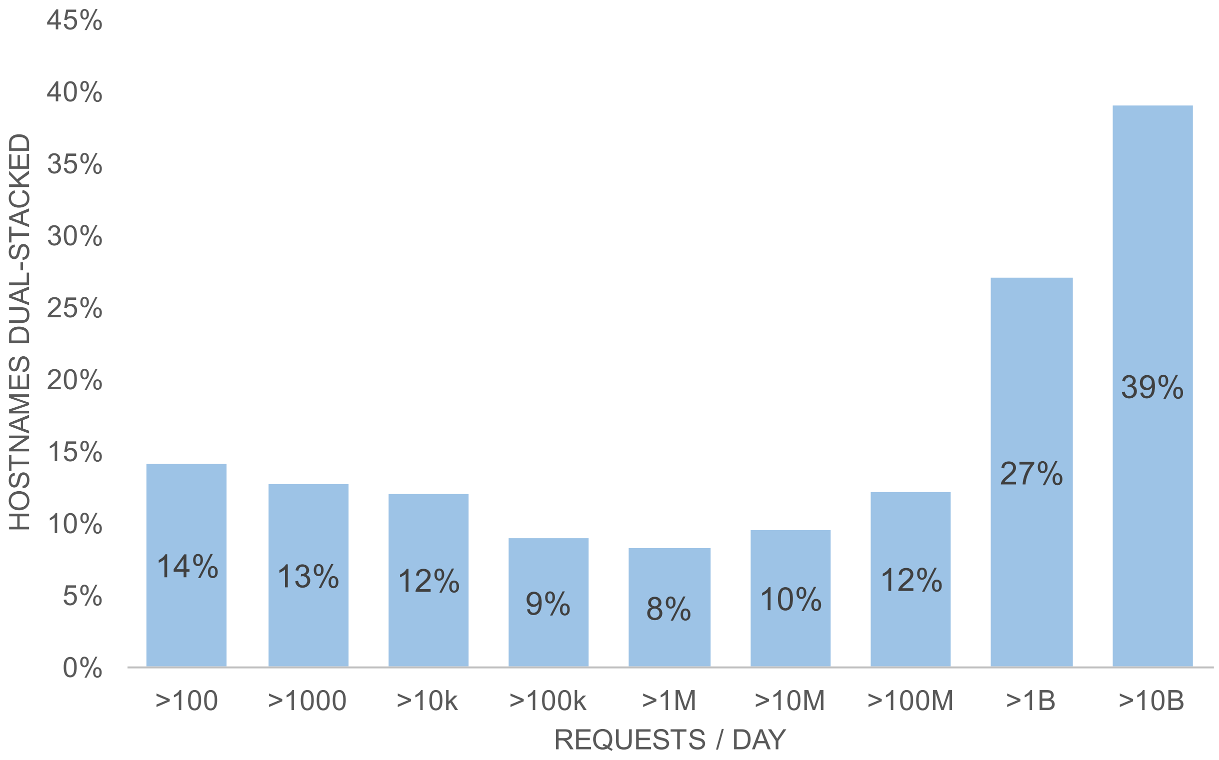
IPv6 Landscape: Content

Many major sites and content dual-stacked today:

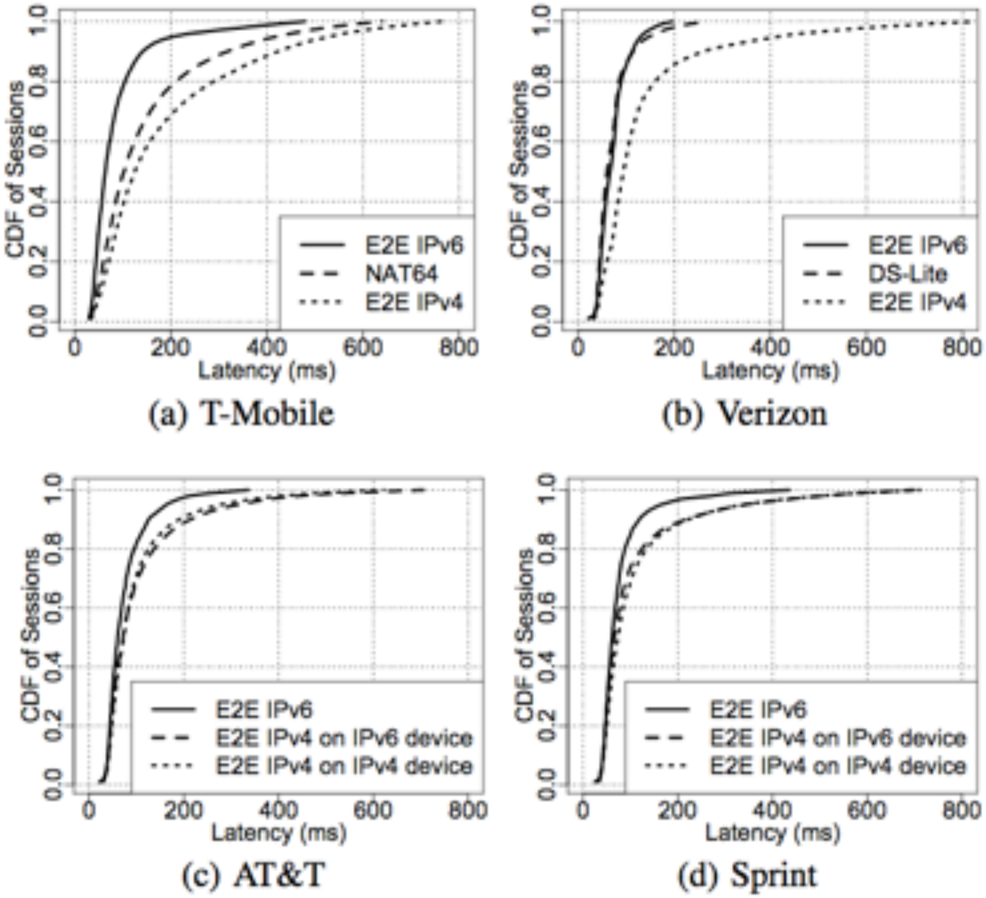
Tens of thousands of hostnames on Akamai for over 700 customers

Default in Property Manager for new hostnames on Akamai since mid-2016

Hundreds of dual-stacked hostnames on Akamai serving over 1B requests/day



Performance: IPv6 has lower TCP RTT/Latency

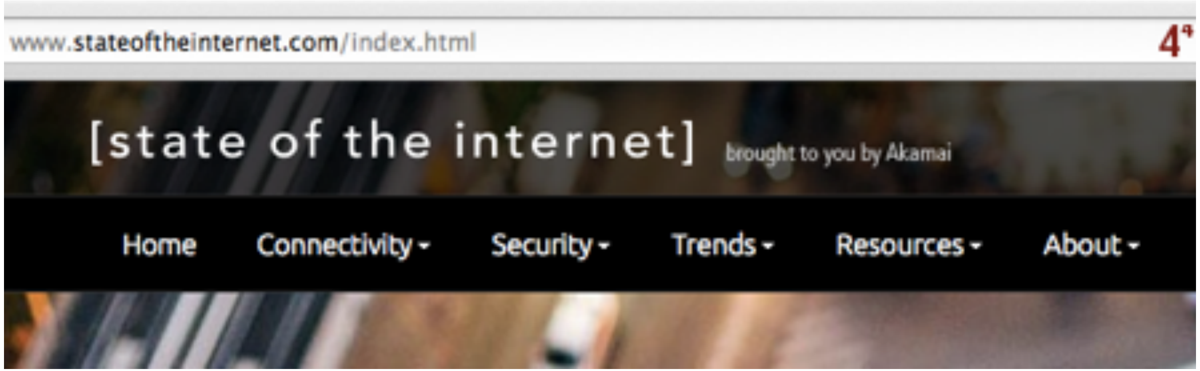


For selected Android devices in top-4 US mobile networks.

Source:
U. Goel, M.Steiner, et al "A case for faster mobile web in cellular IPv6 networks." Mobicom 2016

- Akamai's quarterly "State of the Internet" report
- Network & country IPv6 adoption visualizations linked from:

    http://www.StateOfTheInternet.com/ipv6

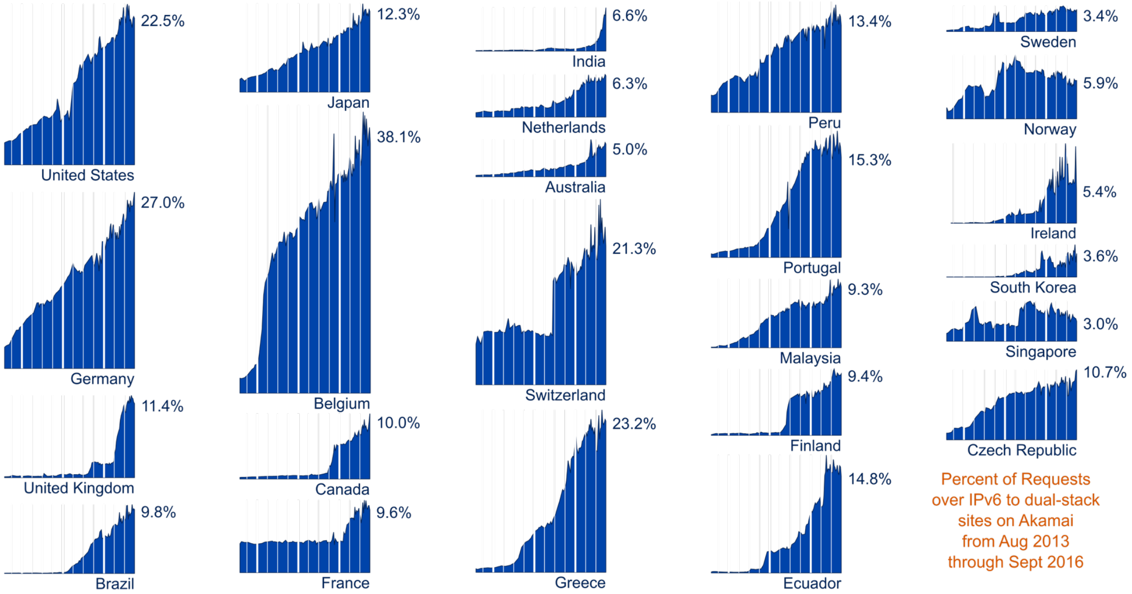


What You Can Do

- Develop a roadmap: gain experience and target key areas
- Get IPv6 connectivity to your corporate network environment
  - Makes testing, debugging, and diagnostics much easier
- Incorporate IPv6 support into purchasing requirements
  - Especially for security products, networking gear, & cloud providers
- Make content available over IPv6
  - Akamai helps makes this easy!
  - Dual-stack new hostnames and migrate existing ones
- Support IPv6 when building new systems
  - Leveraging IPv6 may even simplify some architectures, especially with IPv6-only

Additional Resources for IPv6

- https://www.akamai.com/ipv6
- http://www.worldipv6launch.org/
- http://6lab.cisco.com
- http://test-ipv6.com/



Percent of Requests over IPv6 to dual-stack sites on Akamai from Aug 2013 through Sept 2016

Erik Nygren, <nygren@akamai.com>

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- Global Warming? What does this have to do with Global Warming?

Similarities between IPv6 Adoption and Global Warming

- We saw this coming 25 years ago
- We developed the new protocol 20 years ago
- Hardly anyone deployed it until we started really running out of IPv4 addresses (APNIC April 15, 2011)
- Even now, Google sees only 16% of all clients globally can reach Google via IPv6.
- 1% in January 2013, roughly double each year since then.
- Good news: On track for 64% by January, 2019 and near complete deployment by January, 2020

Questions?

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