IPv6 is Here:
The Future is Now

Owen DeLong
Akamai Technologies
2017 North American IPv6 Summit

Agenda

- IPv6 Background
- What is Taking So Long?
- Adoption & Landscape
- Preparing for IPv6
- Akamai and IPv6
- What You Can Do
  - … for example, IPv4+IPv6 dual-stack your Akamai content

IPv6 Background

(the super short version)

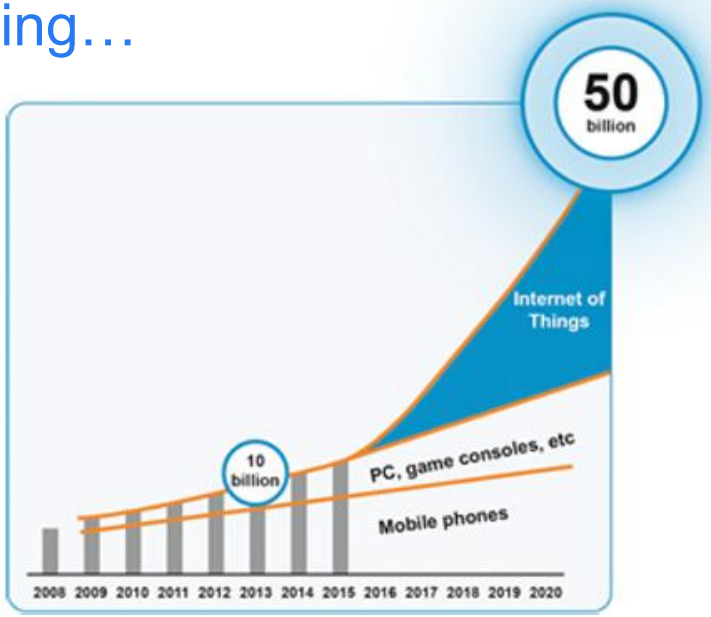
Only 4 billion IPv4 addresses…

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

NAT: the only alternative for large and growing networks

Photo: Xinhua News

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

Some consequences…

- Top mobile and broadband ISPs rapidly deploying IPv6
  - Over 58% 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
  - Should just work if using NSURLSession or CFNetwork with connect by name
  - Apps using IPv4 literals or low-level socket code may need changes
  - NAT64+DNS64 in IPv6-only networks: content may remain IPv4-only (for now…)
- 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

Akamai's goals around IPv6

- Committed to help customers with a smooth transition
  - Enable customers to make IPv6 content available to users
  - Maintain or improve performance & reliability
  - Deliver content from nearby dual-stack servers
  - Provide IPv6+IPv4 edge to IPv4-only origin translation service
  - Soon: Provide an IPv6+IPv4 edge to IPv6-only origin translation service!

- Most Akamai products & solutions include robust support for IPv6
  - Many products have switched from opt-in to opt-out for new configs

What's Taking So Long?

(we only started in the 1990's…)

Blockers for IPv6 adoption

- OS support
- Client software support
- Infrastructure/backbone support
- Content availability
- End-user connectivity
- End-user CPE device support

Blockers for IPv6 user adoption

- [x] OS support
- [x] Client software support
- [x] Infrastructure/backbone support

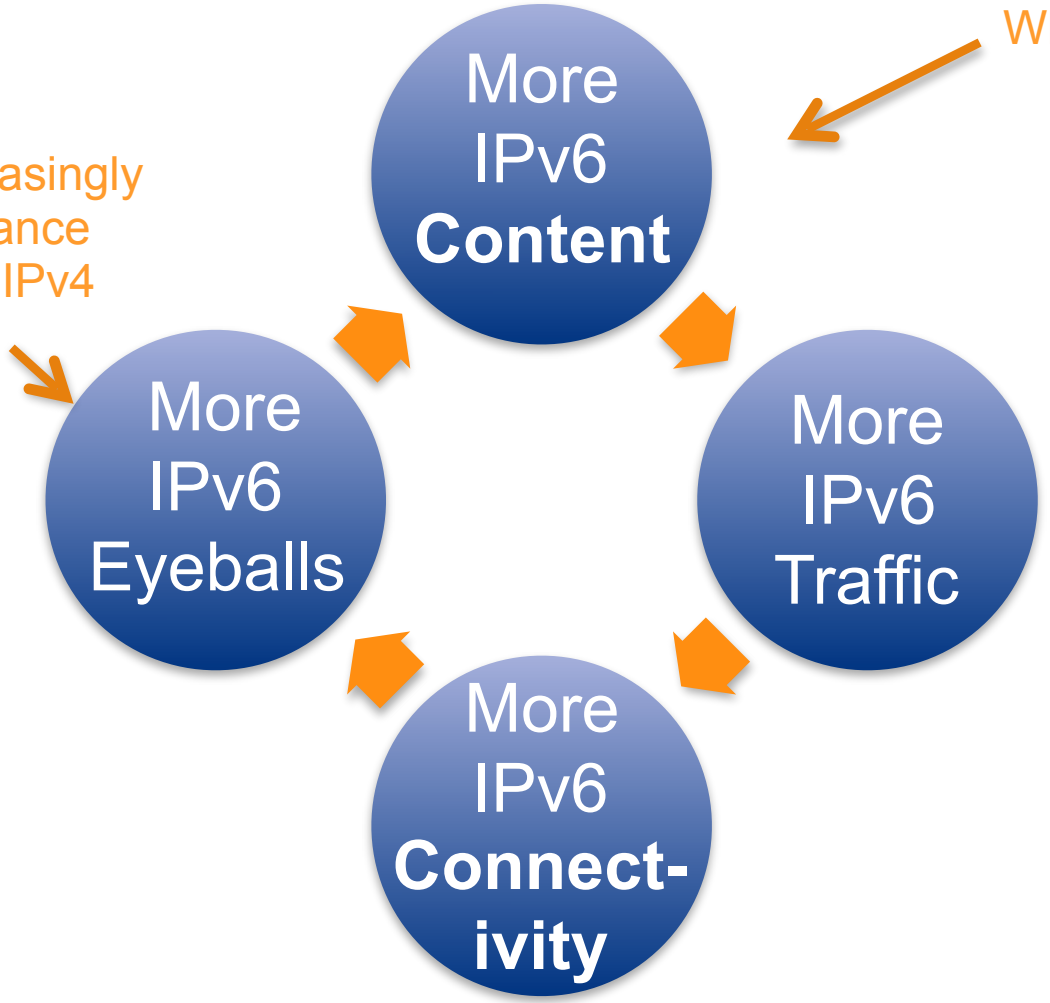
Small issues remain

- [x] Content availability
- [x] End-user connectivity
- [x] End-user CPE device support

Making solid progress

Virtuous cycle

Ideally, with increasingly better performance over IPv6 than IPv4



IPv6 Adoption Status

(or “why should I bother?”)

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

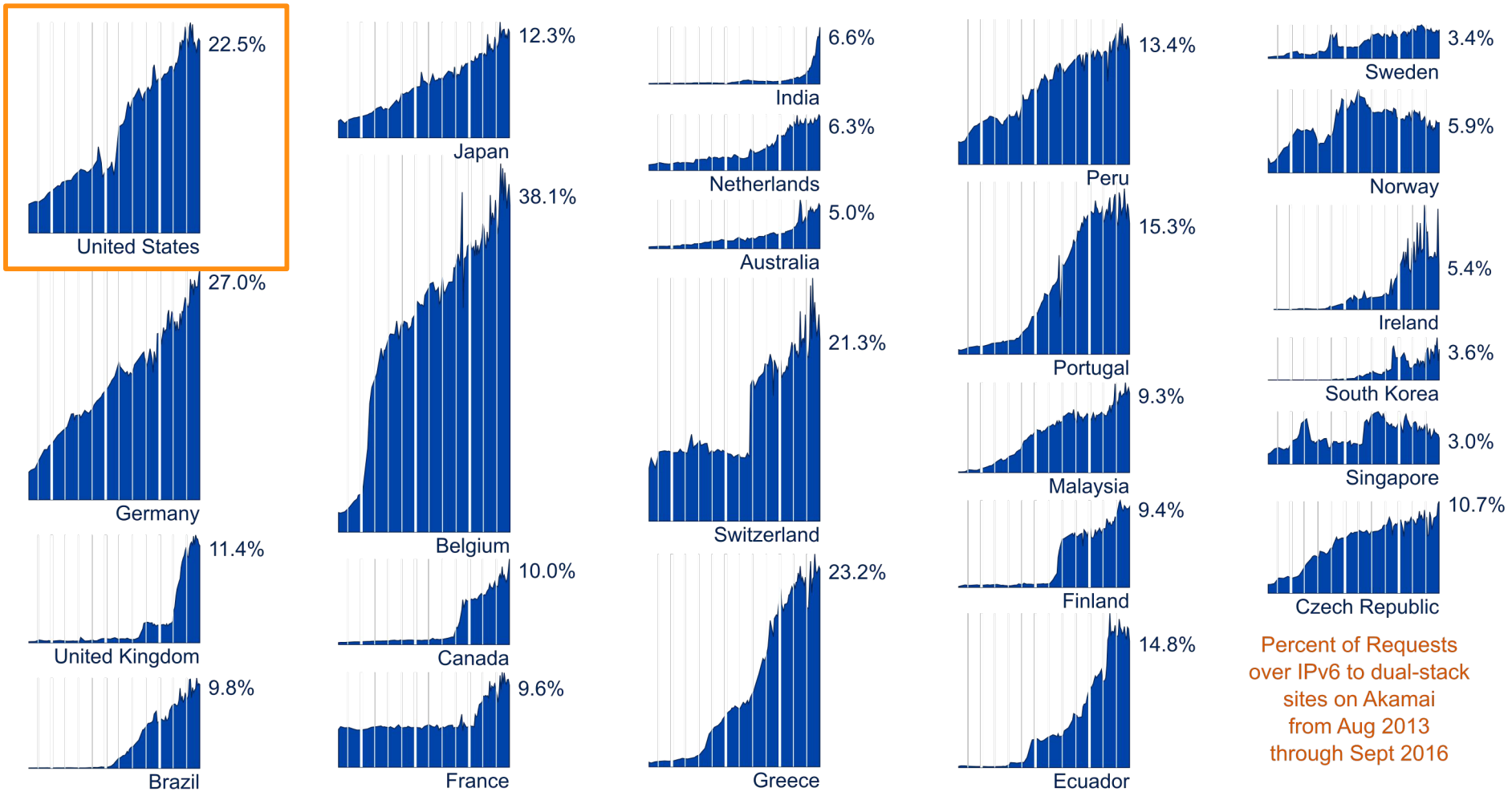
Nearly **3 billion** IPv6 addresses per week

Over **10 billion** IPv6 addresses per month

IPv6 Landscape: OSes and Devices

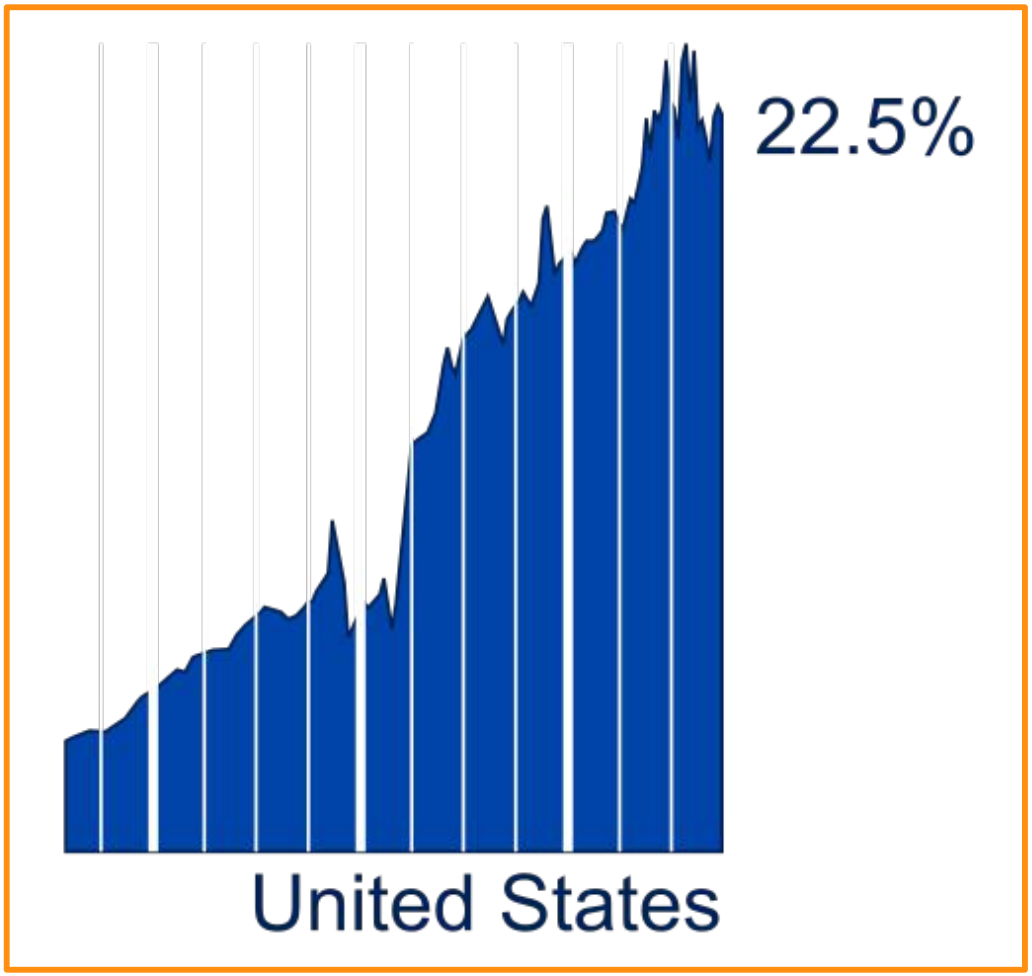
- Robust/mature IPv6 support in most recent operating systems
  - Even some search and page rendering bots use IPv6
- Some embedded devices and custom client software lag behind
- Anecdotes for IPv6 preference from leading devices:
  - iOS on top-4 US mobile networks: 46%
  - *Climbing rapidly with iOS 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, 82% in BSkyB, 39% in DT
  - 28% across entire United States

Leading Countries: three years of IPv6 growth

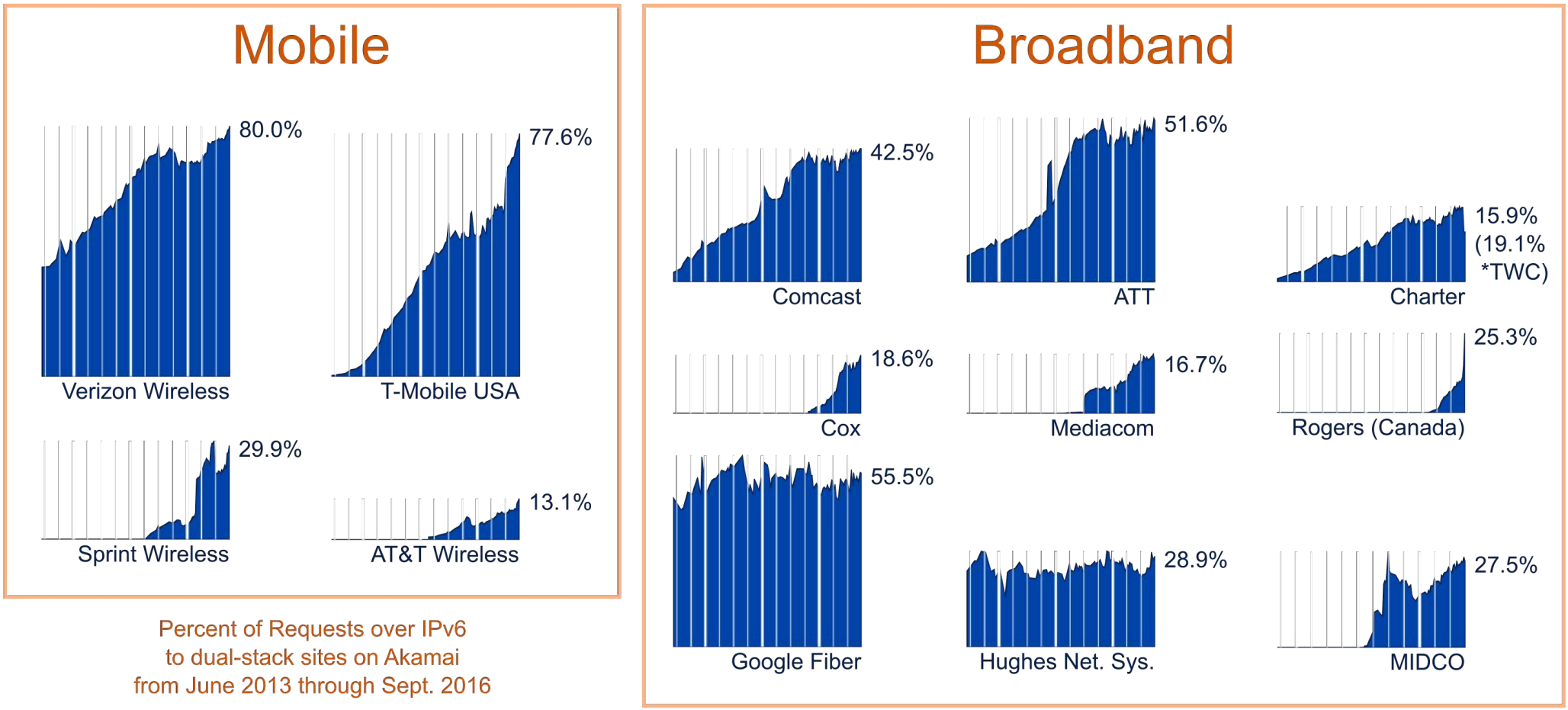


Percent of Requests over IPv6 to dual-stack sites on Akamai from Aug 2013 through Sept 2016

Leading Countries: three years of IPv6 growth

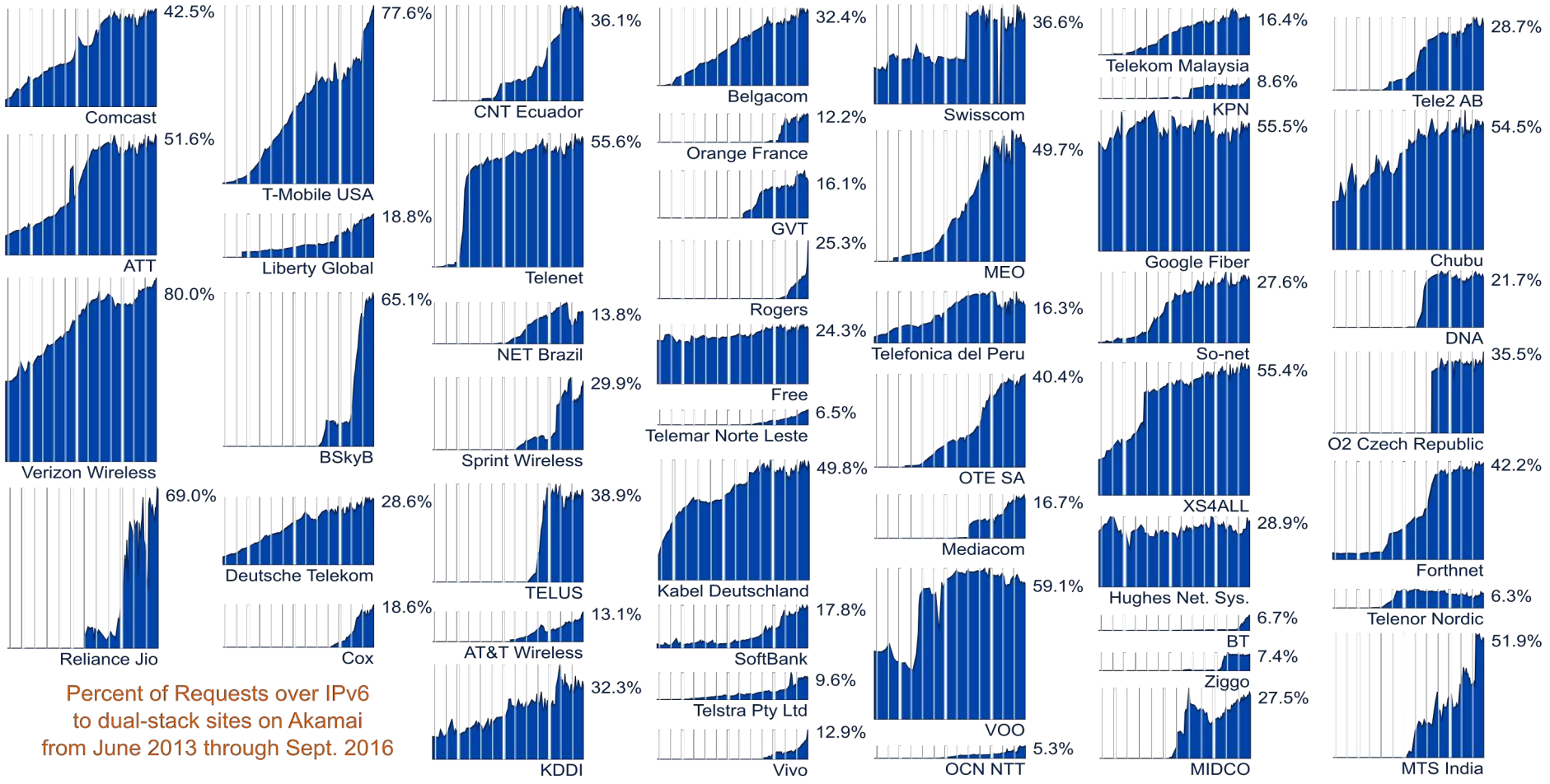


Leading U.S. end-user networks: 3 years of IPv6 growth



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

Leading global networks: 3 years of IPv6 growth



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

IPv6 Landscape: Content

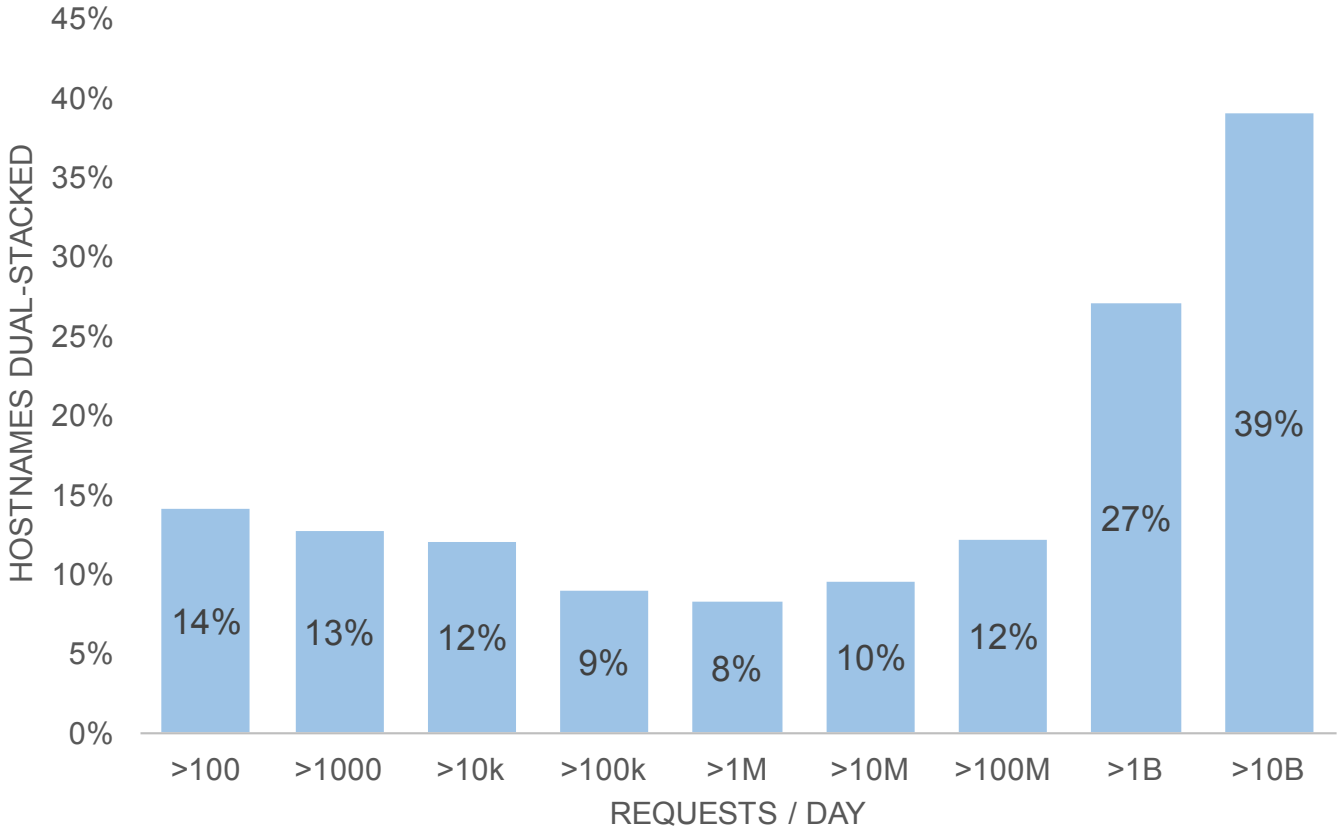
Many major sites and content dual-stacked today:

Tens of thousands of hostnames on Akamai for over 700 customers

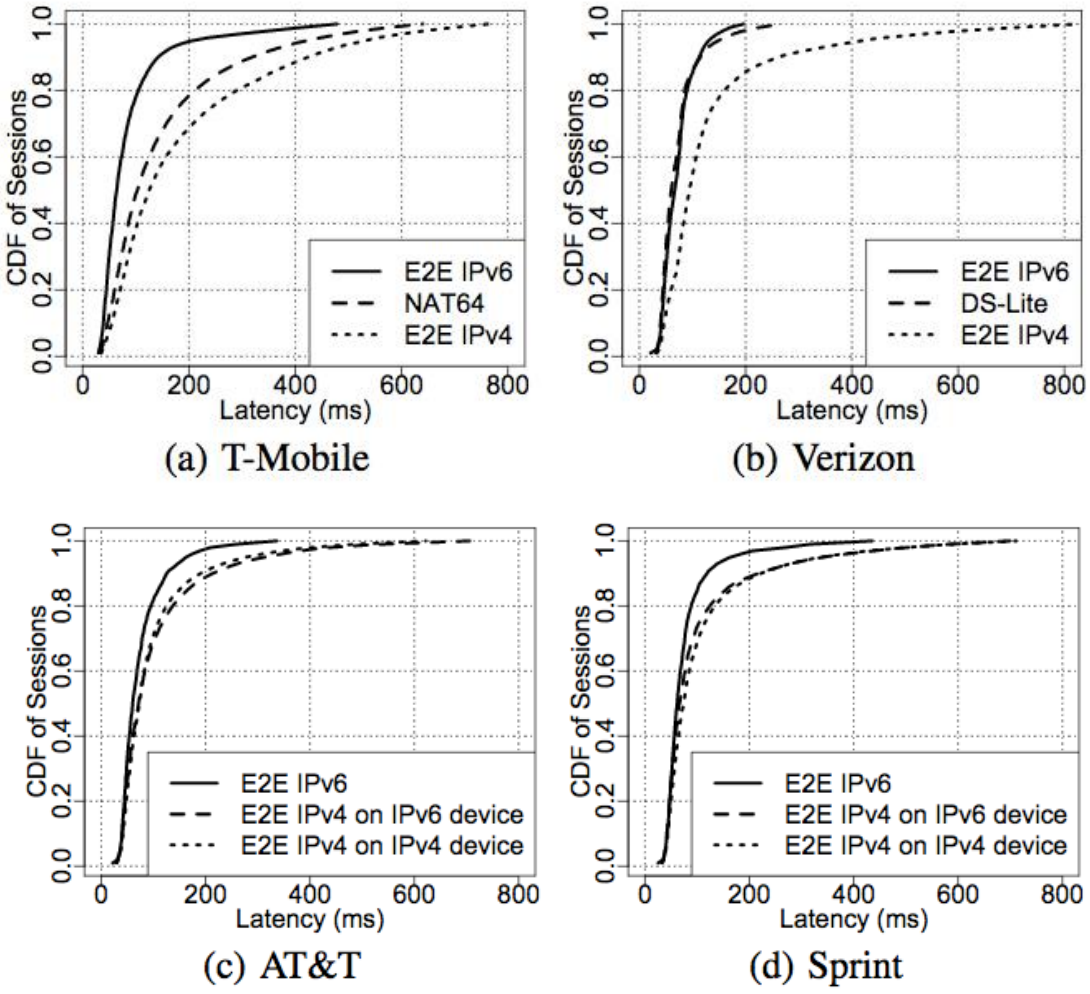
Default in Property Manager for new hostnames on Akamai since mid-2016

Content dual-stacked on Akamai

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

More Stats: Akamai's State of the Internet

- Akamai's quarterly "State of the Internet" report
- Network & country IPv6 adoption visualizations linked from:
  http://www.StateOfTheInternet.com/ipv6

Preparing for IPv6

(pitfalls and common gotchas…)

Another thing supporting IPv6: Bots!

Even in 2011 we observed one set of infected hosts that saw a AAAA record appear and followed it

I guess the malware was IPv6-ready?

Akamai blocking ongoing probes over IPv6

Over 15 million per day in 2015 from all around the world!

Make sure your firewalls support IPv6!

Most Akamai security features support IPv6 today

- ***Systems handling IP addresses may need updates***
- Storing Client IP addresses in a database
  - Ex: trying to store a 39 char IPv6 addr in a 15 char client_ip DB field
- Auth & session cookies with IP addresses highly problematic
  - Multi-homed or dual-stacked client may use multiple addresses
- Client reputation, fraud prevention, and auditing systems using IPs
- IP ACLs, especially in the case of split IPv4-only VPNs
- IP Geo location
- Custom client software, such as on mobile devices
- Parsing IP addresses in logs

Other common IPv6 pitfalls

- Not everything claiming to support IPv6 does so fully
- IPv6 connectivity still spotty in some areas
  - Pockets of IPv6 Internet have poor connectivity to other pockets
  - Client “Happy Eyeballs” behavior often shields users from breakage
  - (Fast fail-over from IPv6 to IPv4 when IPv6 is broken or slower)
- IPv6 PMTUD is a common area for breakage
  - Vendors, end networks, & content providers must regularly test
  - Could benefit from better technology and testing tools
  - Impact (today) limited to small set of users
- Increased complexity from IPv4 and IPv6 in-parallel
- In the end-game, IPv6-only is simpler than dual-stack

How much to worry?

- The pros of moving to IPv6 typically outweigh the cons
- Migration to IPv6 is inevitable
  - Waiting just increases risk
- So far very few customers have reported origin-side issues.
  Most common:
  - Fraud-prevention systems
  - IP address storage in databases

Akamai and IPv6

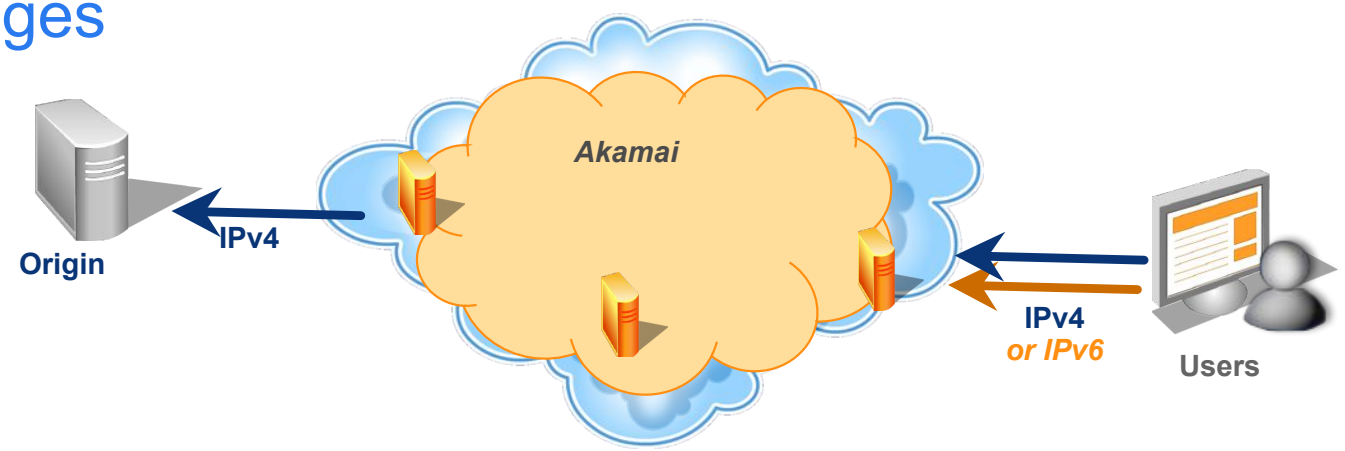
(so how do I leverage IPv6, already?)

Akamai and IPv6: current deployment status

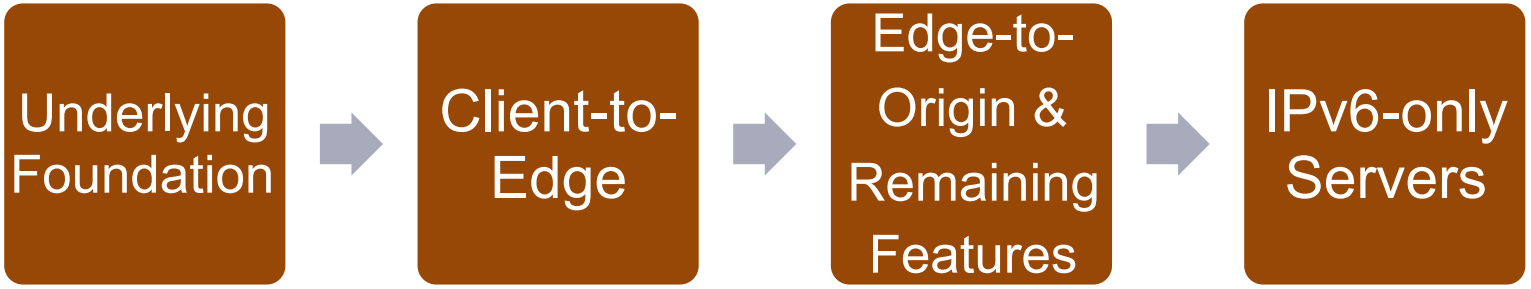
- IPv6 now configured and live on Akamai servers in…
  … over 109 countries
  … over 600 cities
  … over 700 networks
  … over 1,900 server locations
  (limited by some of our network partners not yet having working IPv6)

- IPv6 peak traffic on Akamai has exceeded 2 Tbps

- Dual-stacking edge servers
- Customer properties can be dual-stacked
  - Terminate IPv4 and IPv6 connections in server software
  - Can go forwards to customer origin via IPv4 (and IPv6 soon)
  - End-to-end testing often advised, with occasional origin changes

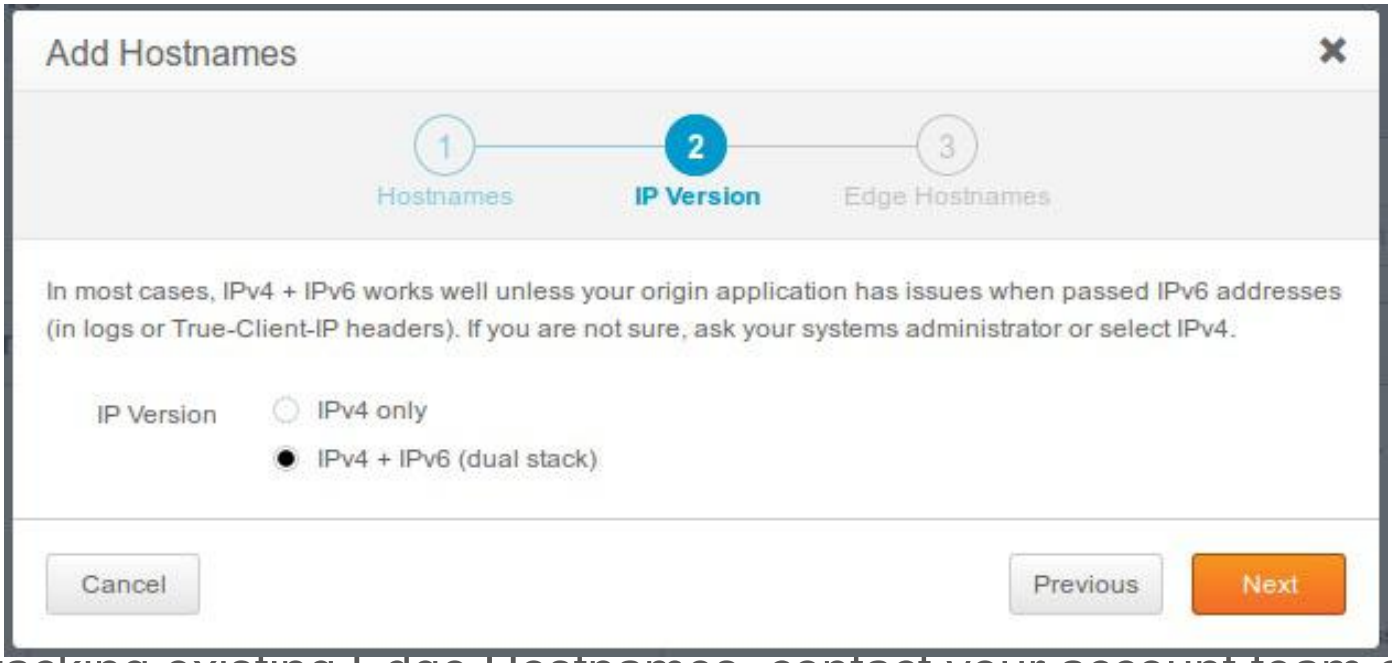


Transition to IPv6 for Akamai - History



- IPv6 client-to-edge HTTP support first launched in 2011
- Now defaulting many products to dual-stack for new hostnames
- Soon: support self-service dual-stacking existing edge hostnames
- Evaluating areas we can safely/proactively migrate services to dual-stack
  - Most Akamai DNS zones now have IPv6/AAAA authorities
  - May migrate some streaming content after notifications

For new hostnames, just leave “IPv4+IPv6 (dual stack)” selected:



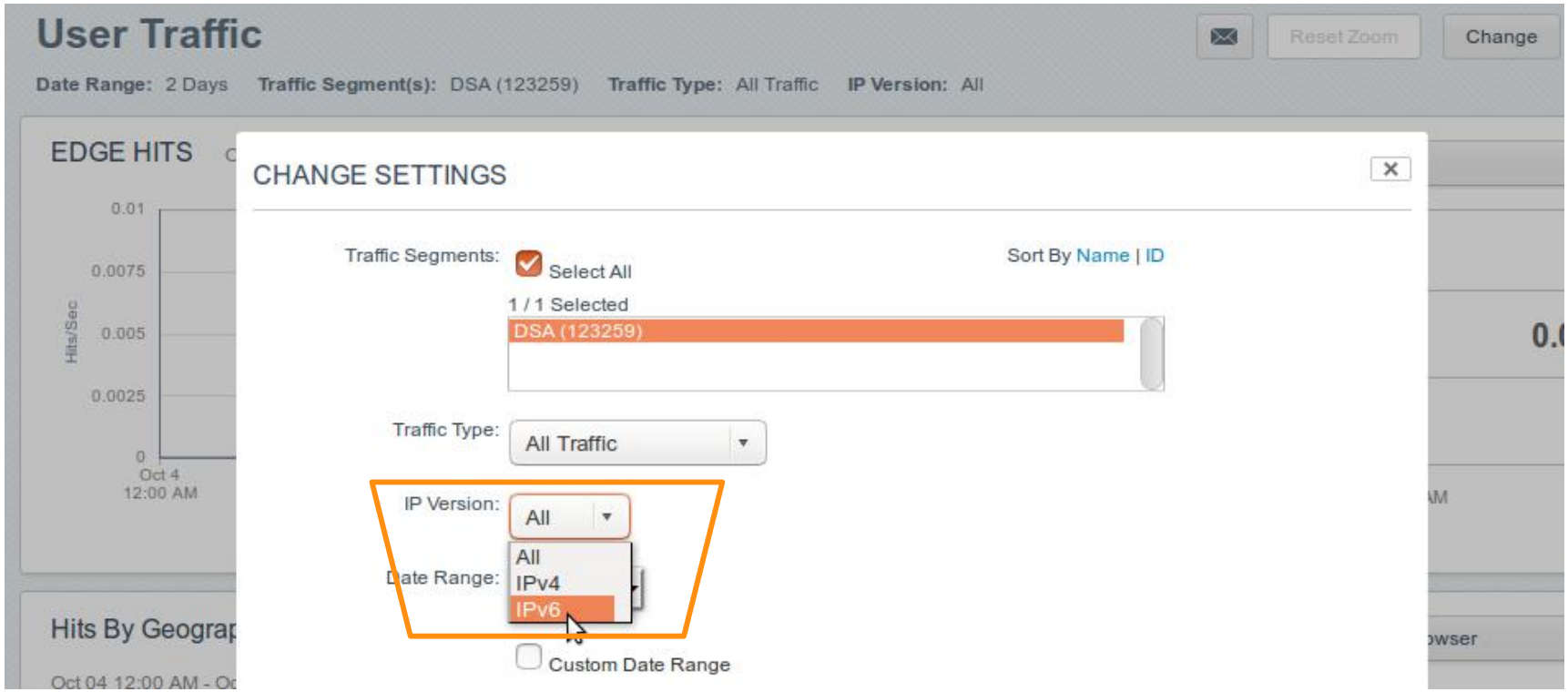
For dual stacking existing Edge Hostnames, contact your account team or AkaTec. Self-service support coming soon.

IP addresses in Logs, Headers, DLRs, WAF rules, …

- Expect “IP address” and “IP prefix” fields to have either IPv4 or IPv6

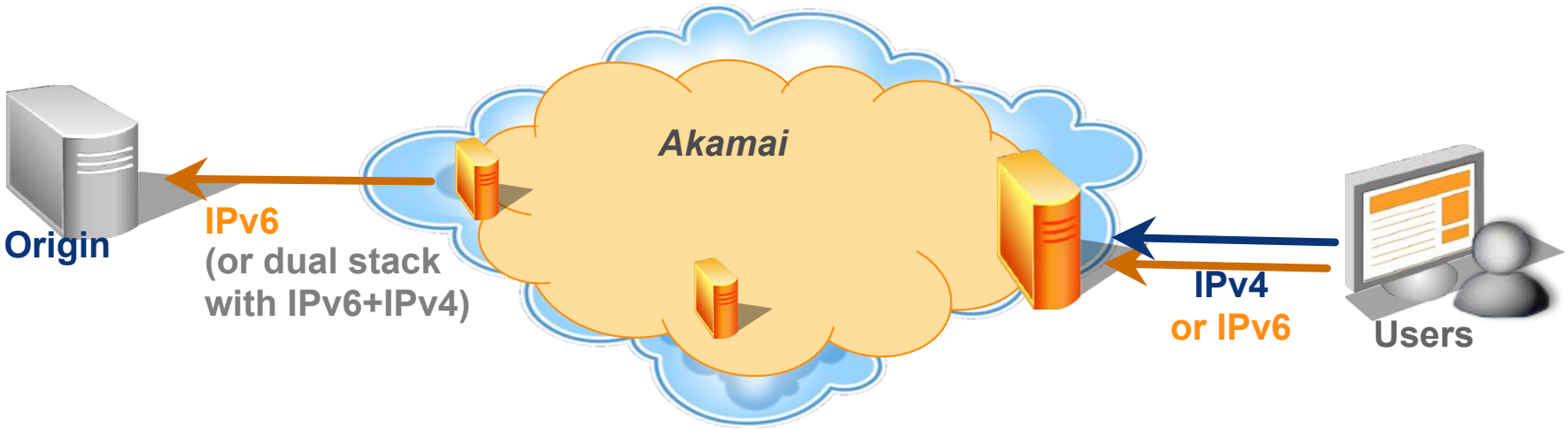
- For example:
  - True-Client-IP headers
  - IP address in Download Receipt templates
  - Network/IP List APIs and rules (WAF, Client IP matches, …)
  - IP addresses in LDS logs
  - Soon: SiteShield and Firewall Rule lists
  - IP lists for Edge IP Binding
  - ...

Many Luna reporting interfaces prove IPv4 vs IPv6 break-downs:



Coming soon…

Deliver content to IPv4 and IPv6 end-users from dual-stacked or IPv6-only servers and data centers!



** Contact your account team with interest*

What You Can Do

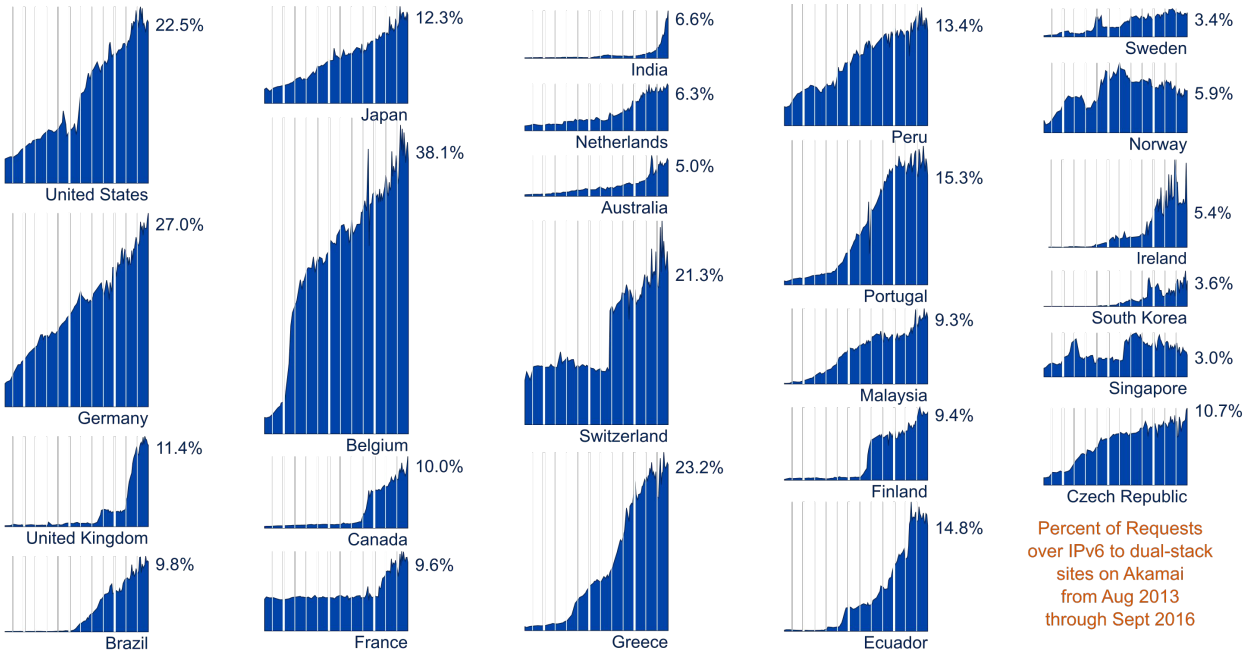
(go forth and dual-stack…)

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
- **Make content available over IPv6**
  - **Akamai helps makes this easy!**
  - **Dual-stack new hostnames and migrate existing ones**
- Ensure your mobile apps work in IPv6-only environments
- Incorporate IPv6 support into purchasing requirements
  - Especially for security products, networking gear, & cloud providers
- Support IPv6 when building new systems
  - Make sure client software and embedded devices support IPv6
  - Leveraging IPv6 may even simplify architectures, esp. with IPv6-only

Additional Resources for IPv6

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



Erik Nygren, <nygren@akamai.com>

Questions?

Erik Nygren, <nygren@akamai.com>

The End…

Support Slides Follow

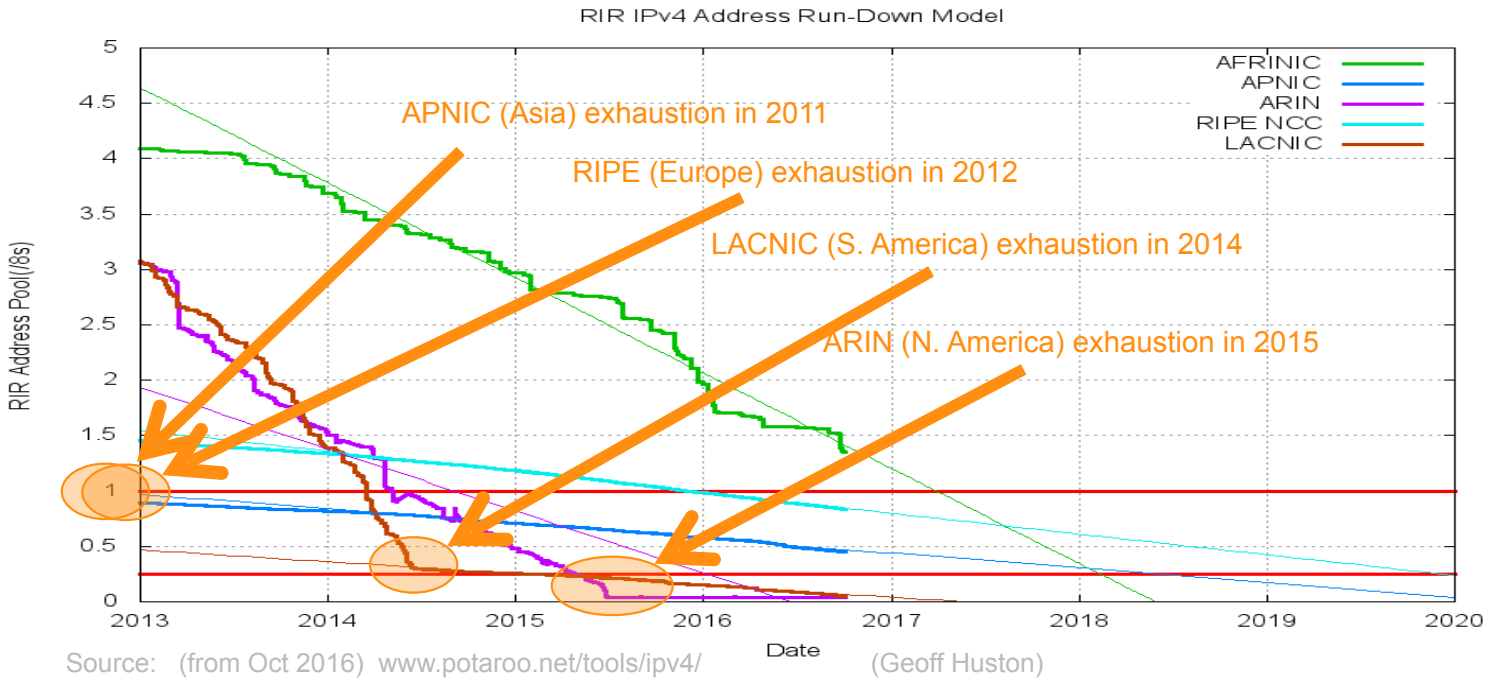
Motivation: Running out of IPv4 addresses

Four Billion IPv4 addresses (32-bit value)

- Some is reserved (multicast, localhost, RFC1918, …)

Used by clients, servers, mobile devices, SSL VIPs, and more

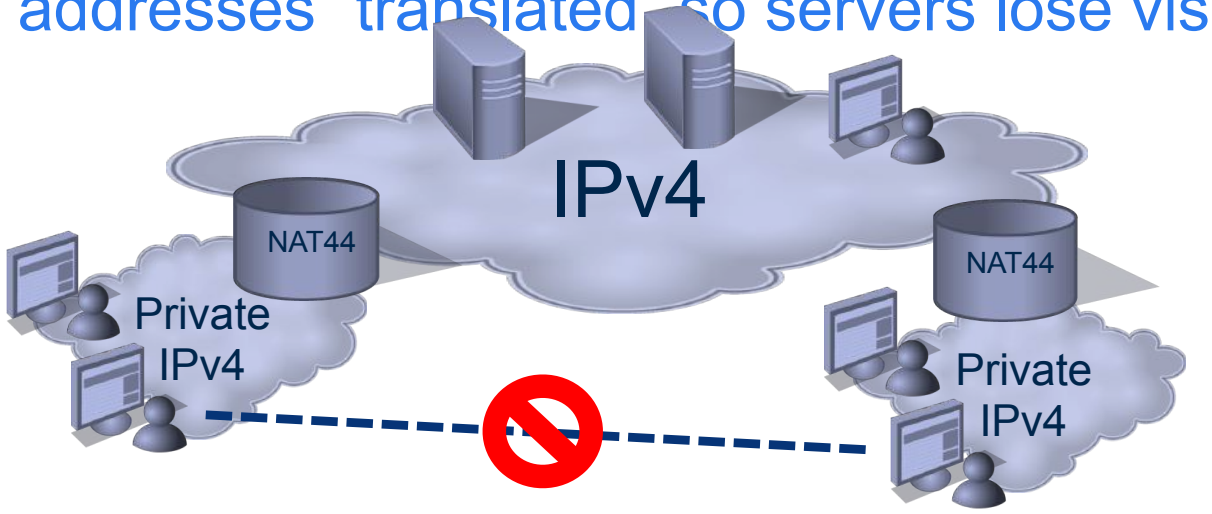
Impacts of IPv4 as a constrained resource to be more visible



Source: (from Oct 2016) www.potaroo.net/tools/ipv4/ (Geoff Huston)

The ugly alternative: NAT/CGN

- Constrained IPv4 space means more NAT44
  - NAT gateways may be performance bottlenecks
  - Not an option for servers
  - Pockets of machines that can't directly communicate
  - Client addresses "translated" so servers lose visibility



Enter IPv6…

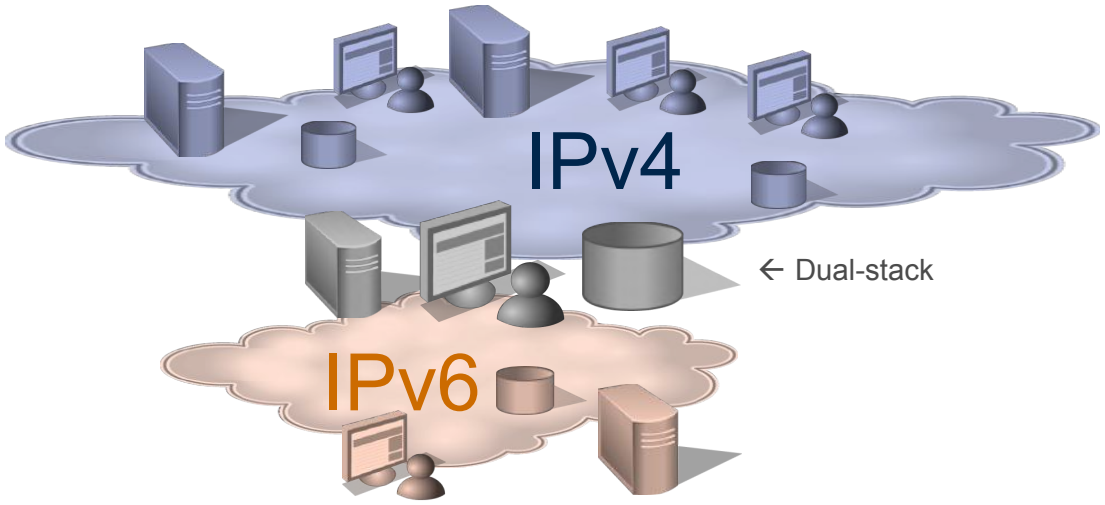
IPv4  32 bits

Only 4 billion addresses

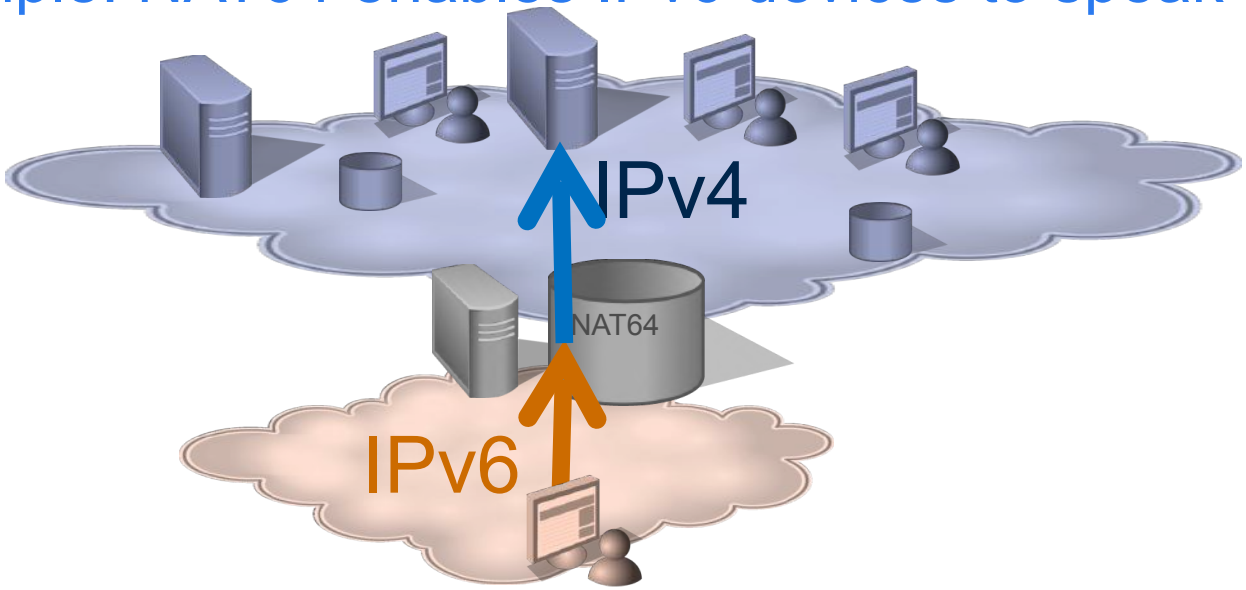
IPv6  128 bits

Over **10^{38}** possible addresses
Enough to give 50 million addresses to every bacteria on Earth!
Under development/deployment since late 1990's

- No direct compatibility, so effectively two Internets
- Many hosts and devices will live on both (“dual-stack”)
  - Dual-stack devices have both IPv4 and IPv6 addresses
- NAT technologies can adapt IPv6 to IPv4 (e.g., NAT64)



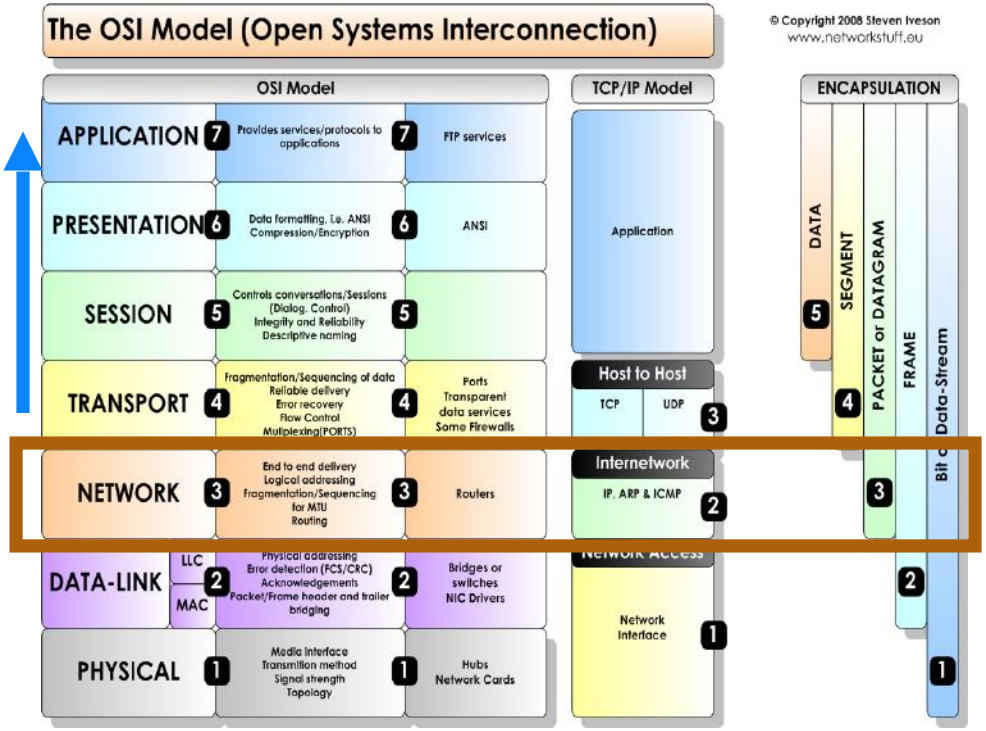
- Dual-stack
- Transition technologies
  - Many still have downsides of NAT44
  - Example: NAT64 enables IPv6 devices to speak to IPv4



At Network Layer (below TCP, above Ethernet)

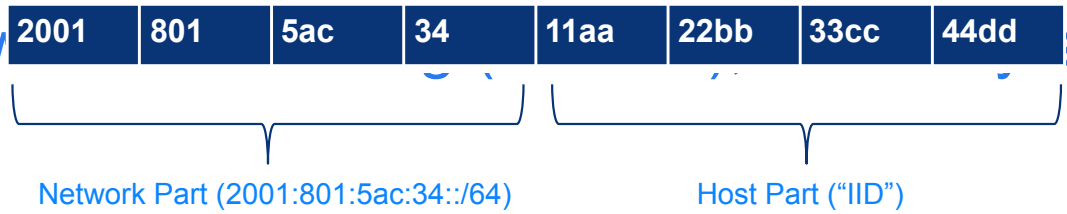
Changes have impact up the stack

IPv4 and IPv6 live here →



- Specify network prefix with *NETWORK/PREFIX*
  - Examples:
  - 2002::/16 = 2002:0:0:0:0:0:0:0/16
  - 2001:a:b:c::/64
  - 2001:a:b:c::2:3/128

- Top 64 bits is *often* network prefix
  - For netw…select bottom 64 bits



- DNS controls content availability, along w/ client behavior
  - IPv4: DNS “A” record returns IPv4 addresses
  - IPv6: DNS “AAAA” record returns IPv6 addresses
- Same name can have both A and AAAA records

- Example dual-stacked DNS:

```
www.example.com     A      192.0.42.2
www.example.com     A      192.0.42.5
www.example.com     AAAA   2001:db8:0:44::a11:aba3
```

- Dual-stack clients may lookup *both* A and AAAA records
  - Will *often* prefer IPv6 if AAAA records are returned
  - Client/browser heuristics vary widely
  - Happy Eyeballs: many clients fall back to IPv4 if IPv6 doesn't work
  - Teredo and 6to4 no longer used by modern clients
- IPv6-only clients will lookup *only* AAAA records
  - DNS64 resolver may construct AAAA record: NAT64 + A lookup
- Protocol used for lookup will often differ from the question
  - Example: A lookups over IPv6 and AAAA lookups over IPv4

IPv6 Device Support: “Happy Eyeballs”

- Many devices/clients will try both IPv4 & IPv6 w/ fail-over

- Example: iOS 9.3+ does races with a slight bias towards IPv6
- Example: Firefox races SYNs to both IPv6 and IPv4 and uses IPv6 if it SYN-ACKs fast enough

- Additional benefit: two alternate network paths from client
  (sometimes IPv4 is better, sometimes IPv6 is better)
- Downside: obscures failures

- 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