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IP Version 6 (IPv6)
Past, Present, and Future

Bob Hinden / Check Point Fellow

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CYBER SECURITY

CLOUD • MOBILE • THREAT PREVENTION

IPv6 Background

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- In the early 1990s it was not clear that TCP/IP was going to be successful
- There were many competitors
  - OSI CLNP, ATM, AT&T Business, etc.
- Predictions of Internet melt downs
- The IETF was not considered to be an official standards organization
- Not having a plan for what follows IPv4 was a real issue

Some Old Slides from ~1995

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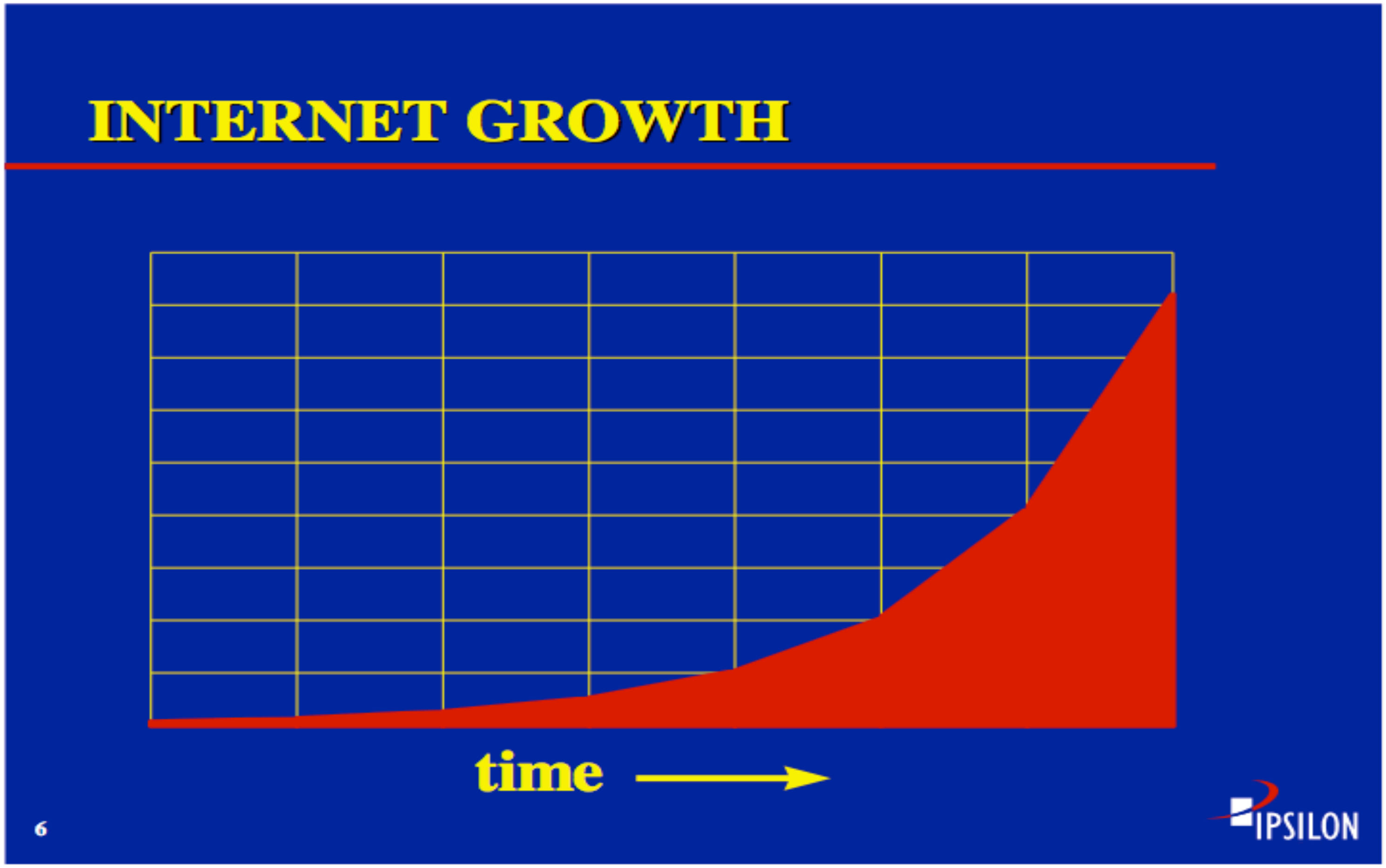

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FACTORS CAUSING GROWTH

- More of what we have Today
  - All Computers on Internet
  - Real Commerce / Advertising
- New Users
  - Large Countries (China, India, ...)
  - New Industries (cable, mobile, ...)
- Networked Everything
  - All Information Devices (FAX, Printers, ...)
  - Energy Management (meters, controllers, switches....)

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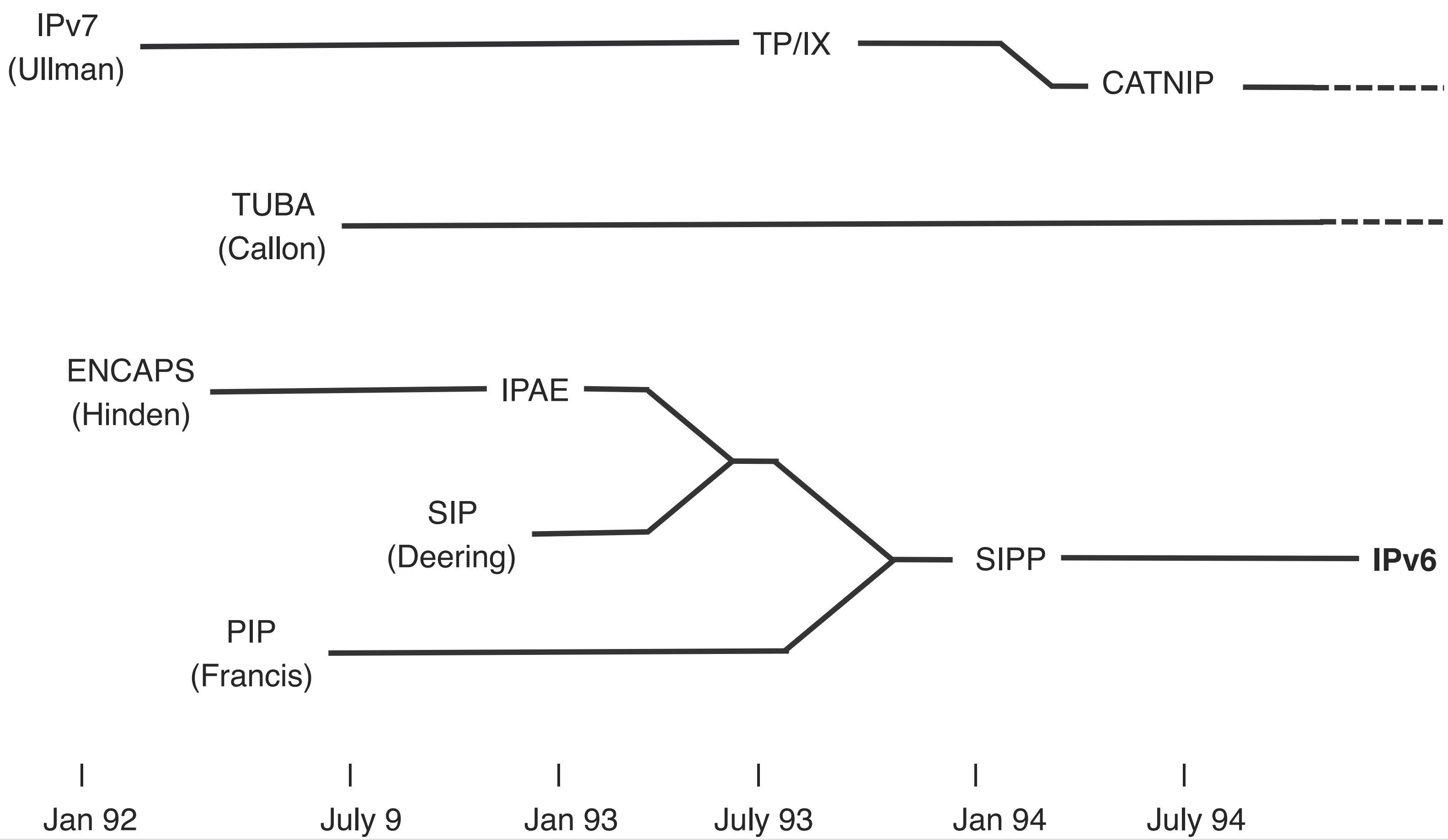
IPSILON

IETF IPng Time Line

- ~1990
  - Internet growing exponentially and started looking like running out of IP addresses
  - Projected exhaustion of Class B Address space
- 1991
  - Routing and Addressing (ROAD) group formed
    - Recommended implementing CIDR and develop IP Next Generation (IPng)
- 1992
  - IAB issues "IP Version 7"
    - This came to be known as the "Kobe Incident"
- 1992 (cont)
  - IETF issues call for IPng proposals
- 1993
  - IESG took on IPng responsibility
  - IPng Area formed
    - Scott Bradner & Allison Mankin area directors
  - RFC1550 Call for IPng Solicitation published
- 1994
  - IPng Recommendation

IPng Candidates



IP Version Numbers

Version	Name
0-3	Unassigned
4	Internet Protocol (current IPv4)
5	Stream Protocol (ST) (not an IPng)
6	SIP – SIPP – IPv6
7	IPv7 – TP/IX – CATNIP
8	Pip
9	TUBA
10-15	unassigned

Classless Inter-Domain Routing (CIDR)

- Relaxed fixed boundaries in IP address allocation
  - Original IP allocation strategy was “flat”
- Allocate blocks of IP addresses to Providers
  - Now called prefixes
  - Routing protocols changed to aggregate all routes to a single provider
- CIDR made address utilization more efficient and greatly improved core routing scaling

CATNIP

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- Common Architecture for Next-generation Internet Protocol (CATNIP)
  - Chair: Vladimir Sukonnik
  - Documented in RFC1707
- Based on work of TP/IX working group
  - Goal was to find common ground between OSI and Novell protocols, and to increase the scale and performance
- Not well specified, interesting ideas, but not a complete proposal

TUBA

- TCP/UDP Over Bigger Addresses
  - Chairs: Peter Ford & Mark Knopper
  - Documented in RFC1347

- Approach was to run TCP/UDP over the ISO Connection-Less Network Protocol (CLNP)
  - Leveraged the ISO work

- Strength was CLNP, weakness was CLNP

SIP - Simple IP

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- Simple IP
- Proposal from Steve Deering
  - https://tools.ietf.org/html/draft-deering-sip-00
- Technical
  - 64-bit addresses (twice the number of bits of IPv4)
  - Headers size kept at 20 bytes (same size as IPv4 header)
    - Simplified header, removed fragmentation and options
- Simple and clean design
- Questions about address size, in hindsight would have been the easiest transition

SIPP

- Simple Internet Protocol Plus (SIPP
  - Chairs: Steve Deering, Paul Francis, Bob Hinden
  - Documented in RFC1710
- Based on merger of ENCAPS into IPAE, merged with SIP, and with PIP
  - New version of IP designed to be an evolutionary step from IPv4. Designed to work over a range of speeds and network types.
- Clean design from SIP, addresses too small, extended addresses too complex.

The Address Size Debate

- Fixed length 64-bit addresses (SIP)
  - Met requirements by 3 orders of magnitude, 10^{12} sites, 10^{15} nodes at .0001 allocation
  - Minimizes growth of packet
  - Efficient for software processing
- Variable length addresses, up to 160-bits (TUBA)
  - Compatible with OSI NSAP address plans
  - Large enough for auto-configuration using IEEE 802 addresses
  - Could start with short addresses and grow later
- Compromised on fixed length 128-bit addresses

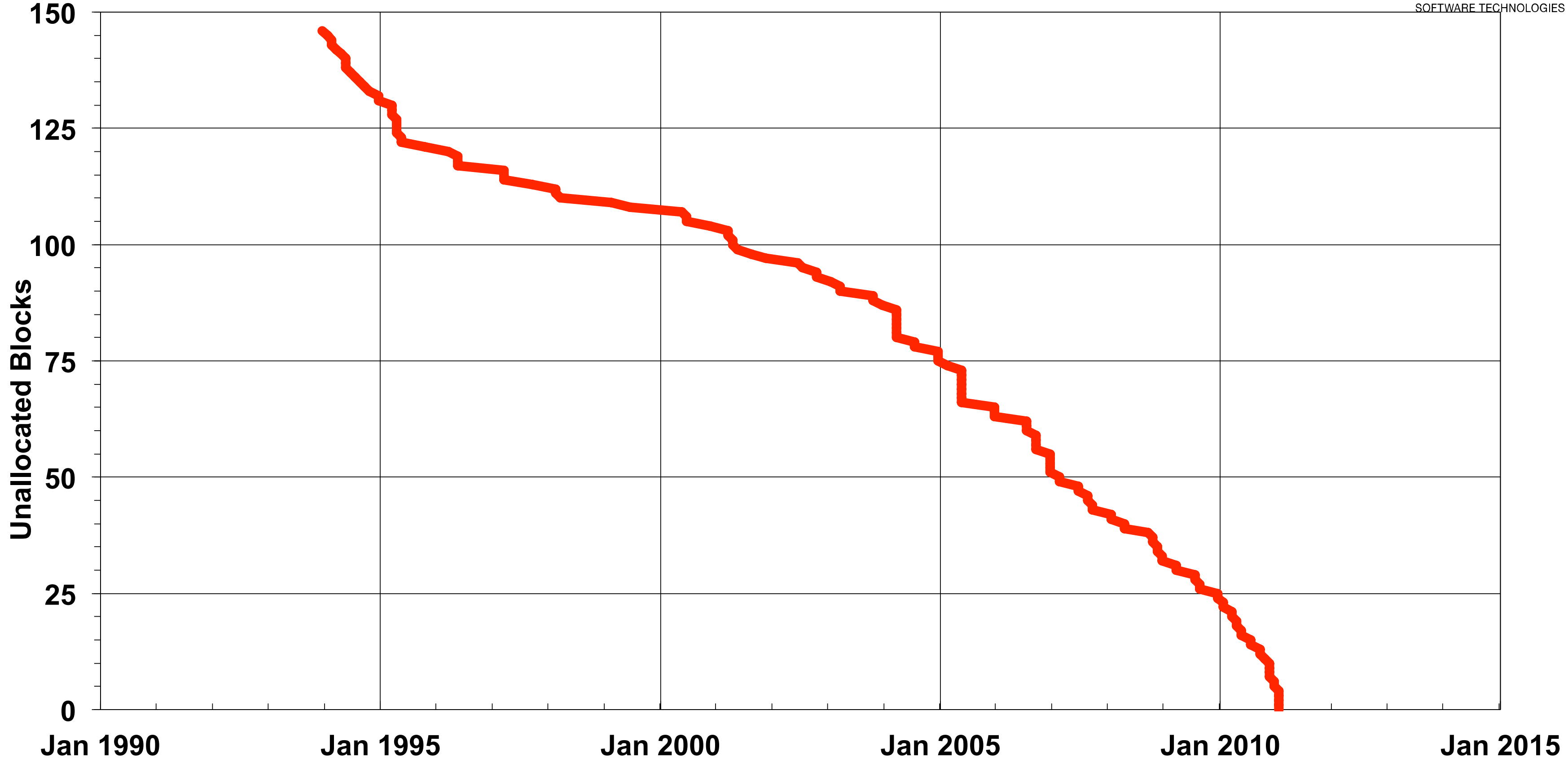
IPng Recommendation

- IPng based on SIPP with 128-bit addresses

- IPng working group created to create specifications and standardize IPv6
  - Chairs: Steve Deering, Ross Callon
  - Document editor: Bob Hinden

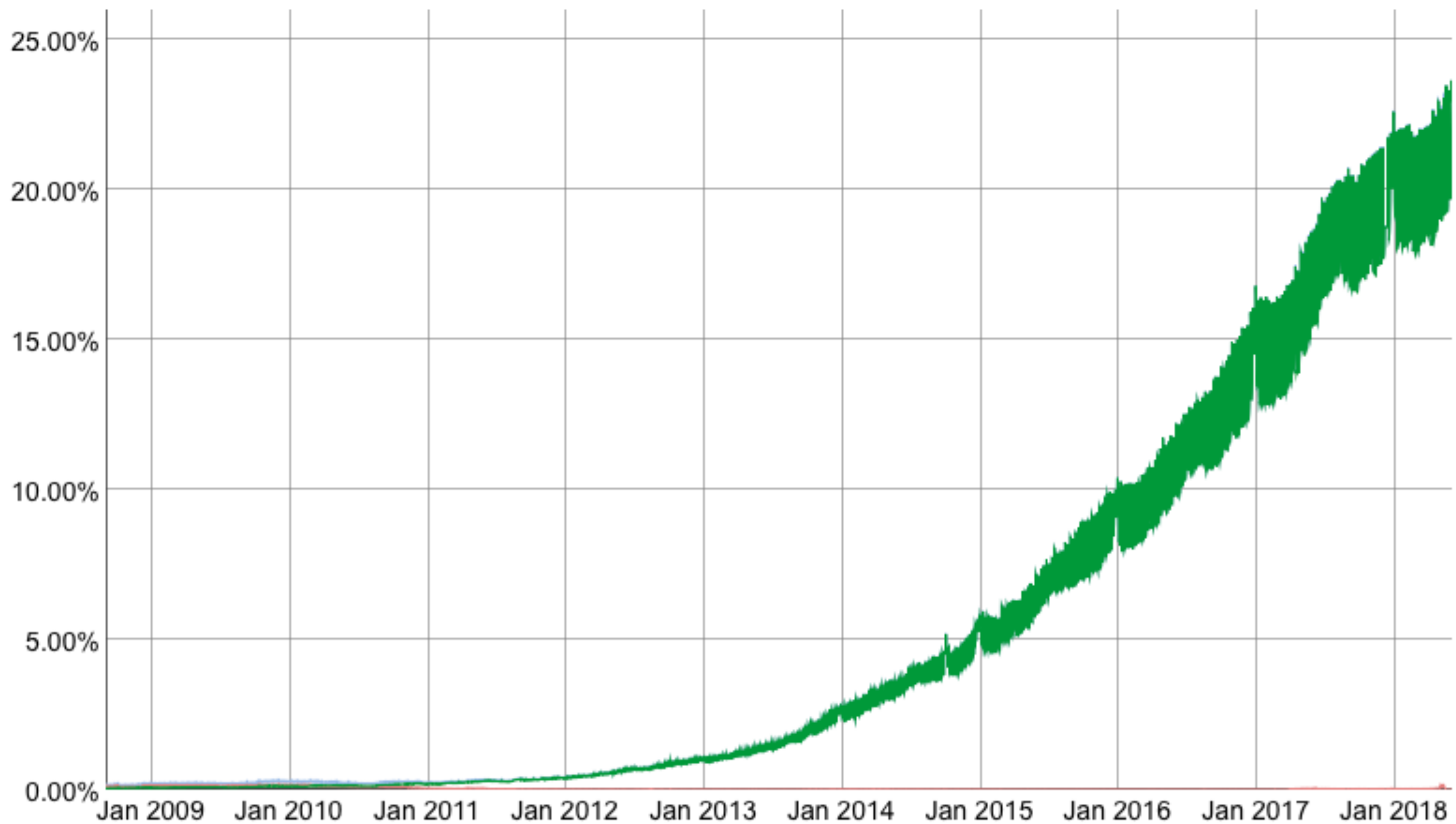
- Goal to resolve remaining issues, complete unfinished work, move to Proposed Standard
  - IPv6 first published as RFC1883 December 1995

We did Run Out of IPv4 Addresses



(Last allocation to RIRs from the IANA free pool 31 Jan 2011)

~24% of User Access to Google is with IPv6



https://www.google.com/intl/en/ipv6/statistics.html

ISP Status

ISP	Percentage
Verizon Wireless	84%
AT&T	51%
Comcast	54%
T-Mobile	87%
Reliance Jio	83%
Sprint	44%
Time Warner Cable	30%
Deutsche Telekom	44%

https://www.akamai.com/uk/en/about/our-thinking/state-of-the-internet-report/state-of-the-internet-ipv6-adoption-visualization.jsp

Adoption by Country

ISP	Percentage
Belgium	66%
USA	40%
India	37%
Greece	32%
Germany	26%
Luxembourg	22%
Switzerland	21%
Finland	21%

https://www.akamai.com/uk/en/about/our-thinking/state-of-the-internet-report/state-of-the-internet-ipv6-adoption-visualization.jsp

IPv6 is now an Internet Standard

- The IETF published the IPv6 as an Internet Standard in July 2017
  - Internet Standard is the last step in the IETF Standards Process

STD 86

RFC 8200

Title: Internet Protocol, Version 6 (IPv6) Specification

Author: S. Deering, R. Hinden

Status: Standards Track

Date: July 2017

Obsoletes: RFC 2460

IPv6 State Today

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- Major platforms all support IPv6
  - MacOS, Windows 10, Linux, Android, iOS, …
  - Routers, Switches, Firewalls, …
- Major content providers support IPv6
  - Google, Netflix, Facebook, LinkedIn, YouTube, …
- Large ISPs support IPv6
- CDN provide IPv6 access to IPv4 only sites
- AWS now supports IPv6
- Some large Enterprise are starting IPv6 only

Challenges going Forward

- Mid size sites
  - Banks, Commerce, ….
- Enterprises are mostly IPv4 today
- Smaller ISPs
- IoT Devices
- Some new networks products still come IPv4 only
  - IPv6 is on the roadmap, but…

We have come a long way, but more to do

IPv6 Conclusions

- We were right about running out of IPv4 addresses
  - But did not understand the impact of NAT
- We were not right about
  - How long it would take to develop IPv6
  - When IPv4 addresses would run out
  - How hard and long to deploy
- We made IPv6 happen by building a broad community of motivated and dedicated people around the world

Conclusions (2)

- We did not anticipate how Internet would change
  - No longer "build it and they will come"
  - Now there has to be a business case
- A lot of the industry was in denial for a long time
- No one has done this before

The Internet Today

- It's very hard to deploy anything that requires global deployment before it becomes useful
  - Anything new needs immediate return
  - It has to solve a local problem, before it can solve a global problem

- The good news is that IPv6 deployment has become a local problem

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