

Introduction to IPv6

ISP Workshops



These materials are licensed under the Creative Commons Attribution-NonCommercial 4.0 International license (<http://creativecommons.org/licenses/by-nc/4.0/>)

Last updated 29th July 2019

Acknowledgements

- This material originated from the Cisco ISP/IXP Workshop Programme developed by Philip Smith & Barry Greene
- Use of these materials is encouraged as long as the source is fully acknowledged and this notice remains in place
- Bug fixes and improvements are welcomed
 - Please email *workshop (at) bgp4all.com*

Philip Smith

Early Internet History

- Late 1980s
 - Exponential growth of the Internet
- Late 1990: CLNS proposed as IP replacement
- 1991-1992
 - Running out of “class-B” network numbers, blocks of “class-Cs” handed out instead
 - Exponential growth of the “default-free” routing table
 - Eventual exhaustion of 32-bit address space
- Two IETF efforts – short-term vs. long-term
 - More at “The Long and Windy ROAD”
<http://rms46.vlsm.org/1/42.html>

Early Internet History

- CIDR and Supernetting proposed in 1992-3
 - Deployment started in 1994
- IETF “ipng” solicitation – RFC1550, Dec 1993
 - Resulted in many proposals:
 - TUBA – RFC1347, June 1992
 - PIP – RFC1621, RFC1622, May 1994
 - CATNIP – RFC1707, October 1994
 - SIPP – RFC1710, October 1994
 - NIMROD – RFC1753, December 1994
 - ENCAPS – RFC1955, June 1996
 - etc
- Direction and technical criteria for next generation of IP:
 - RFC1752, January 1995

Early Internet History

→ 1996

- IPv6 Specification (RFC1883) published in December 1995
- Other activities included:
 - Development of NAT, PPP, DHCP,...
 - Some IPv4 address reclamation
 - The RIR system was introduced
- → Brakes were put on IPv4 address consumption
- IPv4 32 bit address = 4 billion hosts
 - HD Ratio (RFC3194) realistically limits IPv4 to 250 million hosts

Recent Internet History

The “boom” years → 2001

- IPv6 Development in full swing
 - Rapid IPv4 consumption
 - IPv6 Specification Draft Standard in 1998: RFC2460
 - IPv6 specifications sorted out
 - (Many) Transition mechanisms developed
- 6bone
 - Experimental IPv6 backbone sitting on top of Internet
 - Participants from over 100 countries
- Early adopters
 - Japan, Germany, France, UK,...

Recent Internet History

The “bust” years: 2001 → 2004

- The DotCom “crash”
 - i.e. Internet became mainstream
- IPv4:
 - Consumption slowed
 - Address space pressure “reduced”
- Indifference
 - Early adopters surging onwards
 - Sceptics more sceptical
 - Yet more transition mechanisms developed

2004 → 2011

- Resurgence in demand for IPv4 address space
 - All IPv4 address space was allocated by IANA by 3rd February 2011
 - Exhaustion predictions did range from wild to conservative
 - ...but by early 2011 IANA had no more!
 - ...and what about the market for address space?
- Market for IPv4 addresses:
 - Creates barrier to entry
 - Condemns the less affluent to tyranny of NATs
- IPv6 provides vast address space
 - The only compelling reason for IPv6

Current Situation

- General perception is that “IPv6 still has not yet taken hold”
 - IPv4 Address run-out is “headline news”
 - Yet more discussions and and plans on IPv4 run-out
 - Private sector is still demanding a business case to “migrate”
 - No easy Return on Investment (RoI) computation
- But reality is very different from perception!
 - IPv6 enabled networks see upwards of 60% of all traffic on IPv6
 - IPv6 Specification fully standardised: RFC8200/STD86
 - Something has to be done to sustain the Internet growth
 - IPv6 or NAT or both or something else?

Do we really need a larger address space?

- Internet population
 - ~630 million users in 2002 – 10% of world pop.
 - ~1320 million users in 2007 – 20% of world pop.
 - ~2512 million users in 2012 – 35% of world pop.
 - ~3750 million users in 2017 – 50% of world pop.
 - Future? (World pop. ~9B in 2050)
- US uses 96 /8s – this is 5.0 IPv4 addresses per person
 - Repeat this the world over...
 - 7 billion population could require 35 billion IPv4 addresses
 - (9.4 times larger than the entire IPv4 address pool)

Do we really need a larger address space?

□ Other Internet Economies:

- China 20.2 IPv4 /8s
- Japan 12.1 IPv4 /8s
- UK 7.3 IPv4 /8s
- Germany 7.1 IPv4 /8s
- Korea 6.7 IPv4 /8s
- Source: <http://bgp.potaroo.net/iso3166/v4cc.html>

□ Emerging Internet economies need address space:

- China would need more than a /4 of IPv4 address space if every student (320M) is to get an IPv4 address
- India lives behind NATs (using only 2.2 /8s)
- Africa lives behind NATs (using 4.5 /8s)

Do we really need a larger address space?

- **Mobile Internet is THE FUTURE**
 - Smartphones & Tablets >2 billion units in 2017
 - Far in excess of declining PC market (200 million units)
 - Source: Gartner
 - Enable through several technologies, eg: 5G/LTE, 802.11,...
- **Transportation – Mobile Networks**
 - >1B motor vehicles
 - Internet access on planes, trains,...
- **Consumer, Home and Industrial Appliances**
 - “Internet of Things”

Do we really need a larger address space?

- RFC 1918 is not sufficient for large environments
 - Cable Operators (e.g. Comcast – NANOG37 presentation)
 - Mobile providers (fixed/mobile convergence)
 - Large enterprises
- The Policy Development process of the RIRs turned down a request to increase private address space
 - RIR community guideline is to use global addresses instead
 - This leads to an accelerated depletion of the global address space
- Some wanted 240/4 as new private address space
 - But how to back fit onto all TCP/IP stacks released since 1995?

Do we really need a larger address space?

- Large variety of proposals to “help” with IPv6 deployment
 - NAT444
 - IPv4 NAT in Core and Edge
 - Dual Stack Lite and 464XLAT
 - Running IPv4 over an IPv6 backbone
 - Activity of IETF Softwires and v6ops Working Groups
 - NAT64
 - Translation between IPv6 and IPv4
 - Activity of IETF Behave Working Group
 - 6rd
 - Dynamic IPv6 tunnel from SP to customer
 - Activity of IETF Softwires Working Group

IPv6 Geo-Politics

- Regional and Countries IPv6 Task Force
 - Europe – www.ipv6-taskforce.org/
 - Belgium, France, Spain, Switzerland, UK,...
 - North-America – www.nav6tf.org/
 - Japan IPv6 Promotion Council – www.v6pc.jp/en/index.html
 - China, Korea, India,...
- Relationship
 - Economic partnership between governments
 - China-Japan, Europe-China,...
- Recommendations and project's funding
 - IPv6 2005 roadmap recommendations – Jan. 2002
 - European Commission IPv6 project funding: 6DEPLOY & Euro6IX
- Tax Incentives
 - Japan only – 2002-2003 program

Status in Internet Operational Community

- Service Providers get an IPv6 prefix from their regional Internet Registries
 - Very straight forward process when compared with IPv4
- List of IPv6 deployments
 - <https://www.vyncke.org/ipv6status/>
- Much discussion amongst operators about transition:
 - NOG experiments of 2008
 - <http://www.civil-tongue.net/6and4/>
 - What is really still missing from IPv6
 - <http://www.nanog.org/meetings/nanog41/presentations/Bush-v6-op-reality.pdf>
 - Many presentations on IPv6 deployment experiences

Service Provider Status

- Many transit ISPs have “quietly” made their backbones IPv6 capable as part of infrastructure upgrades
 - Native is common (dual stack)
 - Providers using MPLS use 6PE/6VPE
 - Tunnels still used (despite significant community effort to discontinue them)
- Today finding IPv6 transit is simple
 - Not nearly as challenging as it was before 2010

OS, Services, Applications

□ Operating Systems

- MacOS X, Linux, BSD Family, many SYS V
- Windows: XP SP2 (hidden), Vista, 7, 8, 10
- All use IPv6 first if available
 - MacOS 10.7 has "happy eyeballs"
 - MacOS 10.11 has "happier eyeballs" – IPv6 gets 30ms head start

□ Applications

- Browsers
 - Firefox, Chrome, Opera have "happy eyeballs"
- E-mail clients, IM, bittorrent,...

□ Services

- DNS, Apache WebServer, E-mail gateways,...

Content

- Content Availability
 - Operators and end-users content needs to be on IPv4 and IPv6
- Content & Social Media Providers:
 - Google – fully IPv6
 - Facebook – fully IPv6
 - Akamai – fully IPv6
 - Cloudflare – fully IPv6
 - LinkedIn – fully IPv6
 - ...
- More at:
 - <https://www.vyncke.org/ipv6status/>

Why are we still waiting...?

- That killer application?
 - Internet Gaming or Peer to Peer applications?
- IPv4 to run out?
 - Too late, it has!
- Our competitors?
 - Any network deployed since 2008 will be IPv6 capable
 - Even if not enabled!
- The end-user?
 - The end-user won't choose protocols
 - Remember "Turbo" button on early IBM PC clones?

The On-going Debate (1)

- IPv6 Multihoming
 - Same toolset as IPv4 — long term non-scalable
 - ‘Ultimate Multihoming Solution’ no nearer discovery
- Early rigid IPv6 address allocation model
 - Now removed across all RIR regions
 - “One size fits all” barrier to deployment:
 - Only ISPs “should” get IPv6 space from RIRs
 - Enterprises “should” get IPv6 space from ISPs only
 - Routing table entries matter, not the nature of business
 - What is an ISP?
 - **Today’s simple model:**
 - **Network Operator gets from RIR**
 - **End user gets from Network Operator**

The On-going Debate (2)

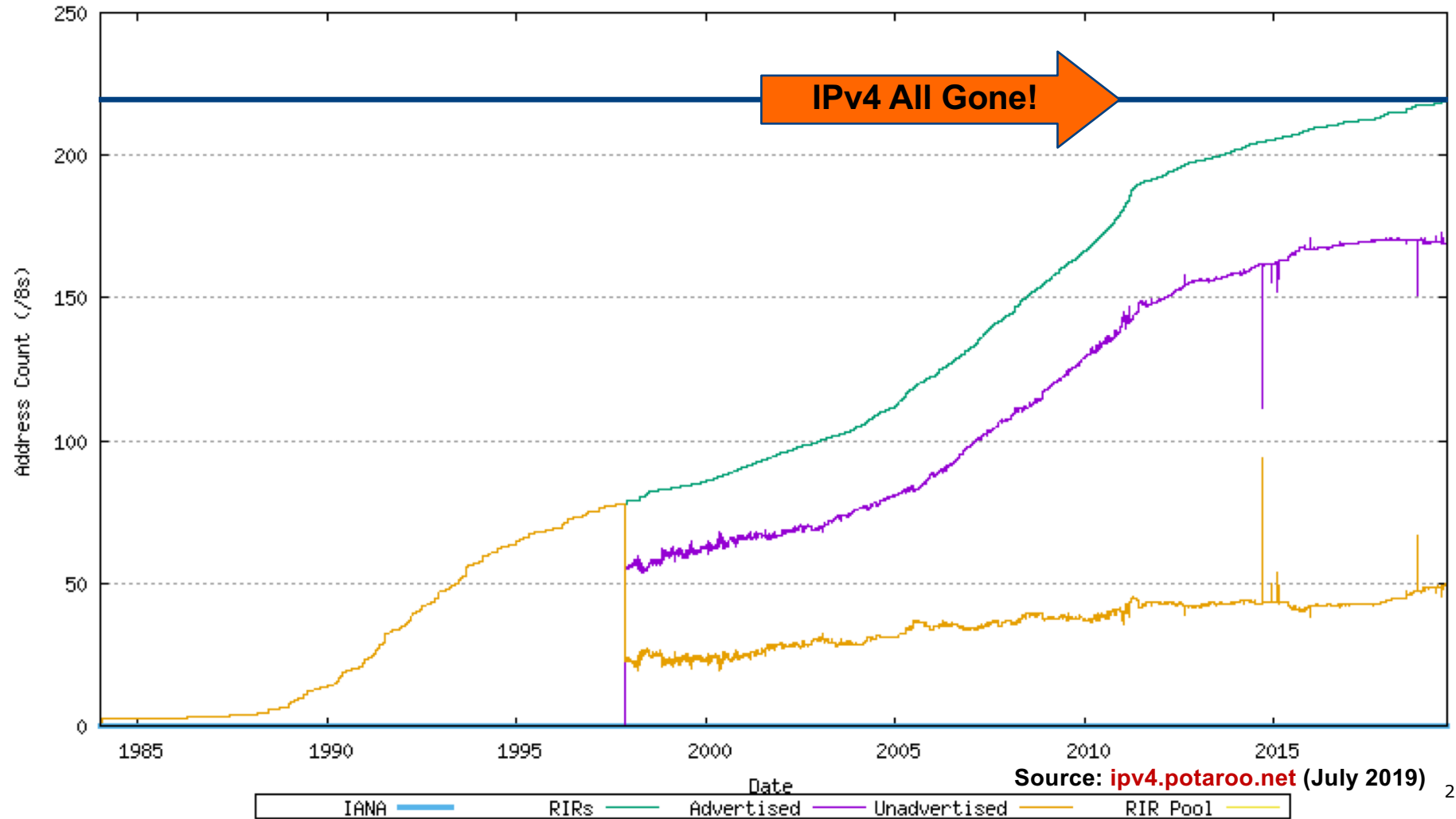
- Not every IPv4 device is IPv6 capable
 - Do we really need to replicate all IPv4 capability in IPv6 prior to considering deployment?
- “We have enough IPv4”
 - Those with plenty denying those with little/nothing
- Migration versus Co-existence
 - Realistically IPv6 and IPv4 will co-exist for many years
 - Dual-stack operating systems in network equipment makes this trivial

Why not use Network Address Translation?

- ❑ Private address space and Network address translation (NAT) could be used instead of IPv6
- ❑ But NAT has many serious issues:
 - Breaks the end-to-end model of IP
 - Breaks end-to-end network security
 - Serious consequences for Lawful Intercept
 - Non-NAT friendly applications means NAT has to be upgraded
 - Some applications don't work through NATs
 - Layered NAT devices
 - Mandates that the network keeps the state of the connections
 - How to scale NAT performance for large networks??
 - Makes fast rerouting and multihoming difficult
 - How to offer content from behind a NAT?

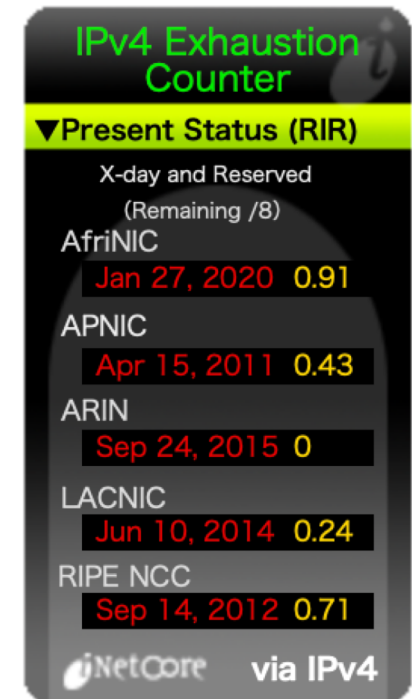
“The times, They are a’ changin’”

IPv4 Pool Status



Is IPv4 really running out?

- Yes!
 - IANA IPv4 free pool ran out on 3rd February 2011
 - RIR IPv4 free pool is starting to run out now
 - www.potaroo.net/tools/ipv4/
 - (depends on RIR soft-landing policies)
- The runout gadgets and widgets are now watching when the RIR pools will run out:
 - inetcore.com/project/ipv4ec/index_en.html
 - (shows 1 RIR with no IPv4 left, and 3 out of 4 RIRs in run out austerity phase)
 - ipv6.he.net/statistics/



IPv4 run-out

- Policy Development process in each RIR region has discussed and implemented many proposals relating to IPv4 run-out, for example:
 - The Last /8
 - All RIRs received one /8 from the IANA free pool
 - IPv4 address transfer
 - Permits LIRs to transfer address space to each other rather than returning to their RIR
 - Soft landing
 - Reduce the allocation sizes for an LIR as IPv4 pool is depleted
 - IPv4 distribution for IPv6 transition
 - Reserving a range of IPv4 address to assist with IPv6 transition (for Large Scale NATs etc)

Issues Today

- More content needs to be available on IPv6
 - Google, Akamai, *etc* all are dual stack now
 - World IPv6 Day on 8th June 2011 helped a little
 - World IPv6 Launch on 6th June 2012 helped a little more
- Service Provider Claim: 'Giving IPv6 to customers might confuse'
 - Also increased tech support if IPv6 version of content is 'down', but IPv4 version works
- 'Happy eyeballs' (RFC6555) and 'Happier eyeballs' (RFC8305) has made a significant difference
- Still need to 'prolong' IPv4 so there is time for all content to be available on IPv6

Conclusion

- There is a need for a larger address space
 - IPv6 offers this – will eventually replace NAT
 - But NAT will be around for a while too
 - Market for IPv4 addresses looming also
- Many network operators still in denial

Introduction to IPv6



ISP Workshops