Introduction to IPv6

ISP Workshops

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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*

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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

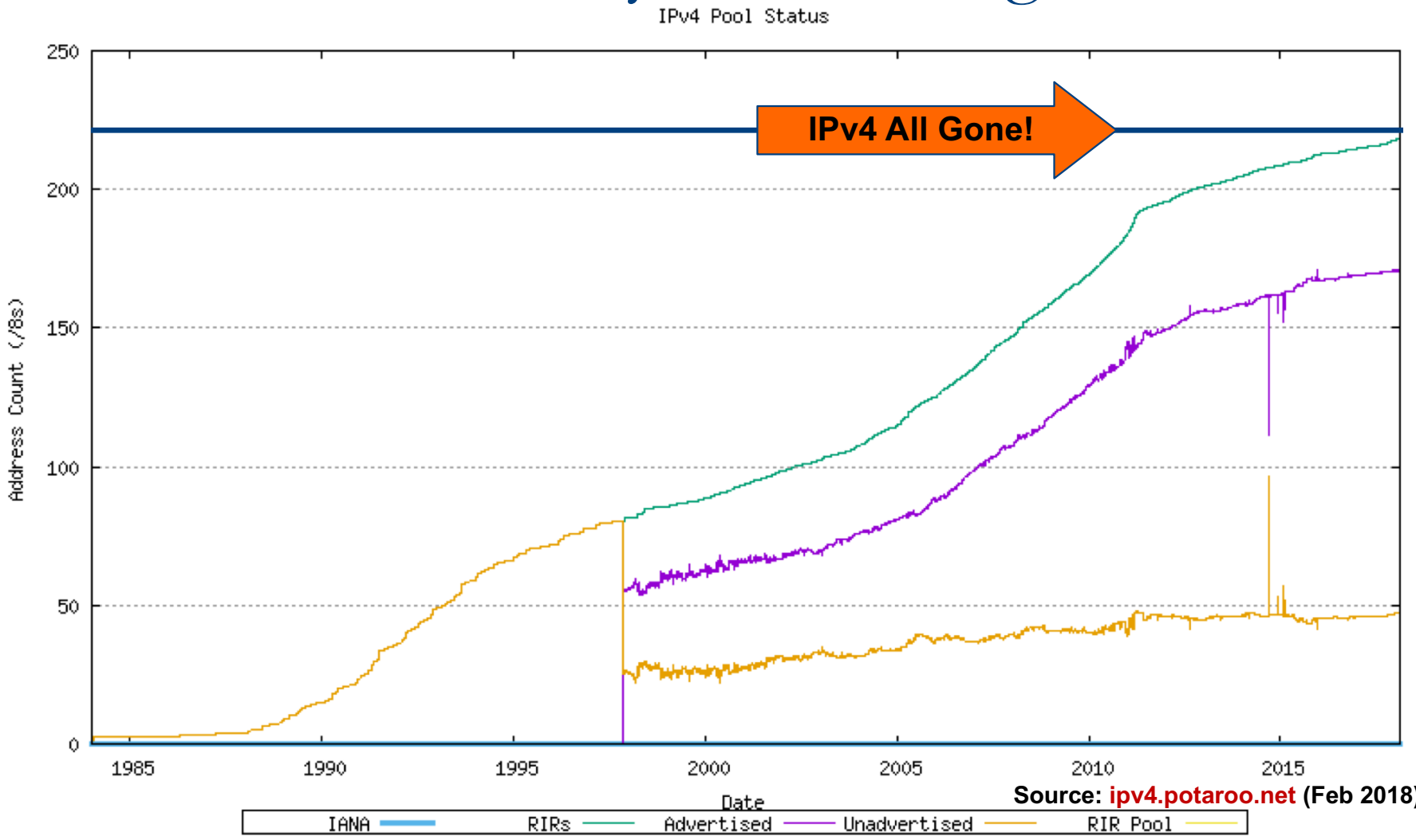
The On-going Debate (2)

- 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?

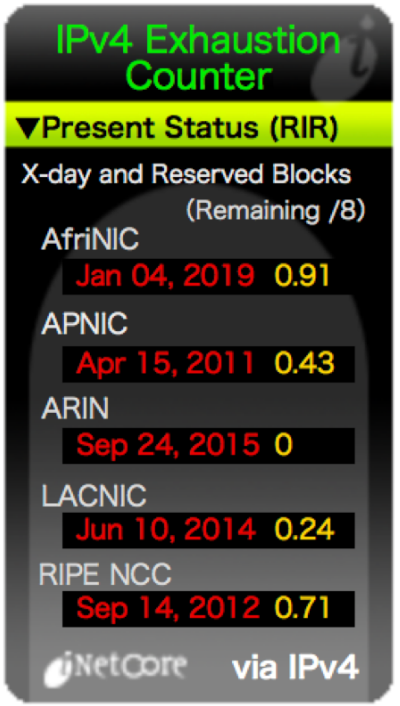
"The times, They are a' changin'"



Source: ipv4.potaroo.net (Feb 2018)

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
- '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

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