Introduction to IPv6

ISP Workshops

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
  - Explosive growth of the "default-free" routing table
  - Eventual exhaustion of 32-bit address space
- Two 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
- Proliferation of 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
- Direction and technical criteria for ipng choice
  - RFC1752, January 1995

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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 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 offers vast address space
  - The only compelling reason for IPv6

Current Situation

- General perception is that "IPv6 has not yet taken hold"
  - IPv4 Address run-out has now made it into "headline news"
    - More discussions and run-out plans proposed
  - Private sector still demanding a business case to "migrate"
    - No easy Return on Investment (RoI) computation
- But reality is very different from perception!
  - Something needs 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 end of 2002 – 10% of world pop.
  - ~1320 million users end of 2007 – 20% of world pop.
  - Doubles every 5 years (approximately)
  - Future? (World pop. ~9B in 2050)
- US uses 93.7 /8s – this is 6.4 IPv4 addresses per person
  - Repeat this the world over…
  - 6 billion population could require 26 billion IPv4 addresses
  - (7 times larger than the IPv4 address pool)

Do we really need a larger address space?

- Other Internet Economies:
  - China   19.7 IPv4 /8s
  - Japan   12.0 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 2.1 /8s)
  - Africa lives behind NATs (using less than 1.5 /8s)

Do we really need a larger address space?

- Mobile Internet introduces new generation of Internet devices
  - PDA (~20M in 2004), Mobile Phones (~1.5B in 2003), Tablet PC
  - Enable through several technologies, eg: 3G, 802.11,…
- Transportation – Mobile Networks
  - 1B automobiles forecast for 2008 – Begin now on vertical markets
  - Internet access on planes, e.g. Connexion by Boeing
  - Internet access on trains, e.g. Narita Express
- Consumer, Home and Industrial Appliances

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 and 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

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Status in Internet Operational Community

- Service Providers get an IPv6 prefix from their regional Internet Registries
  - Very straight forward process when compared with IPv4
- 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 (unfortunately)
- Today finding IPv6 transit is not as challenging as it was 5 years ago

OS, Services, Applications, Content

- ❑ **Operating Systems**
  - ■ MacOS X, Linux, BSD Family, many SYS V
  - ■ Windows: XP SP2 (hidden away), Vista, 7
  - ■ All use IPv6 first if available
    - ❑ (MacOS 10.7 has "happy eyeballs")
- ❑ **Applications**
  - ■ Browsers
    - ❑ Firefox has "happy eyeballs"
  - ■ E-mail clients, IM, bittorrent,…
- ❑ **Services**
  - ■ DNS, Apache WebServer, E-mail gateways,…
- ❑ **Content Availability**
  - ■ Needs to be on IPv4 and on IPv6

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 in last 3 years will be IPv6 capable
  - Even if not enabled!
- The end-user?
  - The end-user should not have to 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
    - LISP is making some progress though
- Early rigid IPv6 address allocation model
  - "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
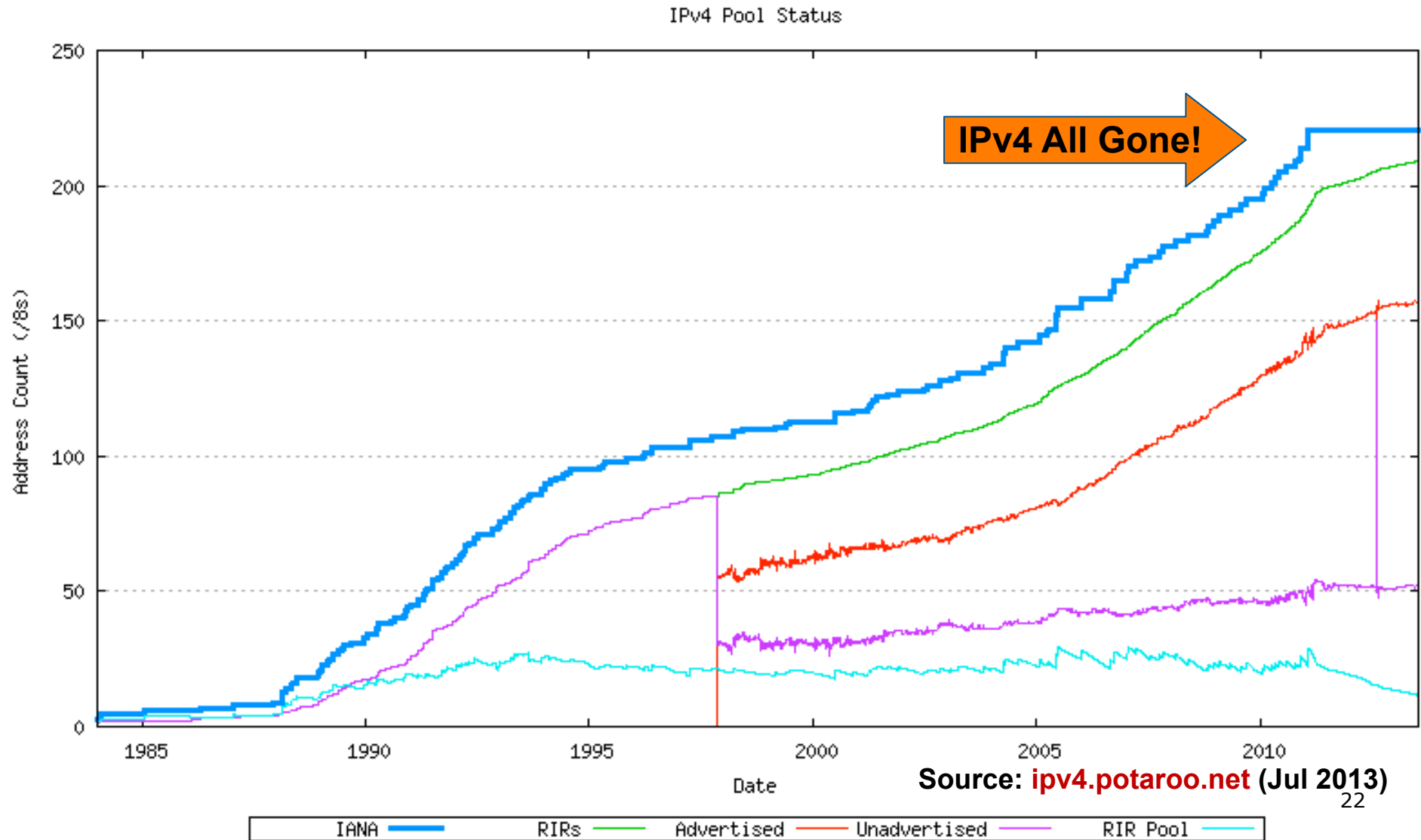   - What is an ISP?

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

IPv4 All Gone!

Source: ipv4.potaroo.net (Jul 2013)

Legend: IANA — RIRs — Advertised — Unadvertised — RIR Pool

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Is IPv4 really running out?

- Yes!
  - IANA IPv4 free pool ran out on 3rd February 2011
  - RIR IPv4 free pool will run out soon after
  - 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
  - ipv6.he.net/statistics/

IPv4 Exhaustion Counter

▼Present Status (RIR)

X-day and Reserved Blocks
(Remaining /8)

AfriNIC
Nov 03, 2020 2.97

APNIC
Apr 15, 2011 0.85

ARIN
Apr 14, 2014 2.04

LACNIC
Aug 26, 2014 1.77

RIPE.NCC
Sep 14, 2012 0.98

iNetCore   via IPv4

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 will receive 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

- Minimal content is available on IPv6
  - Notwithstanding ipv6.google.com
  - 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
  - Browsers, e-mail clients, etc are smart
  - But increased tech support if IPv6 version of content is 'down', but IPv4 version works
- 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 challenges ahead

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