

# Introduction to IPv6



ISP Training Workshops

# Early Internet History

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- 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

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- ❑ 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 – RFC1719 and RFC1726, Dec 1994

# Early Internet History

→ 1996

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- ❑ 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

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- ❑ 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

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- ❑ 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

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- 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 today it has all gone!
  - ...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

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- 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?

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- Internet population
  - ~630 million users end of 2002 – 10% of world pop.
  - ~1320 million users end of 2007 – 20% of world pop.
  - Future? (World pop. ~9B in 2050)
- US uses 92 /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?

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## ❑ Other Internet Economies:

- China 17.5 IPv4 /8s
- Japan 11.2 IPv4 /8s
- Korea 6.3 IPv4 /8s
- Germany 5.5 IPv4 /8s
- UK 4.9 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 1.8 /8s)
- Africa lives behind NATs (using less than 1.5 /8s)

# Do we really need a larger address space?

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- ❑ 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?

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- ❑ 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?

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- ❑ Large variety of proposals to “help” with IPv6 deployment
  - NAT444
    - ❑ Lots of IPv4 NAT
  - Dual Stack Lite
    - ❑ Improvement on NAT464 (tunneling IPv4 over IPv6 backbone)
    - ❑ Activity of IETF Softwires Working Group
  - NAT64 & IVI
    - ❑ 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

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- ❑ Regional and Countries IPv6 Task Force
  - Europe – [www.ipv6-taskforce.org/](http://www.ipv6-taskforce.org/)
    - ❑ Belgium, France, Spain, Switzerland, UK,...
  - North-America – [www.nav6tf.org/](http://www.nav6tf.org/)
  - Japan IPv6 Promotion Council – [www.v6pc.jp/en/index.html](http://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: 6NET & Euro6IX
- ❑ Tax Incentives
  - Japan only – 2002-2003 program

# Status in Internet Operational Community

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- ❑ 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/mtg-0710/presentations/Bush-v6-op-reality.pdf>
  - Many presentations on IPv6 deployment experiences

# Service Provider Status

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- ❑ 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
  - Tunnels still used (unfortunately)
- ❑ Examples:
  - NTT/Verio has been long time IPv6 capable
  - HE, OpenTransit/FT, TATA International, Telecom Italia, GlobalCrossing, Telefonica, C&W (EU),...



# OS, Services, Applications, Content

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- ❑ Operating Systems
  - MacOS X, Linux, BSD Family, many SYS V
  - Windows: XP SP2 (hidden away), Vista, 7
  - All use IPv6 first if available
- ❑ Applications
  - Browsers, 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...?

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- ❑ That killer application?
  - Internet Gaming or Peer to Peer applications?
  - Windows 7 (?), Apple iPad (?)
- ❑ 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)

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- ❑ IPv6 Multihoming
  - Same toolset as IPv4 — long term non-scalable
  - 'Ultimate Multihoming Solution' no nearer discovery
    - ❑ LISP is making interesting 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)

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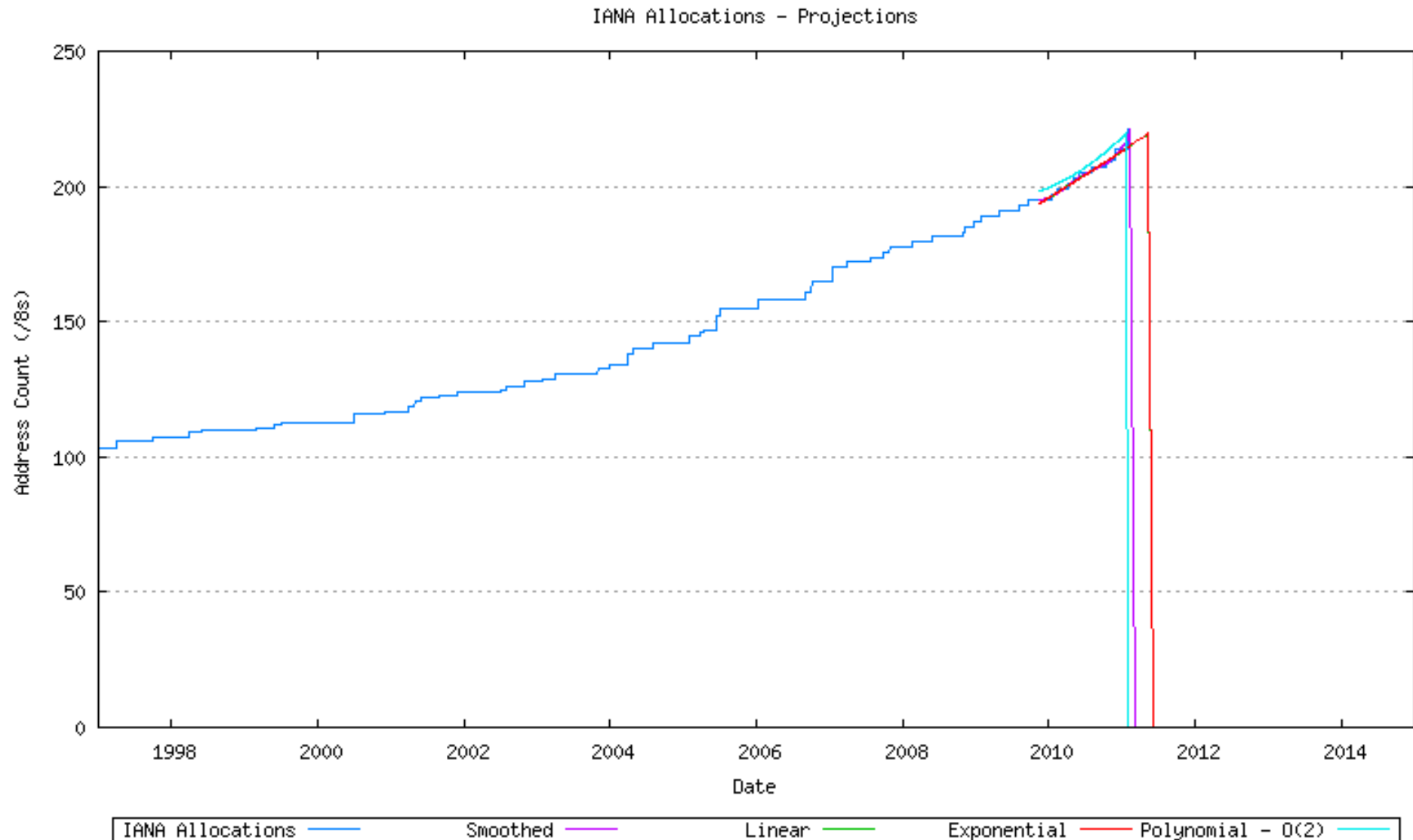
- ❑ Not every IPv4 device is IPv6 capable
  - Do we really need to replicate all IPv4 capability in IPv6 prior to considering deployment?
- ❑ “We have enough IPv4”
  - Those with plenty denying those with little/nothing
- ❑ Migration versus Co-existence
  - Realistically IPv6 and IPv4 will co-exist for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

# Why not use Network Address Translation?

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- ❑ 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?

# Is IPv4 really running out?



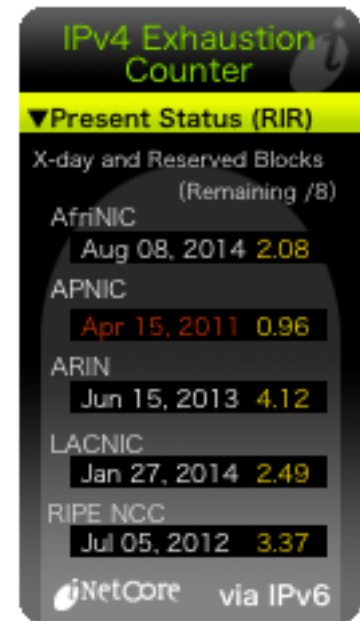
# Is IPv4 really running out?

## □ Yes!

- IANA IPv4 free pool ran out on 3rd February 2011
- RIR IPv4 free pool will run out soon after
- (APNIC entered final /8 phase on 14 April 2011)
  - [www.potaroo.net/tools/ipv4/](http://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](http://inetcore.com/project/ipv4ec/index_en.html)
- [ipv6.he.net/statistics/](http://ipv6.he.net/statistics/)



# IPv4 run-out

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- ❑ 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

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- ❑ Minimal content is available on IPv6
  - Notwithstanding [ipv6.google.com](http://ipv6.google.com)
  - World IPv6 Day on 8th June 2011 helped a little – World IPv6 week planned for mid-2012
- ❑ 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

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- ❑ 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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