



# Introduction to IPv6

ISP/IXP 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
- Direction and technical criteria for ipng choice – RFC1719 and RFC1726, Dec 1994
- 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

# Early Internet History

## → 1996

- 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 → Today

- 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

- 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.

  - 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?

- 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?

- 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 want 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

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

- Regional and Countries IPv6 Task Force
  - Europe – <http://www.ipv6-taskforce.org/>  
Belgium, France, Spain, Switzerland, UK,...
  - North-America – <http://www.nav6tf.org/>
  - Japan IPv6 Promotion Council – <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

- 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

- 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),...

- OCCAID

- IPv6-only transit ISP effort (linking Asia, N-America, EU)



# 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

- 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...?

- 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)

- 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)

- 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

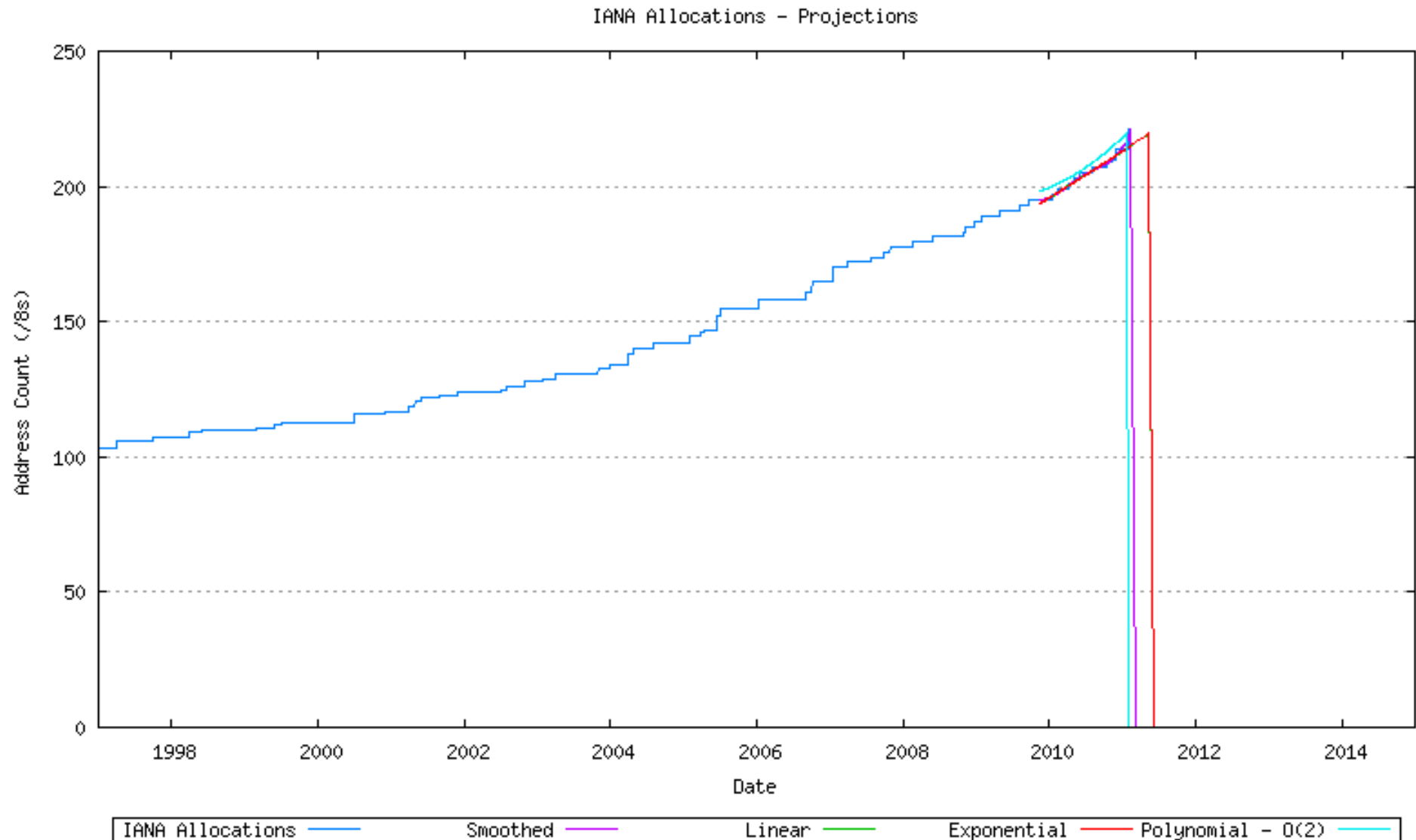
Realistically IPv6 and IPv4 will co-exist for many years

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?

# 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

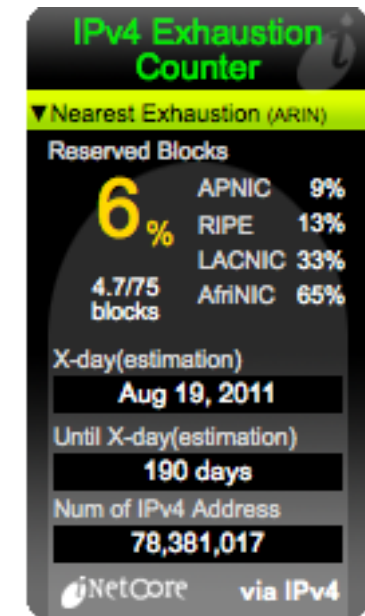
<http://www.potaroo.net/tools/ipv4/>

(depends on RIR soft-landing policies)

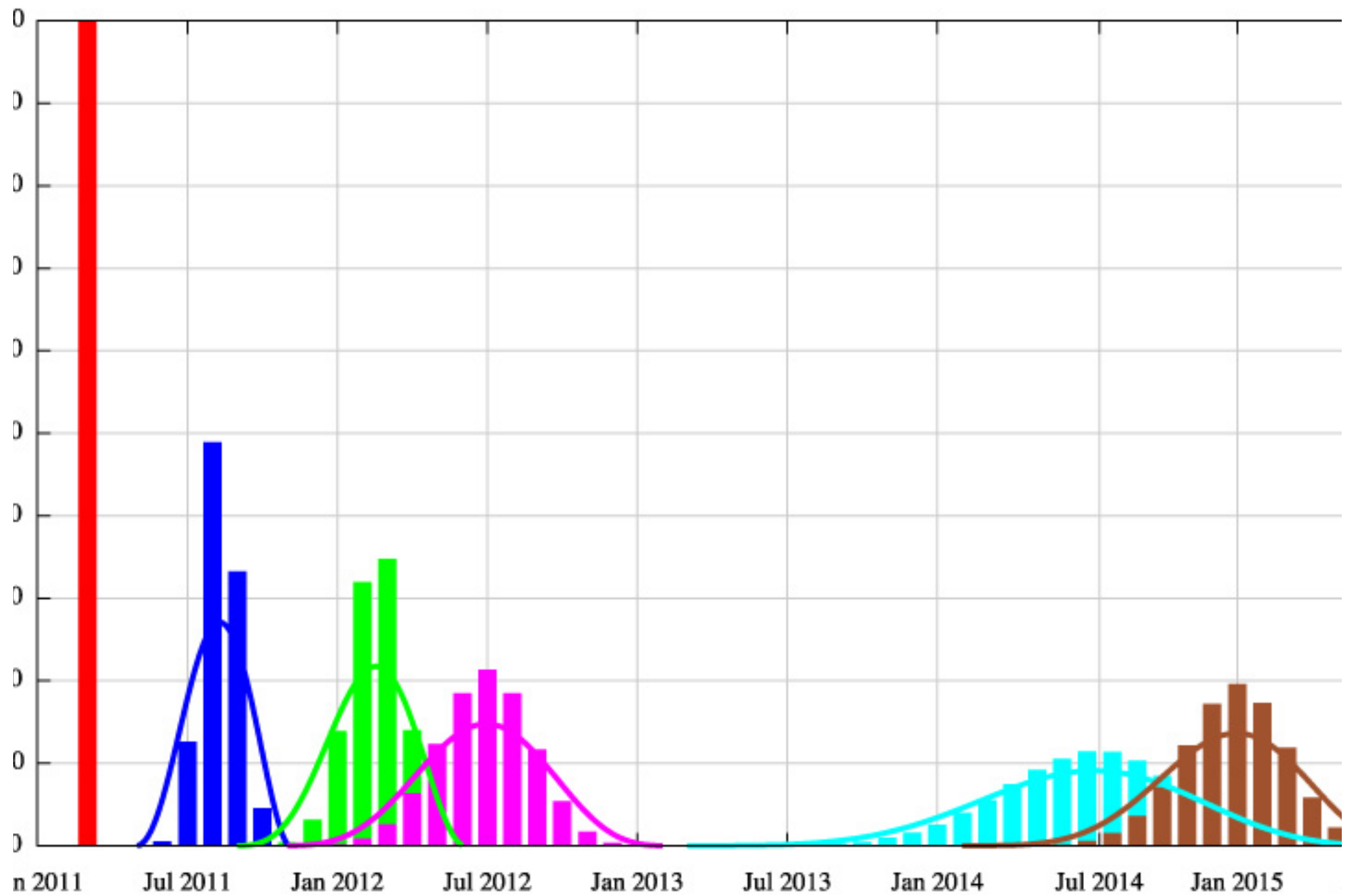
- The runout gadgets and widgets are now watching when the RIR pools will run out:

[http://inetcore.com/project/ipv4ec/index\\_en.html](http://inetcore.com/project/ipv4ec/index_en.html)

<http://ipv6.he.net/statistics/>



### Registry Exhaustion Dates





# 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](http://ipv6.google.com)
- 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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