# IPv6 Deployment: Why and Why not?

HostingCon 2013, Brisbane, Australia

21st October 2013

Miwa Fujii

<miwa@apnic.net>

APNIC

# Agenda

- About APNIC
- Status of IPv4 address exhaustion
- IPv6 readiness in the world
  - Review of several statistics
  - Transit providers and CPs
  - IPv6 ready end users
- IPv6 security consideration
- Anecdotal IPv6 stories
- Conclusion

# Introduction to APNIC & Regional Internet Registry

APNIC

# Regional Internet Registries

# Who is APNIC?

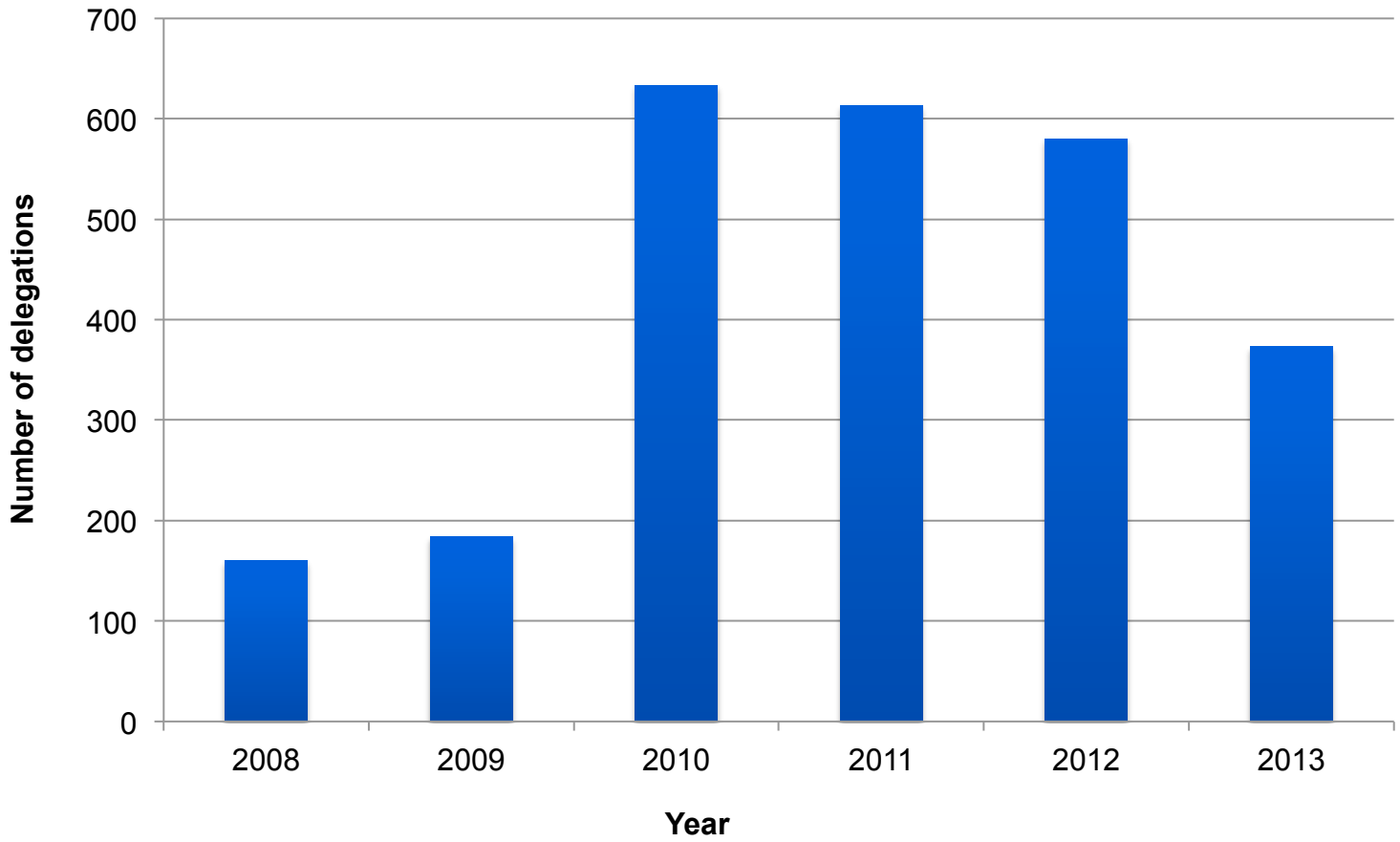
- The Regional Internet Registry (RIR) for the Asia Pacific
  - Delegates IP addresses and AS numbers
  - Maintains the APNIC's Whois Database
  - Manages the reverse DNS delegations

- Not for profit and membership based organization
  - Over 3700 Members
  - But NOT a domain name registry

# APNIC's Mission

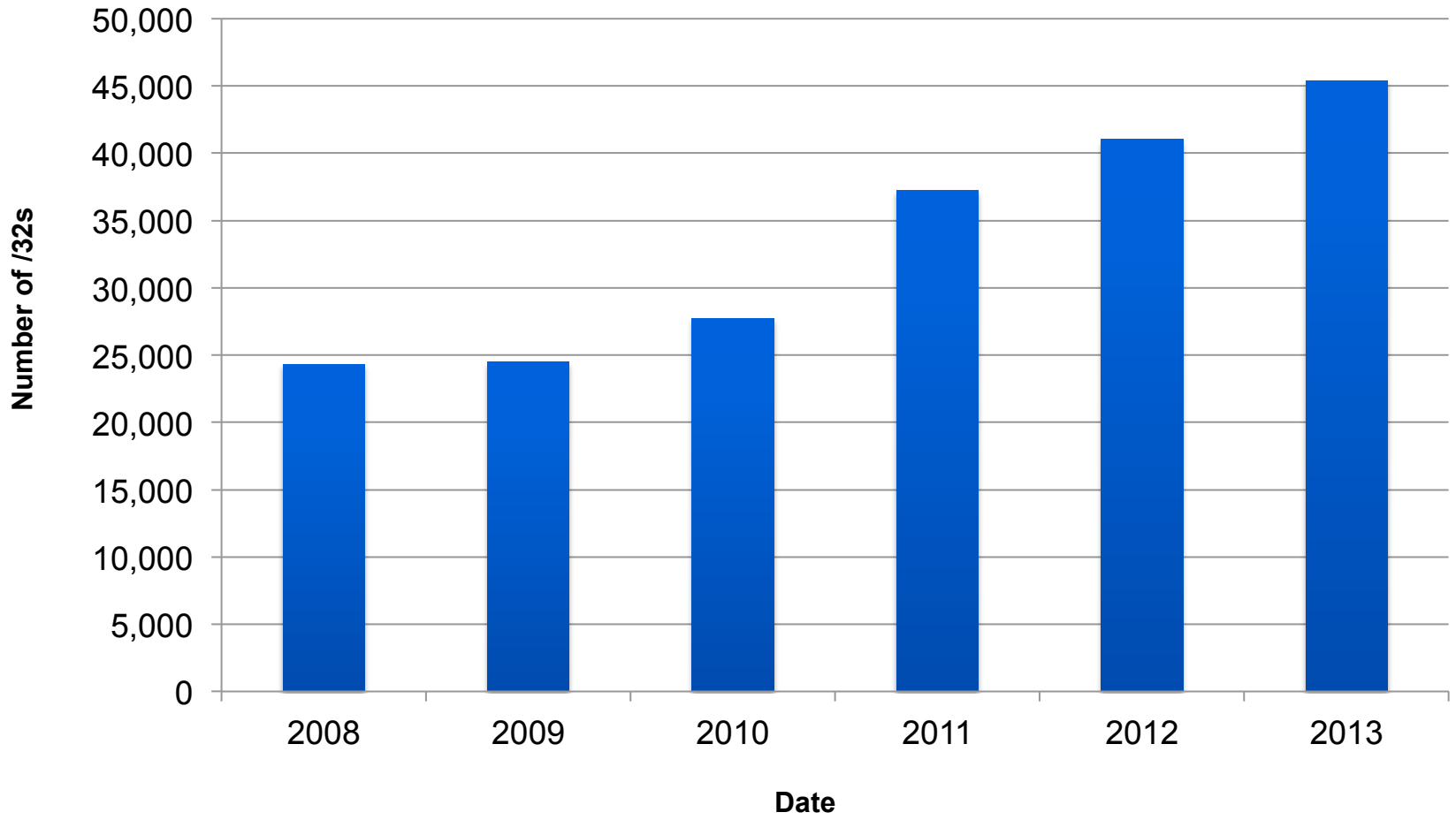
- Function as the Regional Internet Registry for the Asia Pacific, in the service of the community of Members and others
- Provide Internet registry services to the highest possible standards of trust, neutrality, and accuracy
- Provide information, training, and supporting services to assist the community in building and managing the Internet
- Support critical Internet infrastructure to assist in creating and maintaining a robust Internet environment
- Provide leadership and advocacy in support of its vision and the community
- Facilitate regional Internet development as needed throughout the APNIC community

# IPv6 delegations by year




As at 30 September 2013

# Cumulative IPv6 delegations (/32s)



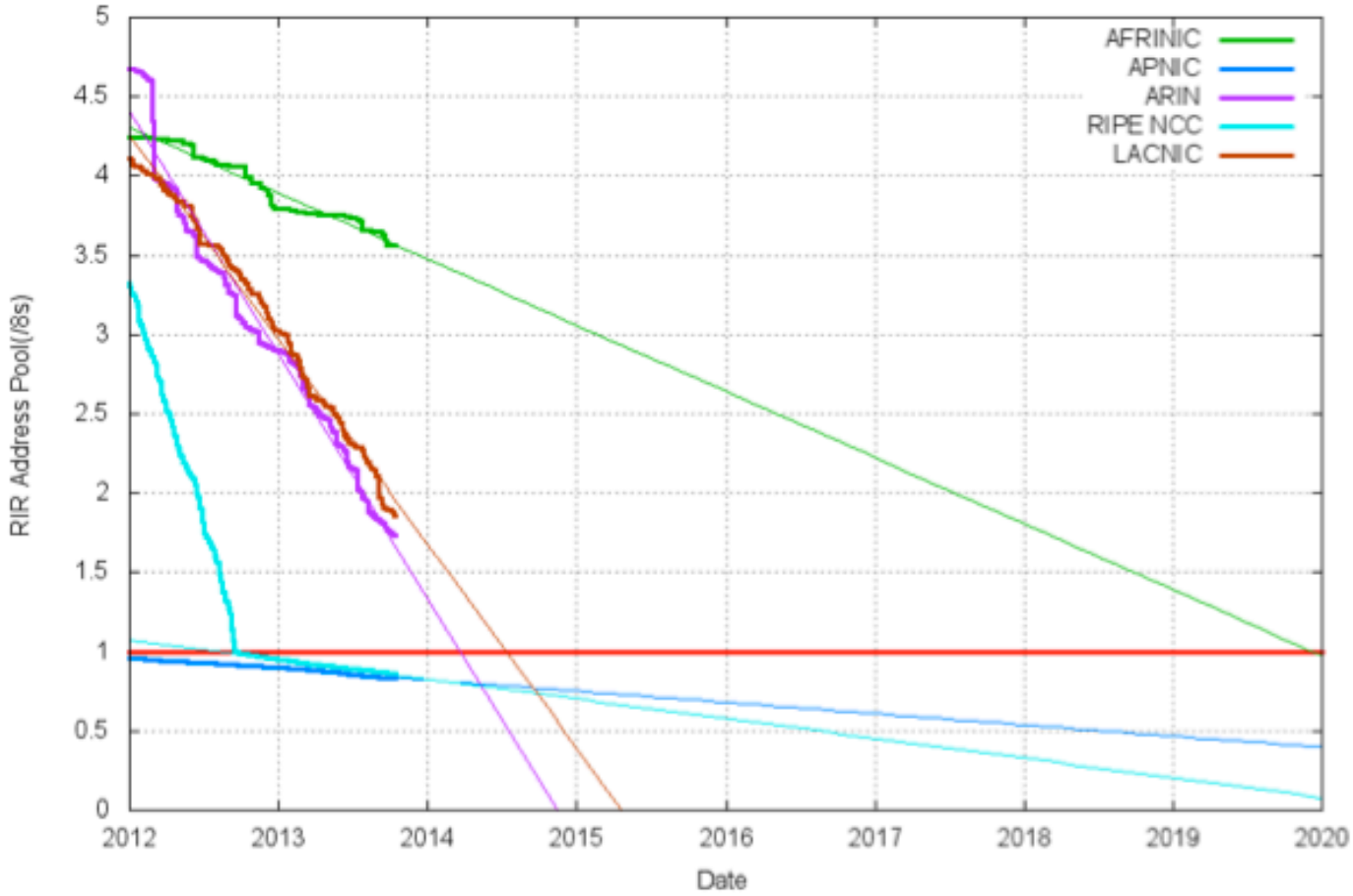

As at 30 September 2013

# Status of IPv4 address exhaustion

# IPv4 address exhaustion

- What exactly is “IPv4 exhaustion?”
  - Internet Assigned Numbers Authority (IANA) exhausted its IPv4 free pool (Feb 2011)
  - RIRs exhaust their unallocated pools
    - APNIC reached the final /8 IPv4 free pool (April 2011)
  - Expanding networks (ISPs, Content Providers, Hosting and Cloud Service Providers, enterprises etc.) exhaust their pools of unused addresses
- Current IPv4 address management policy
  - AP organizations can each request one /22 (1024 addresses) of the final /8

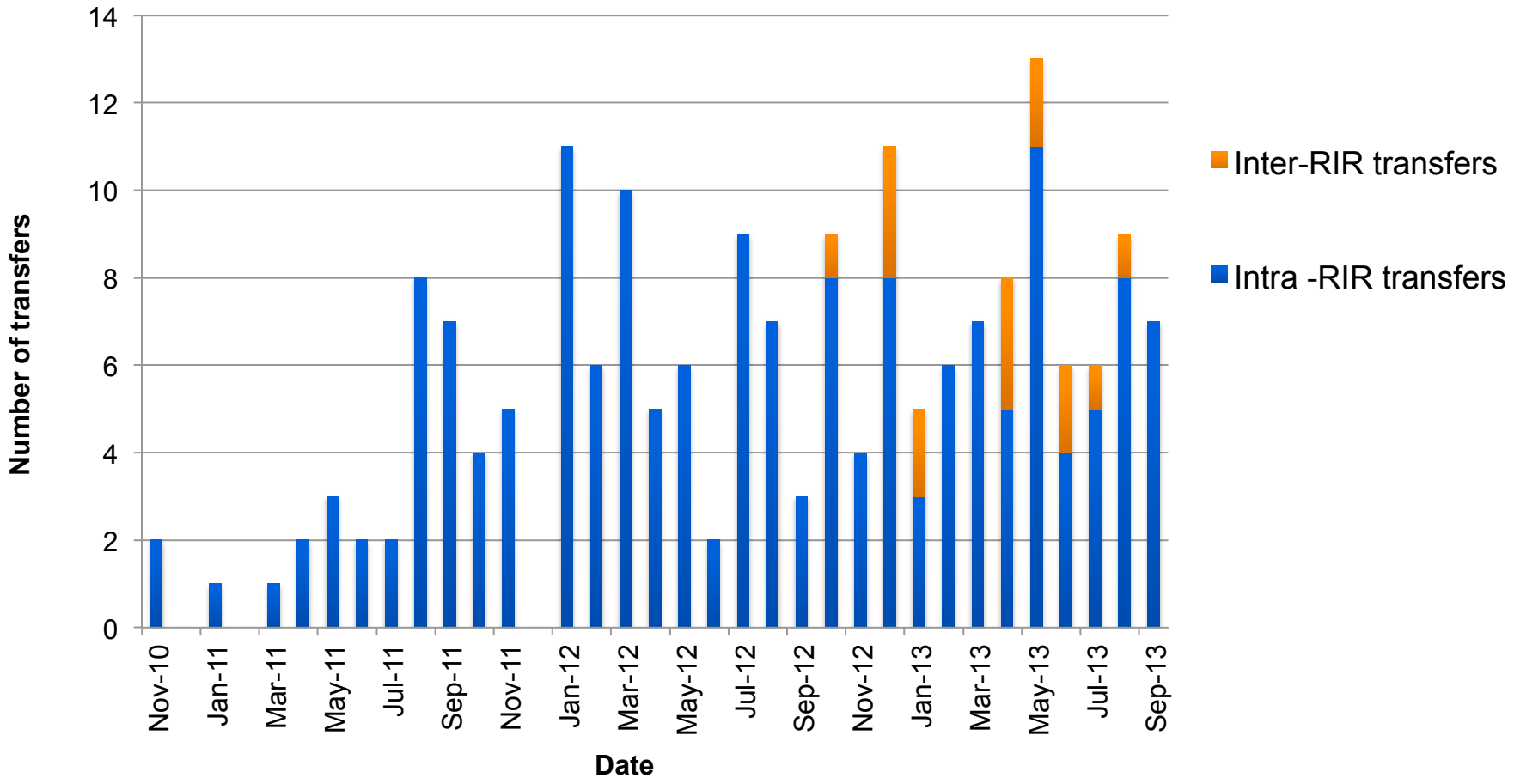
# Projection of IPv4 address exhaustion




***Projection of consumption of Remaining RIR Address Pools***

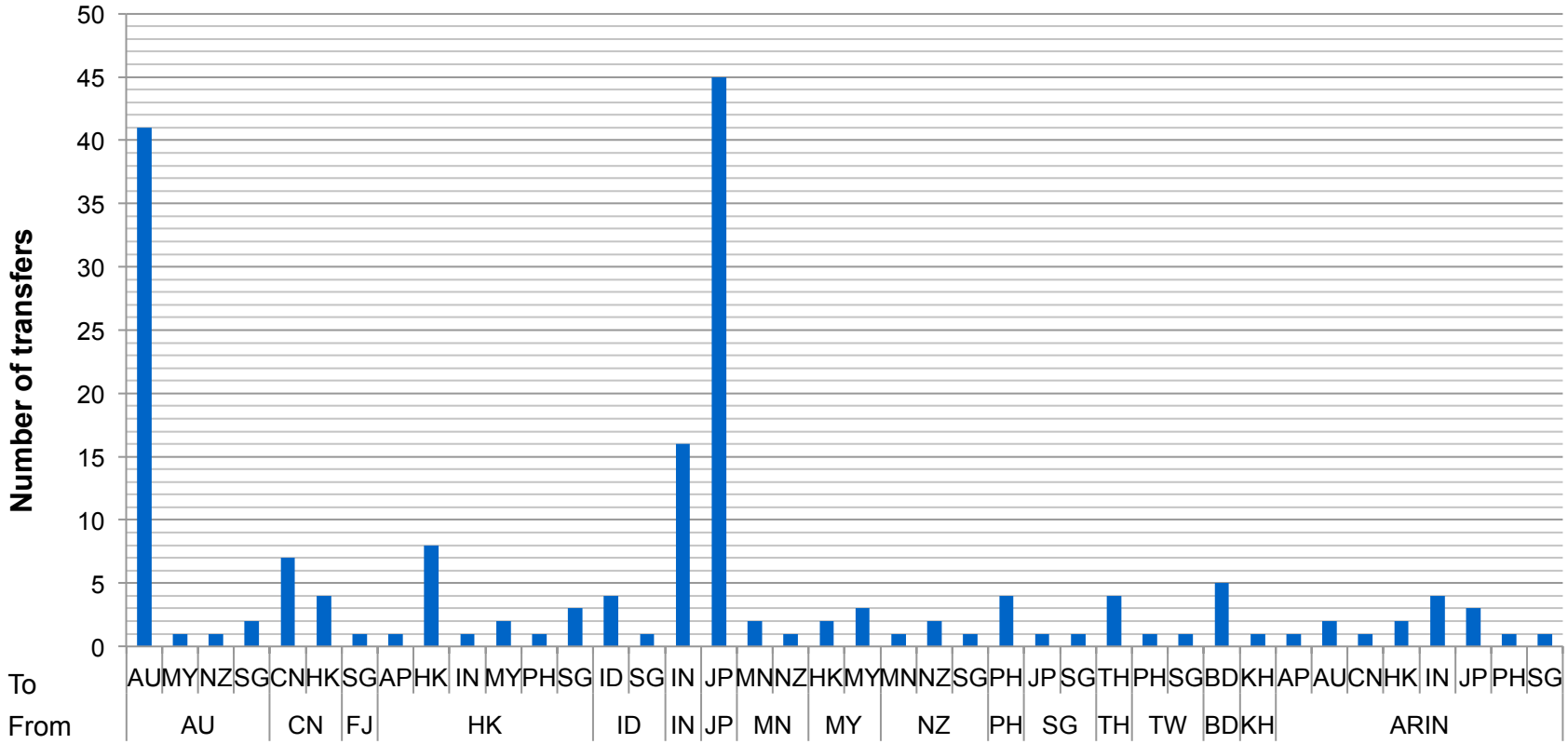
http://www.potaroo.net/tools/ipv4/index.html

# IPv4 market transfers




As at 30 September 2013

# IPv4 market transfer by economy




As at 30 September 2013

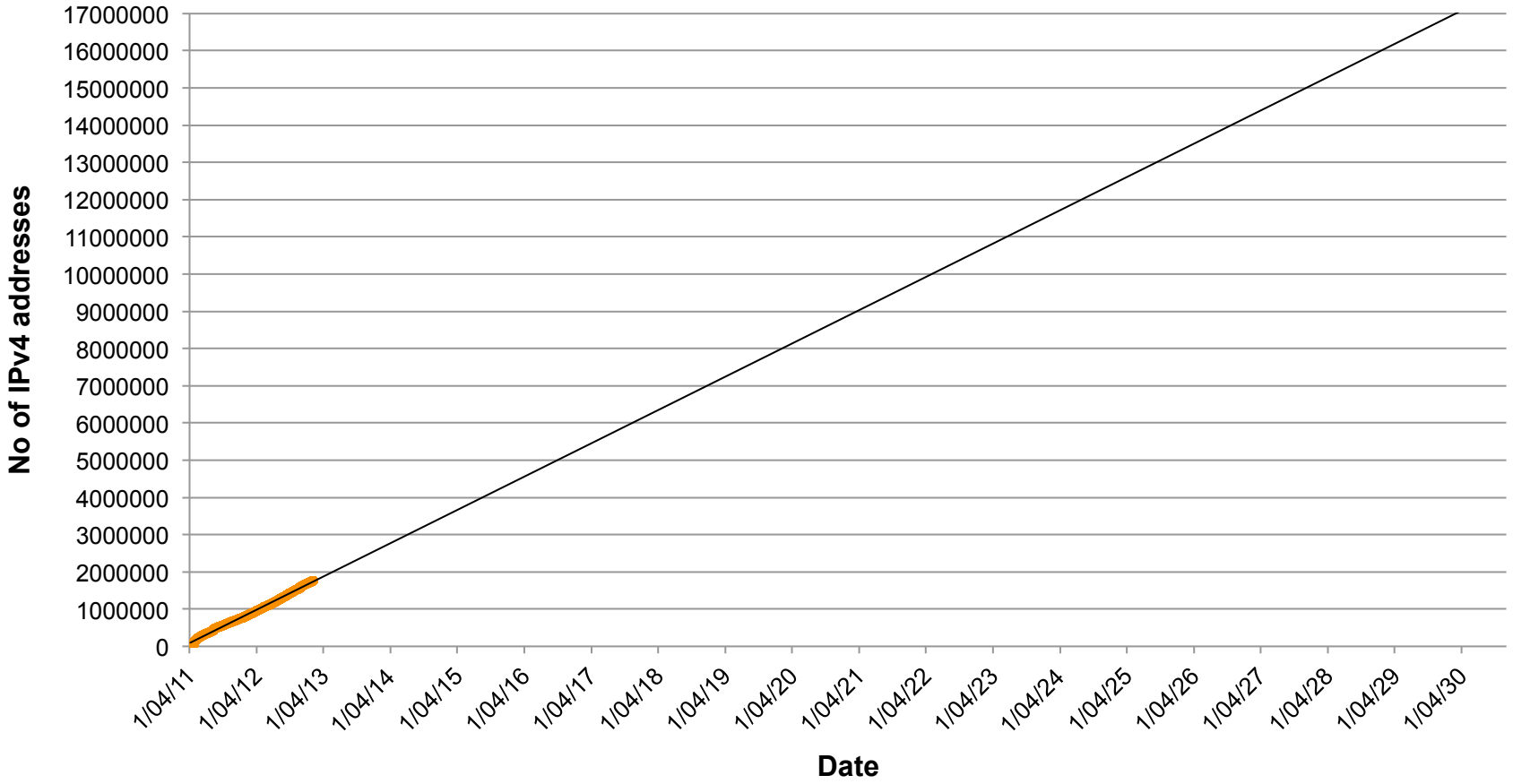
# IPv4 Address Transfer Services

- Support for intra and inter-RIR transfers
- Pre-approval service, with opt-in anonymous listing
- Broker listing; five registered so far
  - www.apnic.net/transfer-brokers
- Mailing list to enable the source and recipients of IPv4 address transfers and IPv4 brokers to discuss topics relevant to transfers
  - apnic-transfers@apnic.net
- Public transfer log
  - ftp://ftp.apnic.net/public/transfers/apnic
- Transfer fees applied
  - 20% of the transferred block's annual fee (other holdings not included in the calculation)
  - Payable by the recipient, or by the source if transferred out of the APNIC region

# Inter-RIR Transfers

- Completed transfers: eight from ARIN to APNIC (Nov 2012 – April 2013)
- Transfer time (including evaluation): one – two weeks
- Successfully transferred live network
  - ARIN-managed resources transferred into the AP region, to be managed by APNIC
- ARIN and APNIC stats overlap one day after the transfer due to the time zone difference

# IPv4 last /8 delegation trend

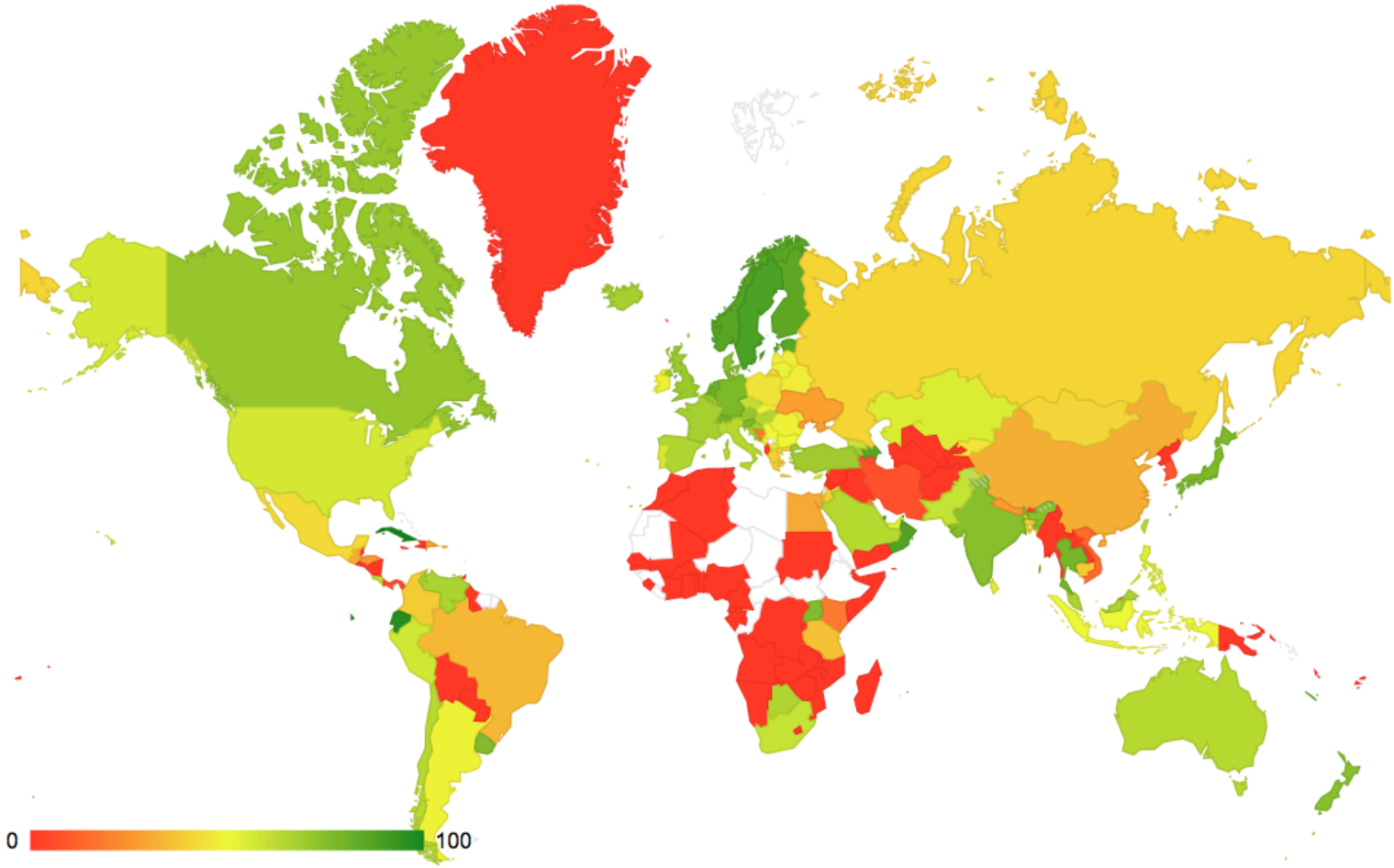


# IPv6 readiness in the world

Review of several statistics

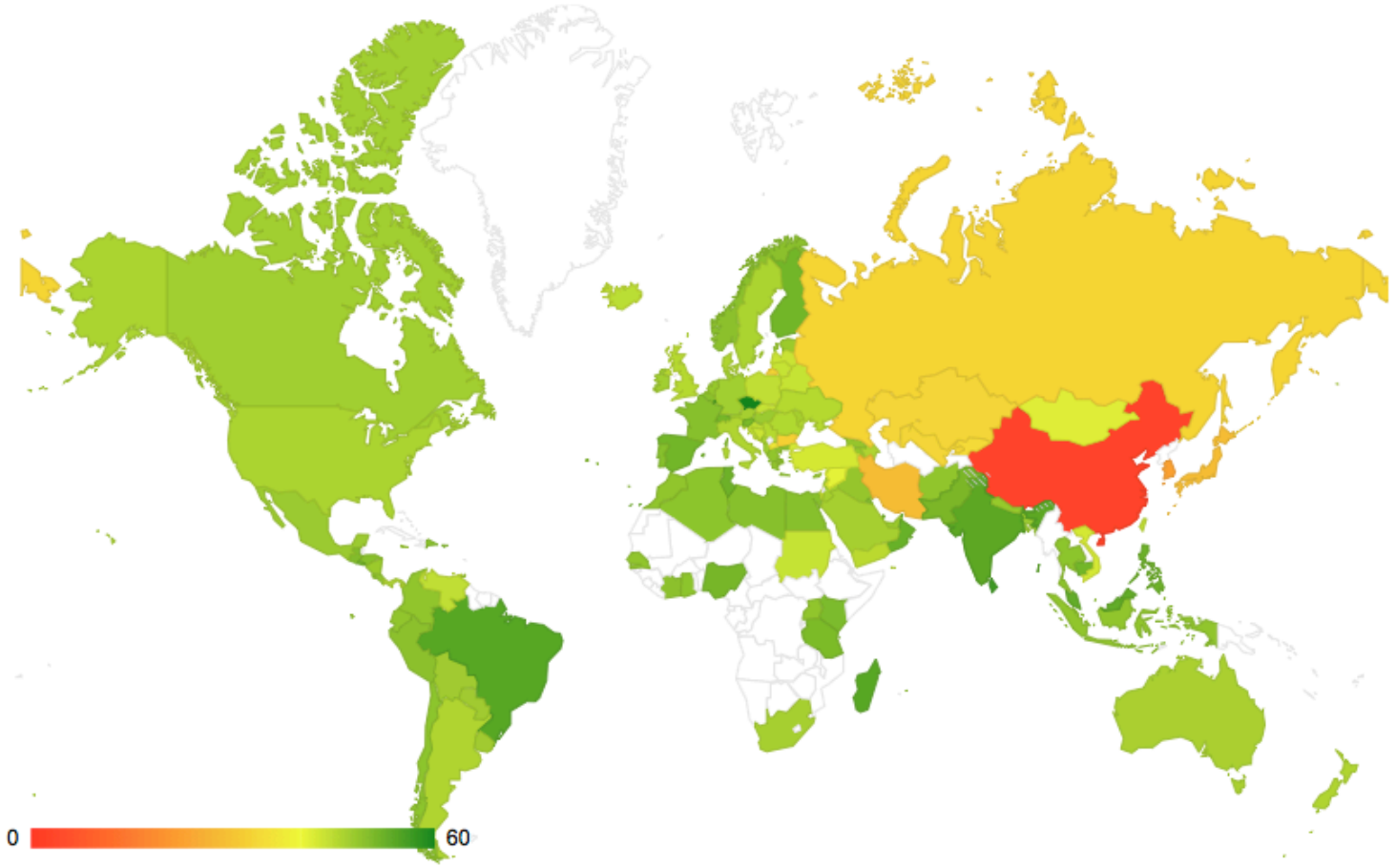
APNIC

# IPv6 transit AS
# IPv6 readiness in core of the Internet




http://6lab.cisco.com/stats/index.php

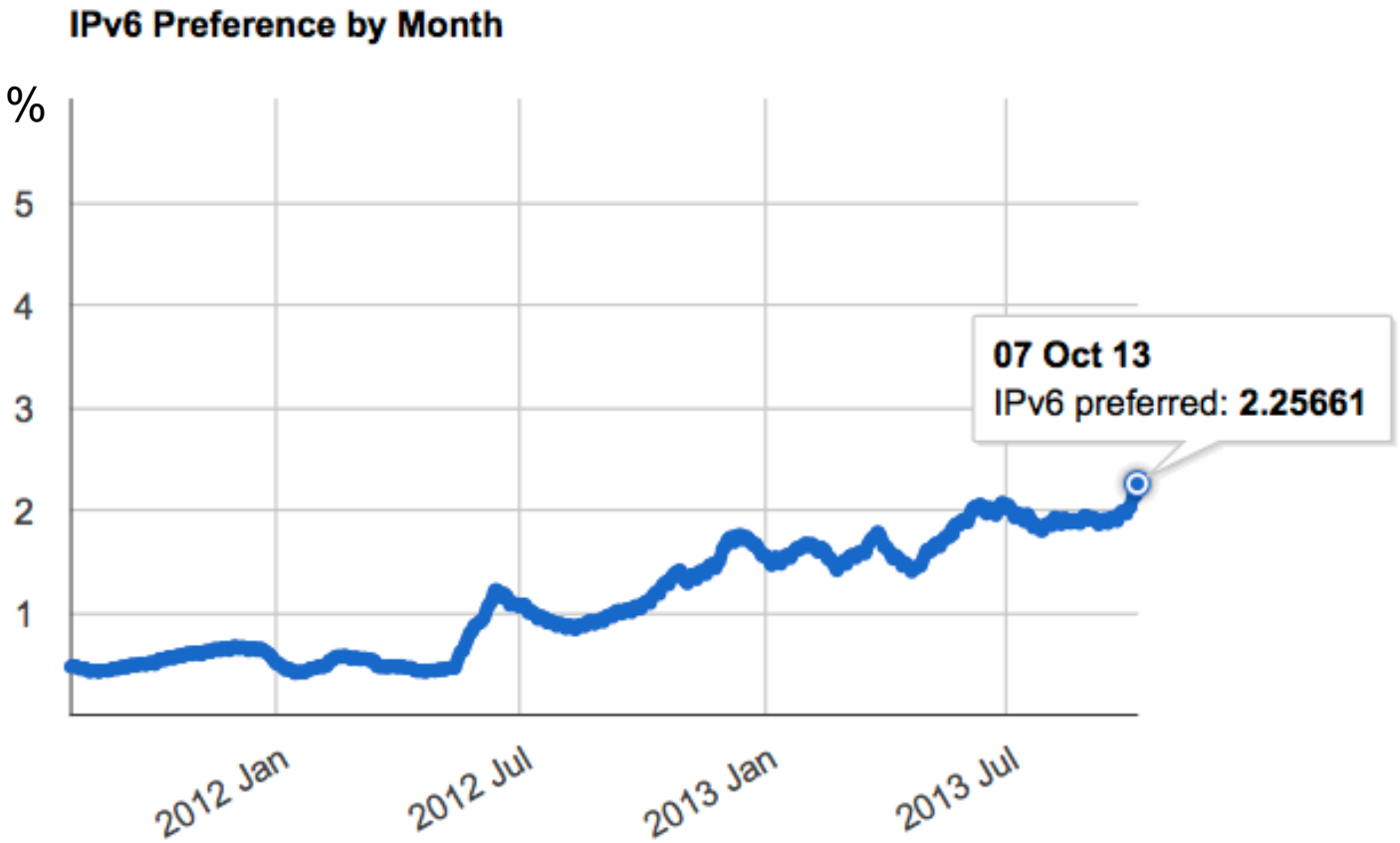
# World ranking
# IPv6 ready web sites




Alexa top 500 website / economy

http://6lab.cisco.com/stats/index.php

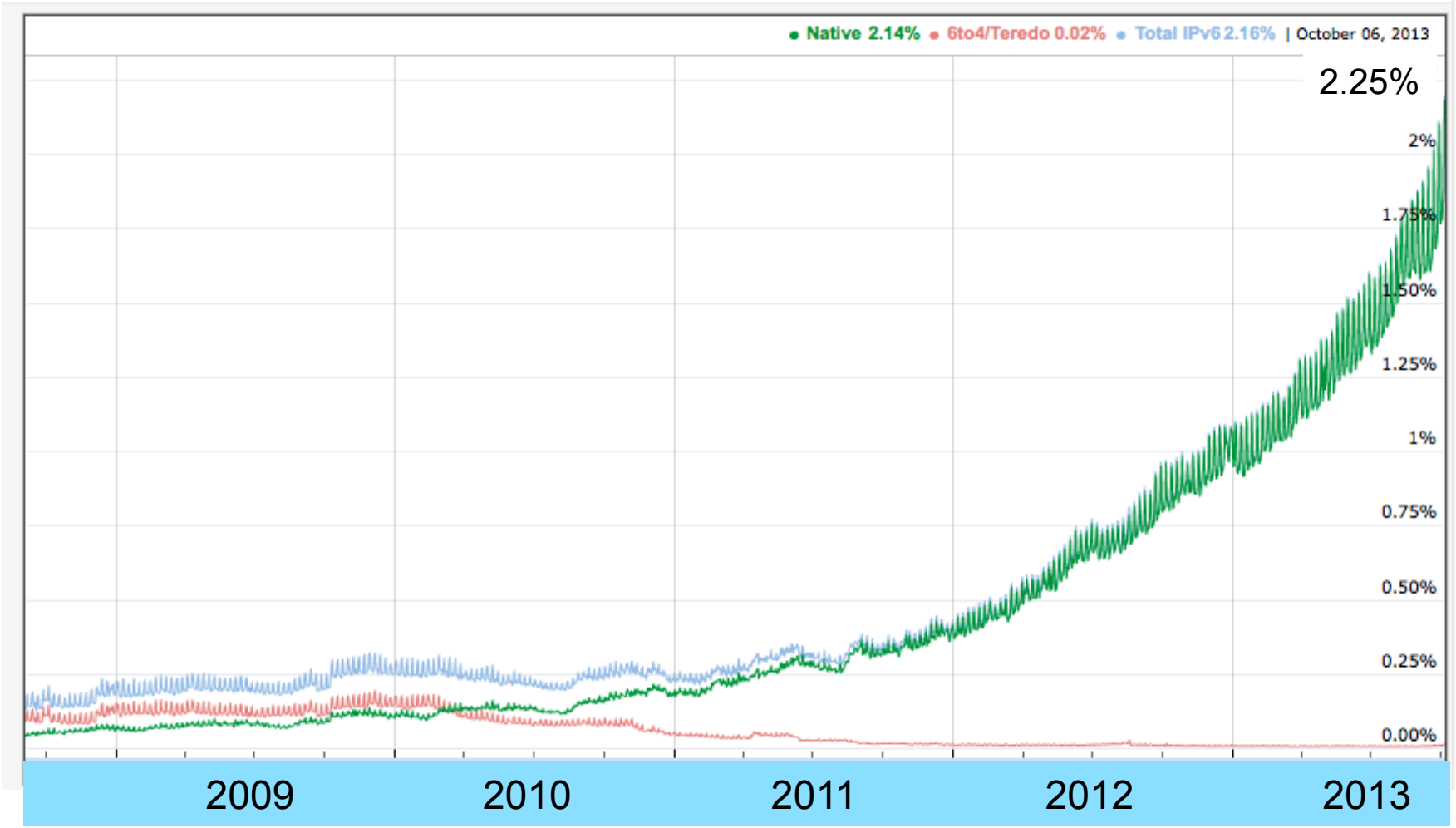
# IPv6 measurement
# End user readiness: World




Data source from “flash” and “JavaScript” and including viewers from mobile devices

http://labs.apnic.net/ipv6-measurement/Regions/001%20World/ as of 29/09/2013

# IPv6 adoption
# % of users accessing Google over IPv6




http://www.google.com/ipv6/statistics.html as of 09/10/2013

# IPv6 deployment leaderboard in the world

| ASN | Entity | Economy | IPv6 preferred rate |
|---|---|---|---|
| 32934 | Facebook | US | 78.10 |
| 22394 | Cellco Verizon Wireless | US | 38.46 |
| 2516 | KDDI KDDI CORPORATION | JP | 29.17 |
| 18126 | CTCX Chubu Telecommunications Company; Inc. | JP | 28.43 |
| 8708 | RCS-RDS SA | RO | 23.38 |
| 3303 | Swisscom | CH | 22.20 |
| 4739 | INTERNODE-AS Internode Pty Ltd | AU | 14.34 |
| 4773 | MOBILEONELTD-AS-AP MobileOne Ltd. Mobile/ Internet Service Provider Singapore | SG | 9.90 |
| 7922 | Comcast | US | 9.51 |
| 23655 | SNAP-NZ-AS Snap Internet Limited | NZ | 8.72 |
| 55430 | STARHUBINTERNET-AS-NGNBN Starhub Internet Pte Ltd | SG | 8.53 |

http://labs.apnic.net/ipv6-measurement/AS/ 09/10/2013

# Observation

- IPv6 deployment status is varied among regions, economies and individual ASN (network operators)
  - IPv6 deployment is not happening all at once
  - Some economies have been very active in terms of IPv6 deployment
  - Some ASNs have been very active in terms of IPv6
- See more details in
  - http://labs.apnic.net
  - http://www.apnic.net/community/ipv6-program/data

# The Situation Today

- Public IPv4 Address space is running out
  - APNIC and RIPE NCC are in their “austerity” phases
  - ARIN and LACNIC are a few months away from running out
  - AfriNIC and still have about a few years of IPv4 left
- The Internet infrastructure operators have 3 simple choices facing them:

1. **Do Nothing**
2. **Prolong IPv4**
3. **Deploy IPv6**

# Choice 1: Doing Nothing

- Advantages:
  - Business as usual, they have enough IPv4 for the foreseeable future
  - Easiest strategy – no investment needed
- Disadvantages:
  - Depends on IPv4 address availability
    - /22 (1024 addresses only from APNIC and RIPE NCC)
    - Limited transfer market activity
    - Address transfer costs
  - Customers have no access to IPv6-only content
    - If/when IPv6-only content is available
  - Lagging behind early adopters
    - Lacking operational experience in the new protocol

# Choice 2: Prolonging IPv4

- This means:
  - Deploying NAT more widely
  - IPv4 address trading/market
- Advantages:
  - Continues what is known
  - Public addresses still available for network operators' public infrastructure
- Disadvantages:
  - Customers forced to use NAT
  - Investment in large NAT devices
  - Rearchitecting network infrastructure around NAT
  - Address reputation (NAT as well as traded addresses)

# Choice 2: Prolonging IPv4

- NAT issues:
  - Restricts provision of services to those with public addresses
  - Reputation of shared addresses
    - Behavioural, security, liability
  - Lawful intercept
  - Tracking and logging association of address/port and subscriber
  - Performance & scaling of NAT devices
  - Cost of “enterprise” scale NAT devices
  - Resource demands of some applications
  - Double or even Triple NAT likely
  - “How many ports does one user need?”

# Choice 2: Prolonging IPv4

- Address transfer issues:
  - Routability of transferred addresses
  - Reputation of transferred addresses
  - More rapid growth of Internet routing table
  - Risk to integrity of routing system if transfers are unregistered
  - Cost to acquire addresses
  - Financial pressure on operators to dispose of addresses they still require

# Choice 3: Deploying IPv6

- Original goal of IPv6 developers – Dual Stack
  - IPv6 running alongside IPv4
  - Public addresses for both IPv4 and IPv6
  - Once IPv6 universally deployed, IPv4 would be turned off
- Now:
  - Dual stack with public addresses still possible in some places
  - In other places, Dual Stack means public IPv6 and NATed IPv4
  - Not all network operators have deployed IPv6
  - Not all infrastructure devices can support IPv6
  - Meaning “transition” techniques required to “bypass” those

# Choice 3: Deploying IPv6

- Advantages:
  - Network runs both IPv4 and IPv6
  - Once IPv6 universally available, IPv4 is simple to turn off
- Disadvantages
  - Depends on Public IPv4 address availability, or NATs
  - New protocol, staff training
  - New protocol, updated/new equipment
  - Extra resources on existing equipment (e.g. RIB/FIB limits)
  - Protocols are incompatible: IPv6 cannot talk to IPv4 and vice-versa
  - Updating end-user CPE

# Choice 3: Deploying IPv6

- In addition to Dual Stack, Transition Techniques maybe also be required:
  - Means of getting IPv6-only to talk to IPv4-only

    **NAT64**
  - Transport IPv6 over IPv4-only infrastructure

    **Tunnels & 6rd**
  - Transport IPv4 over IPv6-only infrastructure

    **DS-Lite, 464XLAT**

# Which choice will you make?

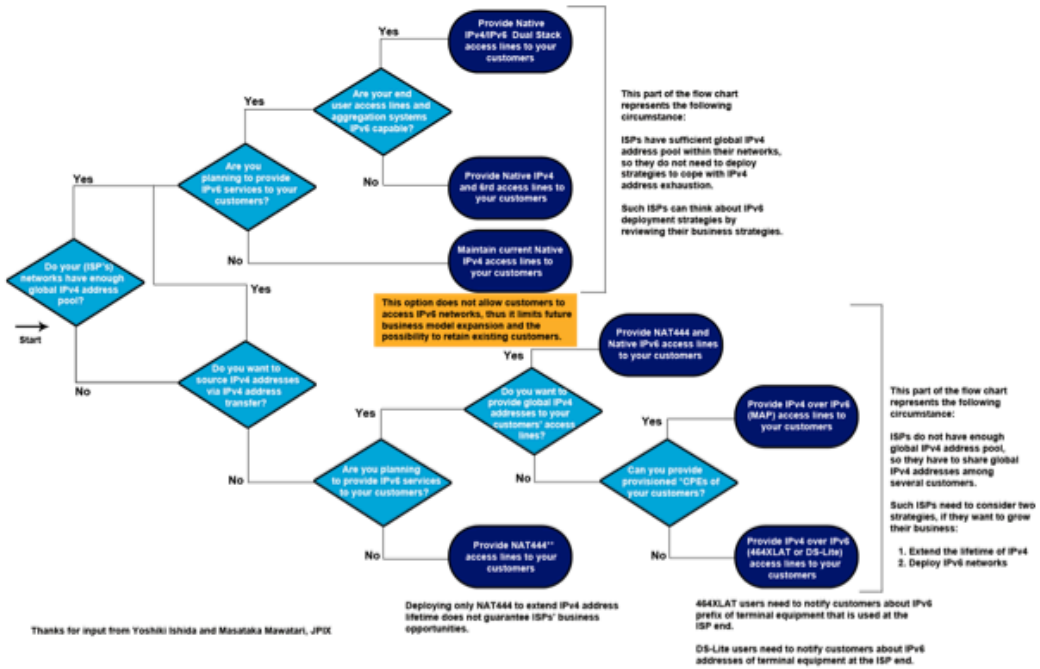
- Doing nothing
  - Costs nothing
- Prolonging IPv4
  - Impact of taking IPv4 addresses back from customers?
  - Economics of deploying NAT?
    - **e.g. Lee Howard's (TimeWarner Cable) whitepaper on the economics of NATs**
    - **http://www.apnic.net/community/ipv6-program/about-cgn**
  - Operational impact, depending on regulatory requirements
    - Lawful intercept, logging, user tracking, reputation
  - Address transfer costs and address reputation
    - Routing system integrity – may have addresses but are they routable?

# Which choice will you make?

- Deploying IPv6
  - Apparently easiest option
  - Most network infrastructure devices support both IPv4 and IPv6
  - Devices not supporting IPv6 need upgrading/replacing
  - Staff training?
  - Operational management tools?
  - Last mile infrastructure impacts (especially if contracted)
  - Transition technologies needed (e.g. NAT64, 6rd, 464XLAT…)
- IPv6 for CTO
  - http://www.apnic.net/community/ipv6-program/ipv6-cto

# IPv6 for CTOs

http://www.apnic.net/community/ipv6-program/ipv6-cto




A quick glance of the options currently available:

IPv6 transition while extending IPv4 address life time:

# IPv6 security consideration

APNIC

# IPv6 security

- Enabling IPv6 on any device means that:
  - The device is accessible by IPv6
  - Interface filters and firewall rules already present in IPv4 **must** be replicated for IPv6
  - Router vty filters already present in IPv4 **must** be replicated for IPv6
- Failure to protect the device after enabling IPv6 means that it is wide open to abuse through IPv6 transport
  - Even though the IPv4 security is in place
- If your network does not run IPv6 yet
  - Are you safe?
  - Attackers can sends rogue Router Advertisement
  - Your host configures silently to IPv6

http://conference.apnic.net/__data/assets/pdf_file/0016/50821/ipv6-security_1346214191.pdf
IPv6 Security ISP Workshop by Philip Smith, APNIC

# Should I care about IPv6?

- Is IPv6 in my IPv4 network?
  - Easy to check!
- Look inside IPv6 NetFlow records
  - Protocol 41: IPv6 over IPv4 or 6to4 tunnels
  - IPv4 address: 192.88.99.1 (6to4 anycast server)
  - UDP 3544, the public part of Teredo, yet another tunnel!
- Look into DNS request log for ‘ISATAP’

# IPv6 population mix (2012)

| Address Type | Unique IPv6 Addresses | Percentage |
|---|---|---|
| Native | LACNIC.....1.3K<br>APNIC.....41.6K<br>RIPE.....90.9K<br>ARIN.....40.5K<br>AFRINIC.....0.1K<br>TOTAL.....174.4K | 1.3 |
| Teredo | 11.12M | 79.2 |
| 6to4 | 2.75M | 19.5 |
| Total IPv6 hosts | 14.04M | 100% |
| IPv6 Ready Hosts | 1.37M | 9.75% |
| Additional IPv6 Capable Hosts (Literal-only) | 3.90M | 27.7% |

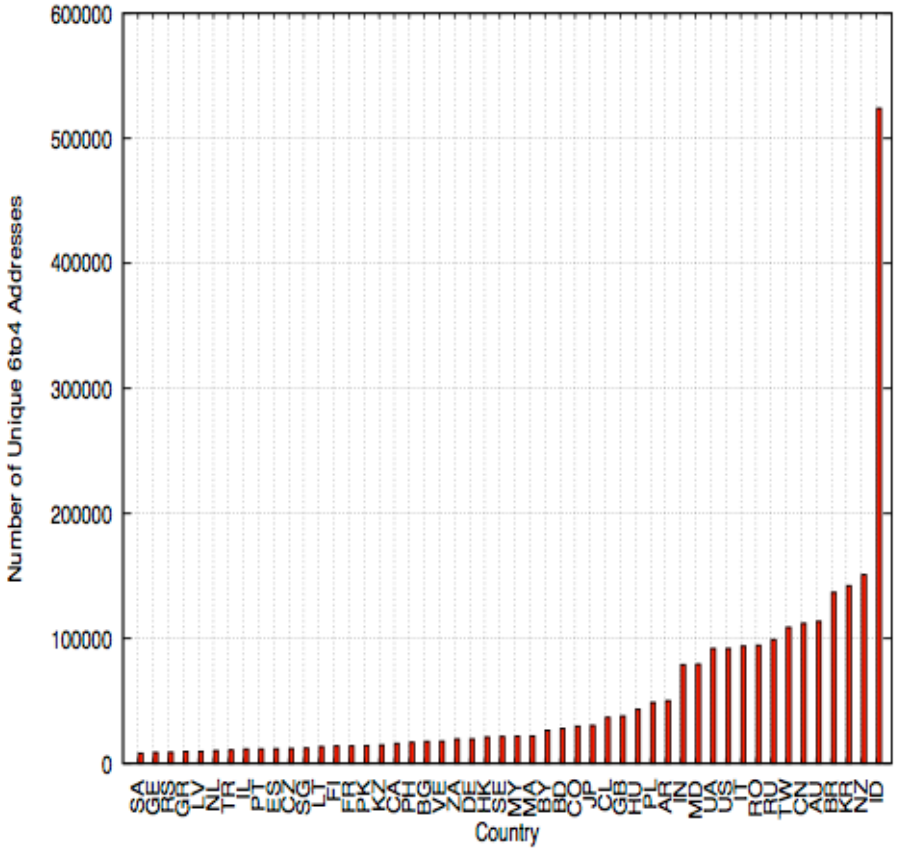
**Table 1.** IPv6 capability population mix

https://www.nanog.org/meetings/nanog56/presentations/Tuesday/tues.lightning.karir.pdf

# 6to4 usage by country

IPv4: 192.0.2.4

IPv6: 2002:c000:0204::/48




- Prefix: 2002::/16
- Next 32 bits are IPv4 address

- 2.78M unique 6to4 addresses
- RIPE- 92K, 1.4M – APNIC, 112K – ARIN, 292K – LACNIC, 65K – AFRINIC
- 205 unique country codes
- Indonesia largest – 500K – 18%
- New Zealand, Korea, Brazil, Australia, China ~100K - 4% each

https://www.nanog.org/meetings/nanog56/presentations/Tuesday/tues.lightning.karir.pdf

# IPv6 attacks with strong IPv4 similarities

- Sniffing
  - Without IPSec, IPv6 is no more or less likely to fall victim to a niffing attack than IPv4
- Rogue devices
  - Rogue devices will be easy to insert into an IPv6 network as in IPv4
- Man-in-the-Middle Attacks (MITM)
  - Without strong mutual authentication, any attacks utilizing MITM will have the same likelihood in IPv6 as in IPv4
- Flooding
  - Flooding attacks are identical between IPv4 and IPv6
- Application layer attacks
  - The majority of vulnerabilities on the Internet today are at the application layer, something that IPSec will do nothing to prevent

http://conference.apnic.net/__data/assets/pdf_file/0016/50821/ipv6-security_1346214191.pdf

# Security issues specific to IPv6

- No IPv6 network = no problem? Wrong!
- IPv6 header manipulation
- IPv4 to IPv6 transition challenges
  - Dual stack/fate sharing
  - IPv6 transition techniques

http://conference.apnic.net/__data/assets/pdf_file/0016/50821/ipv6-security_1346214191.pdf

# ICMPv4 vs. ICMPv6

- Significant changes from IPv4
- More relied upon

| ICMP Message Type | ICMPv4 | ICMPv6 |
|---|---|---|
| Connectivity Checks | X | X |
| Informational/Error Messaging | X | X |
| Fragmentation Needed Notification | X | X |
| Address Assignment | | X |
| Address Resolution | | X |
| Router Discovery | | X |
| Multicast Group Management | | X |
| Mobile IPv6 Support | | X |

- ICMP policy on firewalls need to change
  - Example: RFC4890

# Security enforcement is possible

- So, nothing really new in IPv6
- Revisit your IPv4 security policy
- Review necessary modification to integrate IPv6 into the existing security policy
  - Prepare IPv6 access-lists (ACL) to filter traffic and restrict access to network devices
- Control your IPv6 traffic as you do for IPv4
- Lack of operational experience may hinder security for a while => **Staff training is a must**
- Leverage IPsec to secure IPv6 when suitable
- Plan ahead (last minute implementation of IPv6 infrastructure security is not a good way)

http://conference.apnic.net/__data/assets/pdf_file/0016/50821/ipv6-security_1346214191.pdf
IPv6 Security ISP Workshop by Philip Smith, APNIC

# Anecdotal story 1

Akamai

APNIC

# IPv6 deployment @AKAMAI

| IPv6 is live in | June 2012 | June 2013 |
|---|---|---|
| Countries | 53 | 64 |
| Cities | 175 | 240 |
| Networks | 225 | 300 |
| Akamai server locations | 600 | 800 |
| Akamai servers | 37,000 | 70,000 |

Total of 1100+ networks in 83 countries

http://conference.apnic.net/data/36/20130826-apnic-2013_13775025031.pdf

# IPv6 deployment @AKAMAI

## World IPv6 Launch Anniversary: A closer look from Akamai

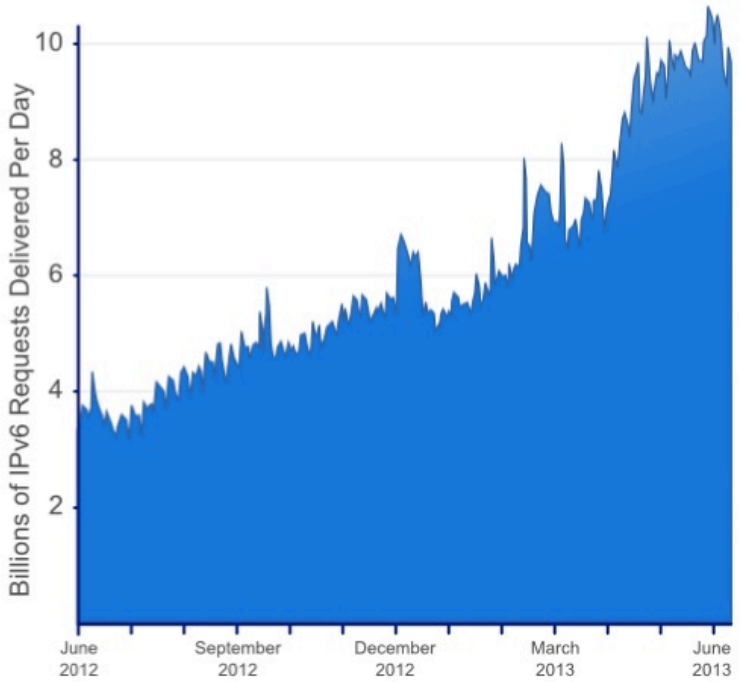
Akamai

### IPv6 Addresses

- 2011: 280,229
- 2012: 18,899,253
- ***67x***
- 2013: 200m – 300m
- ***10x***

### IPv6 Requests/Day

- 2011: 8,343,590
- 2012: 3,394,971,156
- ***460x***
- 2013: >10 billions
- ***2.5x***




IPv6 Requests/Day on Akamai from June 2012 to June 2013

©2012 AKAMAI | FASTER FORWARD™

http://conference.apnic.net/data/36/20130826-apnic-2013_13775025031.pdf

# IPv6 growth path @AKAMAI

## World IPv6 Launch Anniversary: IPv6 and Mobile

| Mobile Operating System | IPv6 as % of Requests |
|---|---|
| Windows Phone OS 8 | 12% |
| BlackBerry OS 10 | 5.9% |
| Android 4.1/4.2 ("JellyBean") | 10.8% |
| Android 4.0 ("Ice Cream Sandwich") | 3.2% |
| Android 2.3 ("Gingerbread") | 1.6% |
| Apple iOS 6 | 1.8% |
| Apple iOS 5 | 1.4% |
| Apple iOS 3/4 | 1.1% |

- using Akamai's Mobile Browser Detection for categorization
- Within Android, there are individual device types where well over 50% of the traffic to dual-stacked websites arrived over IPv6.

©2012 AKAMAI | FASTER FORWARD™

http://conference.apnic.net/data/36/20130826-apnic-2013_13775025031.pdf

# IPv6 growth path @AKAMAI

## World IPv6 Launch Anniversary: IPv6 and Desktop/Laptop Operating Systems

| Operating System | Browser | IPv6 as % of Requests |
|---|---|---|
| Microsoft Windows 8 | | 4.1% |
| Microsoft Windows Vista | | 3.3% |
| Microsoft Windows 7 | | 2.5% |
| Microsoft Windows XP | | 0.5% |
| Mac OS X 10.5 & 10.6 | Chrome & Firefox | 3.4% |
| Mac OS X 10.5 & 10.6 | Safari | 3.3% |
| Mac OS X 10.7 & 10.8 | Chrome & Firefox | 3.3% |
| Mac OS X 10.7 & 10.8 | Safari | 2.1% |

- Happy Eyeballs

©2012 AKAMAI | FASTER FORWARD™

http://conference.apnic.net/data/36/20130826-apnic-2013_13775025031.pdf

# What AKAMAI sees

World IPv6 Launch Anniversary:
Three drivers of IPv6 growth


1. Content availability
   - Customers opting in to have their sites, content, and applications permanently available dual-stacked.
2. Availability of IPv6 from access network providers
   - IPv6 in production networks, e.g. Verizon Wireless, AT&T, and Comcast.
   - Some ISPs, Universities and Research Labs in Europe and Asia that have had IPv6 deployed
3. End-user device support
   - Recent desktop and laptop OS and client software supports IPv6
   - Many home routers / gateways start to support IPv6 recently.
   - 4G LTE smart phones.

©2012 AKAMAI | FASTER FORWARD™

http://conference.apnic.net/data/36/20130826-apnic-2013_13775025031.pdf

# Anecdotal story 2

Verizon Wireless (VZW)

APNIC

# IPv6 deployment @VZW

verizon wireless

## Background

- **Largest mobile carrier in US with >94 M subscribers**
- **Operate LTE and CDMA networks**
- **Legacy VZW RAN (1x and HRPD) only supports IPv4**
  - **Originally globally routable IPv4 addresses were assigned to UE, but starting in late 2010 NAT IPv4**
- **Launched LTE in 4Q 2010**
- **One of the largest IPv6 networks in existence**
- **Possibly the highest IPv6 penetration of any mobile carrier the world**

Confidential and proprietary material for authorized Verizon Wireless personnel only. Use, disclosure or distribution of this material is not permitted to any unauthorized persons or third parties except by written agreement.


http://conference.apnic.net/__data/assets/pdf_file/0017/50813/vzw_apnic_13462152832-2.pdf

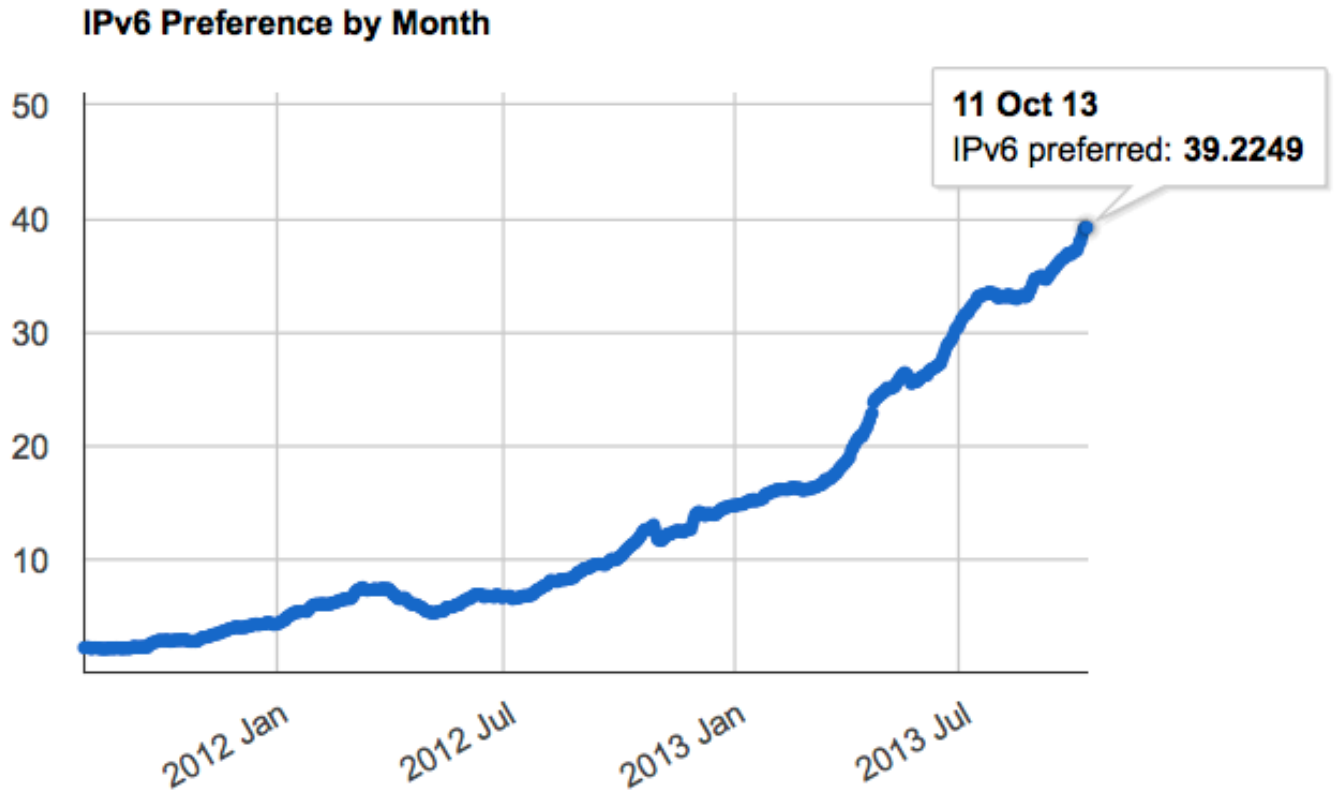
# IPv6 deployment @VZW


- **VZW recognized that IPv6 was a necessity not something "optional"**
  - **Built the network regardless of IPv6 enabled content**
- **IPv4 address exhaustion**
  - **Issue exasperated by modern "always-on" smartphones**
  - **Workaround : CGN**
- **IPv4 NAT problematic in certain situations**
  - **Certain apps / protocols have issues working with NAT**
  - **Prolongs the move to IPv6**
  - **IP based auth does not work**

Confidential and proprietary material for authorized Verizon Wireless personnel only. Use, disclosure or distribution of this material is not permitted to any unauthorized persons or third parties except by written agreement. 3

http://conference.apnic.net/__data/assets/pdf_file/0017/50813/vzw_apnic_13462152832-2.pdf

# IPv6 deployment @VZW Today




http://labs.apnic.net/ipv6-measurement/AS/2/2/3/9/4/ as of 11/10/2013

# Anecdotal story 3

APNIC

APNIC

# F5 BigIP at APNIC

- APNIC hosts:
  - Whois Database, DNS servers, MyAPNIC (APNIC membership portal sites), office and internal servers
- Sites are in Australia, Japan, HK and the US
  - Anycasted DNS, IX connections, 2DCs and the office in Brisbane
- APNIC fully dual stacked “everything” on BigIP:
  - Virtual servers, pools, nodes, network access clients
- Setting up the F5 BigIP “dual stacked” balancing IPv4 to IPv4 and IPv6 to IPv6: **it just works!**
  - Create a pool for load balancing traffic to IPv6 nodes
  - Create a virtual server referencing the pool of IPv6 nodes
- Also, implementing 6-to-4 load balancing is easy (not same as NAT64, it’s a proxy service)

# Conclusions

APNIC

# Are you ready?

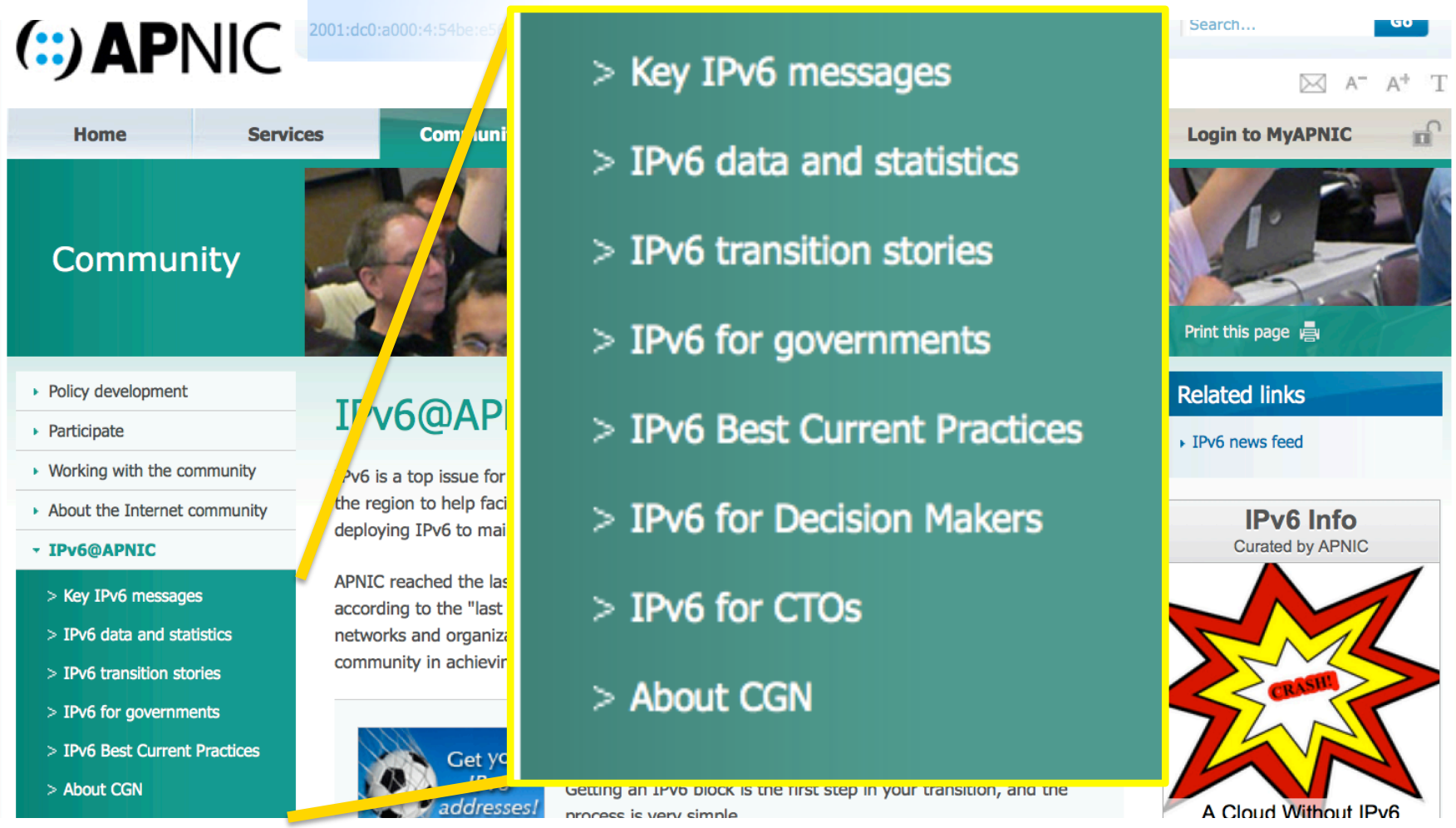
- Savvy customers may ask hosting and cloud providers:
  - Do you have sufficient globally routable IPv4 to guarantee me a unique IP address for my services?
    - I do not want to fate-share on IP address used by any other person
    - Not for HTTP, not for virtualized service on one host
  - Private IP addressing has limitations. Are you considering addressing your services with private addresses?
    - How many customers share the NAT interface to the public Internet?
    - What size of NAT is required?
    - Mapping of private address to public facing address?
  - Do you have sufficient globally routable IPv4 to give me multiple placement in the future?
  - Do you have IPv6 at all your locations or am I locked into a single location for your IPv6 solution?

# Obtain IPv6 address from APNIC


http://www.apnic.net/services/

# www.apnic.net/ipv6

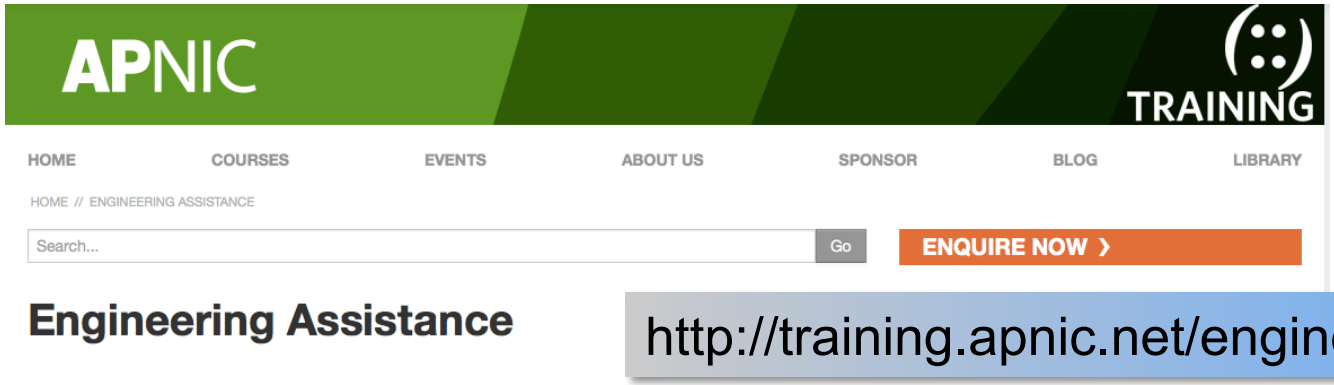
# www.apnic.net/ipv6



# APNIC trainings


http://training.apnic.net/

# APNIC engineering assistance




http://training.apnic.net/engineering-assistance

- Directly support regional infrastructure development
- Bridge the gap between APNIC Training courses and the services of a consultancy organization
- Cost recovery
- Specialist skills
  - Routing protocols, IPv6 technology and deployment, Network infrastructure security etc.

# APRICOT2014 and APNIC37
# Feb 2014

**http://2014.apricot.net/program**

# Thank you!

APNIC