NTT Communications
Q1 2011

IPv6 Overview

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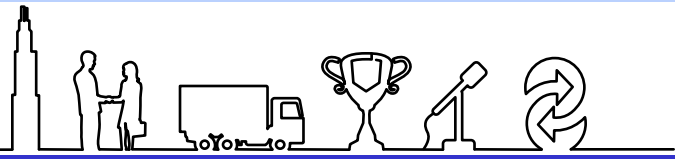
NTT Europe - Global IP Network

Agenda

- IPv4 limitations
  - IP address depletion
  - Dated header definitions
- IPv6 benefits
  - Practically limitless address space
  - Simplified Headers
- NTT's IPv6 Implementations



IPv4: Success has its Pitfalls

Virtually unchanged since 1981.
IPv4 has proven to be

- robust
- easily implemented
- interoperable
- scaling to the size of today's Internet

Unanticipated results to due to its success:

- Exponential growth of the Internet
- Impending exhaustion of the IPv4 address space
- 32-bit address space of IPv4 allows for 4,294,967,296 addresses
  - BUT, previous and current allocation practices limit the number of public IPv4 addresses to a few hundred million.
  - public IPv4 addresses have become relatively scarce
  - Many organizations use a NAT to map a single public IPv4 address to multiple private IPv4 addresses. Although NATs promote reuse of the private address space, they violate the fundamental design principle of the original Internet that all nodes have a unique, globally reachable address, preventing true end-to-end connectivity.

Network Address Translation pitfalls

- Breaks globally unique address model
- Breaks address stability
- Breaks always-on model
- Breaks peer-to-peer model
- Breaks some applications
- Breaks some security protocols
- Breaks some QoS functions
- Introduces a false sense of security
- Introduces hidden costs

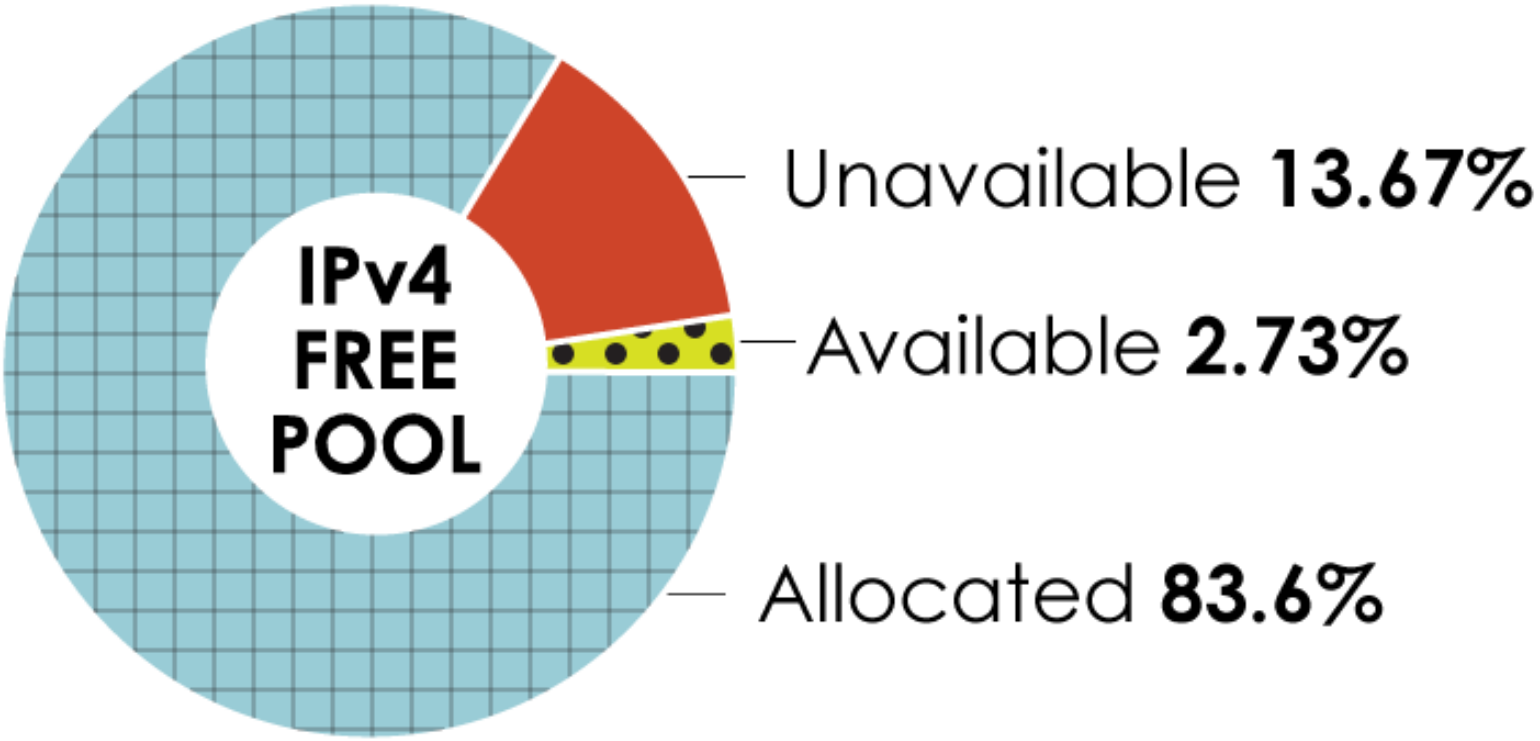
Even More IPv4 Limitations

- Current IPv4 implementations must be either manually configured or use a stateful address configuration protocol such as Dynamic Host Configuration Protocol (DHCP).
  - With more computers and devices using IP, there is a need for a simpler and more automatic configuration of addresses

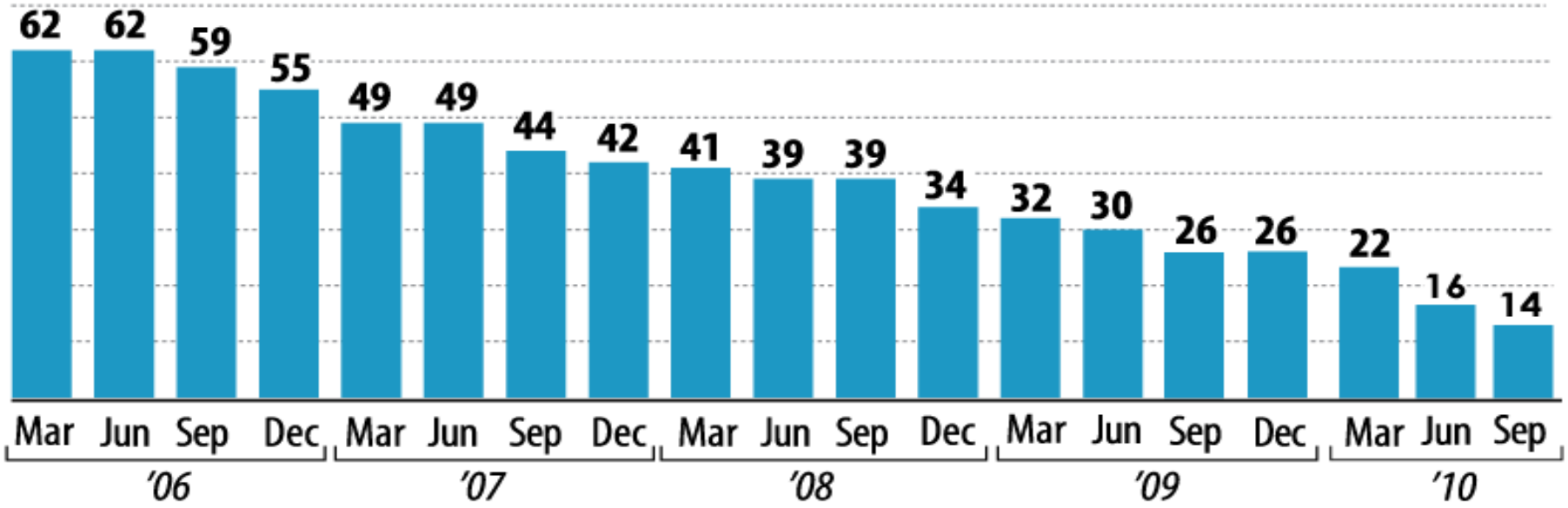
- Security is not built in to the protocol.
  - Although a standard now exists for providing security for IPv4 packets (known as Internet Protocol security, or IPsec), this standard is optional for IPv4 and additional security solutions, some of which are proprietary, are prevalent.

- Quality of Service (QoS)
  - Relies on the 8 bits of the historical IPv4 Type of Service (TOS) field and the identification of the payload, typically using a User Datagram Protocol (UDP) or Transmission Control Protocol (TCP) port.
  - Limited functionality and, over time, has been redefined and has different local interpretations.
  - Payload identification that uses a TCP or UDP port is not possible when the IPv4 packet payload is encrypted.

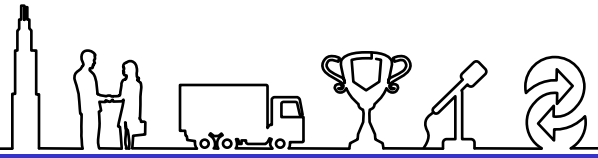
NAT


IPv4
FREE
POOL
Unavailable 13.67%
Available 2.73%
Allocated 83.6%

IPv4 Allocation History



In 2010, RIRs have been allocated nineteen /8 blocks as of November, leaving seven /8s unallocated (7/256 - 2.73%).



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IPv6 Advantages at a Glance.

Increased address space

- **128 bits = 340 trillion trillion trillion addresses**
- **(2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456)**
- **= 67 billion billion addresses per cm^2 of the planet surface**

Hierarchical address architecture

- **Improved address aggregation**

More efficient header architecture

- **Improved routing efficiency, in some cases**

Neighbor discovery and autoconfiguration

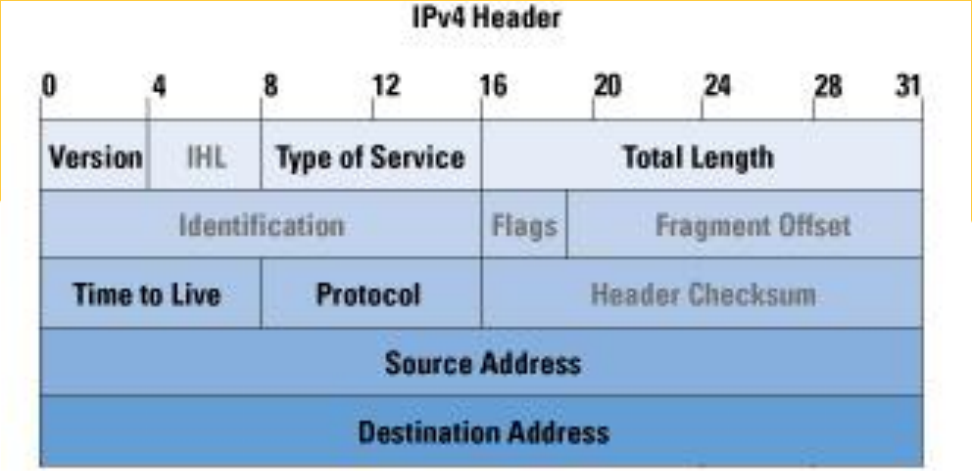
- **Improved operational efficiency**
- **Easier network changes and renumbering**
- **Simpler network applications (Mobile IP)**

Integrated security features

Compare and Contrast

IP version	IPv4	IPv6
Deployed	1981	1999
Address Size	32-bit number	128-bit number
Address Format	Dotted Decimal Notation: 192.0.2.76	Hexadecimal Notation: 2001:0DB8:0234:AB00: 0123:4567:8901:ABCD
Number of Addresses	2^{32} = 4,294,967,296	2^{128} = 340,282,366,920,938,463, 463,374,607,431,768,211,456
Examples of Prefix Notation	192.0.2.0/24 10/8 (a "/8" block = 1/256th of total IPv4 address space = 2^{24} = 16,777,216 addresses)	2001:0DB8:0234::/48 2600:0000::/12

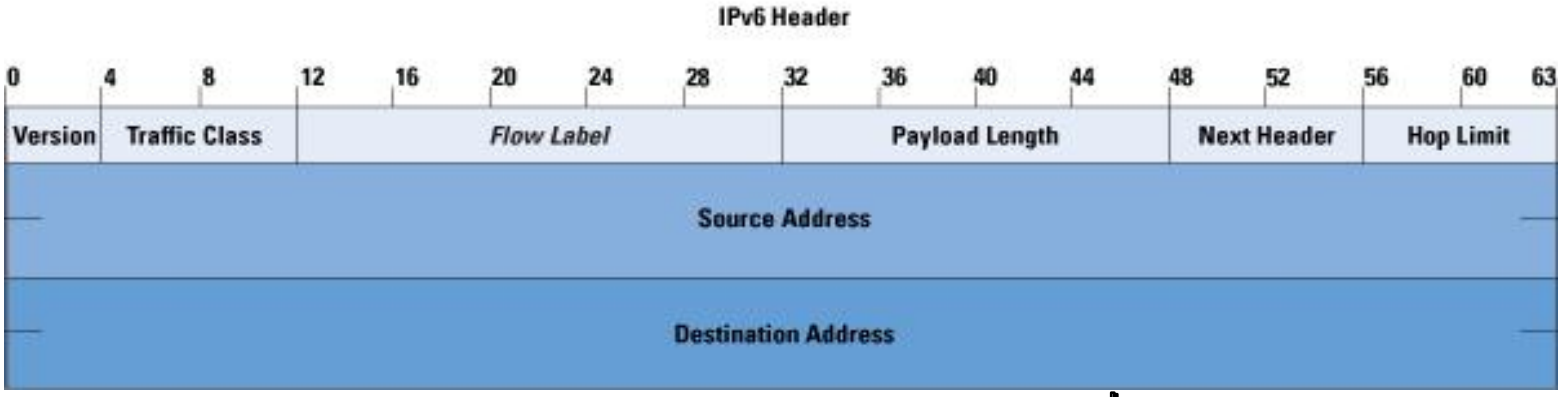
IPv4 Header – What a mess!



1. Version (always set to the value 4 in the current version of IP)
2. IP Header Length (number of 32 -bit words forming the header, usually five)
3. Type of Service (ToS), now known as Differentiated Services Code Point (DSCP)
4. Size of Datagram (in bytes, this is the combined length of the header and the data)
5. Identification (16-bit number which together with the source address uniquely identifies this packet - used during reassembly of fragmented datagrams)
6. Flags (a sequence of three flags (one of the 4 bits is unused) used to control whether routers are allowed to fragment a packet (i.e. the Don't Fragment, DF, flag), and to indicate the parts of a packet to the receiver)
7. Fragmentation Offset (a byte count from the start of the original sent packet, set by any router which performs IP router fragmentation)
8. Time To Live (Number of hops /links which the packet may be routed over)
9. Protocol (e.g. 1 = ICMP; 2= IGMP; 6 = TCP; 17= UDP).
10. Header Checksum (Used to detect processing errors introduced into the packet inside a router or bridge. Packets with an invalid checksum are discarded by all nodes in an IP network)
11. Source Address (the IP address of the original sender of the packet)
12. Destination Address (the IP address of the final destination of the packet)
13. Options (not normally used, but, when used, the IP header length will be greater than five 32-bit words to indicate the size of the options field)

IPv6 Header – Simple and Neat

1. Version - Indicates the version of the Internet Protocol.
2. Traffic class - Previously the type-of-service (ToS) field in IPv4
3. Flow label - The flow label identifies all packets belonging to a specific flow
4. Payload length - Previously the total length field in IPv4, the payload length field specifies the length of the IPv6 payload.
5. Next header - Previously the protocol field in IPv4, the Next Header field indicates the next extension header to examine.
6. Hop limit - Previously the time-to-live (TTL) field in IPv4
7. Source address - Identifies the address of the source node sending the packet.
8. Destination address - Identifies the final destination node address for the packet



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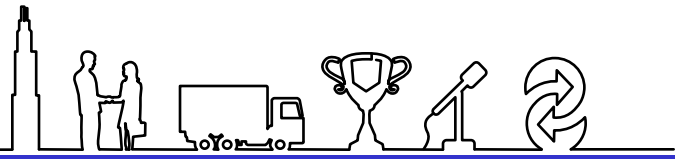


NTT Communications IPv6 Service History

1996 — **NTT Labs started** one of the world's largest global IPv6 research networks

1998 — **Verio begins participation** in PAIX native IPv6 IX

1999 — **NTT Com begins IPv6** tunneling trial for Japanese customers

2000 — **Verio obtains IPv6** sTLA from ARIN

2001 — **NTT Com pioneers world's first IPv6** connectivity service on a commercial basis

2002 — **World Communications Association (WCA) awards** NTT Communications with "Best Technology Foresight" for its IPv6 global products

2002 — **NTT/VERIO launches IPv6** Native, Tunneling, and Dual Stack commercial service in North America

2003 — **Communications Solutions Magazine** names NTT/VERIO IPv6 Gateway Services "Product of the Year"

2004 — NTT IPv6 Native and Dual Stack services **available around the globe**

NTT Communications IPv6 Service History
(continued)

2004 — **Dual stack Virtual Private Server released**. First ISP to offer an IPv6 managed firewall service

2005 — **NTT Com wins** the World Communications Association "Best New Service" award for IPv6/IPv4 Global Dual Service

10/2006 — **Launched** the NTT Communications IPv6 Transition Consultancy

2/2007 — **Awarded GSA Schedule 70** contract for IPv6 IP transit

1/2008 — **NTT America demos IPv6** at ICAC at U.S. Senate

3/2008 — **IDC names NTT America Top 20** IPv6 Influencer Working with the U.S. Government

4/2008 — **NTT Com named Best** Wholesale Carrier at the Telecom Asia Awards for Global IP Network Service and services incorporating IPv6 and advanced security technologies

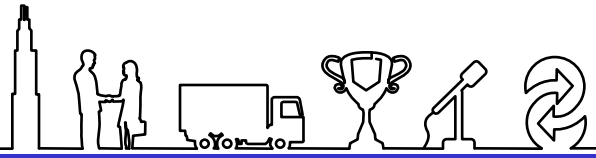
5/2008 — **European Commission invites** NTT to speak at European IPv6 Day

1/2009 — **NTT America demos IPTV** over IPv6 at ICAC at U.S. Senate

NTT IPv6 Customer Profile

January 2009 IPv6 Customer Breakdown	
Education & Government	6%
Hardware & Manufacturing	19%
Internet & Telecom	64%
Webhosting & Web Services	11%
Total	**100%**

- Approximately 30% of our customers purchase IPv6 transit
- Over 55 Gbps of purchased IPv6 or dual stack capacity



Network Upgrade Considerations

- All backbone equipment needed to be audited and upgraded if necessary
  - Chassis, cards, memory, etc.
  - Operating systems
- What features will are offered and can the network support these features

- How will deployment take place
  - Core first then the aggregation routers
  - Both at the same time
  - Set up an entire separate (parallel) network
  - Use tunnels
- A test environment needs to be set up (everything needs to be tested)

Support Infrastructure

- Router configuration tools
- Route Registry
- Address allocation database and procedures
- DNS support (records and access method)
- Customer interfaces (looking glass, control panels, etc.)

- Access feature support
  - Access methods (TDM, Ethernet, Frame, etc.)
  - Features (shadow, managed router, etc.)
  - Security (ACLs, Firewall, etc.)
- Billing system support

Monitoring and Support

- Network Monitoring
- Troubleshooting tools
- Training for NOC and IPeng personnel
- SLA monitoring and display tools
- Any other support and monitoring tools need to be upgraded

Background - NTT Communications and IPv6

1996 — NTT Labs started one of the world's largest global IPv6 research networks

1997 — Equipment procurement
Started working with vendors for IPv6 support

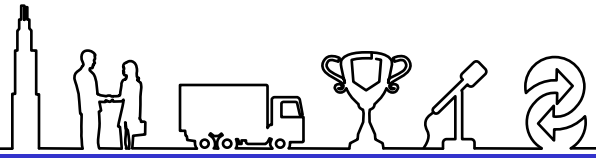
1998 — Equipment procurement
Started pushing hard for commercial support

1999 — NTT obtained an sTLA from APNIC (Asia)

2000 — IPv6 was officially on NTT Communications' product road map

sTLA was obtained from ARIN (N.A.)

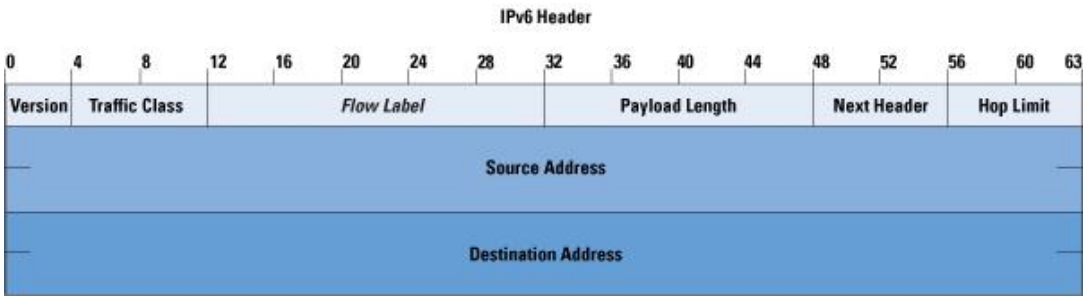
6bone was used for testing initially - later a private IPv6 lab in Dallas was used

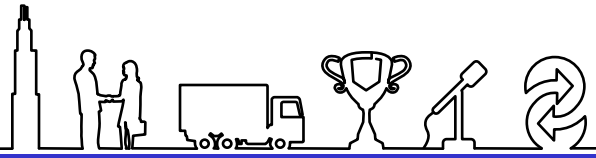


Steps For Deploying IPv6

NTT treated the deployment of IPv6 similar to launching a new product

- Set up a core team representing all necessary groups
- Set up a project plan, document project requirements, design documents, test plans, etc.
- Deploy IPv6 in a phased approach:
  - (I) Precommercial Phase
  - (II) Commercial
  - (III) Follow up releases





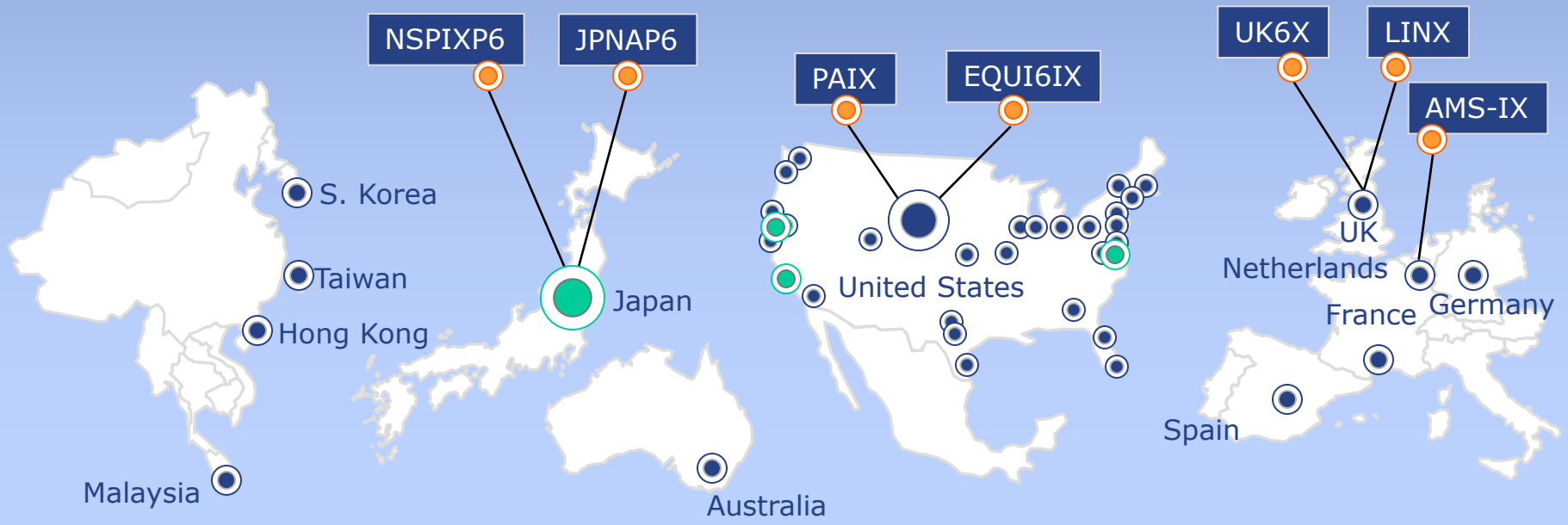
NTT's Pre-commercial IPv6 Service in the US

- In June of 2003, NTT Communications launched pre-commercial IPv6 service in the US
- Native IPv6 was available in three locations
  - Bay Area
  - Los Angeles
  - Washington D.C. Area
- Cisco 7206 routers in these three locations running dual stack - tunneling across the backbone (backbone not dual stack)
- Tunneling (RFC 2893 manually configured IPv6 over IPv4) available in all other POPs (tunnel built to one of the locations above)

Pre-commercial Service Objectives

- Pre-commercial service was offered from June 2003 to December 2003
  (at which time commercial service was launched)
- Pre-commercial objectives
  - Bring on a small, manageable number of customers
  - Test provisioning and support procedures
  - Train NOC staff
  - Finalise JunOS/IOS IPv6 testing
  - Develop internal tools
  - Allowed time to upgrade backbone to dual stack
- Still just a few dual stack routers with tunneling across the backbone everywhere else

Pre-commercial Service Map (June 2003)



IPv6 Native Service Availability

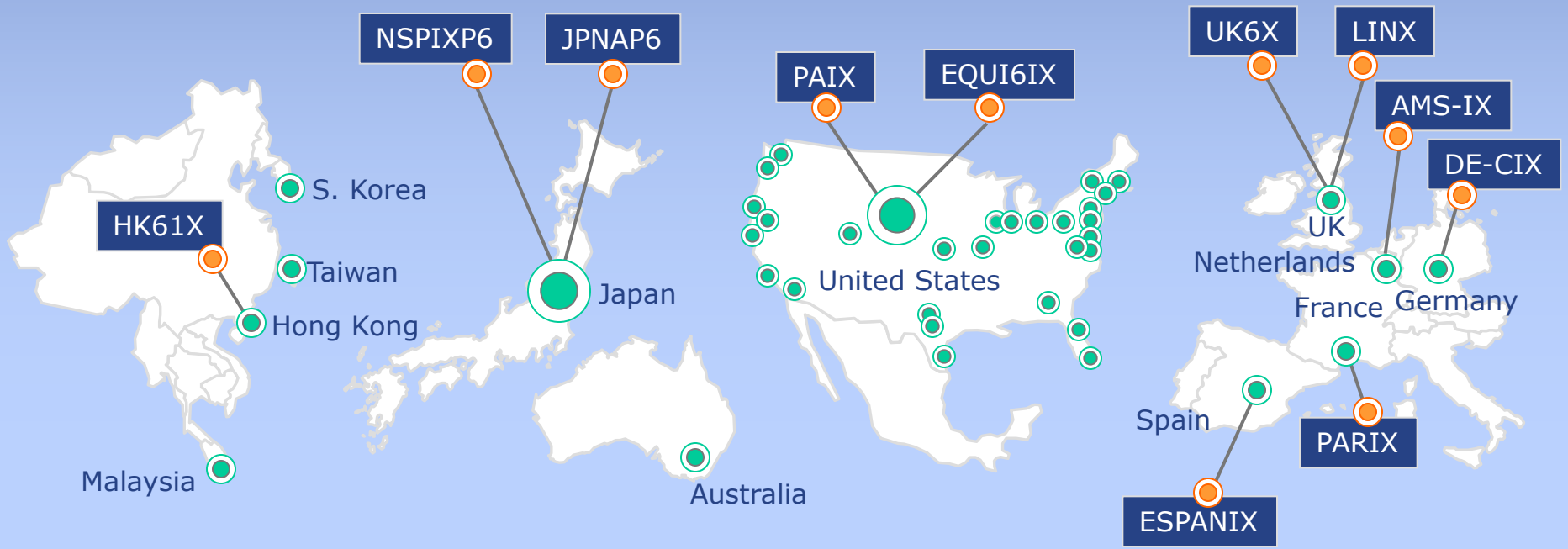
IPv6 Tunneling Service Availability

IPv6 Primary Exchange Point

NTT's Commercial IPv6 Service Launch

- In 4Q2003 global backbone was upgraded to dual stack
  (Asia, Australia, North America, and Europe)
- In December, 2003, three types of IPv6 service were offered on a commercial basis
  - Native IPv6 (available at every POP)
  - Manually configured IPv6 over IPv4 tunneling
  - Dual stack IPv4/IPv6
- AS2914 core completely dual stack (globally)
- 7x24 NOC support and SLAs
- Still service functionality gaps

Pre-commercial Service Map (December 2003)



IPv6 Native Service Availability

IPv6 Primary Exchange Point

IPv6 Follow Up Releases

- Since the commercial launch in December 2003, follow up releases have been pushed out to fill functionality gaps
- Added IPv6 support for
  - Off-net Tunneling
  - Managed Router Service
  - Shadow support for TDM and Ethernet
  - Managed Firewall
  - Dual stack Virtual Private Server

Our goal and philosophy is to offer all features and services in IPv4 and IPv6

IPv6/IPv4 Dual Stack Backbone

- IPv6/IPv4 Dual Stack Backbone has shown excellent performance with no critical problems so far
- Core routers / routing protocols have had no problems handing IPv6 traffic (in addition to the IPv4 traffic/routing)
- But still, we have some operational gaps
  - Stats tools are still lacking in the IPv6 environment (IPv6 MIB support, SNMP over IPv6 support…)
  - IPv6 jitter measurement system compatible with our IPv4 system
  - Limited netflow v9 collector support

Dual Stack IP Backbone

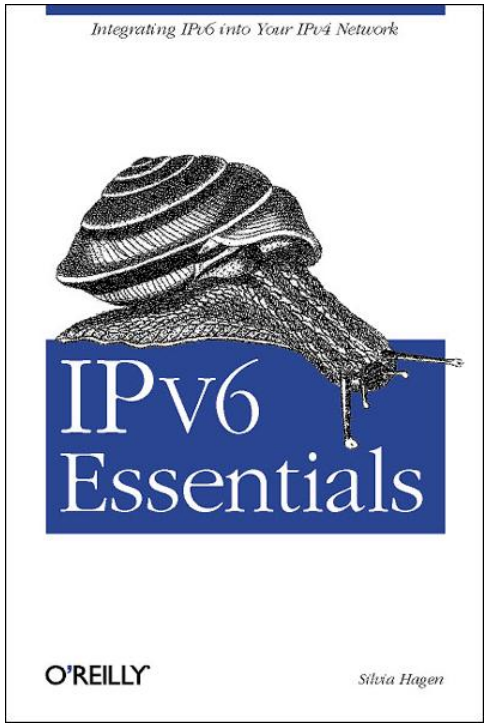
- Highest quality global Tier-1 IP backbone
- Fully redundant network backed by industry leading SLA's
- Global IPv6/IPv4 dual stack network
- Shortest access between Europe and Asia-Pacific available via new cable route

Summary and Recommendations

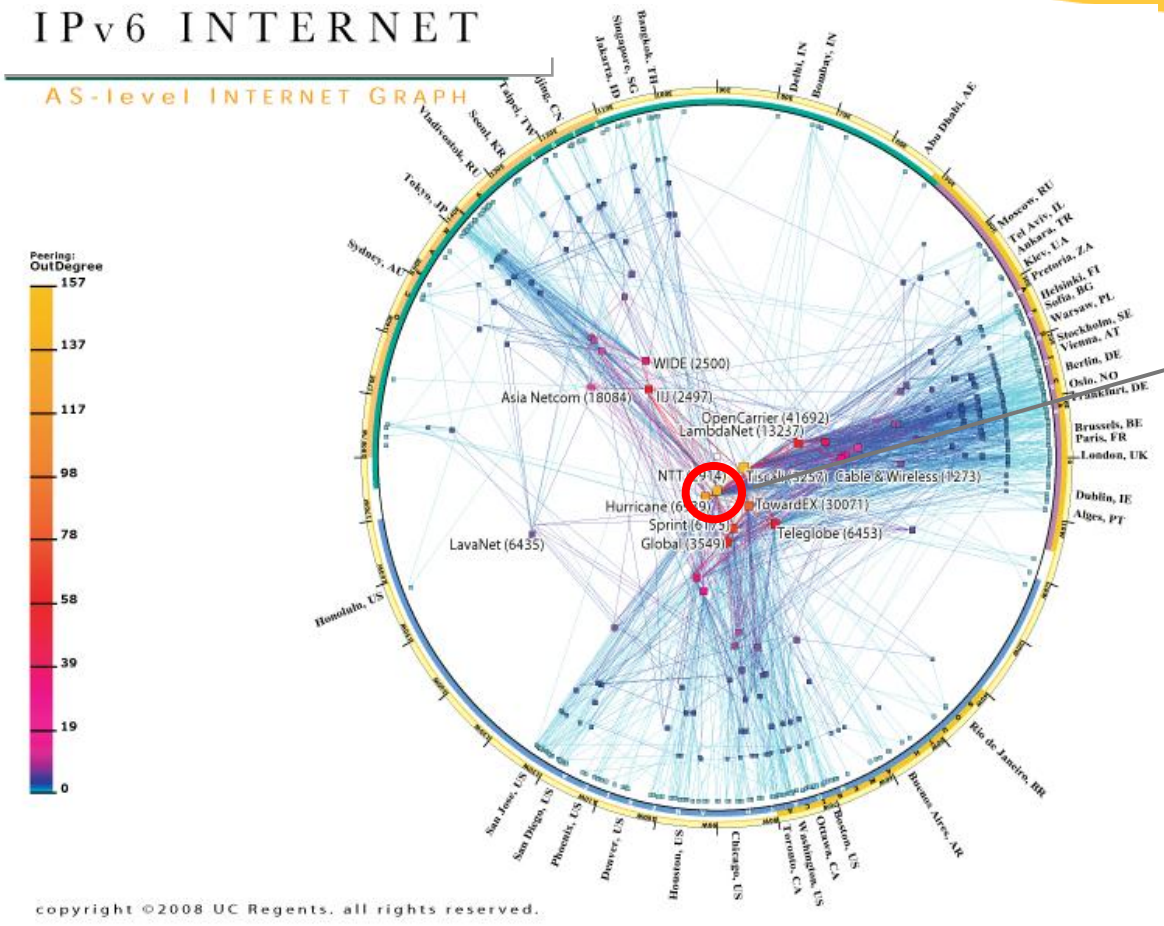
- Create a core project team with representation from all pertinent groups in your organizations
- Plan well in advance and make purchasing decisions based on IPv6 support
- Proper planning reduces cost and pain
- Select the best backbone migration approach for your network - running IPv4/IPv6 dual stack is recommended if possible
- Set up a test environment and/or use existing test beds
- Get training for engineering, provisioning, and support personnel
- Employ a phased rollout approach
  - Allows to continue testing
  - Get internal resources trained and up to speed
  - Solidify internal processes and tools
  - Can fill in functionality gaps over time
- Make sure your security policy also includes IPv6
- Get outside help if needed
- IPv6 roll out should be easier today with the increased maturity of IPv6

The “Snail Book”

- IPv6 Essentials (O’Reilly)
  by Silvia Hagen
  - ISBN 0-596-10058-2
  - Chapter 10 includes case studies, including NTT’s
- Global IPv6 Strategies (Cisco Press)
  by Patrick Grossetete, Ciprian P. Popoviciu, Fred Wettling
- IPv6 Security (Cisco Press)
  by Scott Hogg and Eric Vyncke



At the heart of the internet



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