IPV6 BASICS

Outline

- Protocol Background
- Technology Differences
- Enhanced Capabilities
- Inaccuracies & Speculation
- Transition Technologies

Protocol Background

Why a New IP?

- 1991 – ALE WG studied projections about address consumption rate showed exhaustion by 2008.

- Bake-off in mid-1994 selected approach of a new protocol over multiple layers of encapsulation.

What Ever Happened to IPv5?

0	IP (deprecated)	March 1977 version	
1	IP (deprecated)	January 1978 version	
2	IP	February 1978 version A	(deprecated)
3	IP	February 1978 version B	(deprecated)
4	IPv4	September 1981 version	(current widespread)
5	ST	Stream Transport	(not a new IP, little use)
6	IPv6	December 1998 version	(formerly SIP, SIPP)
7	CATNIP	IPng evaluation	(formerly TP/IX; deprecated)
8	Pip	IPng evaluation	(deprecated)
9	TUBA	IPng evaluation	(deprecated)
10-15		unassigned	

Do We Really Need a Larger Address Space?

- Internet Users or PC
  - ~530 million users in Q2 CY2002, ~945 million by 2004
  - (Source: Computer Industry Almanac)
  - Emerging population/geopolitical and Address space
- PDA, Pen-Tablet, Notepad,…
  - ~20 million in 2004
- Mobile phones
  - Already 1 billion mobile phones delivered by the industry
- Transportation
  - 1 billion automobiles forecast for 2008
  - Internet access in Planes
- Consumer devices
  - Billions of Home and Industrial Appliances

Explosion of New Internet Appliances

IP Address Allocation History

1981 - IPv4 protocol published

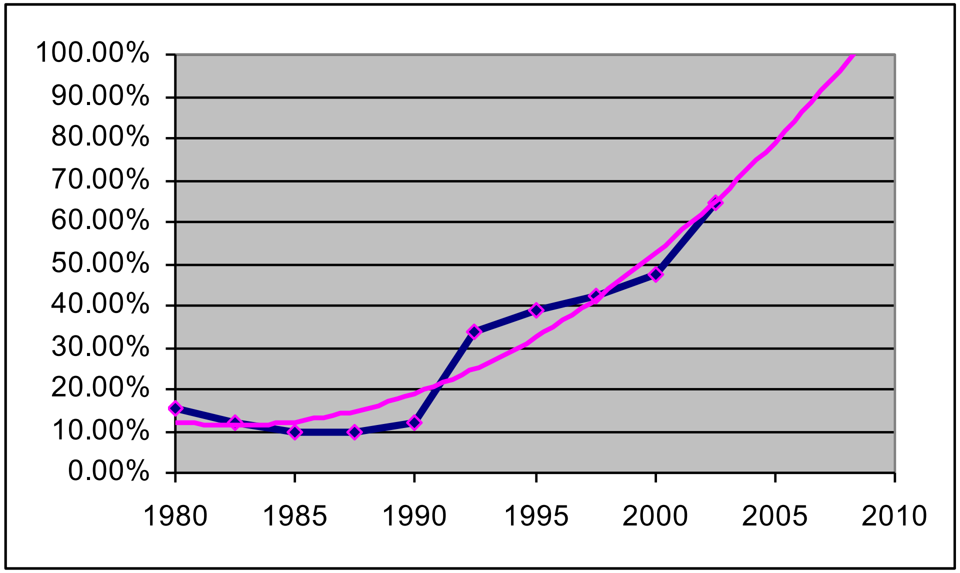
1985 ~ 1/16 of total space

1990 ~ 1/8 of total space

1995 ~ 1/3 of total space

2000 ~ 1/2 of total space

2002.5 ~ 2/3 of total space



- This despite increasingly intense conservation efforts
  - PPP / DHCP address sharing
  - NAT (network address translation)
  - CIDR (classless inter-domain routing)
  - plus some address reclamation
- Theoretical limit of 32-bit space: ~4 billion devices

  Practical limit of 32-bit space: ~250 million devices (RFC 3194)

What were the goals of a new IP design?

- Expectation of a resurgence of "always-on" technologies
  - xDSL, cable, Ethernet-to-the-home, Cell-phones, etc.
- Expectation of new users with multiple devices.
  - China, India, etc. as new growth
  - Consumer appliances as network devices
    - (10^{15} endpoints)
- Expectation of millions of new networks.
  - Expanded competition and structured delegation.
    - (10^{12} sites)

Why was 128 bits chosen as the IPv6 address size?

Proposals for fixed-length, 64-bit addresses

- Accommodates 10^{12} sites, 10^{15} nodes, at .0001 allocation efficiency (3 orders of mag. more than IPng requirement)
- Minimizes growth of per-packet header overhead
- Efficient for software processing on current CPU hardware

Proposals for variable-length, up to 160 bits

- Compatible with deployed OSI NSAP addressing plans
- Accommodates auto-configuration using IEEE 802 addresses
- Sufficient structure for projected number of service providers

Settled on fixed-length, 128-bit addresses

- (340,282,366,920,938,463,463,374,607,431,768,211,456 in all!)

IPv6 Technology Scope

IP Service	*IPv4 Solution*	*IPv6 Solution*
Addressing Range	32-bit, Network Address Translation	128-bit, Multiple Scopes
Autoconfiguration	DHCP	Serverless, Reconfiguration, DHCP
Security	IPSec	IPSec Mandated, works End-to-End
Mobility	Mobile IP	Mobile IP with Direct Routing
Quality-of-Service	Differentiated Service, Integrated Service	Differentiated Service, Integrated Service
IP Multicast	IGMP/PIM/Multicast BGP	MLD/PIM/Multicast BGP, Scope Identifier

Summary of Main IPv6 Benefits

- Expanded addressing capabilities
- Structured hierarchy to manage routing table growth
- Serverless autoconfiguration and reconfiguration
- Streamlined header format and flow identification
- Improved support for options / extensions

IPv6 Advanced Features

- Security - Built-in, strong IP-layer encryption and authentication
- Mobility - More efficient and robust mechanisms
- Quality of Service
- Privacy Extensions for Stateless Address Autoconfiguration (RFC 3041)
- Source address selection

How to get an IPv6 allocation?

```
Seans-MacBook-Pro:~ Sean$ ifconfig
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        options=3<RXCSUM,TXCSUM>
        inet6 ::1 prefixlen 128
        inet 127.0.0.1 netmask 0xff000000
        inet6 fe80::1%lo0 prefixlen 64 scopeid 0x1
        nd6 options=1<PERFORMNUD>
gif0: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
stf0: flags=0<> mtu 1280
en0: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        options=b<RXCSUM,TXCSUM,VLAN_HWTAGGING>
        ether c8:bc:c8:a4:ec:84
        inet6 fe80::cabc:c8ff:fea4:ec84%en0 prefixlen 64 scopeid 0x4
        inet6 fd67:e15c:e04c:e71c:cabc:c8ff:fea4:ec84 prefixlen 64 autoconf
        inet6 fd67:e15c:e04c:e71c:f839:280:d4c1:840c prefixlen 64 autoconf temporary
        inet 192.168.69.101 netmask 0xffffff00 broadcast 192.168.69.255
        nd6 options=1<PERFORMNUD>
        media: autoselect (1000baseT <full-duplex,flow-control>)
        status: active
en1: flags=8823<UP,BROADCAST,SMART,SIMPLEX,MULTICAST> mtu 1500
        ether c8:bc:c8:e6:a4:9a
        nd6 options=1<PERFORMNUD>
        media: autoselect (<unknown type>)
        status: inactive
fw0: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 4078
        lladdr dc:2b:61:ff:fe:e6:82:96
        nd6 options=1<PERFORMNUD>
        media: autoselect <full-duplex>
        status: inactive
p2p0: flags=8802<BROADCAST,SIMPLEX,MULTICAST> mtu 2304
        ether 0a:bc:c8:e6:a4:9a
        media: autoselect
        status: inactive
Seans-MacBook-Pro:~ Sean$
```

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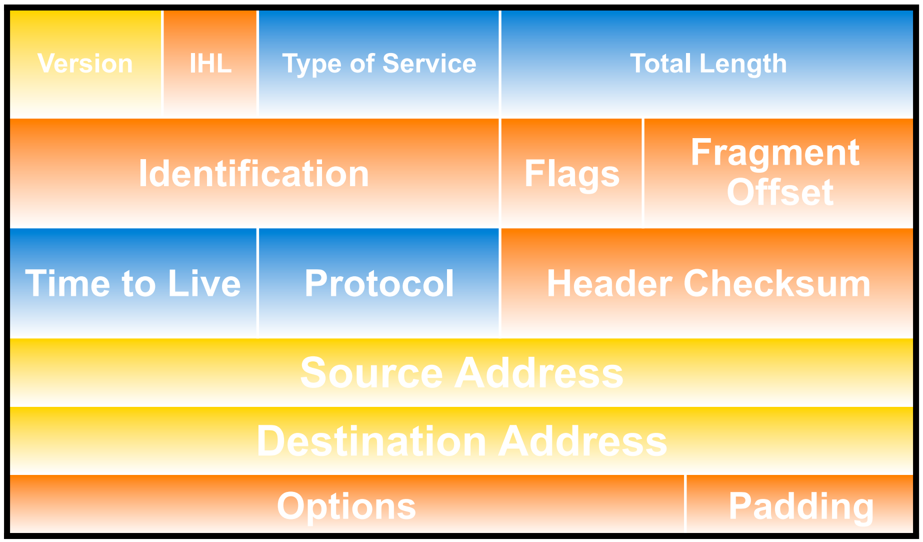
A New Header

IPv4 & IPv6 Header Comparison

IPv4 Header



IPv6 Header

Legend

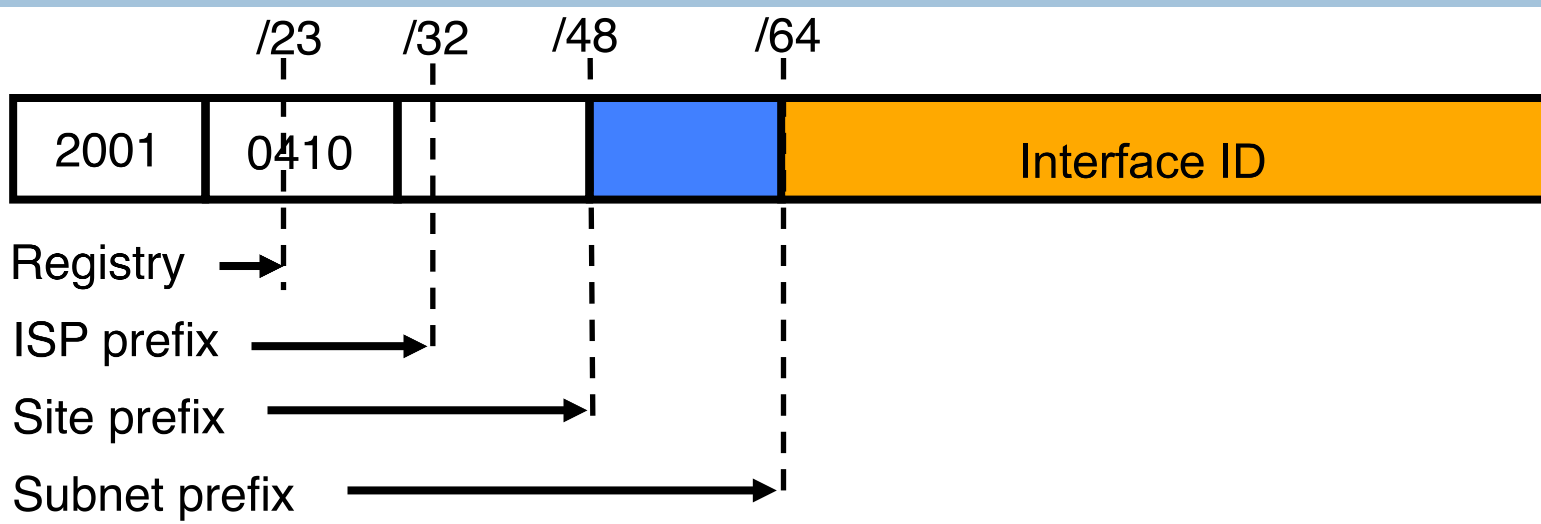
- field’s name kept from IPv4 to IPv6
- fields not kept in IPv6
- Name & position changed in IPv6
- New field in IPv6

Summary of Header Changes between IPv4 & IPv6

- Streamlined
  - Fragmentation fields moved out of base header
  - IP options moved out of base header
  - Header Checksum eliminated
  - Header Length field eliminated
  - Length field excludes IPv6 header
  - Alignment changed from 32 to 64 bits
- Revised
  - Time to Live ’ Hop Limit
  - Protocol ’ Next Header
  - Precedence & TOS ’ Traffic Class
  - Addresses increased 32 bits ’ 128 bits
- Extended
  - Flow Label field added

Addressing

Address Allocation



- The allocation process was recently updated by the registries:
  - IANA allocates from 2001::/16 to regional registries
  - Each regional registry allocation is a ::/23
  - ISP allocations from the regional registry is a ::/36 (immediate allocation) or ::/32 (initial allocation) or shorter with justification
  - Policy expectation that an ISP allocates a ::/48 prefix to each customer

Text Representation of Addresses

"Preferred" form: 1080:0:FF:0:8:800:200C:417A

Compressed form: FF01:0:0:0:0:0:0:43

becomes FF01::43

IPv4-mapped: 0:0:0:0:0:FFFF:10.1.68.3

or ::FFFF:10.1.68.3

IPv6 - Addressing Model

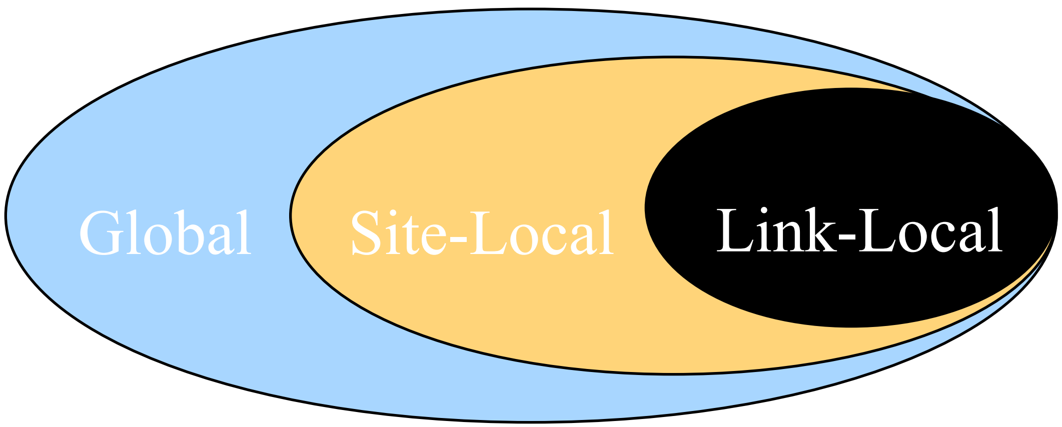
Addresses are assigned to interfaces

- change from IPv4 model :

Interface 'expected' to have multiple addresses

Addresses have scope

- Link Local
- Site Local
- Global



Addresses have lifetime

- Valid and Preferred lifetime

IPv6 Routing

IPv6 routing

IPv6 still uses the longest-prefix match routing algorithm.

- RIPv2, supports split-horizon with poisoned reverse (RFC 2080)
- OSPFv3 (RFC 2740)
- ISIS (draft-ietf-isis-ipv6-02)
- BGP4+ (RFC 2858 and RFC 2545)

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Security

IPv6 Security

- All implementations required to support authentication and encryption headers ("IPsec")
- Authentication separate from encryption for use in situations where encryption is prohibited or prohibitively expensive
- Key distribution protocols are under development (independent of IP v4/v6)
- Support for manual key configuration required

Quality of Service

IP Quality of Service Approaches

Two basic approaches developed by IETF:

- "Differentiated Service" (diff-serv)
  - coarse-grain (per-class), qualitative promises (e.g., higher priority), no explicit signaling
- "Integrated Service" (int-serv)
  - fine-grain (per-flow), quantitative promises (e.g., x bits per second), uses RSVP signaling

IPv6 Support for Diff-Serv

8-bit Traffic Class field to identify specific classes of packets needing special QoS

- same as dscp definition of IPv4 Type-of-Service byte
- may be initialized by source or by router enroute; may be rewritten by routers enroute
- traffic Class value of 0 used when no special QoS requested (the common case today)

Mobility

IPv6 Mobility

- Mobile hosts have one or more home address
  - relatively stable; associated with host name in DNS
- A Host will acquire a care-of address when it discovers it is in a foreign subnet (i.e., not its home subnet)
  - uses auto-configuration or local policy to get the address
  - registers the care-of address with a home agent, i.e, a router on its home subnet
- Packets sent to the mobile's home address(es) are intercepted by home agent and forwarded to the care-of address, using encapsulation
- Mobile IPv6 hosts sends binding-updates to correspondent to remove home agent from flow

Serverless Autoconfiguration ("Plug&Play")

- Hosts generally will construct addresses from RA:
  - subnet prefix(es) learned from periodic multicast advertisements from neighboring router(s)
  - interface IDs generated locally
  - MAC addresses : pseudo-random temporary
- Other IP-layer parameters also learned from router adverts (e.g., router addresses, recommended hop limit, etc.)
- Higher-layer info (e.g., DNS server and NTP server addresses) discovered by multicast / anycast-based service-location protocol [details being worked out]
- DHCP is available for those who want explicit control

Auto-Reconfiguration ("Renumbering")

- New address prefixes can be introduced, and old ones withdrawn
  - we assume some overlap period between old and new,
    i.e., no "flash cut-over"
  - hosts learn prefix lifetimes and preference order from router advertisements
  - old TCP connections can survive until end of overlap; new TCP connections use longest preferred lifetime
- Router renumbering protocol, to allow domain-interior routers to learn of prefix introduction / withdrawal

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Lack of demand

- There is no shortage of v4 space
- The only people who ask about IPv6 are people who have heard something about it
- IPv6 exhibits no added functionality over IPv4 + NAT
  - True for client/server apps with server on public side
  - False for peer-to-peer apps & servers behind nat

Deployments

- IPv6 deployments will occur piecewise from the edge.
  - Core infrastructure only moving when significant customer usage demands it.
  - Consumers should never be exposed to which protocol they are running, so demand will be implicit.
  - Platforms and products that are updated first need to address the lack of ubiquity. Whenever possible, devices and applications should be capable of both IPv4 & IPv6, to minimize the delays and potential failures inherent in translation points.

Routing

- IPv6 routing will change drastically before it becomes production
- Routing is still a big problem in IPv6
  - IPv6 allocations and routing are cidr based; massive aggregation through new allocations; <12k origin AS's for explicit policy
  - - only problem is providers punching holes in their aggregates

Interface IDs

- IPv6 has many privacy issues because it uses an interface ID derived from hardware
  - Lowest-order 64-bit field of unicast address may be assigned in several different ways:
  - auto-configured from a 64-bit EUI-64, or expanded from a 48-bit MAC address (e.g., Ethernet address)
  - auto-generated pseudo-random number RFC3041
    - (specifically designed to address privacy concerns)
  - assigned via DHCP
  - manually configured
  - possibly other methods in the future (crypto derived)

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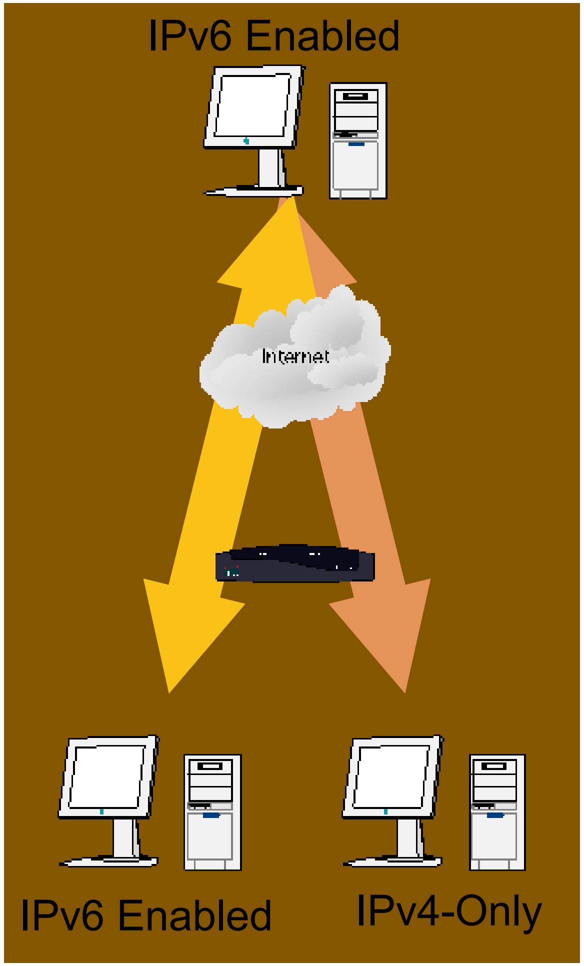
IPv4-IPv6 Transition / Co-Existence

A wide range of techniques have been identified and implemented, basically falling into three categories:

- (1) Dual-stack techniques, to allow IPv4 and IPv6 to co-exist in the same devices and networks
- (2) Tunneling techniques, to avoid order dependencies when upgrading hosts, routers, or regions
- (3) Translation techniques, to allow IPv6-only devices to communicate with IPv4-only devices

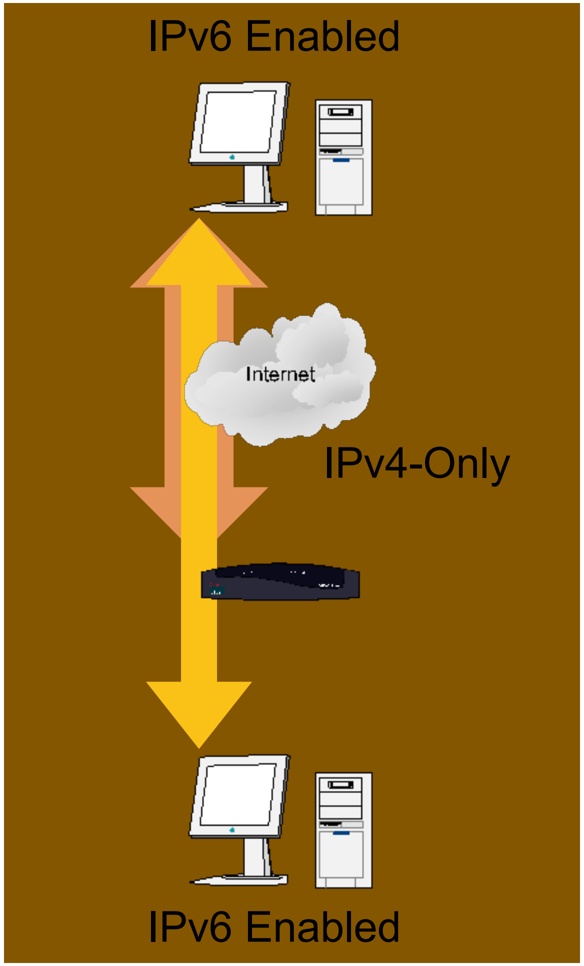
Expect all of these to be used, in combination

Tools – Dual Stack



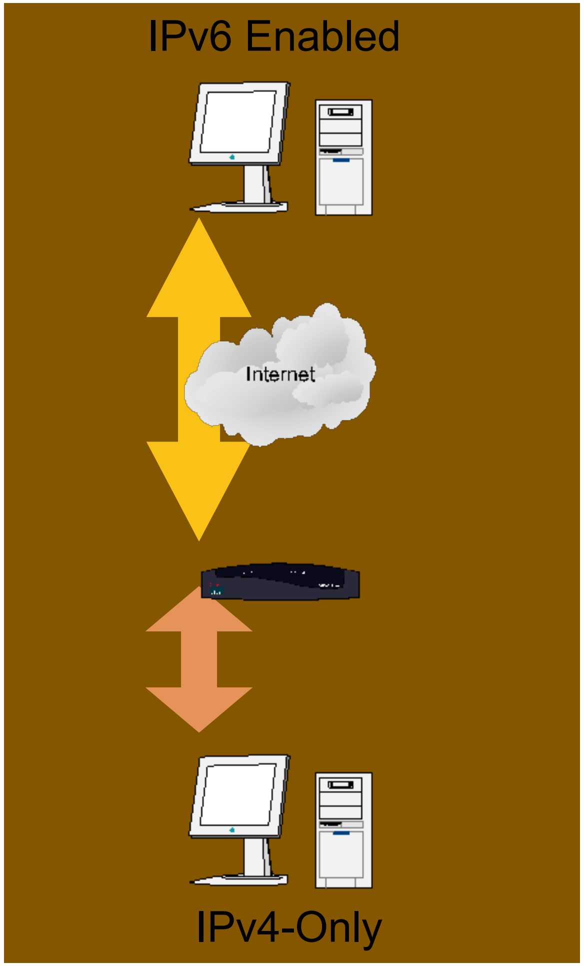
- Primary tool
- Allows continued 'normal' operation with IPv4-only nodes
- Address selection rules generally prefer IPv6
- DSTM variant allows temporary use of IPv4 pool

Tools – Tunneling



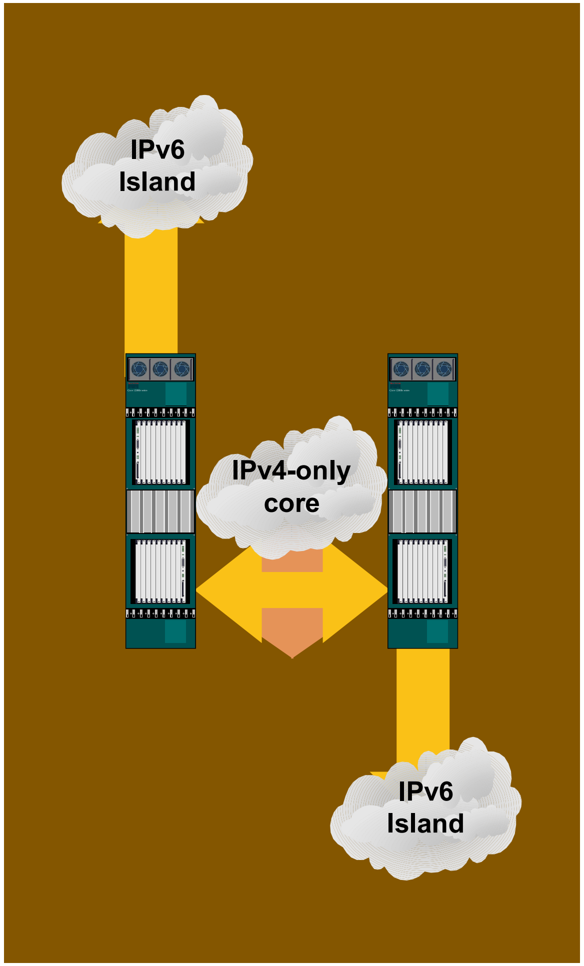
- Nodes view IPv4 network as a logical NBMA link-layer
- May be used in conjunction with dual-stack

Tools – Translation



- Allows for the case where some components are IPv6-only while others are IPv4-only
- Tool of last resort
- Pay attention to scaling properties
- Same application issues as IPv4/IPv4 translation

Tools – BGP tunnel



- Service provider can incrementally upgrade PE routers with active customers
- Sites are connected to Dual Stack MP-BGP-speaking edge router
- Transport across the IPv4 core can be any tunneling mechanism