IPv6 Deployment Concepts

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Outline

- Review of basics
- Environment descriptions
- Tools appropriate for each environment

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Review

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Do We Really Need a Larger Address Space?

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- 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 millions 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

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IP Address Allocation History

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1981 - IPv4 protocol published

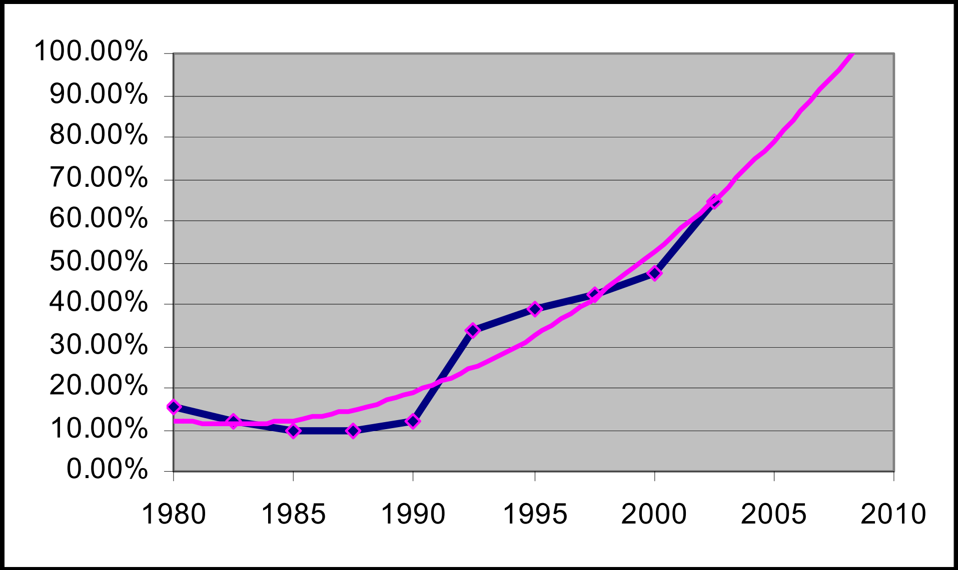
1985 ~ 1/16 of total space

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)

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Explosion of New Internet Appliances

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IPv6 Timeline
(A pragmatic projection)

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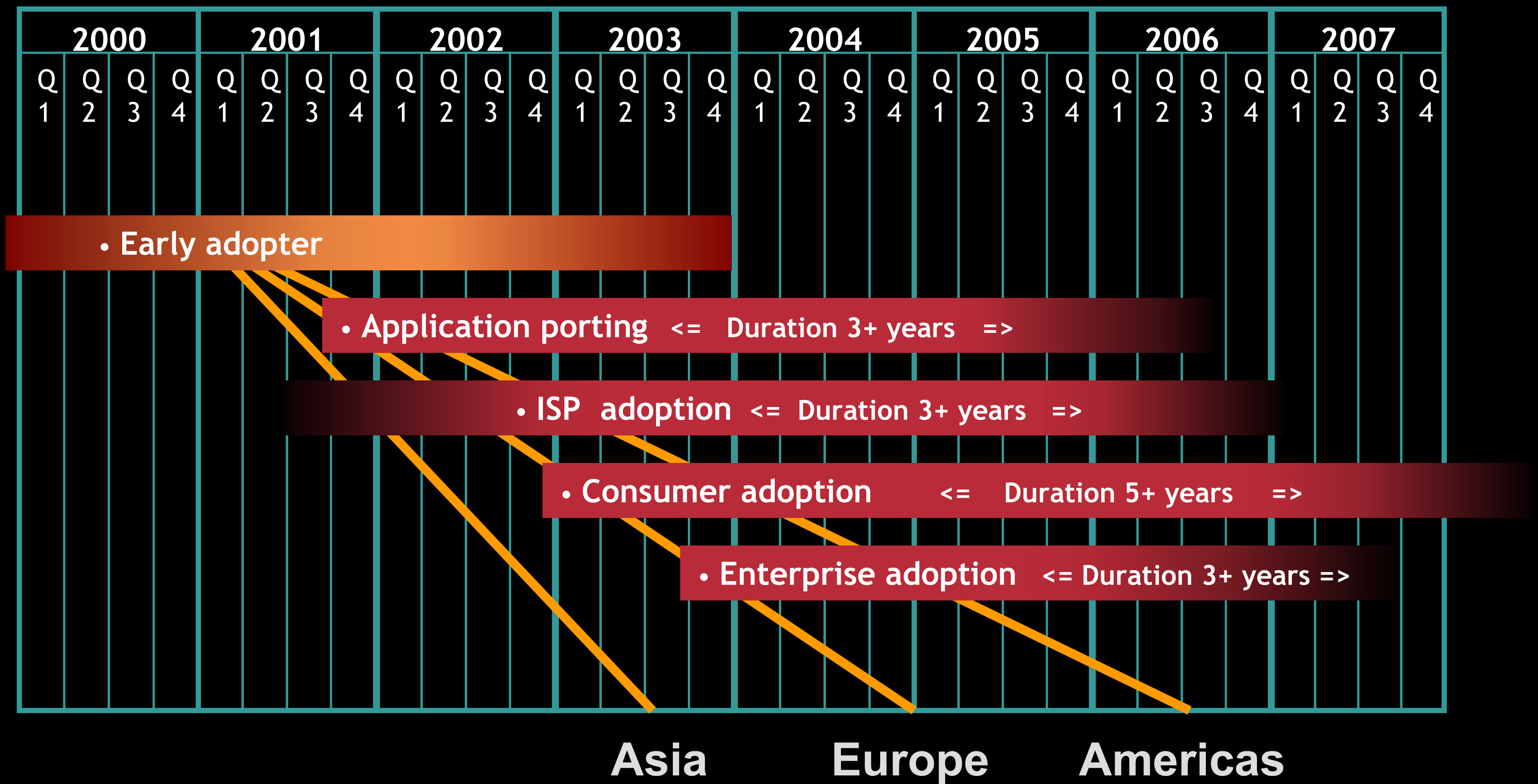

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IPv6 Technology Scope

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

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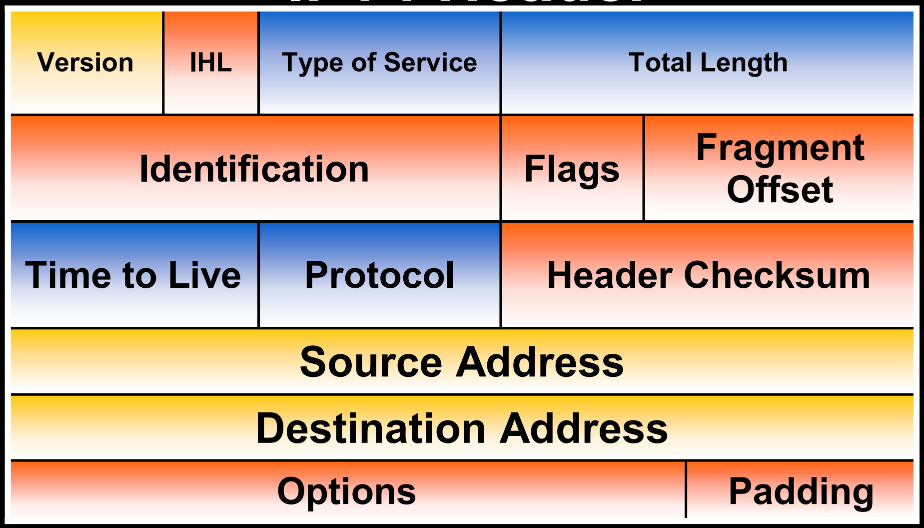
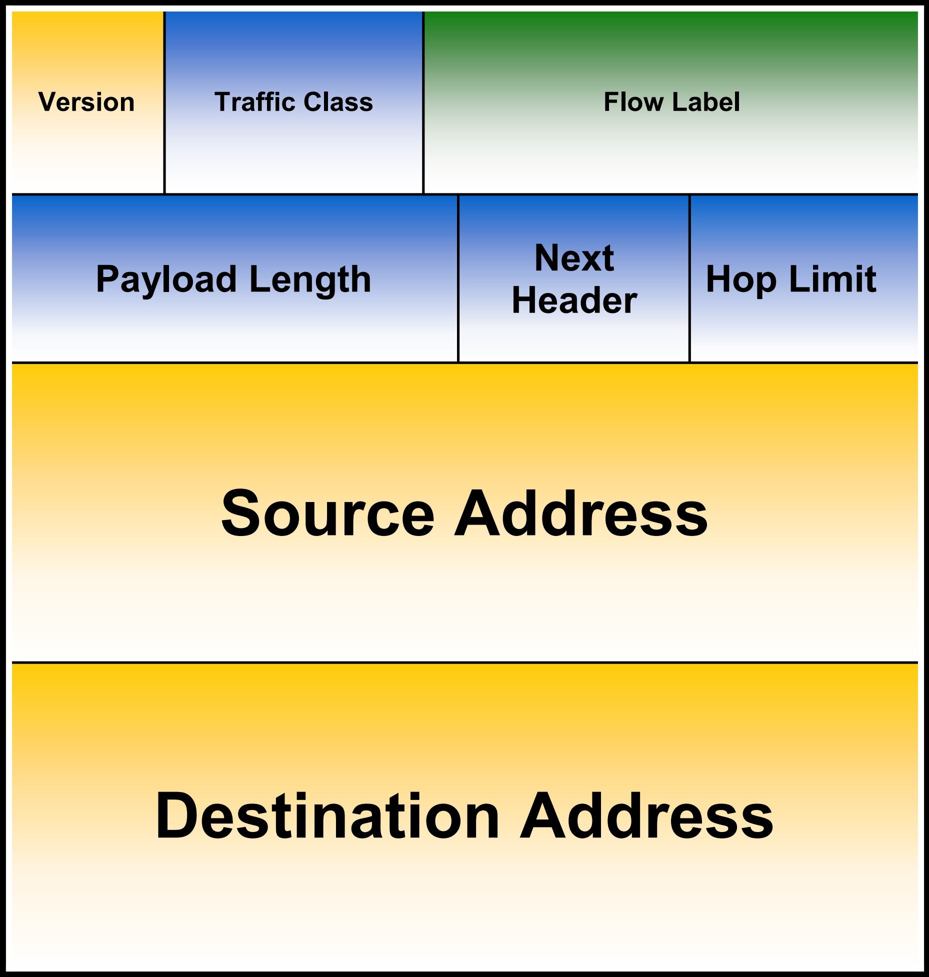
IPv4 & IPv6 Header Comparison

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

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IPv6 - Addressing Model

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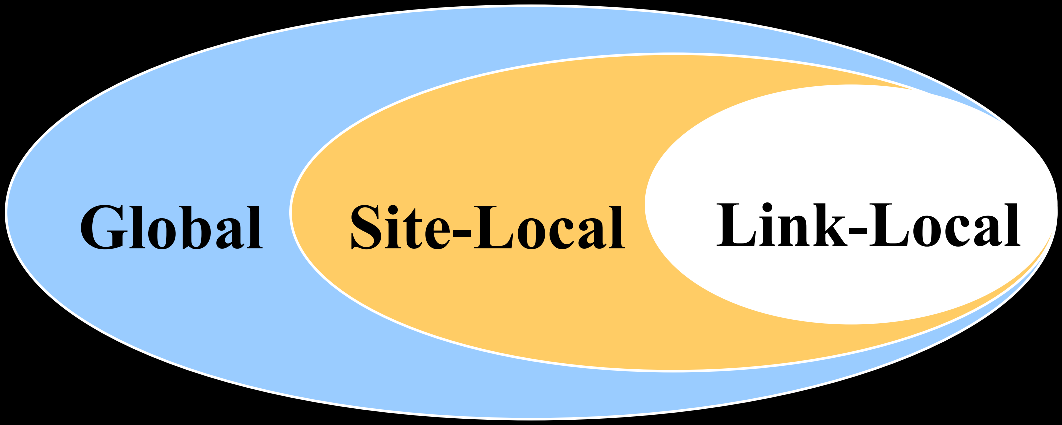
- Addresses are assigned to interfaces
  - change from IPv4 model :
- Interface 'expected' to have multiple addresses

- Addresses have scope
  - Link Local
  - Site Local
  - Global



- Addresses have lifetime
  - Valid and Preferred lifetime

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Interface Address set

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- Loopback (only assigned to a single interface per node)
- Link local (required on all interfaces)
- Site local
- Auto-configured 6to4 (if IPv4 public is address available)
- Auto-configured IPv4 compatible (operationally discouraged)
- Solicited node Multicast (required for neighbor discovery)
- All node multicast
- Global anonymous
- Global published

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Unicast Address Formats

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Link Local

FP (10bits)	RESERVED (54bits)	Interface ID (64bits)
1111111010	MUST be 0	MAC derived

Site Local

FP (10bits)	Subnet (38bits)	Subnet (16bits)	Interface ID (64bits)
1111111011	Locally Administered	Locally Administered	MAC derived or Locally Administered

Global

FP (3bits)	Registry / provider assigned (45bits)	Subnet (16bits)	Interface ID (64bits)
001	Provider Administered	Locally Administered	MAC derived or Locally Administered or Random

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Tunneling Unicast Address Formats

Compatible

FP (96bits)	IPv4 ID (32bits)
MUST be 0	Locally administered

6to4

FP (16bits)	IPv4 (32bits)	SLA (16bits)	Interface ID (64bits)
00100010	Provider Administered	Locally Administered	MAC derived or Locally Administered or Random

ISATAP

Any (48bits)	SLA (16bits)	Interface ID (64bits)
Provider Administered	Locally Administered	IPv4 derived

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Multicast Address Format

FP (8bits)	Flags (4bits)	Scope (4bits)	RESERVED (80bits)	Group ID (32bits)
11111111	000T	Lcl/Sit/Gbl	MUST be 0	Locally administered

- **flag field**

  low-order bit indicates permanent/transient group

  (three other flags reserved)

- **scope field:**

  1 - node local
  2 - link-local
  5 - site-local
  8 - organization-local
  B - community-local
  E - global

  (all other values reserved)

- map IPv6 multicast addresses directly into low order 32 bits of the IEEE 802 MAC

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Multicast Address Format Unicast-Prefix based

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FP (8bits)	Flags (4bits)	Scope (4bits)	reserved (8bits)	plen (8bits)	Network Prefix (64bits)	Group ID (32bits)
11111 111	00PT	Lcl/Sit/Gbl	MUST be 0	Locally administered	Unicast prefix	Auto configured

- P = 1 indicates a multicast address that is assigned based on the network prefix
- plen indicates the actual length of the network prefix
- Source-specific multicast addresses is accomplished by setting
  P = 1
  plen = 0
  network prefix = 0

draft-ietf-ipngwg-uni-based-mcast-01.txt

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ICMP / ND Walkthrough

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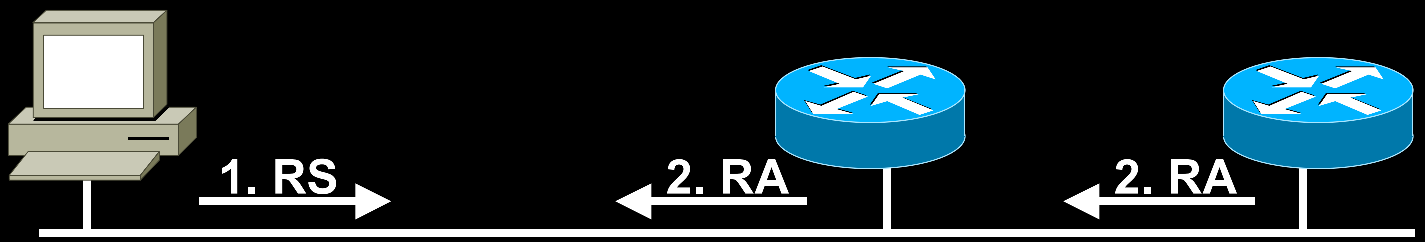
ND Autoconfiguration, Prefix & Parameter Discovery



1. RS:

ICMP Type = 133

Src = ::

Dst = All-Routers multicast Address

query= please send RA

2. RA:

ICMP Type = 134

Src = Router Link-local Address

Dst = All-nodes multicast address

Data= options, prefix, lifetime, autoconfig flag

- Router solicitation are sent by booting nodes to request RAs for configuring the interfaces.

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ND Address Resolution & Neighbor Unreachability Detection

ICMP type = 135 (NS)
Src = A
Dst = Solicited-node multicast of B
Data = link-layer address of A
Query = what is your link address?

ICMP type = 136 (NA)
Src = B
Dst = A
Data = link-layer address of B

A and B can now exchange packets on this link

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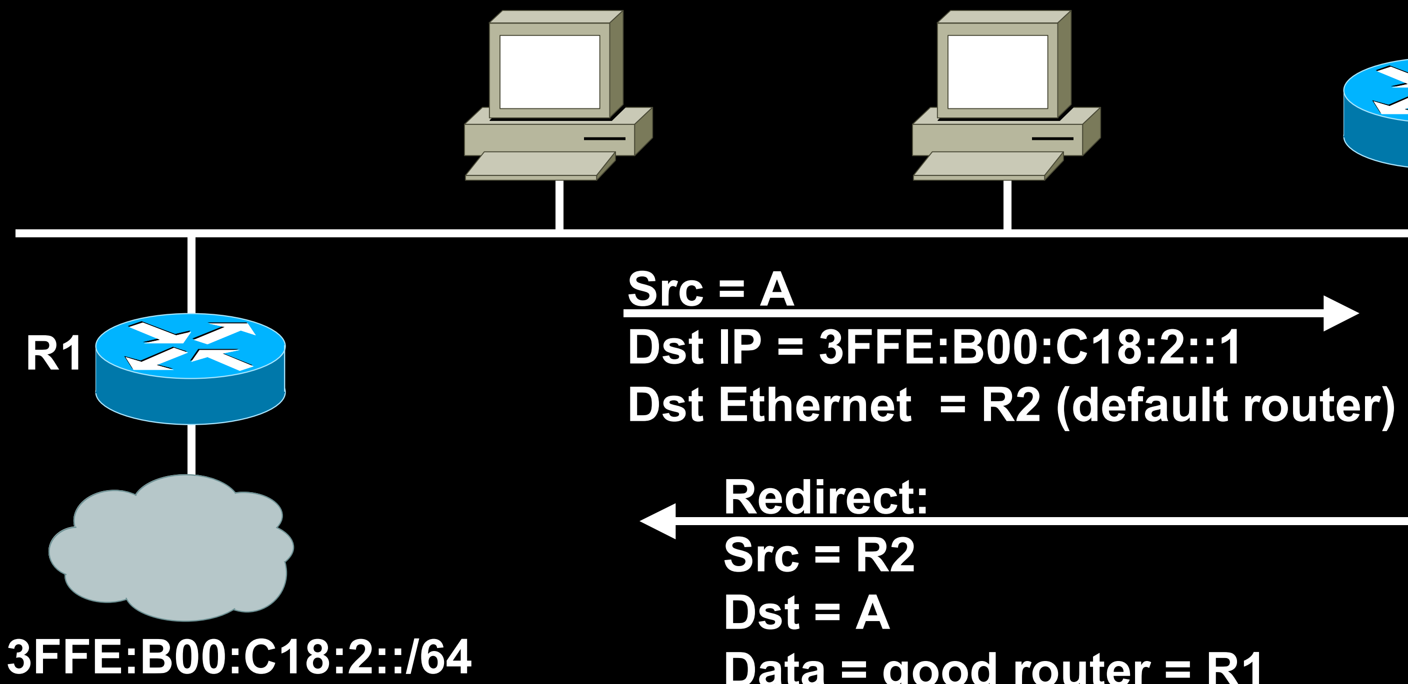
ND Redirect



- Redirect is used by a router to signal the reroute of a packet to an onlink host to a better router or to another host on the link

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- Review of basics
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Environments

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Transition environments

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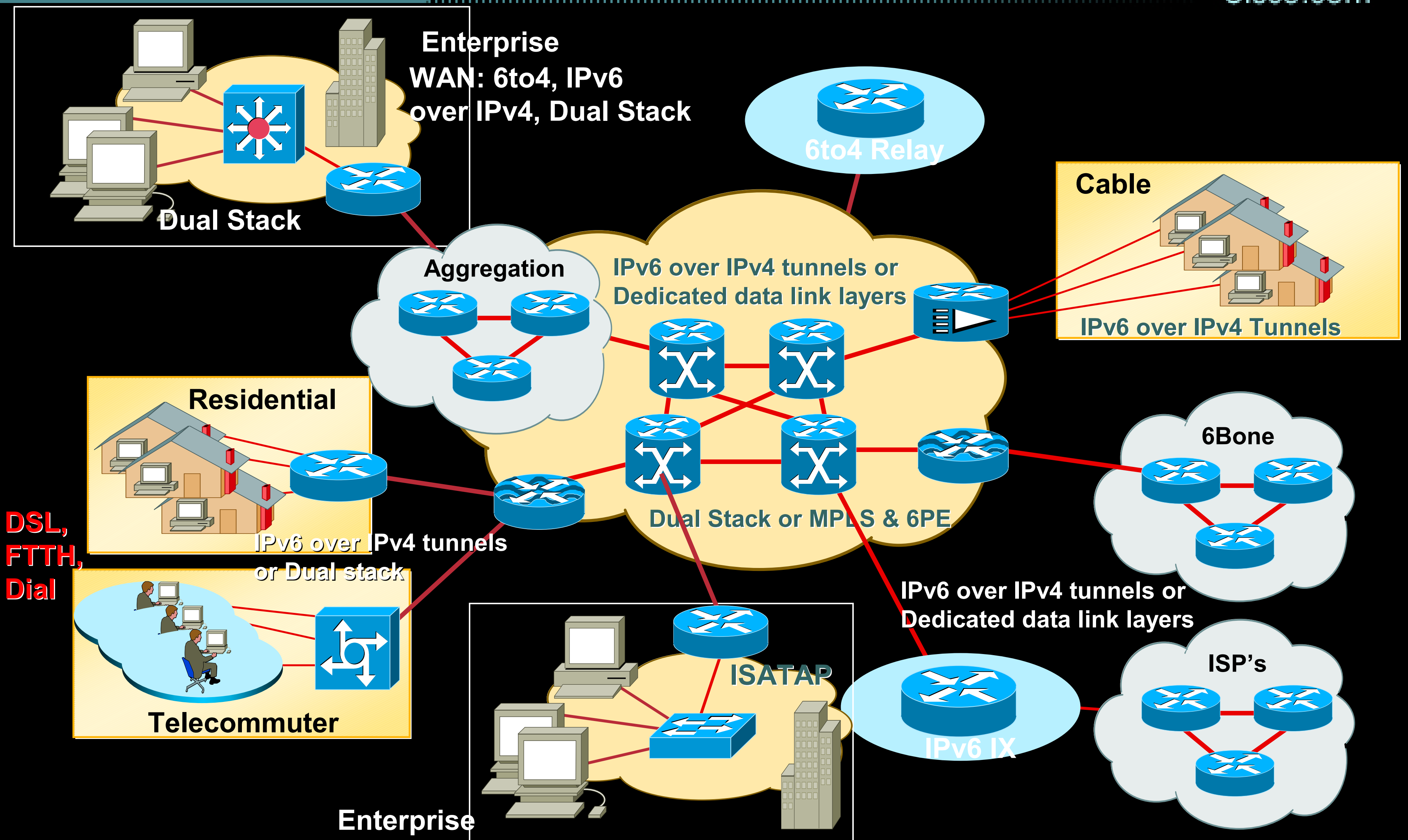

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Environments

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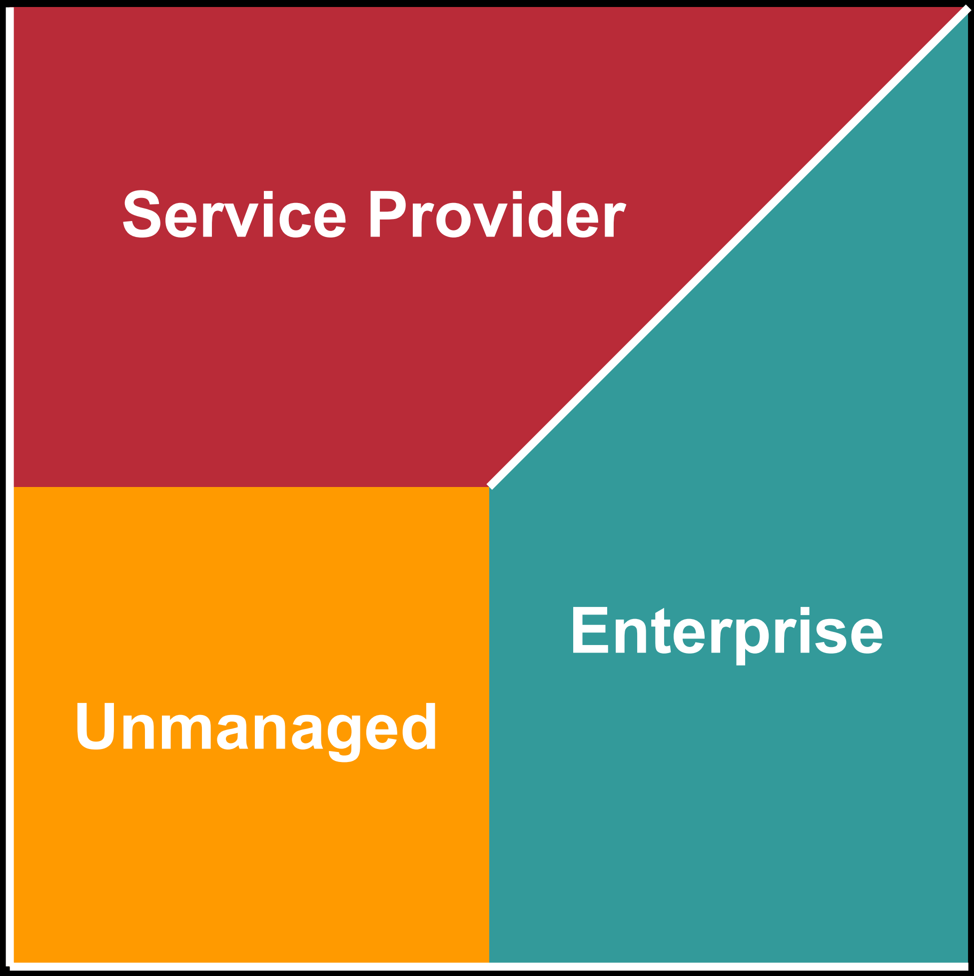

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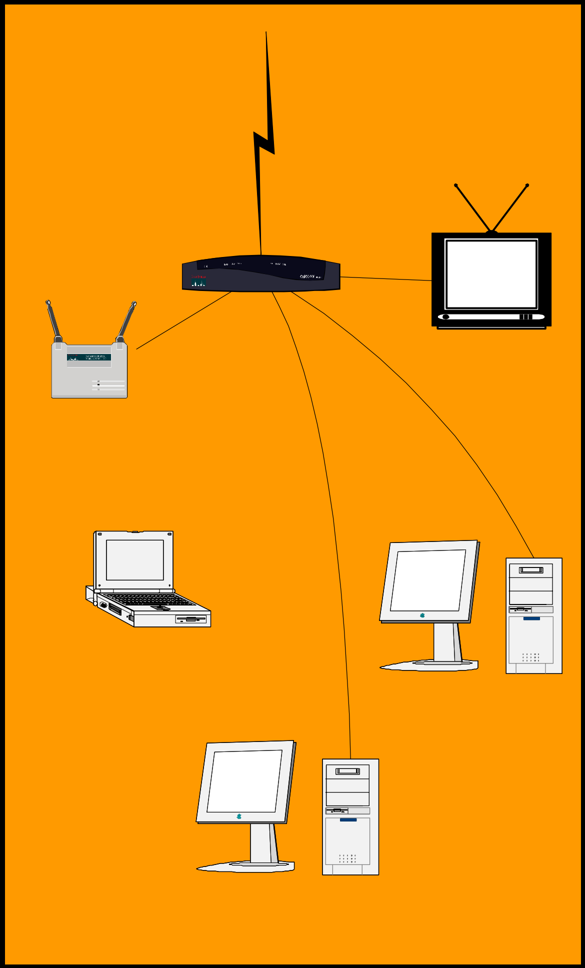
Environments – Unmanaged



- No administrative staff to manage configuration or policies
- Devices need to be plug-n-play appliances
- Network & hosts share administrative policies
- Tool automation a primary concern

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Issues

- ISP offers IPv6 service
    - Edge device acquires a prefix to redistribute
- ISP still IPv4-only service
    - (may be due to device limitations like docsis modems)
    - Tunneling required
    - Prefix from tunnel broker or automated 6to4/Teredo
- If no auto-tunnel to native relays, may need both

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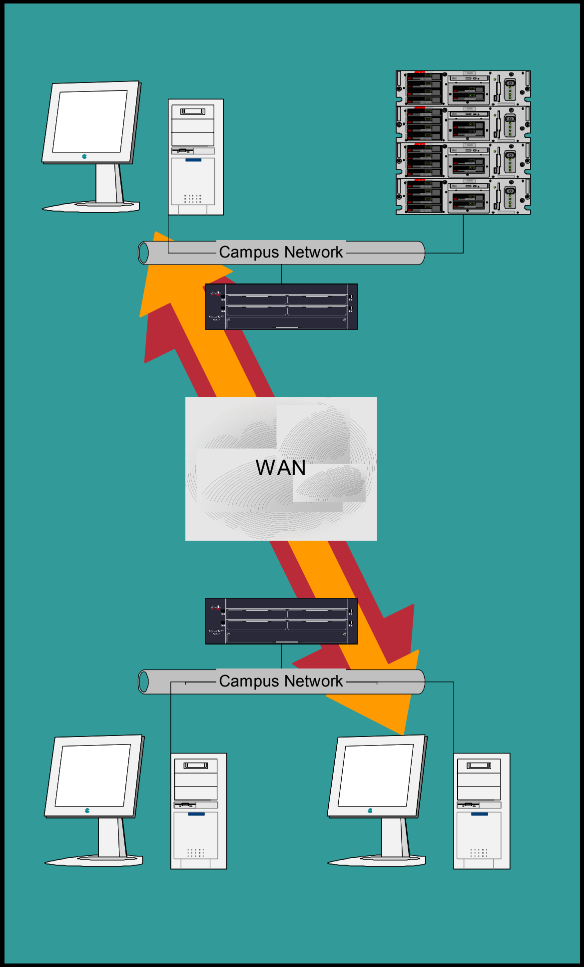
Environments – Managed Enterprise



- Dedicated management staff & tools
- Network & hosts share administrative policies
- Applications will likely require recertification

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Managed networks differentiation

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Single geographic region, single administration & policy

Multiple geographic regions, single administration & policy

Multiple geographic regions, multiple administrations & policy

Use of public network for transit service

- Simple routed case looks like multi-multi above
- VPN tunneled case would look like multi-single w/circuit setup

New enterprise, looking to avoid a transition

- Deployment order - All at once by definition

For each of the 5 categories consider

- Deployment order - Hosts & Apps first vs. Network first
- ISP offering - IPv4-only IPv4 & IPv6 IPv6-only

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Infrastructure concerns

- Critical Applications
- Addressing : Dynamic vs. controlled
- DNS : Dynamic vs. controlled
  Public visibility of name space
- AAA : Internal & external
  Mobility of road warrior & telecommuters
  Mobility of nodes within the enterprise
- ICMP : PMTU & neighbor discovery
- Management tools
  Trust between host & network management teams

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Multiple Address Issues

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- Renumbering simplified as old & new can overlap
- Privacy addresses reduce attack profile
- Preferred vs. valid lifetimes
  - Improper configuration could lead to 100's per interface
- Diagnostics require more effort
- TE via addressing limits multi-homing flexibility
- Site-local allows internal stability

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Routing Issues

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- Allocations of ::/48 should allow self aggregation by organizations with multiple IPv4 prefixes
- Tunneling
  - Decouples network from end system deployment
  - Multicast less efficient
- Native service
  - May require hardware upgrades

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Environments – Managed Service Provider

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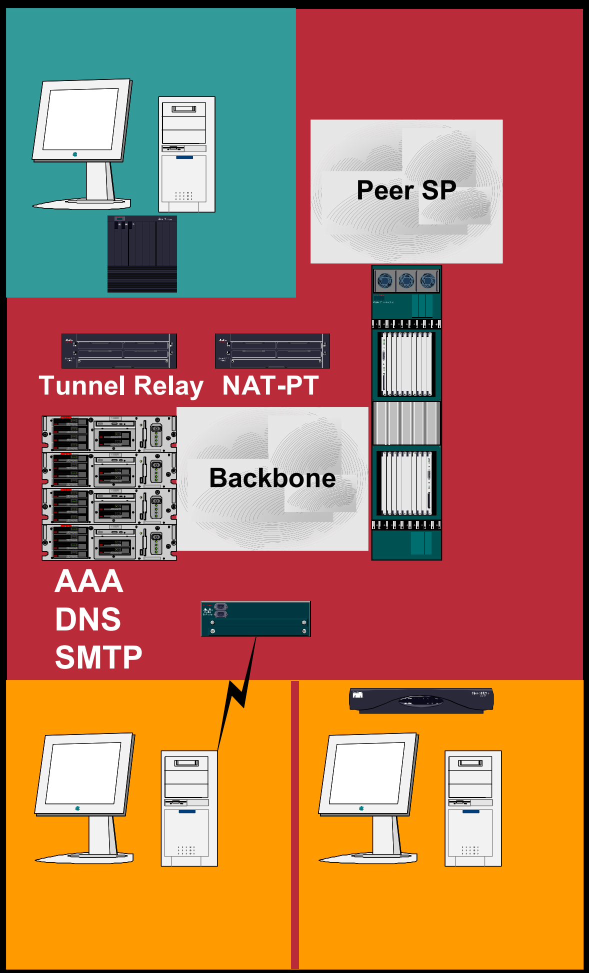

- Dedicated management staff & tools
- Network has different administrative policies than connected hosts or networks
- Interaction with Peer networks may require translation
- Services as Dual-stack
- Distributed tunnel relay service minimizes overhead

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Address Allocation Issues

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- From Regional Registries
  - ::/32 minimum
    - HD ratio based on .8 utilization of ::/48s
- To Customers
  - ::/48 Prefix delegation via DHCPv6
    - (normal customer allocation)
  - ::/64 Prefix delegation via RA or DHCPv6
    - (for single subnet sites, ie: 802.11 hotspots)
- RFC 3041 addresses allow end system anonymity as they move between networks, but the allocated prefix still allows customer identification for LI conformance

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Routing Issues

- **Allocations should allow massive aggregation**
  - **Current allocation policy all PA based, so global BGP table should approach number of origin AS's**
- **Multi-homed sites still an unsolved problem**

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DNS Issues

- Dual-stack servers
- Consistency of the client and referral chain
- IPv6 glue records
- Sub-domain delegation to consumer customers?

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SMTP Issues

- Dual-stack MTAs
- Consistency of clients and MX to A/AAAA mappings
- Broken DNS servers return 'nxdomain' for missing AAAA

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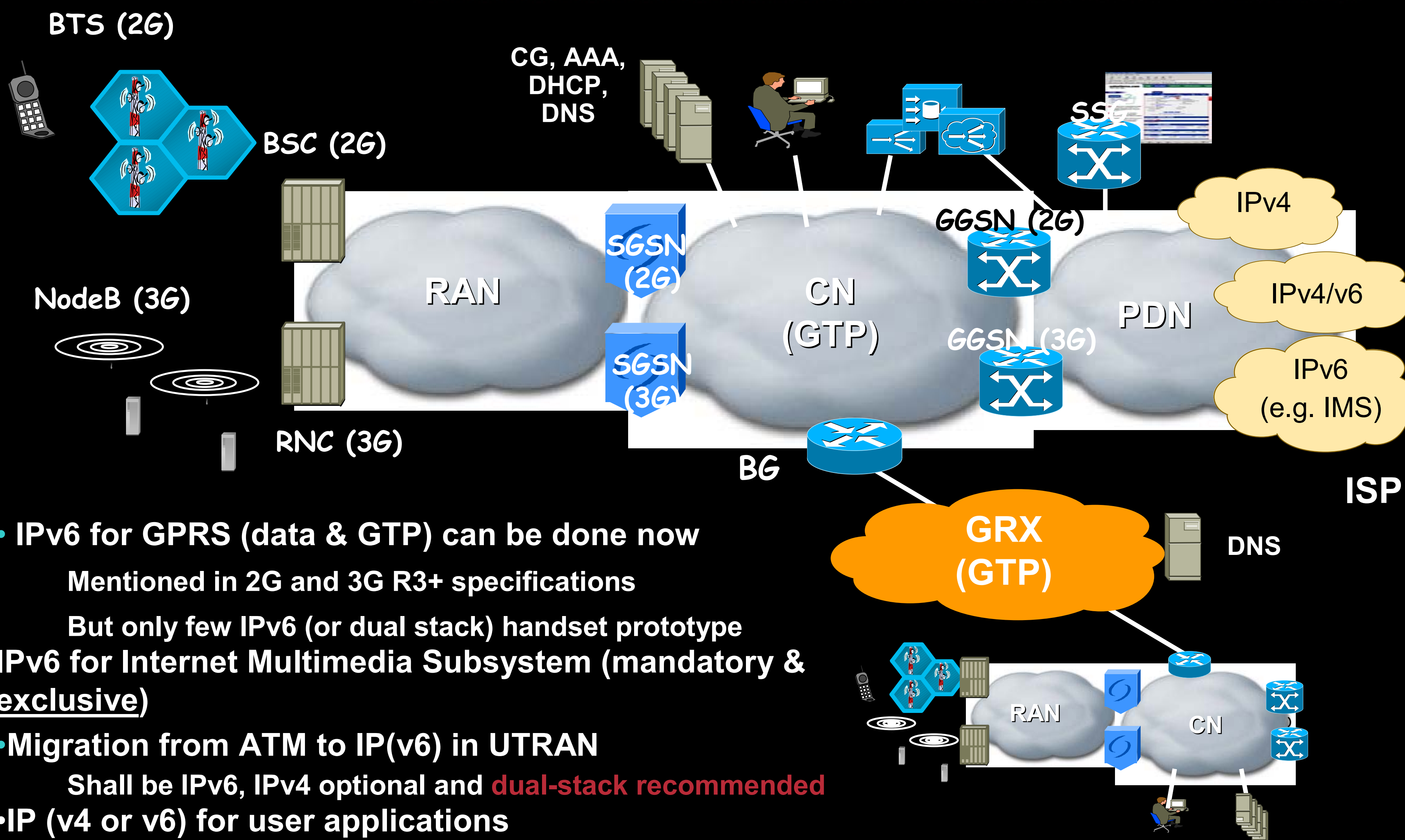
3GPP Mobile Wireless Network Architecture



- IPv6 for GPRS (data & GTP) can be done now
  - Mentioned in 2G and 3G R3+ specifications
  - But only few IPv6 (or dual stack) handset prototype
- IPv6 for Internet Multimedia Subsystem (mandatory & <u>exclusive</u>)
- Migration from ATM to IP(v6) in UTRAN
  - Shall be IPv6, IPv4 optional and dual-stack recommended
- IP (v4 or v6) for user applications

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Issues

- Independent PDP contexts for each version
- Desire to avoid DAD over expensive air link

  Only possible when air link end point has full control of a ::/64 or shorter prefix

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Outline

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- Review of basics
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Deployment tool set

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Transition Variables

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- Business Requirements
  - Time frame required to meet a set of business requirements
  - Need for applications to communicate between administrative domains
  - New functions that can exist without extensive access to legacy IPv4 nodes
  - Mission critical applications that must interoperate with legacy nodes
- Network Security Requirements
  - Firewall support for both IPv4 & IPv6
  - Telecommuters and Mobile Node access methods
- Availability of software & hardware upgrades for existing nodes
  - Source code availability for custom applications
- Order and rate for IPv6 deployment within a network
  - Current use of IPv4 private addresses and NAT
  - Provider support for IPv6

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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

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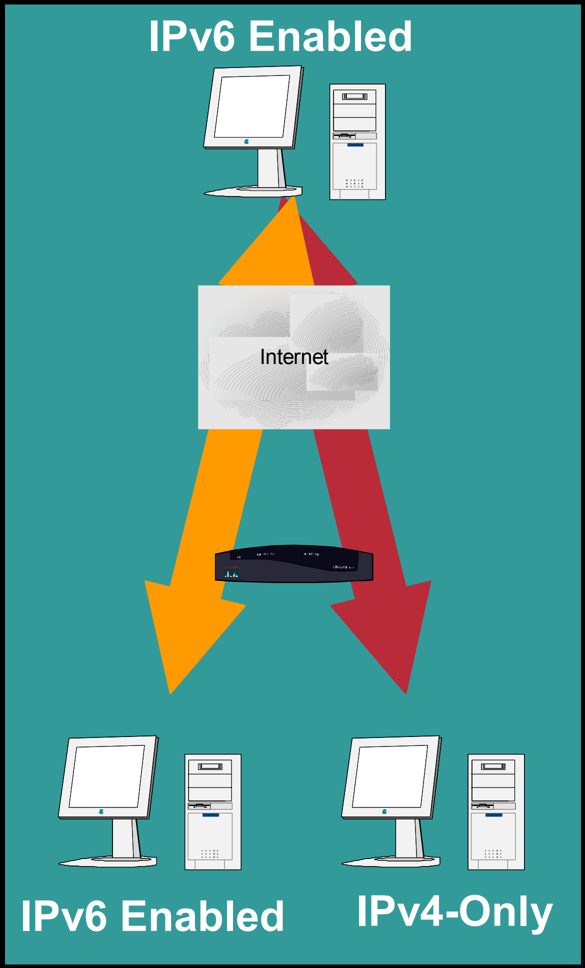
Tools – Dual Stack



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

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Dual-Stack Approach

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- When adding IPv6 to a system, do not delete IPv4
  - this multi-protocol approach is familiar and well-understood (e.g., for AppleTalk, IPX, etc.)
  - note: in most cases, IPv6 will be bundled with new OS releases, not an extra-cost add-on
- Applications (or libraries) choose IP version to use
  - when initiating, based on DNS response:
    - Prefer scope match first, when equal IPv6 over IPv4
  - when responding, based on version of initiating packet
- This allows indefinite co-existence of IPv4 and IPv6, and gradual app-by-app upgrades to IPv6 usage

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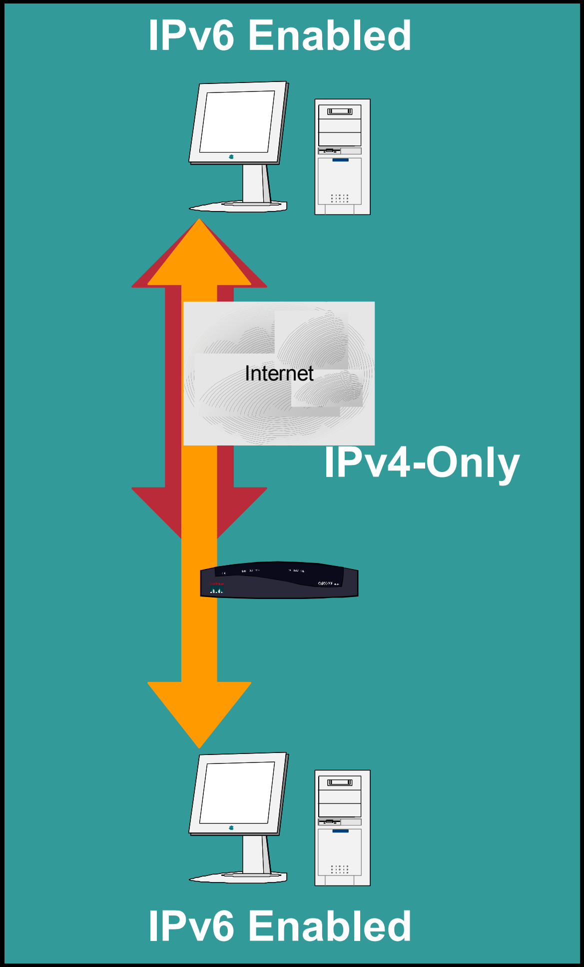
Tools – Tunneling



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

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Tunneling issues

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- IPv4 fragmentation needs to be reconstructed at tunnel endpoint.
- No translation of Path MTU messages between IPv4 & IPv6.
- Translating IPv4 ICMP messages and pass back to IPv6 originator.
- May result in an inefficient topology.

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Tunneling issues II

- **Tunnel interface is always up. Use routing protocol to determine link failures.**
- **Be careful with using the same IPv4 source address for several tunneling mechanisms. Demultiplexing incoming packets is difficult.**

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IPv6 over IPv4 Tunnels

- Several Tunnelling mechanisms defined by IETF
  - Apply to ISP and Enterprise WAN networks
    - GRE, Configured Tunnels, Automatic Tunnels using IPv4 compatible IPv6 Address, 6to4
  - Apply to Campus
    - ISATAP, 6over4
- No impact on Core infrastructure
  - Either IPv4 or MPLS

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Tunnels to Get Through IPv6-Ignorant Routers

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- Encapsulate IPv6 packets inside IPv4 packets (or MPLS frames)
- Many methods exist for establishing tunnels:
  - manual configuration
  - "tunnel brokers" (using web-based service to create a tunnel)
  - automatic (depricated, using IPv4 as low 32bits of IPv6)
  - "6-over-4" (intra-domain, using IPv4 multicast as virtual LAN)
  - "6-to-4" (inter-domain, using IPv4 addr as IPv6 site prefix)
- Can view this as:
  - IPv6 using IPv4 as a virtual NBMA link-layer, or
  - an IPv6 VPN (virtual public network), over the IPv4 Internet

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Tunneling Mechanisms (operationally challenging)

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- Configured
  - Prearranged addresses for both IPv4 & IPv6, manually configured
- Tunnel Broker
  - Builds on configured tunnel via IPv4 auth scheme to establish mapping ; typically default route
- 6over4
  - Any address, but requires IPv4 multicast for ND
- Automatic
  - Host-to-host – IPv4 address embedded in low 32 bits with prefix ::/96
  - Requires injecting IPv4 BGP table into IPv6 routing

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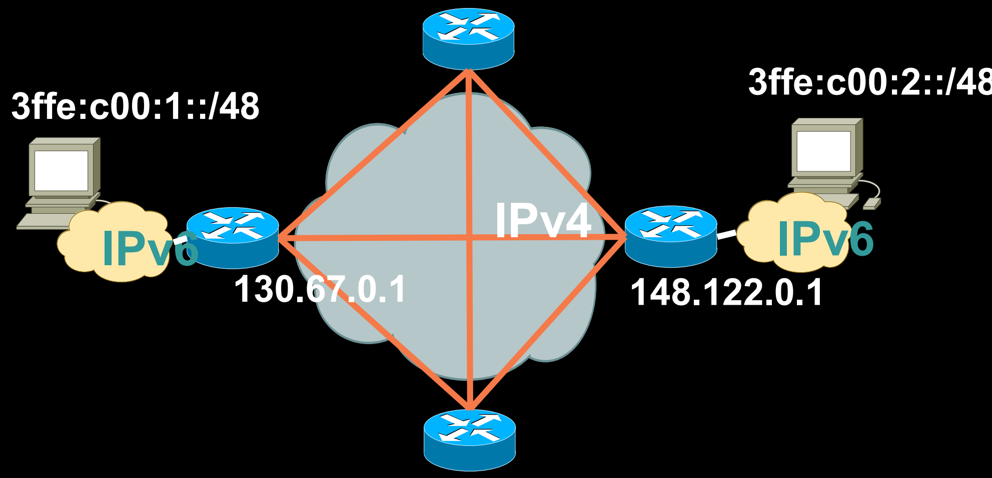
Configured tunnels



Pros	Cons
As point to point links	Has to be configured and managed
Multicast	Inefficient traffic patterns
	No keepalive mechanism, interface is always up

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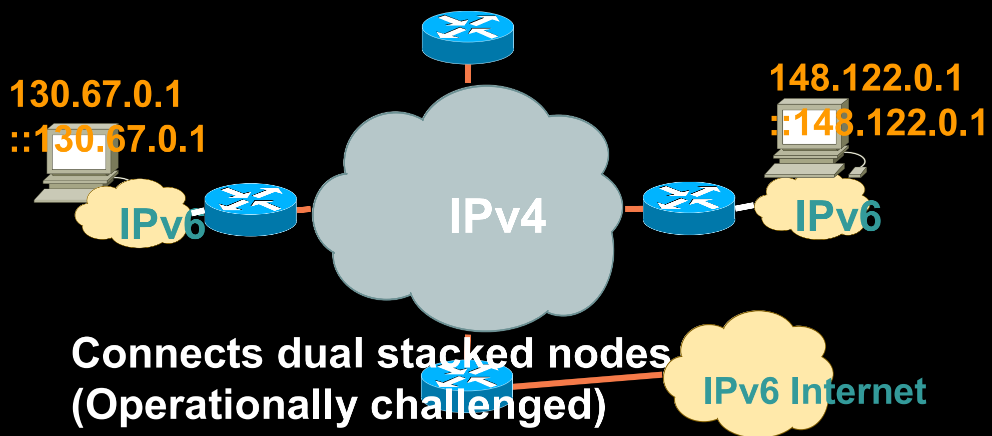
Automatic tunnels

0	IPv4 Address (32bits)
Defined	ISP assigned



Connects dual stacked nodes
(Operationally challenged)

Pros	Cons
Useful for some other mechanisms, like BGP tunnels	Difficult to reach the native IPv6 Internet, without injecting IPv4 routing information in the IPv6 routing table

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Tunneling Mechanisms (primary set)

- **6to4**
  - Automatic prefix allocation based on public IPv4
- **ISATAP**
  - Intra-site automatic tunneling with any prefix
- **Teredo**
  - IPv6 over UDP/IPv4 to traverse NAT

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6to4 tunnels

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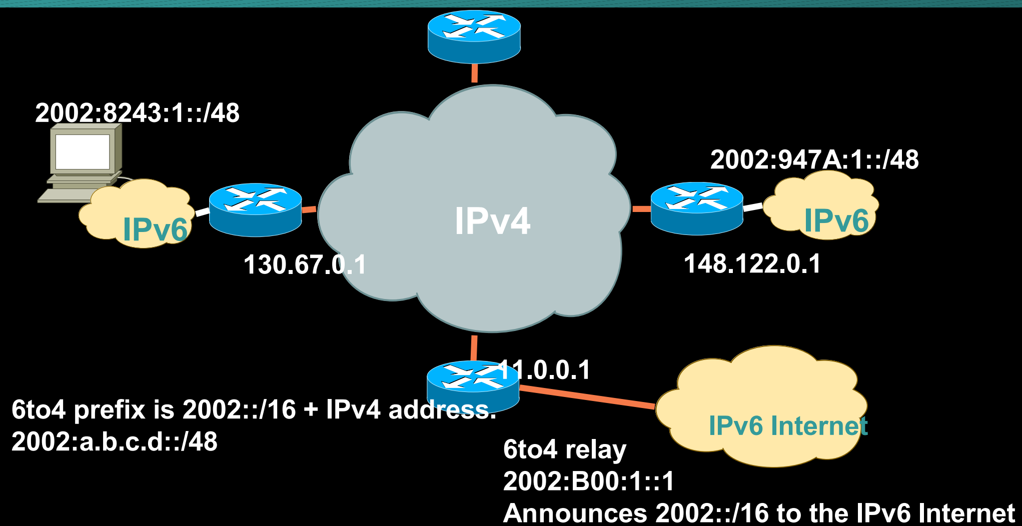
FP (3bits)	TLA (13bits)	IPv4 Address (32bits)	SLA ID (16bits)	Interface ID (64bits)
001	0x0002	ISP assigned	Locally administered	Auto configured



Pros	Cons
Works without adjacent native IPv6 routers	Requires relay router to reach native IPv6 Internet
Only site border router needs to know about 6to4	All issues that NMBA networks have.

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IPv6 over MPLS Infrastructure

- Some Service Providers have already deployed MPLS in their IPv4 backbone for various reasons
  - MPLS/VPN, MPLS/QoS, MPLS/TE, ATM + IP switching
- Several IPv6 over MPLS scenarios
  - IPv6 Tunnels configured on CE (no impact on MPLS)
  - IPv6 over Circuit_over_MPLS (no impact on IPv6)
  - IPv6 Provider Edge Router (6PE) over MPLS (no impact on MPLS core)
  - Native IPv6 MPLS (require full network upgrade)
- Upgrading software to IPv6 Provider Edge Router (6PE)
  - Low cost and risk as only the required Edge routers are upgraded or installed
  - Allows IPv6 Prefix delegation by ISP

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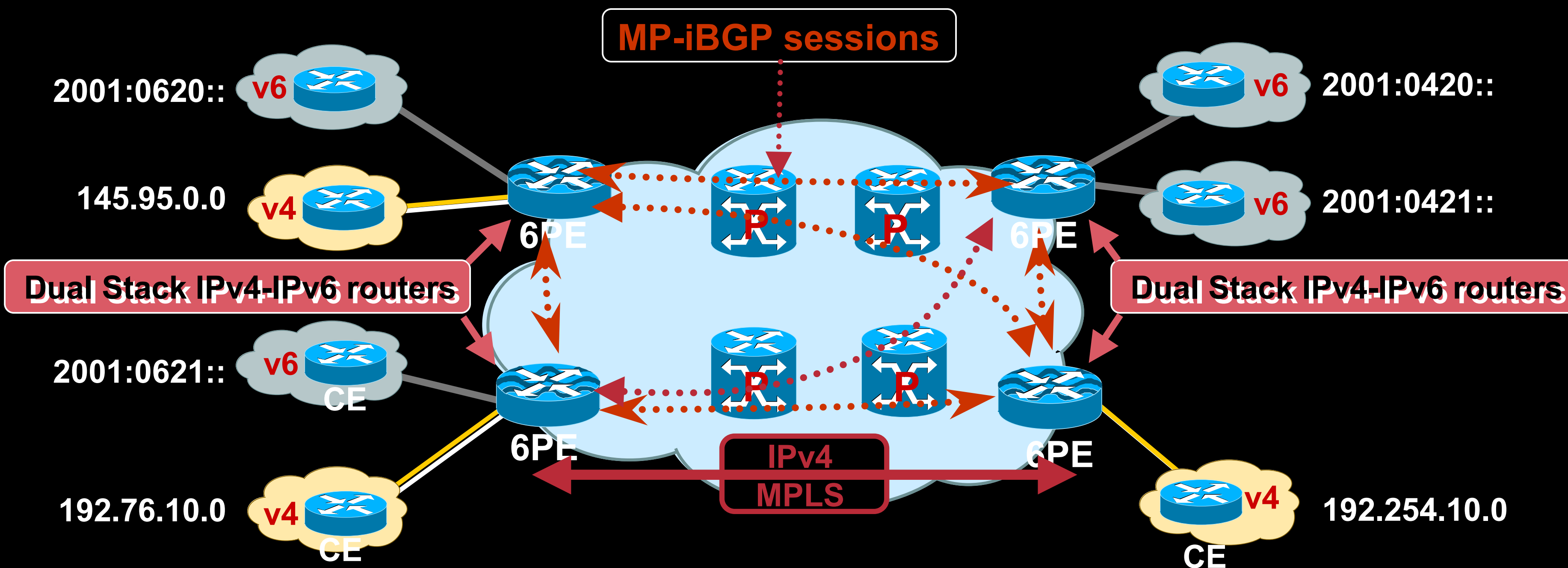
IPv6 Provider Edge Router (6PE) over MPLS



- IPv4 or MPLS Core Infrastructure is IPv6-unaware
- PEs are updated to support Dual Stack/6PE
- IPv6 reachability exchanged among 6PEs via iBGP (MP-BGP)
- IPv6 packets transported from 6PE to 6PE inside MPLS

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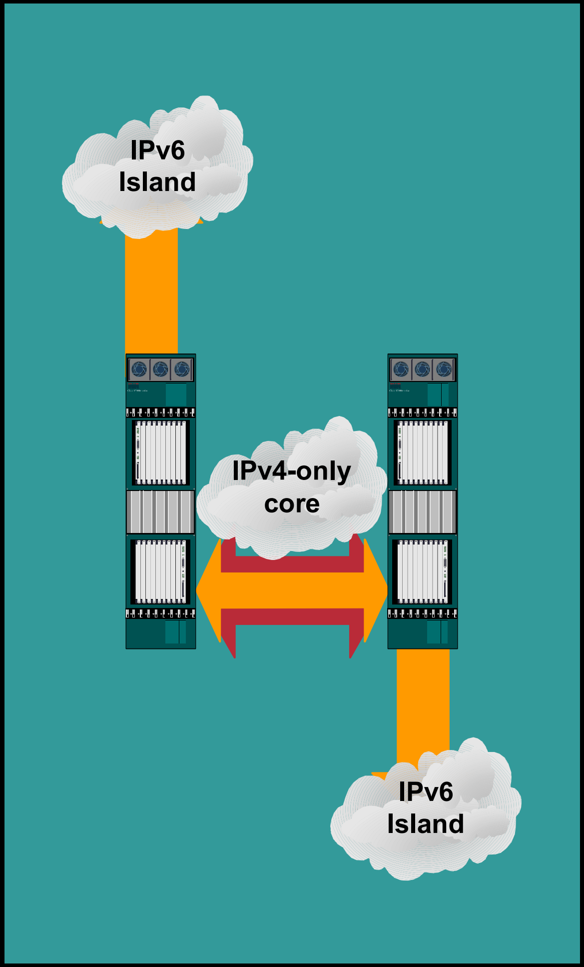
Tools – BGP tunnel



- 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

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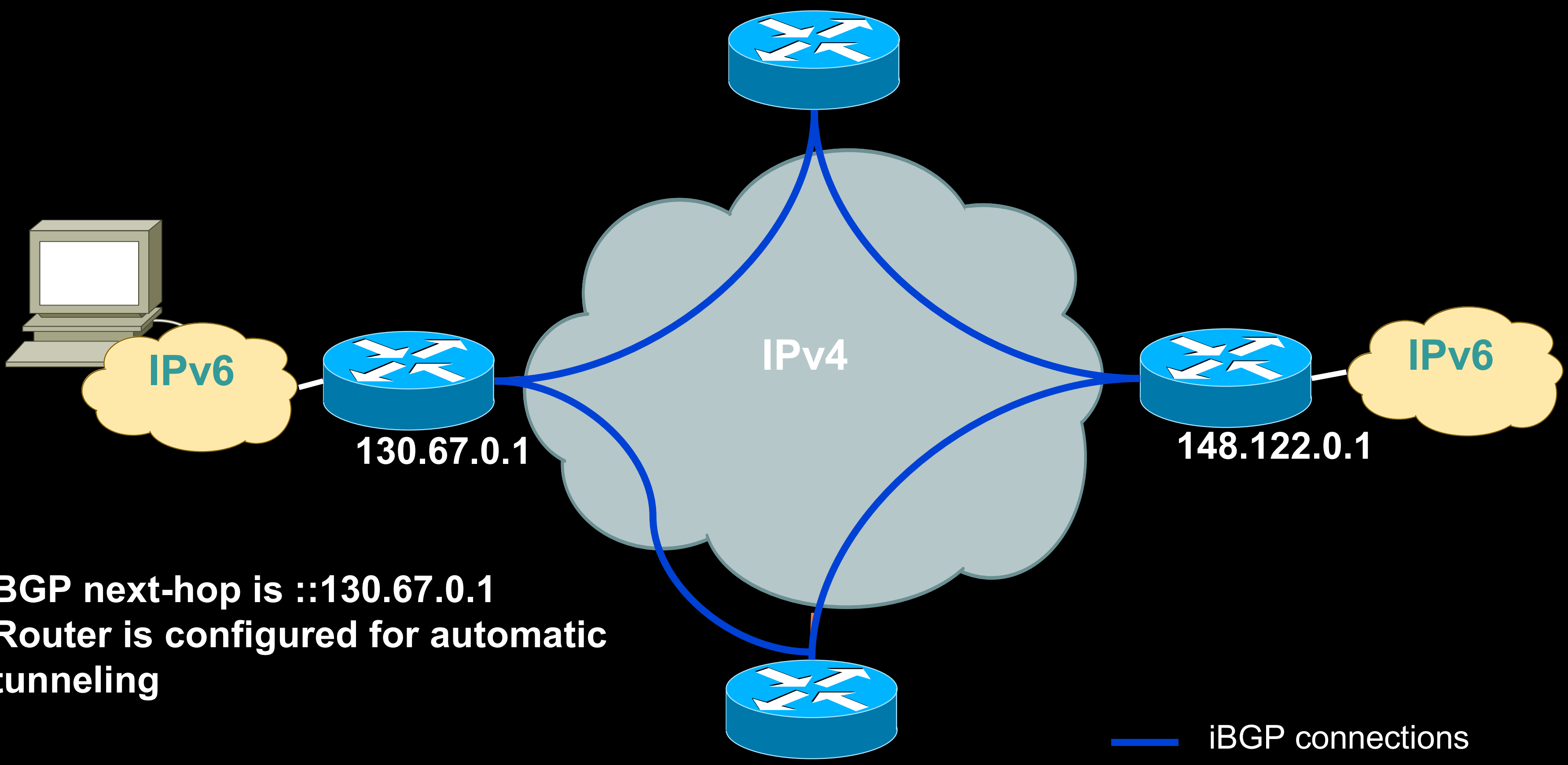
BGP tunnels



BGP next-hop is ::130.67.0.1
Router is configured for automatic tunneling

Useful for connecting IPv6 PE devices over an IPv4 only core.

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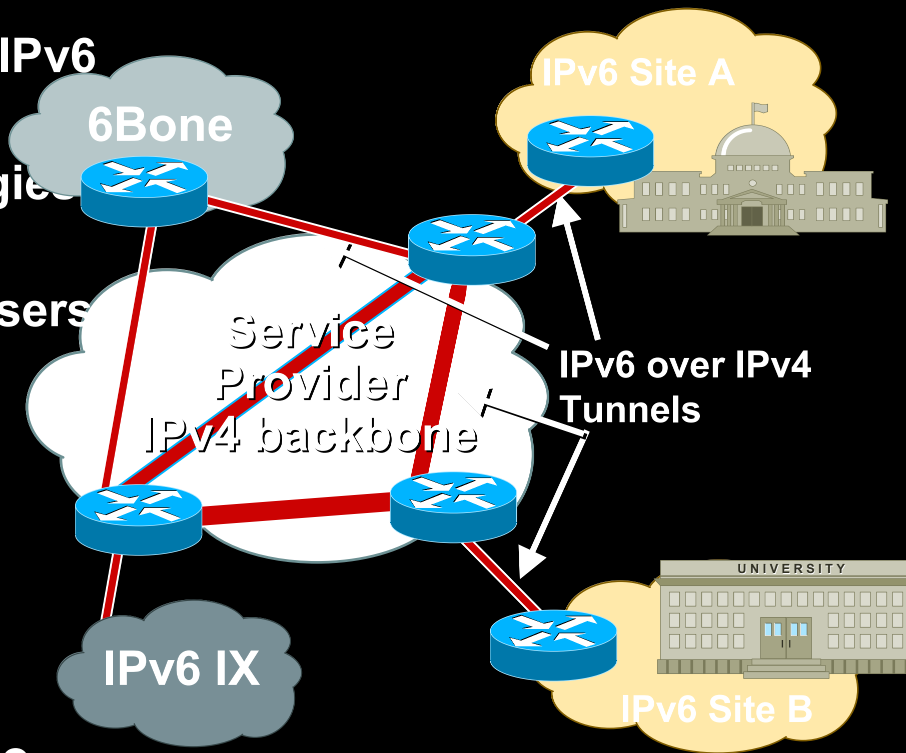
IPv6 Tunnels & Native Case Study

- ISP scenario
  - Configured Tunnels or Native IPv6 between IPv6 Core Routers
  - Configured Tunnels or Native IPv6 to IPv6 Enterprise's Customers
  - Tunnels for specific access technologies eg. Cable
  - MP-BGP4 Peering with other 6Bone users
  - Connection to an IPv6 IX
  - 6to4 relay service
- Enterprise/Home scenario
  - 6to4 tunnels between sites, use 6to4 Relay to connect to the IPv6 Internet
  - Configured tunnels between sites or to 6Bone users
  - ISATAP tunnels or Native IPv6 on a Campus

Use the most appropriate



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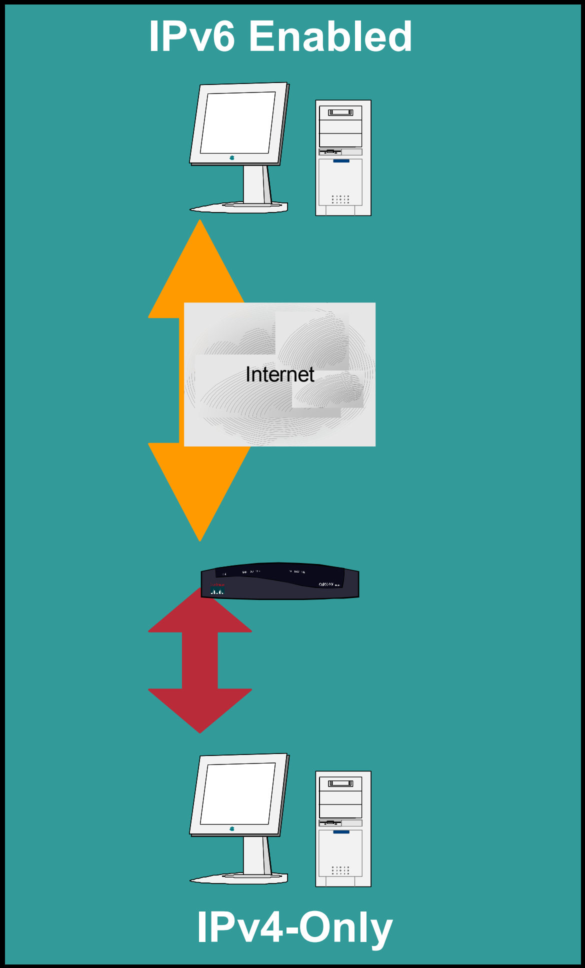
Tools – Translation



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

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Stateful Translation Mechanisms

- NAT-PT
  - Address & protocol translation
- TRT
  - Transport layer relay
- Socks
  - Application layer gateway
- IGMP / MLD proxy
  - Joins opposing groups & maps addresses

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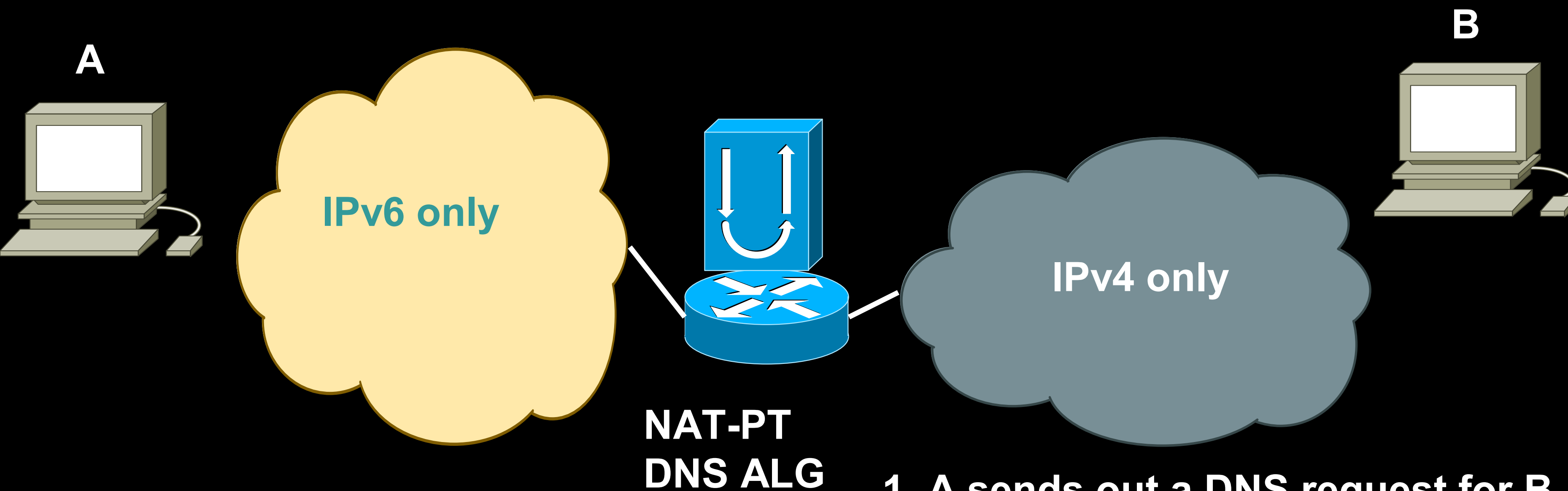
NAT-PT



NAT-Prefix: ipv4-mapped::/96
announced by NAT-PT

1. A sends out a DNS request for B
2. NAT-PT intercepts the DNS reply
   translates from A to AAAA, uses
   prefix:a.b.c.d as the IPv6 address
   NAT-PT creates translation slot
3. Communication can begin

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Stateless Translation Mechanisms

- **SIII**

  Address & protocol translation

- **BIS**

  Augmentation between IPv4 stack & device driver

- **BIA**

  Supports IPv4 apps over IPv6 stack

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Translation

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- May prefer to use IPv6-IPv4 protocol translation for:
  - new kinds of Internet devices (e.g., cell phones, cars, appliances)
  - benefits of shedding IPv4 stack (e.g., serverless autoconfig)
- This is a simple extension to NAT techniques, to translate header format as well as addresses
  - IPv6 nodes behind a translator get full IPv6 functionality when talking to other IPv6 nodes located anywhere
  - they get the normal (i.e., degraded) NAT functionality when talking to IPv4 devices
  - drawback : minimal gain over IPv4/IPv4 NAT approach

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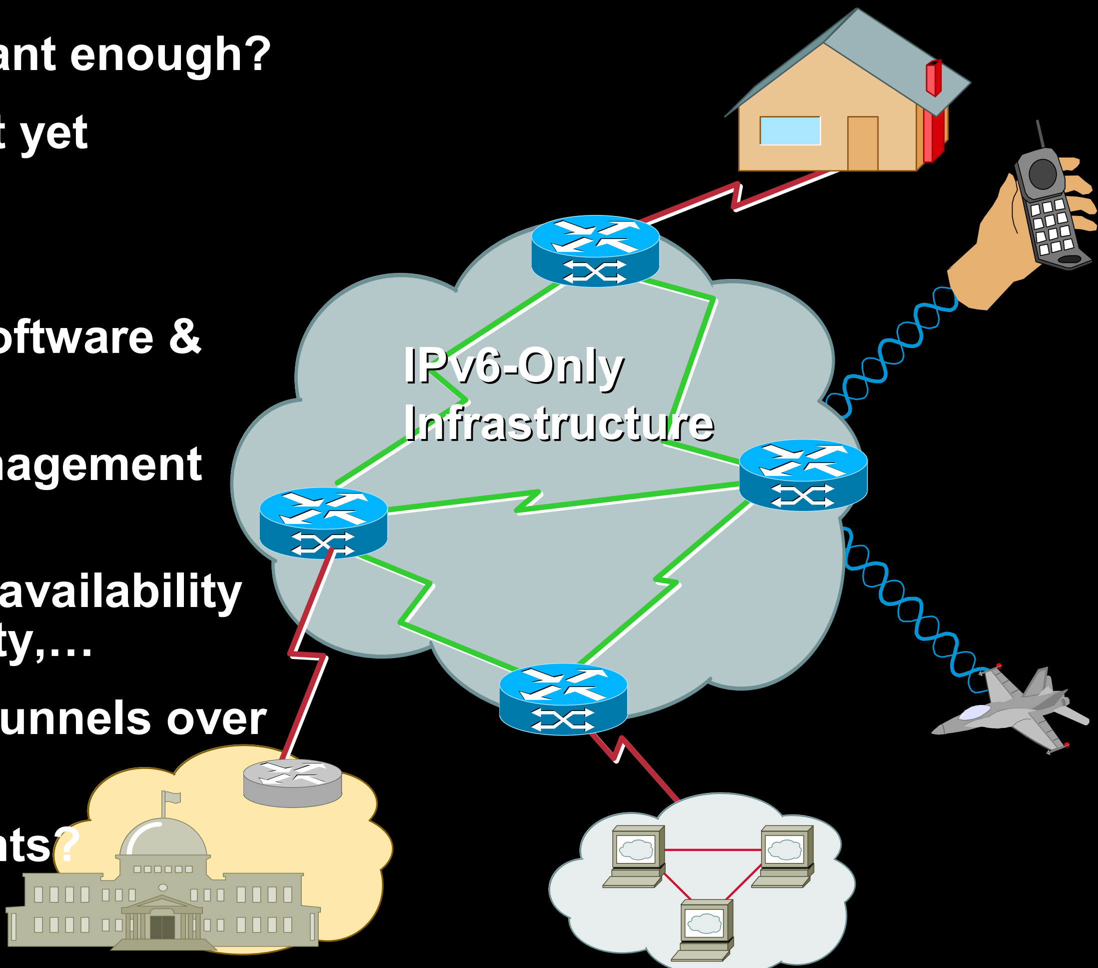
Native IPv6-only Infrastructure?

- Application focus
  - Is the IPv6 traffic important enough?
  - Worldwide DNS Root not yet reachable via IPv6
- Requires
  - Full Network upgrade (software & potentially hardware)
  - Native IPv6 Network Management Solutions
  - Enhanced IPv6 services availability
    - Multicast, QoS, security,…
  - Transport IPv4 through tunnels over IPv6
    - IPv4 traffic requirements?



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Native IPv6 over Dedicated Data Links

- Native IPv6 links over dedicated infrastructures
    - ATM PVC, dWDM Lambda, Frame Relay PVC, Serial, Sonet/SDH, Ethernet
- No impact on existing IPv4 infrastructures
    - Only upgrade the appropriate network paths
    - IPv4 traffic (and revenues) can be separated from IPv6
- Network Management done through IPv4 for now

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Tools – Services

- **DNS**
  - DNS-ALG in NAT-PT distorts perception
  - Referral chain consistency with resolver
  - Remember glue & reverse records for IPv6
- **SMTP**
  - Create MX records for both IPv4 & IPv6 on dual-stack
  - DNS failure on AAAA may cause mail requeue
- **DHCP**
  - Spec about finished; products will follow
  - Prefix allocation current driver

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Summary

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Summary

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- Transition will not be a quick process
- Tool set goal : minimize interdependence
- Dual-stack & Tunneling before Translation

  most difficult cases caused by IPv6-only
- Recognize environment characteristics
- Applications will drive deployments

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Questions?

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For More Information

- http://www.ipv6forum.com
- http://www.ipv6.org
- http://www.cisco.com/ipv6
- http://www.microsoft.com/ipv6
- http://www.6bone.net

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For More Information

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- http://www.ietf.org/html.charters/ipngwg-charter.html
- http://www.ietf.org/html.charters/v6ops-charter.html
- http://playground.sun.com/ipv6/
- http://www.6bone.net/ngtrans/

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For More Information

Cisco.com

- **BGP4+ References**

  RFC2858 Multiprotocol extension to BGP
  RFC2545 BGP MP for IPv6
  RFC2842 Capability negotiation

- **RIPng RFC2080**

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Other Sources of Information

- **Books**

  IPv6, The New Internet Protocol
  by Christian Huitema (Prentice Hall)

  Internetworking IPv6 with Cisco Routers
  by Silvano Gai (McGraw-Hill)

  and many more... (14 hits at Amazon.com)

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