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IPv6 @ Cisco

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Agenda

- IPv6 Business Case
- IPv6 Protocols & Standards
- Integration and Transition
- Cisco IOS IPv6 Roadmap
- IPv6 Deployment scenarios

A need for IPv6?

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- **IETF IPv6 WG began in early 90s, to solve addressing growth issues, but**
  - CIDR, NAT,… were developed
- **IPv4 32 bit address = 4 billion hosts**
  - ~40% of the IPv4 address space is still unused which is different from unallocated
  - BUT
- **IP is everywhere**
  - Data, Voice, Audio and Video integration is a Reality
  - Regional Registries apply a strict allocation control
- **So, Only compelling reason: _more IP addresses!_**

IPv6: The Application's Convergence Layer

Forget a preconceived idea: not only PC's but all things are connected,

So millions of addresses and Plug & Play capability are required = IPv6

IP Address Allocation History

1981 - IPv4 protocol published

1985 ~ 1/16 of total space

1990 ~ 1/8 of total space

1995 ~ 1/4 of total space

2000 ~ 1/2 of total space

- This despite increasingly intense conservation efforts

  PPP / DHCP address sharing

  CIDR (classless inter-domain routing)

  NAT (network address translation)

  plus some address reclamation

- Theoretical limit of 32-bit space: ~4 billion devices
  Practical limit of 32-bit space: ~250 million devices

  (see RFC 3194)

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

Explosion of New Internet Appliances

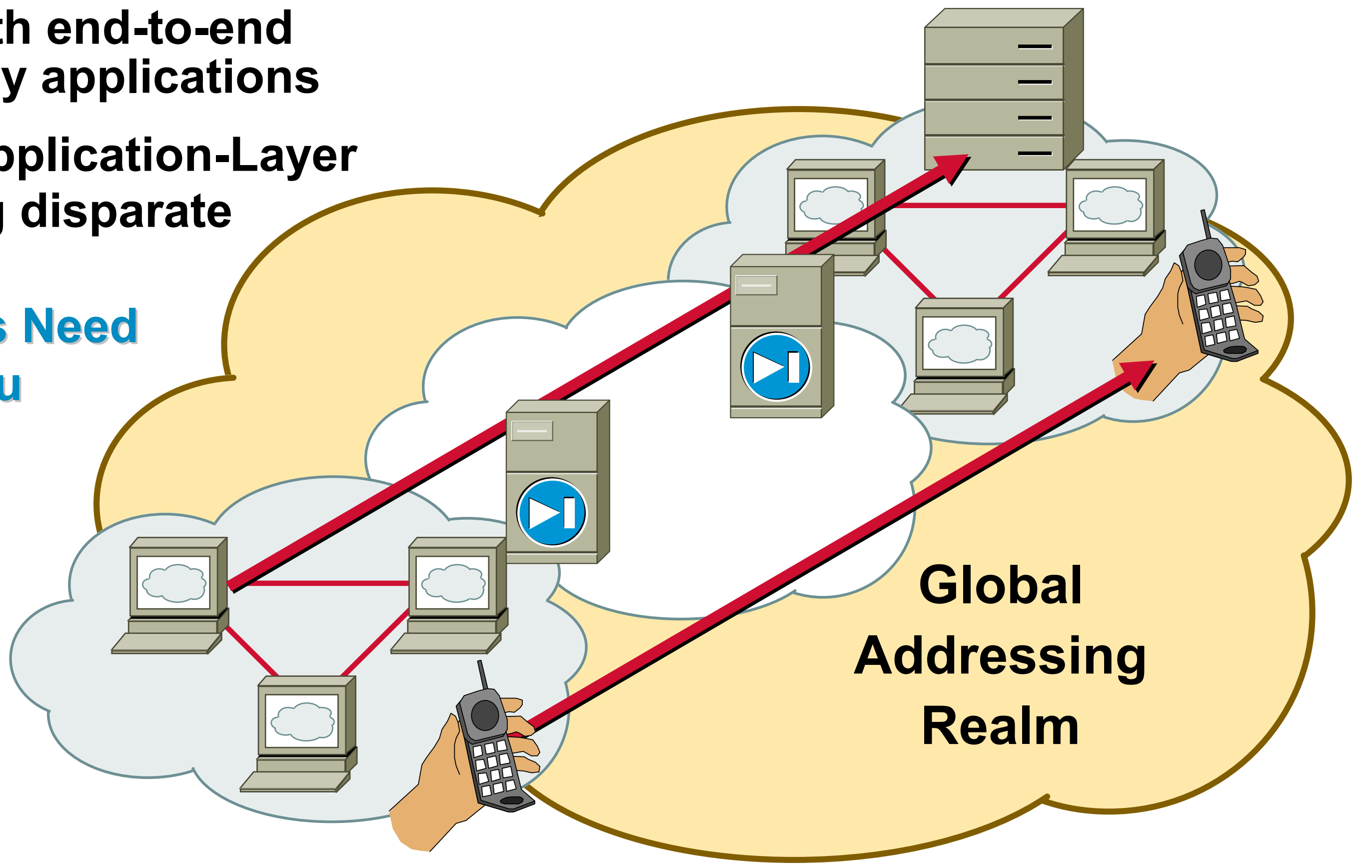
Coming Back to an End-to-End Architecture

New Technologies/Applications for Home Users

'Always-on'—Cable, DSL, Ethernet-to-the-home, Wireless,…

- Internet started with end-to-end connectivity for any applications
- Today, NAT and Application-Layer Gateways connecting disparate networks
- **Always-on Devices Need an Address When You Call Them**, eg.

- Mobile Phones
- Gaming
- Residential Voice over IP gateway
- IP Fax



IPv6 Markets

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- National Research & Education Networks (NREN) & Academia
- Geographies & Politics
- Wireless (PDA, 3G Mobile Phone networks, Car,...)
- Home Networking

  Set-top box/Cable/xDSL/Ethernet-to-the-home

  Eg. Japan Home Information Services initiative
- Distributed Gaming
- Consumer Devices
- Enterprise

  Requires full IPv6 support on O.S. & Applications
- Service Providers

IPv6 O.S. & Applications support

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- **All Operating Systems have an IPv6 stack at some stage of completeness**

  All Unix flavours (Sun Solaris, HP Unix, Compaq True64, SGI, IBM AIX, BSD (kame), Linux,…

  Microsoft Windows flavours, MacOS X, Compaq OpenVMS,…

- **Focus is now on the Applications**

  Ie: Microsoft .NET server, BSD Kame project

- **But still need additional vendors**

  Ie: Oracle & SAP

- **See playground.sun.com/ipv6 and www.hs247.com for latest update**

IPv6 & Geo-Politics

- China
  - Is establishing an IPv6 collaboration with Japan
- Europe
  - European IPv6 Task Force, www.ipv6-taskforce.org
    - IPv6 2005 roadmap recommendations – Jan. 2002
  - European Commission IPv6 project funding: 6NET & EuroIX
- Japan
  - Formal announce to support IPv6 in the "e-Japan Initiative" plan, 2000
  - IPv6 Promotion council
  - Tax incentive program, 2002-2003
- U.S.
  - North-America IPv6 Task Force

6NET Project Overview

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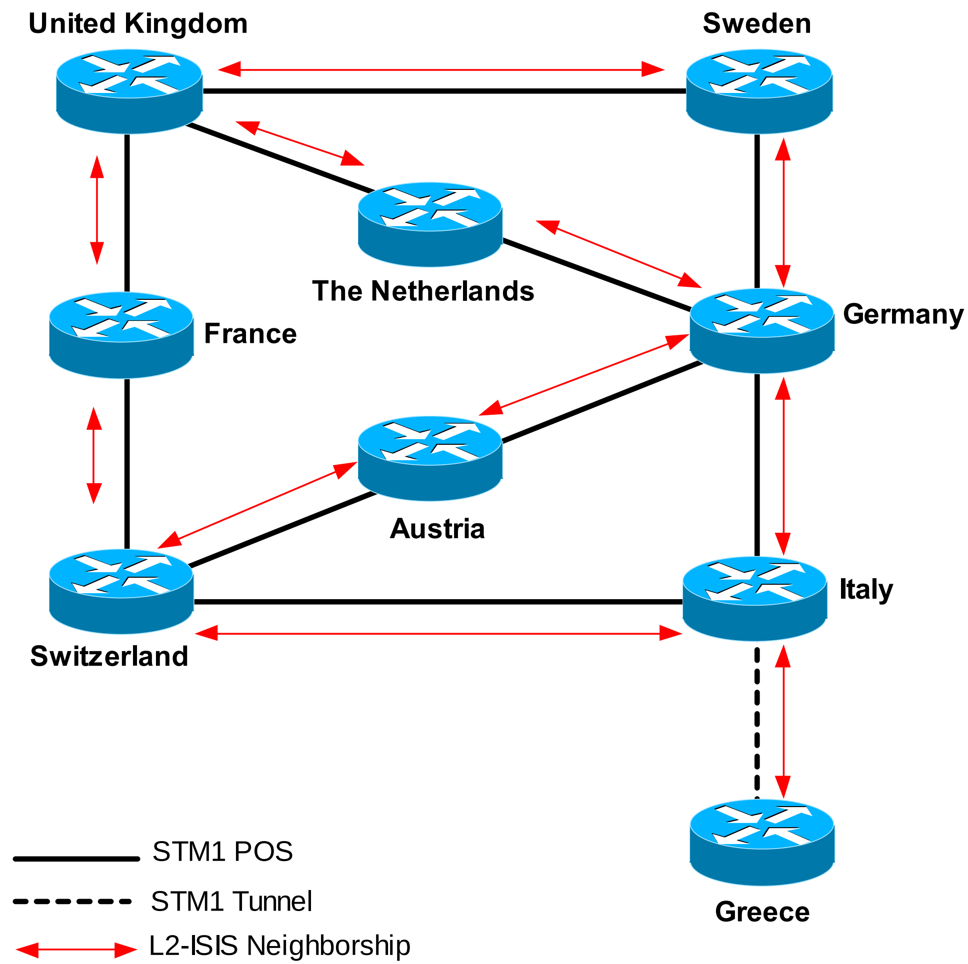
- An IPv6 testbed for the European Community
  - 3 year research project
  - European Commission funding: 9,5M €
- 31 partners
- 7 Work Packages
- www.6net.org
- Cisco 12400 and 7200 series



Service Providers Market

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- **Several Market segments**

  have to get an IPv6 prefix from their Regional Registry

  http://www.ripe.net/ripencc/mem-services/registration/ipv6/ipv6allocs.html

  Bootstrap process including plans for commercial services over the next 12 months

  – **IPv6 Internet eXchange (IX)**

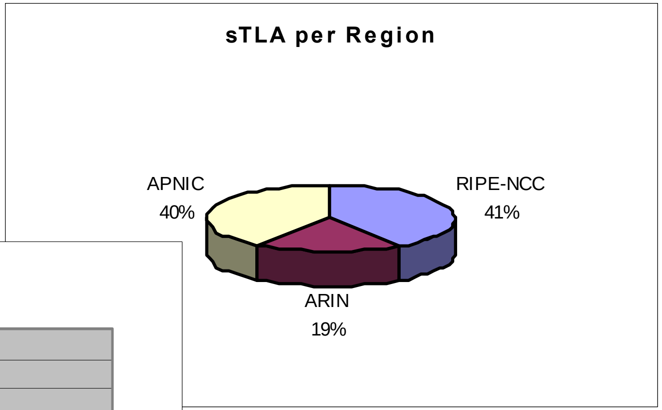
  – **Wireless**

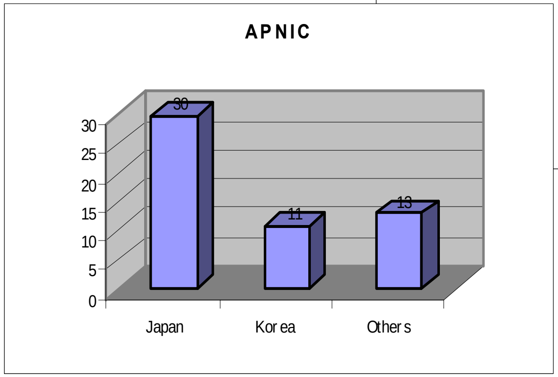
  – **Carriers**

  – **Regional ISP**

  – **Greenfield**

- **No easy ROI computation**

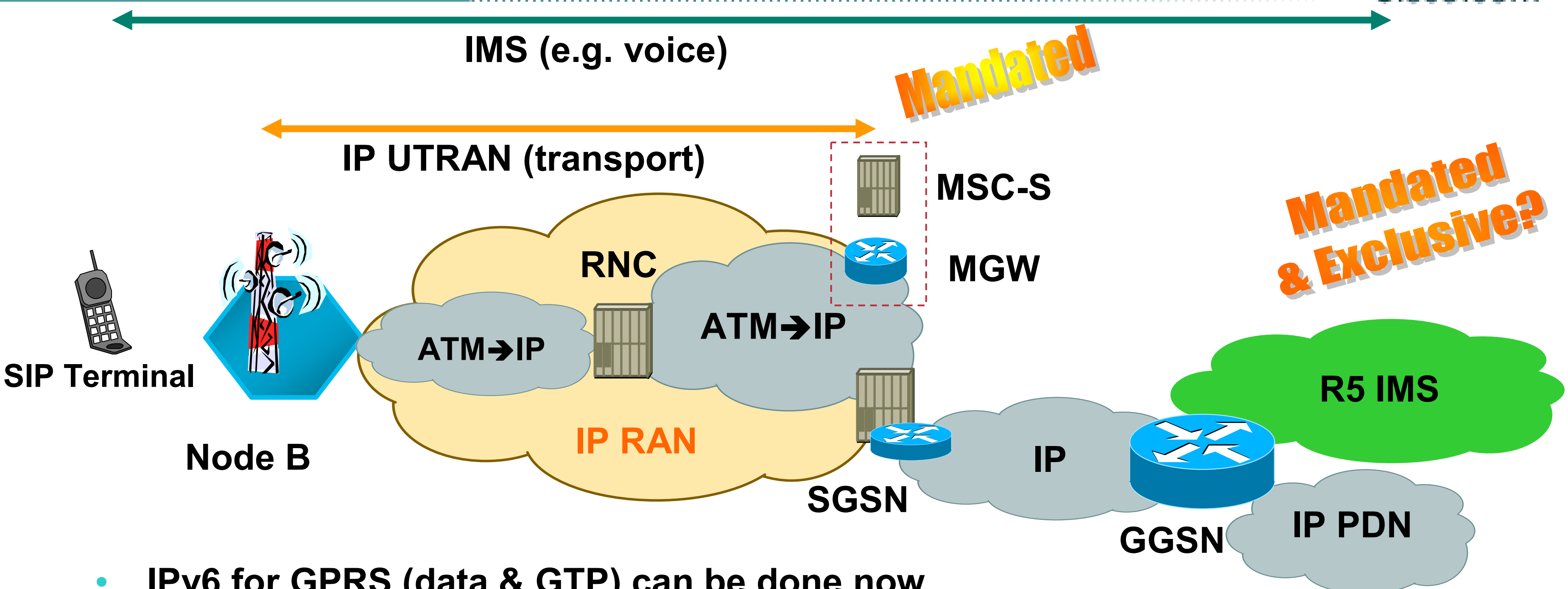




IPv6 & Wireless

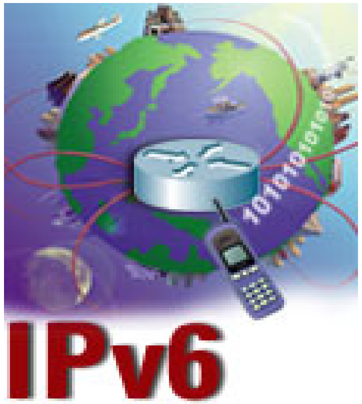
- **Market segments**
  - Mobile phone industry goes to IP: 3GPP/3GPP2/MWIF
  - Vertical markets need the infrastructure: Police, Army, Fire Department, Transports
  - Some Public 802.11 deployment already run IPv6
- **Key driver is the client's device, ie: handset**
  - Eg. Symbian 7.0
- **Before to open a commercial services, several phases happen**
  - RFP/RFI – Integration – Trial – Deployment – Commercial

IPv6 on 3G Networks



- IPv6 for GPRS (data & GTP) can be done now
  - Mentioned in 2G and 3G R3+ specifications
  - But no IPv6 (or dual stack) handset
- IPv6 is mandatory for Internet Multimedia Subsystem (IMS) in 3GPP Release 5
  - But R'5 slipped to November 02 for complete IMS definition
- IP UTRAN in R'5
  - Shall be IPv6, IPv4 optional and dual-stack recommended
  - Does not preclude ATM UTRAN

IPv6 – for an Ubiquitous Internet



- **Connect Everything to the Internet**
  - ***Simply (Plug & Play) and Safety***
- **Enjoy the Internet Everywhere & Anywhere**
  - ***Broadband, wireless,…***
  - ***China, India, Africa,…***
- **Play, Learn, and Live on the Internet for Everybody**
  - ***Peer to Peer & Client/Servers applications***
  - ***Global reachability as well as community of interest***
  - ***Home Information Services***
- **We need One Internet**
  - **Global communications enhances business, trade, research**

How to get an IPv6 Address?

- How to get address space?

  Real IPv6 address space now allocated by APNIC, ARIN and RIPE NCC to ISP

APNIC	2001:0200::/23 & 2001:0C00::/23
ARIN	2001:0400::/23
RIPE NCC	2001:0600::/23 & 2001:0800::/23

- 6Bone 3FFE::/16
- 6to4 tunnels 2002::/16
- Enterprises will get their IPv6 address space from their ISP.
- Further information on www.cisco.com/ipv6

IPv6 Prefix Allocations: APNIC
(whois.apnic.net) – April 2002

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WIDE-JP-19990813 2001:0200::/35
NUS-SG-19990827 2001:0208::/35
CONNECT-AU-19990916 2001:0210::/35
NTT-JP-19990922 2001:0218::/35
KT-KR-19991006 2001:0220::/35
JENS-JP-19991027 2001:0228::/35
HINET-TW-20000208 2001:0238::/35
IIJ-JPNIC-JP-20000308 2001:0240::/35
IMNET-JPNIC-JP-20000314 2001:0248::/35
CERNET-CN-20000426 2001:0250::/35
INFOWEB-JPNIC-JP-2000502 2001:0258::/35
BIGLOBE-JPNIC-JP-20000719 2001:0260::/35
6DION-JPNIC-JP-20000829 2001:0268::/35
DACOM-BORANET-20000908 2001:0270::/35
ODN-JPNIC-JP-20000915 2001:0278::/35
TANET-TWNIC-TW-20001006 2001:0288::/35
SONYTELECOM-JPNIC-JP-20001207 2001:0298::/35
CCCN-JPNIC-JP-20001228 2001:02A8::/35
KORNET-KRNIC-KR-20010102 2001:02B0::/35
NGINET-KRNIC-KR-20010115 2001:02B8::/35
INFOSPHERE-JPNIC-JP-20010207 2001:02C0::/35
OMP-JPNIC-JP-20010208 2001:02C8::/35
ZAMA-AP-20010320 2001:02D0::/35
SKTELECOMNET-KRNIC-KR-20010406 2001:02D8::/35

HKNET-HK-20010420 2001:02E0::/35
DTI-JPNIC-JP-20010702 2001:02E8::/35
MEX-JPNIC-JP-20010801 2001:02F0::/35
SINET-JPNIC-JP-20010809 2001:02F8::/35
PANANET-JPNIC-JP-20010810 2001:0300::/35
HTCN-JPNIC-JP-20010814 2001:0308::/35
CWIDC-JPNIC-JP-20010815 2001:0310::/35
STCN-JPNIC-JP-20010817 2001:0318::/35
KREONET2-KRNIC-KR-20010823 2001:0320::/35
MANIS-MY-20010824 2001:0328::/35
SAMSUNGNETWORKS-KRNIC-KR-20010920 2001:0330::/35
U-NETSURF-JPNIC-JP-20011005 2001:0338::/35
FINE-JPNIC-JP-20011030 2001:0340::/35
QCN-JPNIC-JP-20011031 2001:0348::/35
MCNET-JPNIC-JP-20011108 2001:0350::/35
MIND-JPNIC-JP-20011115 2001:0358::/35
V6TELSTRAINTERNET-AU-20011211 2001:0360::/35
MEDIAS-JPNIC-JP-20011212 2001:0368::/35
GCTRJP-NET-20011212 2001:0370::/35
THRUNET-KRNIC-KR-20011218 2001:0378::/35

OCN-JP-20020115 2001:0380::/35
AARNET-IPV6-20020117 2001:0388::/35
HANINTERNET-KRNIC-KR-20020207 2001:0390::/35
HOTNET-JPNIC-JP-20020215 2001:0398::/35
MULTIFEED-JP-20020319 2001:03A0::/35
GNGIDC-KRNIC-KR-20020402 2001:03A8::/35
KMN-IPV6-20020403 2001:03B0::/35
SO-NET-JP-20020409 2001:03B8::/35

IPv6 Prefix Allocations: ARIN
(whois.arin.net) – April 2002

- ESNET-V6 2001:0400::/35
- VBNS-IPV6 2001:0408::/35
- CANET3-IPV6 2001:0410::/35
- VRIO-IPV6-0 2001:0418::/35
- CISCO-IPV6-1 2001:0420::/35
- QWEST-IPV6-1 2001:0428::/35
- DISN-LES-V6 2001:0430::/35
- ABOVENET-IPV6 2001:0438::/35
- SPRINT-V6 2001:0440::/35
- UNAM-IPV6 2001:0448::/35
- GBLX-V6 2001:0450::/35
- STEALTH-IPV6-1 2001:0458::/35
- NET-CW-10BLK 2001:0460::/35
- ABILENE-IPV6 2001:0468::/35
- HURRICANE-IPV6 2001:0470::/35
- EP-NET 2001:0478::/35
- DREN-V6 2001:0480::/35
- AVANTEL-IPV6-1 2001:0488::/35
- NOKIA-1 2001:0490::/35
- ITESM-IPV6 2001:0498::/35
- IPV6-RNP 2001:04A0::/35
- AXTEL-IPV6-1 2001:04A8::/35
- AOLTIMEWARNER 2001:04B0::/35
- WAYPORT-IPV6 2001:04B8::/35
- PROTEL-RED-1-V6 2001:04C0::/35
- UNINET-NETV6-1 2001:04C8::/35

IPv6 Prefix Allocations: RIPE-NCC
(whois.ripe.net) – April 2002

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EU-UUNET-19990810 2001:0600::/35
DE-SPACE-19990812 2001:0608::/35
NL-SURFNET-19990819 2001:0610::/35
UK-BT-19990903 2001:0618::/35
CH-SWITCH-19990903 2001:0620::/35
AT-ACONET-19990920 2001:0628::/35
UK-JANET-19991019 2001:0630::/35
DE-DFN-19991102 2001:0638::/35
RU-FREENET-19991115 2001:0640::/35
GR-GRNET-19991208 2001:0648::/35
DE-ECRC-19991223 2001:0650::/35
DE-TRMD-20000317 2001:0658::/35
FR-RENATER-20000321 2001:0660::/35
EU-NACNET-20000403 2001:0668::/35
EU-EUNET-20000403 2001:0670::/35
DE-JIPPII-20000426 2001:0678::/35
DE-XLINK-20000510 2001:0680::/35
FR-TELECOM-20000623 2001:0688::/35
PT-RCCN-20000623 2001:0690::/35
SE-SWIPNET-20000828 2001:0698::/35
PL-ICM-20000905 2001:06A0::/35
BE-BELNET-20001101 2001:06A8::/35

SE-SUNET-20001218 2001:06B0::/35
IT-CSELT-20001221 2001:06B8::/35
SE-TELIANET-20010102 2001:06C0::/35
DK-TELEDANMARK-20010131 2001:06C8::/35
RU-ROSNIIROS-20010219 2001:06D0::/35
PL-CYFRONET-20010221 2001:06D8::/35
NL-INTOUCH-20010307 2001:06E0::/35
FI-TELIVO-20010321 2001:06E8::/35
SE-DIGITAL-20010321 2001:06F0::/35
UK-EASYNET-20010322 2001:06F8::/35
NO-UNINETT-20010406 2001:0700::/35
FI-FUNET-20010503 2001:0708::/35
UK-INS-20010518 2001:0710::/35
CZ-TEN-34-20010521 2001:0718::/35
ES-REDIRIS-20010521 2001:0720::/35
UK-VERIO-20010717 2001:0728::/35
AT-TELEKABEL-20010717 2001:0730::/35
HU-HUNGARNET-20010717 2001:0738::/35
DE-VIAG-20010717 2001:0740::/35
DE-ROKA-20010817 2001:0748::/35
IT-EDISONTEL-20010906 2001:0750::/35

UK-NETKONECT-20010918 2001:0758::/35
IT-GARR-20011004 2001:0760::/35
DE-CYBERNET-20011008 2001:0768::/35
IE-HEANET-20011008 2001:0770::/35
LT-LITNET-20011115 2001:0778::/35
DE-NORIS-20011203 2001:0780::/35
FI-SONERA-20011231 2001:0788::/35
EU-CARRIER1-20020102 2001:0790::/35
EU-DANTE-20020131 2001:0798::/35
DE-TELEKOM-20020228 2001:07A0::/35
FR-NERIM-20020313 2001:07A8::/35
DE-COMPLETEL-20020313 2001:07B0::/35
NL-BIT-20020405 2001:07B8::/35
DE-BELWUE-20020411 2001:07C0::/35

Agenda

- IPv6 Business Case
- IPv6 Protocols & Standards
- Integration and Transition
- Cisco IOS IPv6 Roadmap
- IPv6 Deployment scenarios

IPv6 - So what's really changed ?!

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- Expanded Address Space

  Address length quadrupled to 16 bytes

- Header Format Simplification

  Fixed length, optional headers are daisy-chained
  IPv6 header is twice as long (40 bytes) as IPv4 header without options (20 bytes)

- No checksumming at the IP network layer
- No hop-by-hop segmentation

  Path MTU discovery

- 64 bits aligned
- Authentication and Privacy Capabilities

  IPsec is mandated

- No more broadcast

IPv4 & IPv6 Header Comparison

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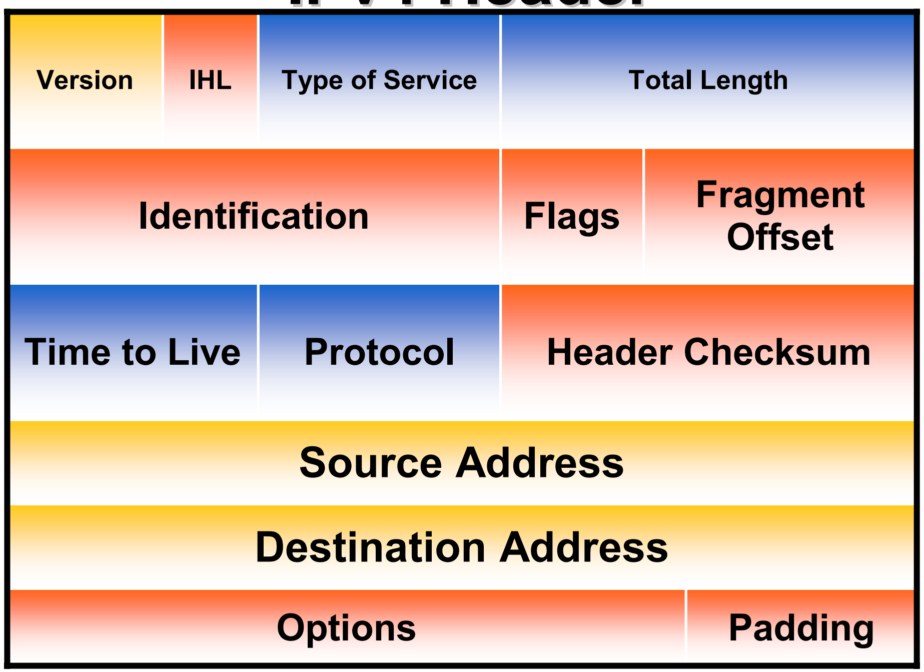
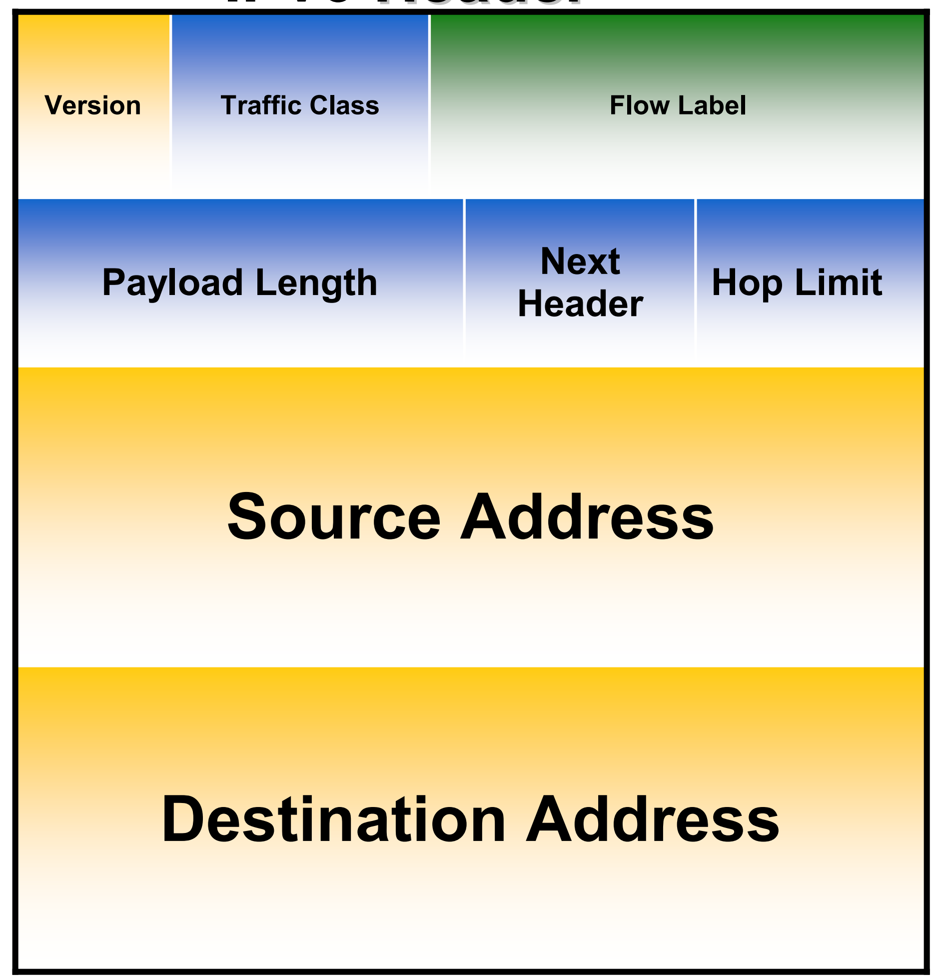
IPv4 Header



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

How Was IPv6 Address Size Chosen?

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- **Some wanted fixed-length, 64-bit addresses**
  - Easily good for 10^{12} sites, 10^{15} nodes, at .0001 allocation efficiency (3 orders of magnitude more than IPv6 requirement)
  - Minimizes growth of per-packet header overhead
  - Efficient for software processing
- **Some wanted variable-length, up to 160 bits**
  - Compatible with OSI NSAP addressing plans
  - Big enough for auto-configuration using IEEE 802 addresses
  - Could start with addresses shorter than 64 bits & grow later
- **Settled on fixed-length, 128-bit addresses**
  - (340,282,366,920,938,463,463,374,607,431,768,211,456 in all!)

IPv6 Addressing

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- IPv6 Addressing rules are covered by multiples RFC's
  - Architecture defined by RFC 2373
- Address Types are :
  - Unicast : One to One (Global, Link local, Site local, Compatible)
  - Anycast : One to Nearest (Allocated from Unicast)
  - Multicast : One to Many
  - Reserved
- A single interface may be assigned multiple IPv6 addresses of any type (unicast, anycast, multicast)
  - No Broadcast Address -> Use Multicast

IPv6 Address Representation

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- 16-bit fields in case insensitive colon hexadecimal representation

  2031:0000:130F:0000:0000:09C0:876A:130B

- Leading zeros in a field are optional:

  2031:0:130F:0:0:9C0:876A:130B

- Successive fields of 0 represented as ::, but only once in an address:
  - 2031:0:130F::9C0:876A:130B
  - 2031::130F::9C0:876A:130B
  - 0:0:0:0:0:0:0:1 => ::1
  - 0:0:0:0:0:0:0:0 => ::

- IPv4-compatible address representation
  - 0:0:0:0:0:0:192.168.30.1 = ::192.168.30.1 = ::C0A8:1E01

IPv6 Addressing

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- Prefix Format (PF) Allocation
  - PF = 0000 0000 : Reserved
  - PF = 001 : Aggregatable Global Unicast Address
  - PF = 1111 1110 10 : Link Local Use Addresses (FE80::/10)
  - PF = 1111 1110 11 : Site Local Use Addresses (FEC)::/10)
  - PF = 1111 1111 : Multicast Addresses (FF00::/8)
  - Other values are currently Unassigned (approx. 7/8th of total)
- All Prefix Formats have to support EUI-64 bits Interface ID setting
  - But Multicast

Aggregatable Global Unicast Addresses

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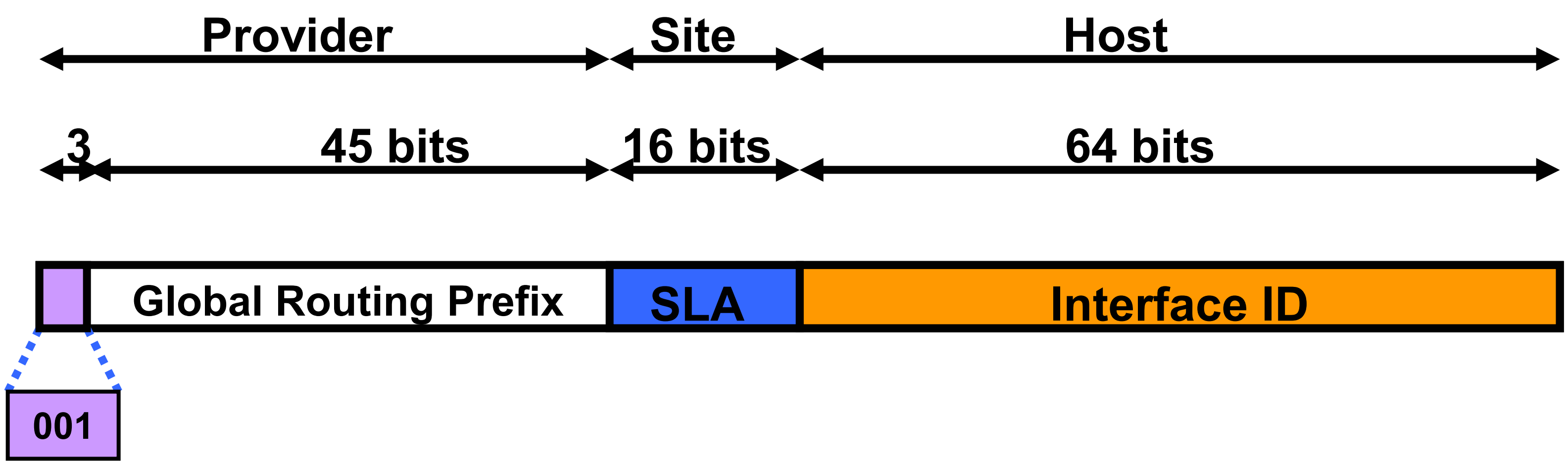


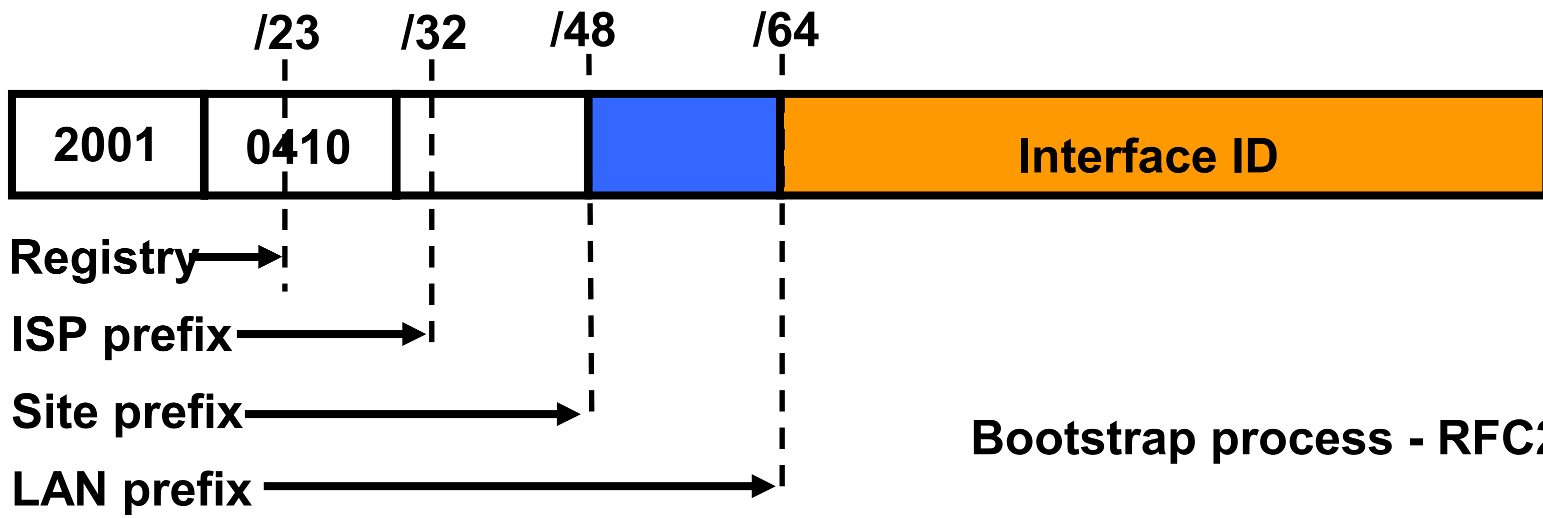
- Aggregatable Global Unicast addresses are:

  Addresses for generic use of IPv6

  Structured as a hierarchy to keep the aggregation

- See draft-ietf-ipngwg-addr-arch-v3-07

Address Allocation



Bootstrap process - RFC2450

- The allocation process is under reviewed by the Registries:
  - IANA allocates 2001::/16 to registries
  - Each registry gets a /23 prefix from IANA
  - Formely, all ISP were getting a /35
  - With the new proposal, Registry allocates a /36 (immediate allocation) or /32 (initial allocation) prefix to an IPv6 ISP
  - Policy is that an ISP allocates a /48 prefix to each end customer
  - ftp://ftp.cs.duke.edu/pub/narten/ietf/global-ipv6-assign-2002-04-25.txt

Hierarchical Addressing & Aggregation

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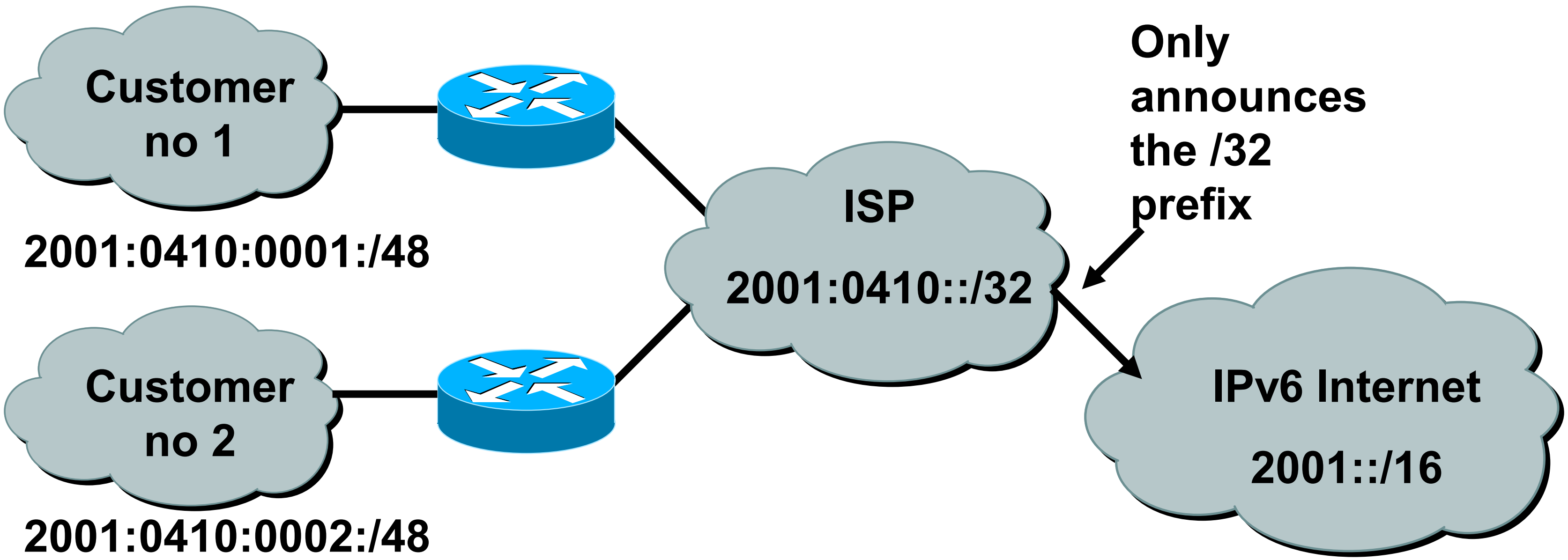


Larger address space enables:

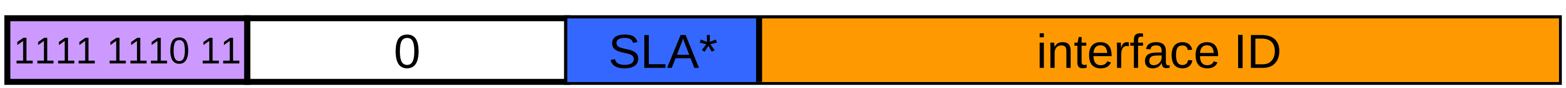
- Aggregation of prefixes announced in the global routing table.
- Efficient and scalable routing.

But current Multi-Homing schemes break the model

Link-Local & Site-Local Unicast Addresses

- **Link-local addresses for use during auto-configuration and when no routers are present:**

- **Site-local addresses for independence from Global Reachability, similar to IPv4 private address space**



Multicast Addresses (RFC 2375)

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11111111	flags	scope	group ID
8	4	4	112 bits

- **low-order flag 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)

more on IPv6 Addressing

80 bits	16 bits	32 bits
0000…………………………….0000	0000	IPv4 Address

IPv6 Addresses with Embedded IPv4 Addresses

80 bits	16 bits	32 bits
0000…………………………….0000	FFFF	IPv4 Address

IPv4 mapped IPv6 address

IPv6 Addressing Examples

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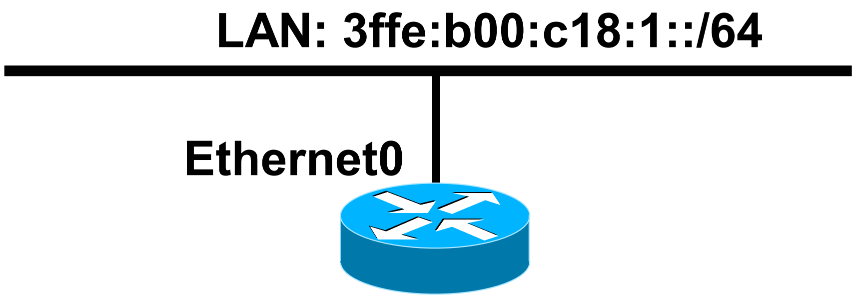


```
interface Ethernet0
 ipv6 address 2001:410:213:1::/64 eui-64
```

MAC address: 0060.3e47.1530

```
router# show ipv6 interface Ethernet0
Ethernet0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::260:3EFF:FE47:1530
Global unicast address(es):
    2001:410:213:1:260:3EFF:FE47:1530, subnet is 2001:410:213:1::/64
  Joined group address(es):
    FF02::1:FF47:1530
    FF02::1
    FF02::2
  MTU is 1500 bytes
```

6BONE

- **The 6bone is an IPv6 testbed setup to assist in the evolution and deployment of IPv6 in the Internet.**

  The 6bone is a virtual network layered on top of portions of the physical IPv4-based Internet to support routing of IPv6 packets, as that function has not yet been integrated into many production routers. The network is composed of islands that can directly support IPv6 packets, linked by virtual point-to-point links called "tunnels". The tunnel endpoints are typically workstation-class machines having operating system support for Ipv6.

- **Over 50 countries are currently involved**
- **Registry, maps and other information may be found on http://www.6bone.net/**

6Bone Addressing

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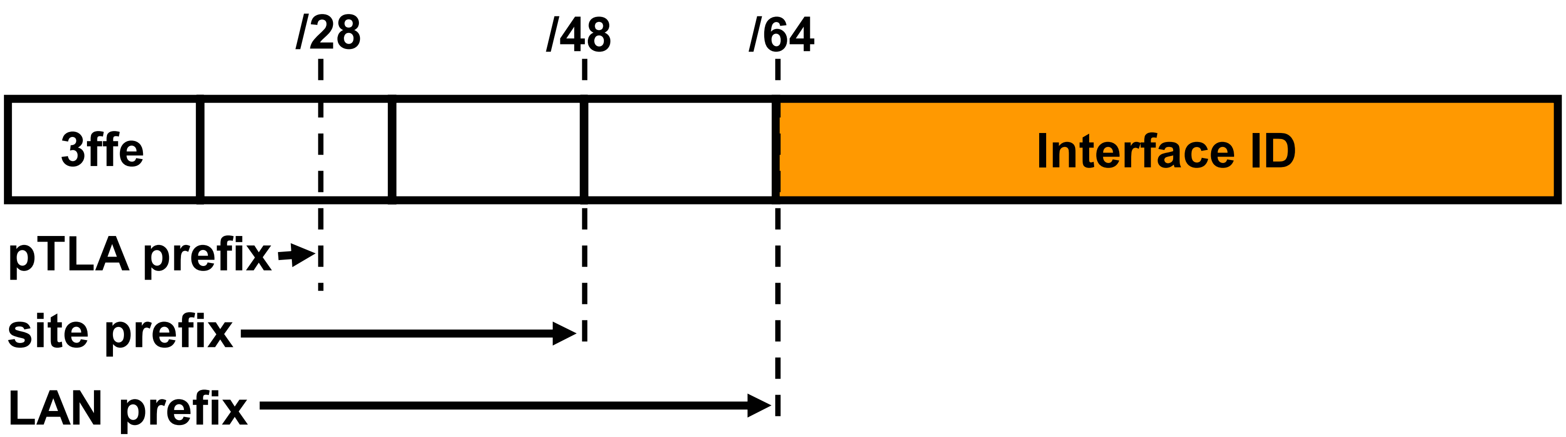

- 6Bone address space defined in RFC2471 uses 3FFE::/16
  - A pTLA receives a /28 prefix
  - A site receives a /48 prefix
  - A LAN receives a /64 prefix
- Guidelines for routing on 6bone - RFC2772

6Bone Topology

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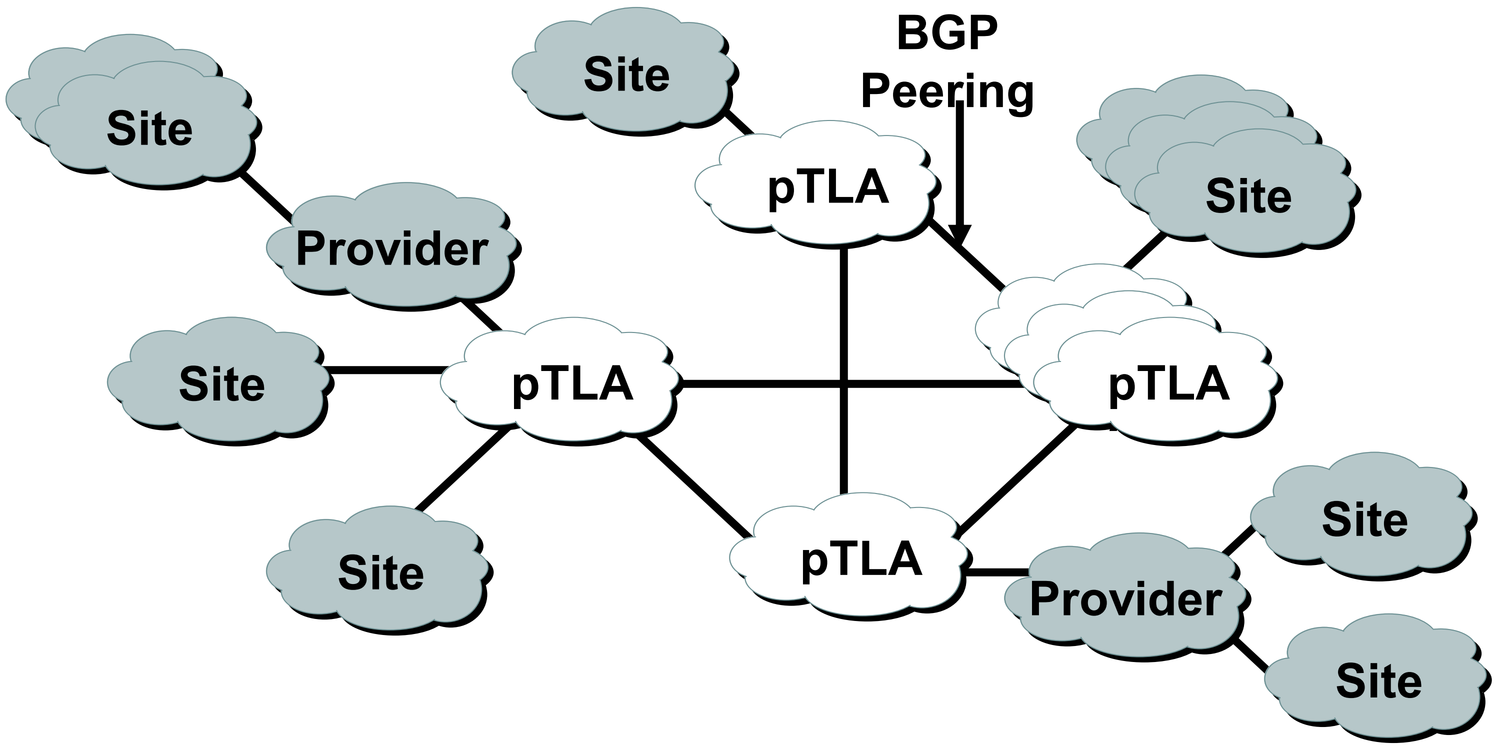
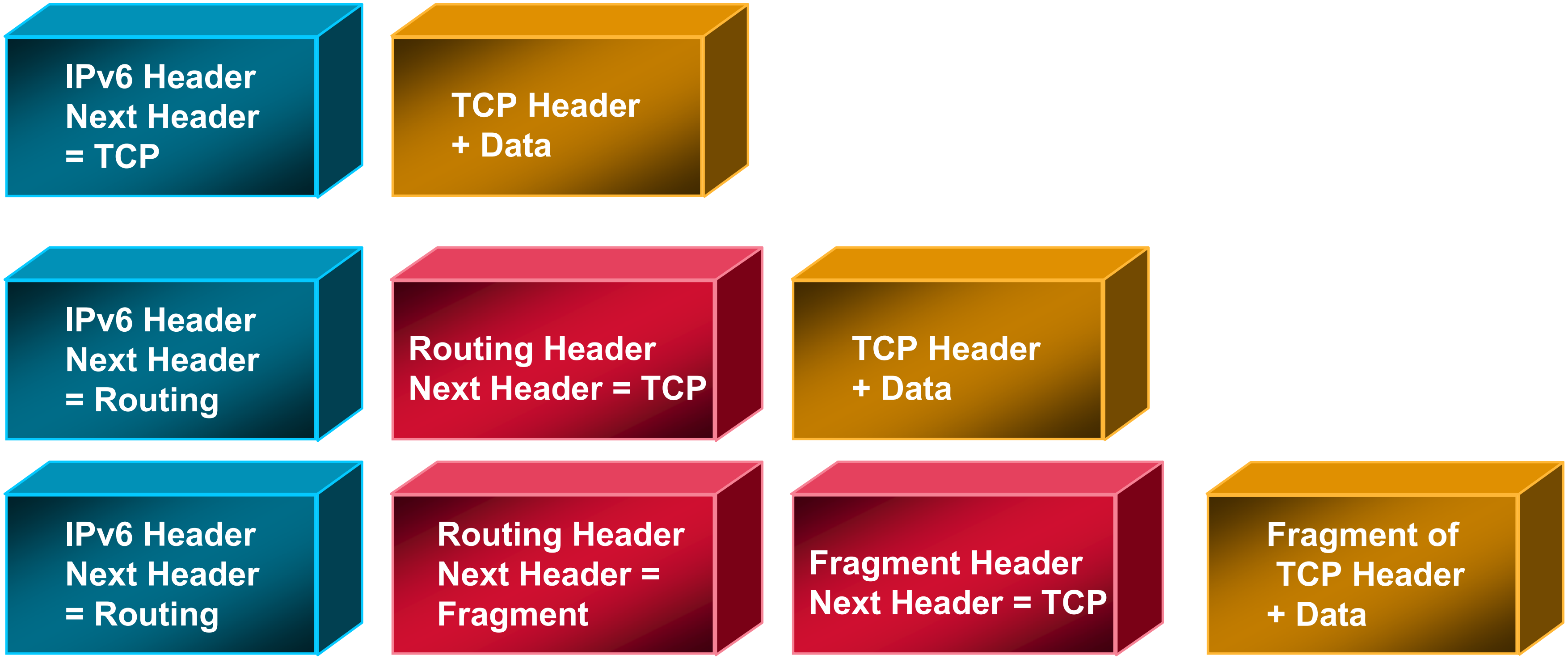


- 6Bone is a test bed network with hundreds of sites from 50 countries
- The 6Bone topology is a hierarchy of providers
- First-level nodes are backbone nodes called pseudo Top-Level Aggregator (pTLA)

IPv6 Header Options (RFC 2460)



- Processed only by node identified in IPv6 Destination Address field => much lower overhead than IPv4 options

  exception: Hop-by-Hop Options header

- Eliminated IPv4's 40-octet limit on options

  in IPv6, limit is total packet size, or Path MTU in some cases

IPv6 Header Options (RFC2460)

- **Currently defined Headers should appear in the following order**

  IPv6 header

  Hop-by-Hop Options header

  Destination Options header

  Routing header

  Fragment header

  Authentication header (RFC 1826)

  Encapsulating Security Payload header (RFC 1827)

  Destination Options header

  upper-layer header

MTU Issues

- minimum link MTU for IPv6 is 1280 octets (versus 68 octets for IPv4)

  => on links with MTU < 1280, link-specific fragmentation and reassembly must be used

- implementations are expected to perform path MTU discovery to send packets bigger than 1280
- minimal implementation can omit PMTU discovery as long as all packets kept ≤ 1280 octets
- a Hop-by-Hop Option supports transmission of “jumbograms” with up to 2^{32} octets of payload

Neighbour Discovery (RFC 2461)

- Protocol built on top of ICMPv6 (RFC 2463)
  - combination of IPv4 protocols (ARP, ICMP, IGMP,…)
- Fully dynamic, interactive between Hosts & Routers
  - defines 5 ICMPv6 packet types

    Router Solicitation / Router Advertisements

    Neighbor Solicitation / Neighbor Advertisements

    Redirect

Neighbour Discovery (RFC 2461)

- defined mechanisms between nodes attached on the same link
    - Router discovery
    - Prefix discovery
    - Parameters discovery, ie: link MTU, hop limit,…
    - Address autoconfiguration
    - Address Resolution (same function as ARP)
    - Next-hop determination
    - Neighbor Unreachability Detection (useful for default routers)
    - Duplicate Address Detection
    - Redirect

IPv6 Auto-Configuration

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- **Stateless (RFC2462)**

  Host autonomously configures its own Link-Local address

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

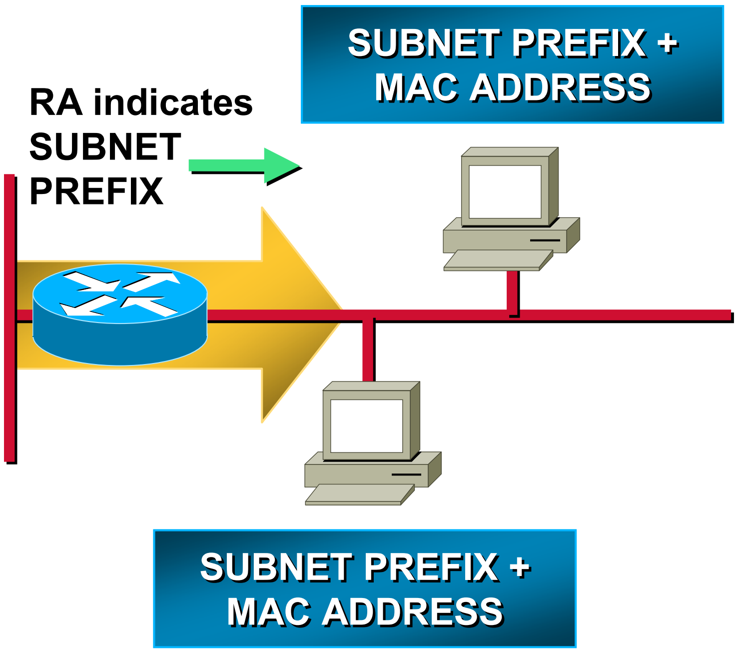
- **Stateful**

  DHCPv6 (under definition at IETF)

- **Renumbering**

  Hosts renumbering is done by modifying the RA to announce the old prefix with a short lifetime and the new prefix.

  Router renumbering protocol (RFC 2894), to allow domain-interior routers to learn of prefix introduction / withdrawal



At boot time, an IPv6 host build a Link-Local address, then its global IPv6 address(es) from RA

Routing in IPv6

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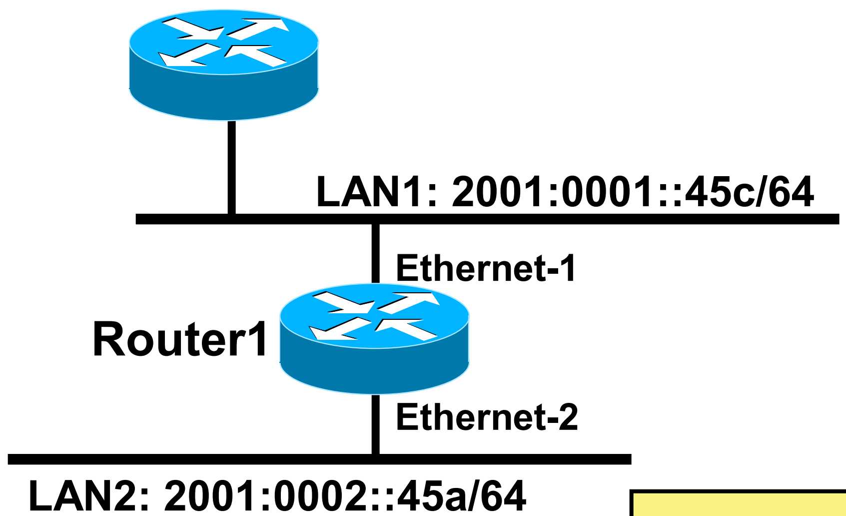
- As in IPv4, IPv6 has 2 families of routing protocols: IGP and EGP
  - IGP are RIPng (RFC 2080), Cisco EIGRP for IPv6, OSPFv3 and Integrated IS-ISv6 EGP is MP-BGP4 (RFC 2858 and RFC 2545)
- IPv6 still uses the longest-prefix match routing algorithm.
- i/IS-ISv6 (draft-ietf-isis-ipv6-02)
  - Integrated IGP for IPv4 & IPv6
- OSPFv3 (RFC 2740)
  - « Ships in the Night » routing, has to run OSPFv2 for IPv4
- Cisco IOS supports all of them
  - Pick one meeting your objectives
- IPv6 tunnels & Routing considerations, eg. 6to4 tunnels

Configuring Cisco IOS IPv6 Routing



OSPFv3

```
Router1#
 interface loopback 0
     ip address 192.222.222.1 255.255.255.0
 interface ethernet-1
     ipv6 address 2001:0001::45c/64
     ipv6 ospf 1 area 1 enable

  interface ethernet-2
     ipv6 address 2001:0002::45a/64
     ipv6 ospf 1 area 1 enable

  ipv6 router ospf 1
          redistribute static
```

Integrated IS-ISv6

```
Router1#
 interface ethernet-1
     ipv6 address 2001:0001::45c/64
     ipv6 router isis

  interface ethernet-2
     ipv6 address 2001:0002::45a/64
     ipv6 router isis

  router isis
      address-family ipv6
      redistribute static
      exit-address-family
      net 42.0001.0000.0000.072c.00
```

IP Mobility

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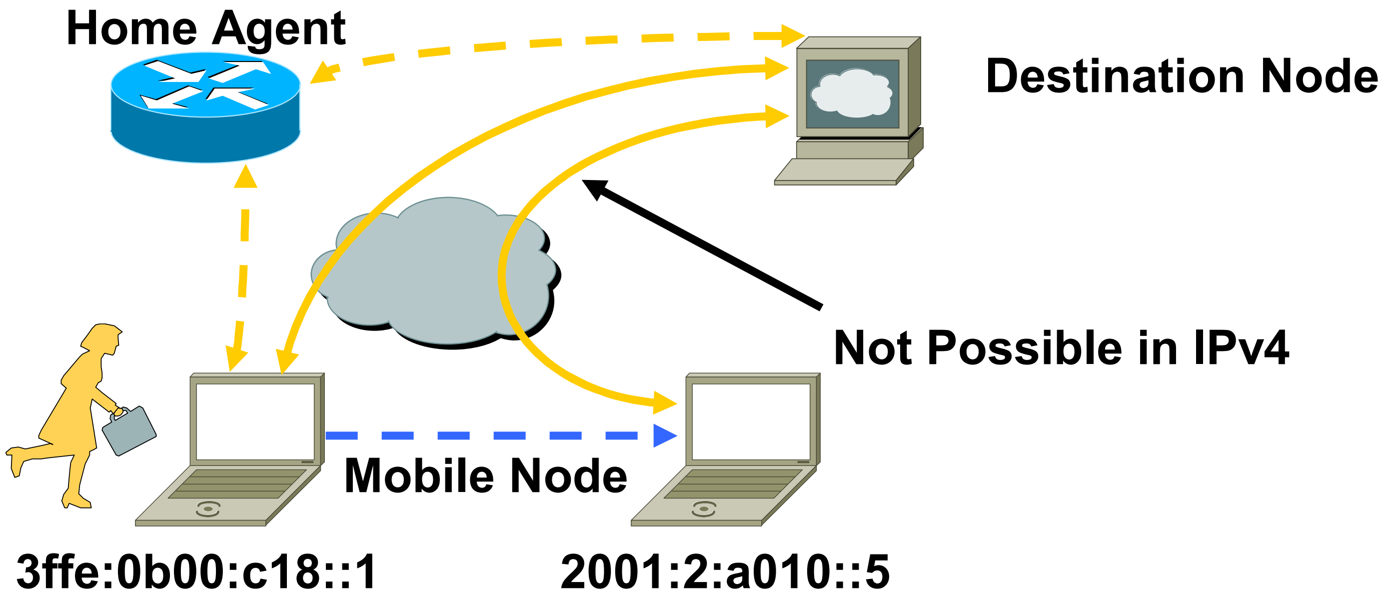


- Mobility means:

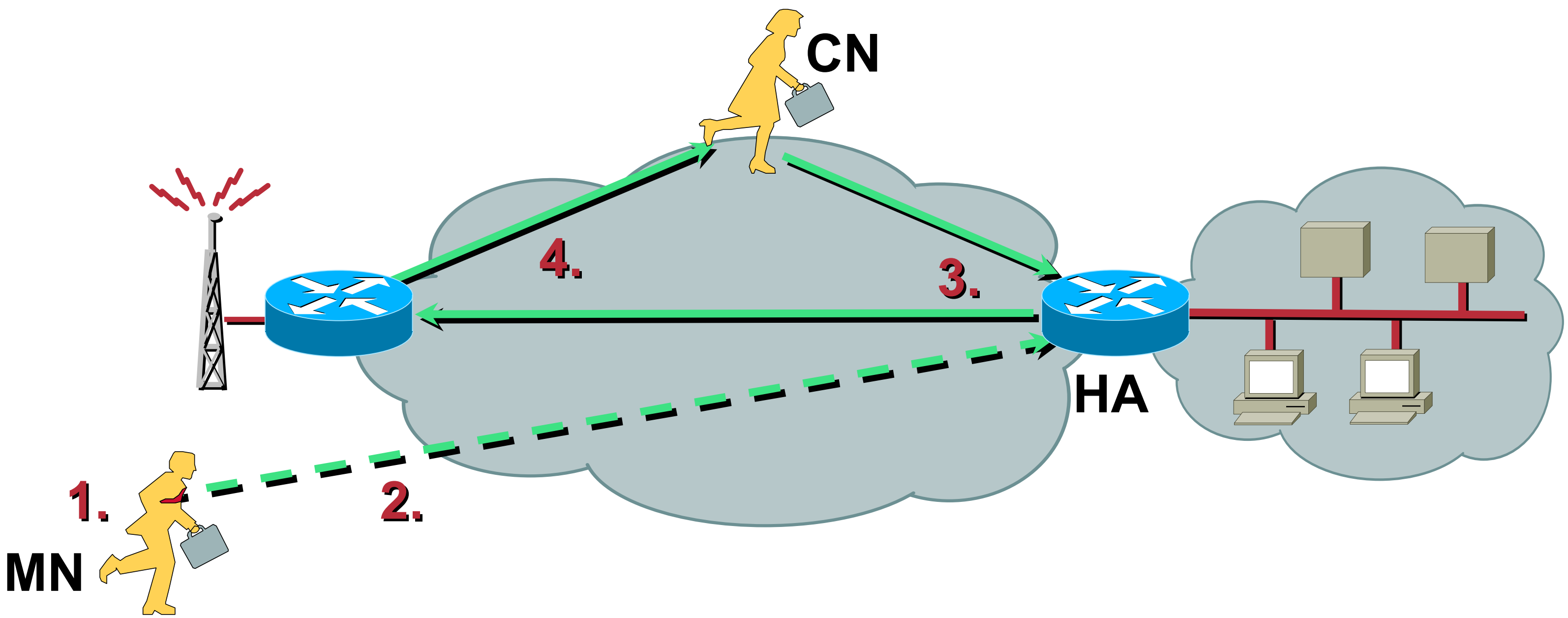
  Mobile devices are fully supported while moving

  Built-in on IPv6

    Any node can use it

  Efficient routing means performance for end-users

Overview of Mobile IPv6 Functionality



- 1. MN obtains IP address using stateless or stateful autoconfiguration
- 2. MN registers with HA
- 3. HA tunnels packets from CN to MN
- 4. MN sends packets from CN directly or via tunnel to HA

What does it do for:

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- **Security**

  Nothing IP4 doesn't do - IPSec runs in both

  but IPv6 mandates IPSec

- **QoS**

  Nothing IP4 doesn't do -

  - **Differentiated and Integrated Services run in both**

  - **So far, Flow label has no real use**

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

IPv6 Standards

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- **Core IPv6 specifications are IETF Draft Standards => well-tested & stable**

  IPv6 base spec, ICMPv6, Neighbor Discovery, PMTU Discovery,...

- **Other important specs are further behind on the standards track, but in good shape**

  mobile IPv6, header compression,...

  for up-to-date status: playground.sun.com/ipv6

- **3GPP UMTS Rel. 5 cellular wireless standards mandate IPv6; also being considered by 3GPP2**

IPv6 Current Status - Standardisation

- **Several key components now on Standards Track:**

Specification (RFC2460)	Neighbour Discovery (RFC2461)
ICMPv6 (RFC2463)	IPv6 Addresses (RFC2373/4/5)
RIP (RFC2080)	BGP (RFC2545)
IGMPv6 (RFC2710)	OSPF (RFC2740)
Router Alert (RFC2711)	Jumbograms (RFC2675)
Autoconfiguration (RFC2462)	

IPv6 over:	PPP (RFC2023)	Ethernet (RFC2464)
	FDDI (RFC2467)	Token Ring (RFC2470)
	NBMA(RFC2491)	ATM (RFC2492)
	Frame Relay (RFC2590)	ARCnet (RFC2549)

Recent IPv6 "Hot Topics" in the IETF

- Multi-homing
- Address selection
- Address allocation
- DNS discovery
- 3GPP usage of IPv6
- Anycast addressing
- Scoped address architecture
- Flow-label semantics
- API issues

  (flow label, traffic class, PMTU discovery, scoping,…)

- Enhanced router-to-host info
- Site renumbering procedures
- Inter-domain multicast routing
- Address propagation and AAA issues of different access scenarios
- End-to-end security vs. firewalls
- And, of course, transition / co-existence / interoperability with IPv4
  (a bewildering array of transition tools and techniques)

Note: this indicates vitality, not incompleteness, of IPv6!

Agenda

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- IPv6 Business Case
- IPv6 Protocols & Standards
- Integration and Transition
- Cisco IOS IPv6 Roadmap
- IPv6 Deployment scenarios

IETF NGTrans Working Group

- **Define the processes by which networks can be transitioned from IPv4 to IPv6**
- **Define & specify the mandatory and optional mechanism that vendors are to implement in Hosts, Routers and other components of the Internet in order for the Transition.**
- **Http://www.ietf.org/html.charters/ngtrans-charter.html**

IPv4-IPv6 Transition / Co-Existence

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

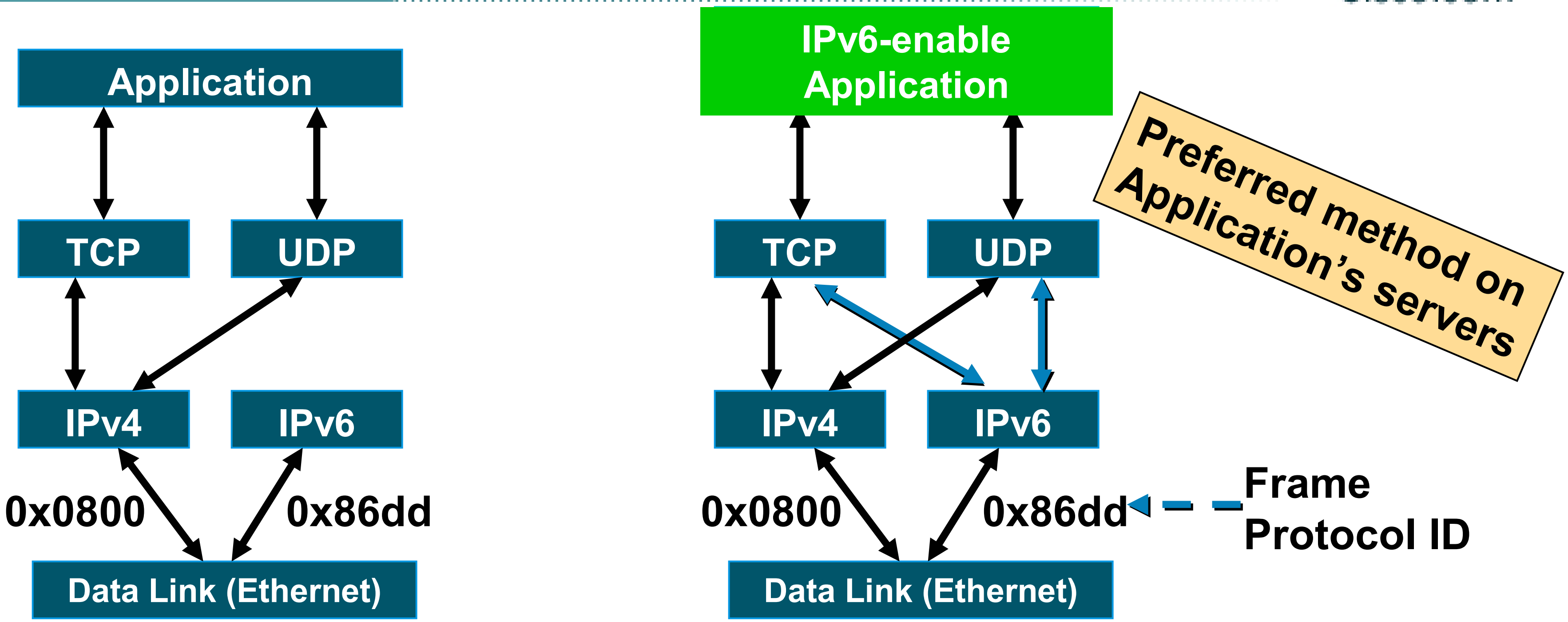
(1) Dual-stack techniques, to allow IPv4 and IPv6 to co-exist in the same devices and networks

(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

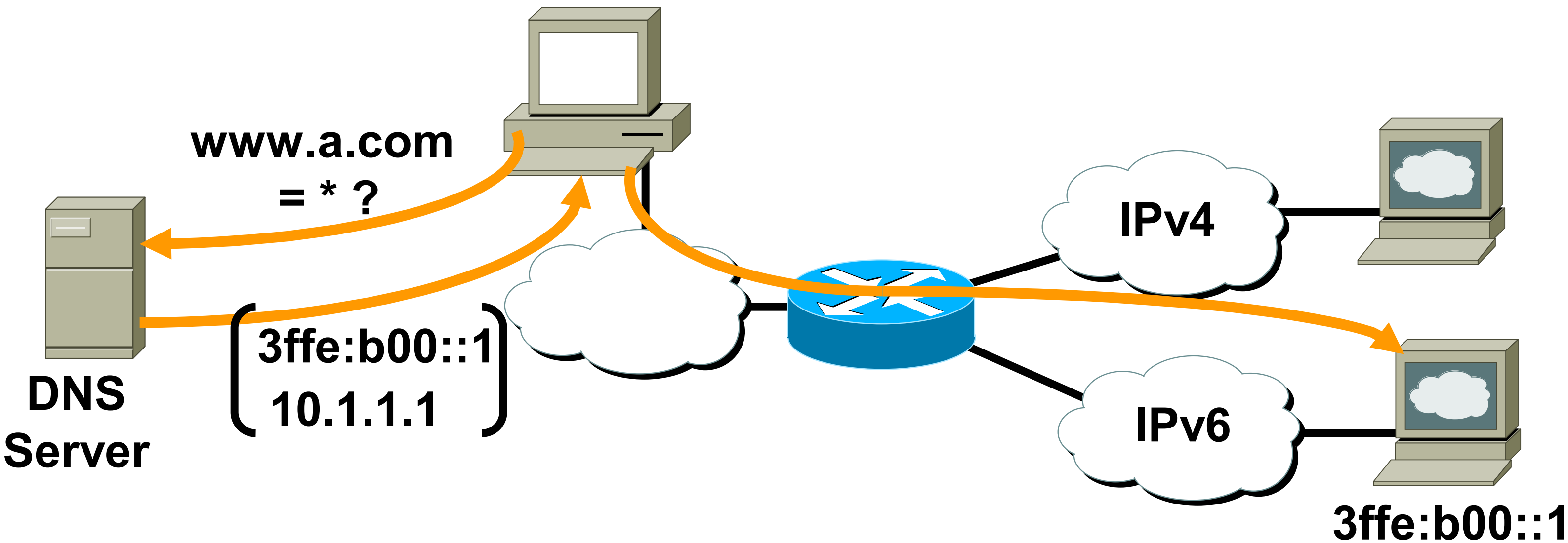
Expect all of these to be used, in combination

Dual Stack Approach



- Dual stack node means:
  - Both IPv4 and IPv6 stacks enabled
  - Applications can talk to both
  - Choice of the IP version is based on name lookup and application preference

Dual Stack Approach & DNS



- In a dual stack case, an application that:

  Is IPv4 and IPv6-enabled

  Asks the DNS for all types of addresses

  Chooses one address and, for example, connects to the IPv6 address

Cisco IOS Dual Stack Configuration

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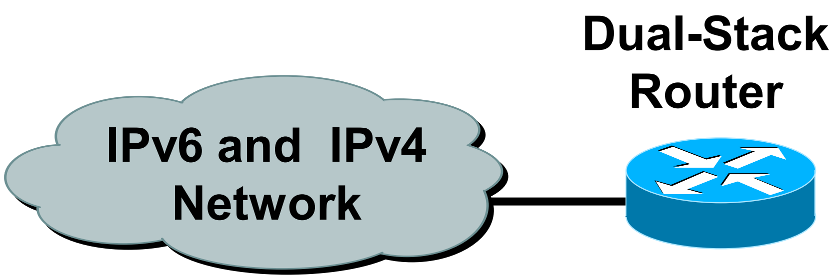



```
router#
ipv6 unicast-routing

interface Ethernet0
 ip address 192.168.99.1 255.255.255.0
 ipv6 address 2001:410:213:1::/64 eui-64
```

IPv4: 192.168.99.1

IPv6: 2001:410:213:1::/64 eui-64

- **Cisco IOS is IPv6-enable:**

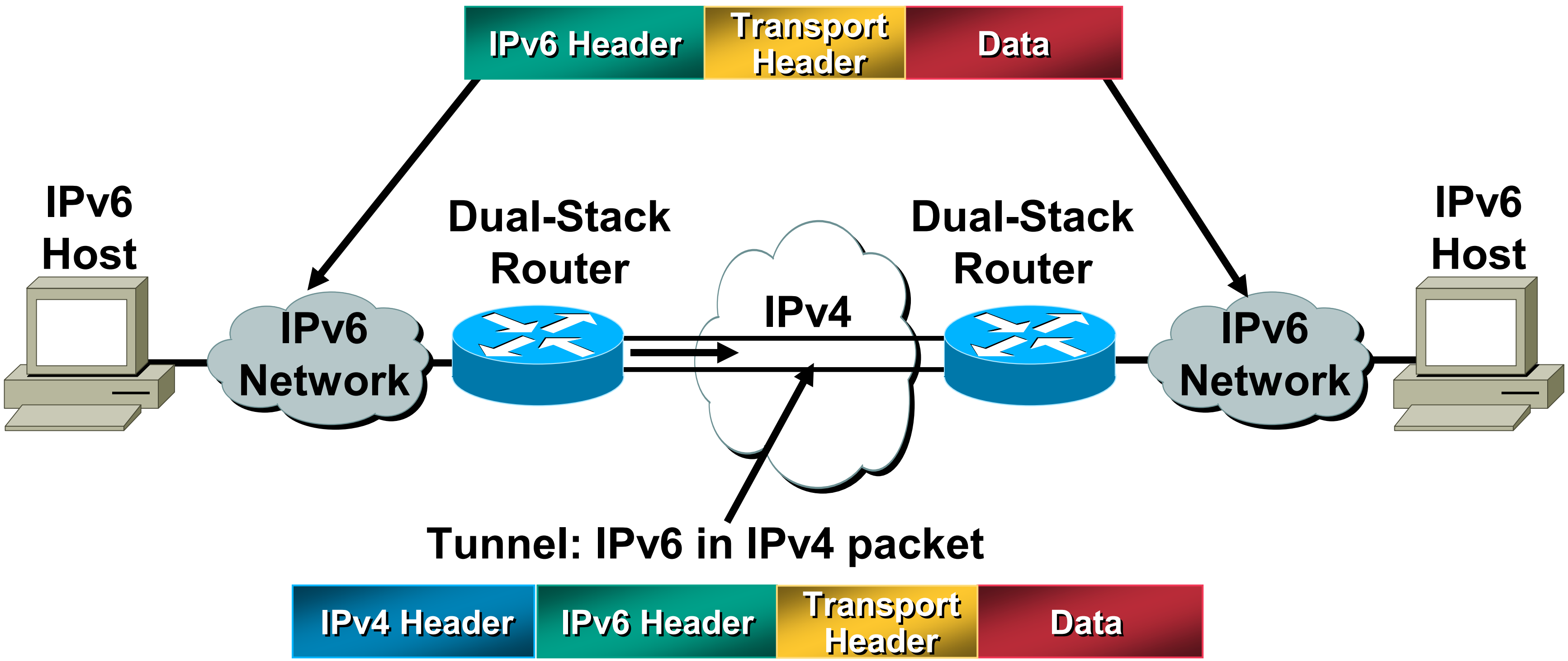
  If IPv4 and IPv6 are configured on one interface, the router is dual-stacked

  Telnet, Ping, Traceroute, SSH, DNS client, TFTP,…

Using Tunnels for IPv6 Deployment

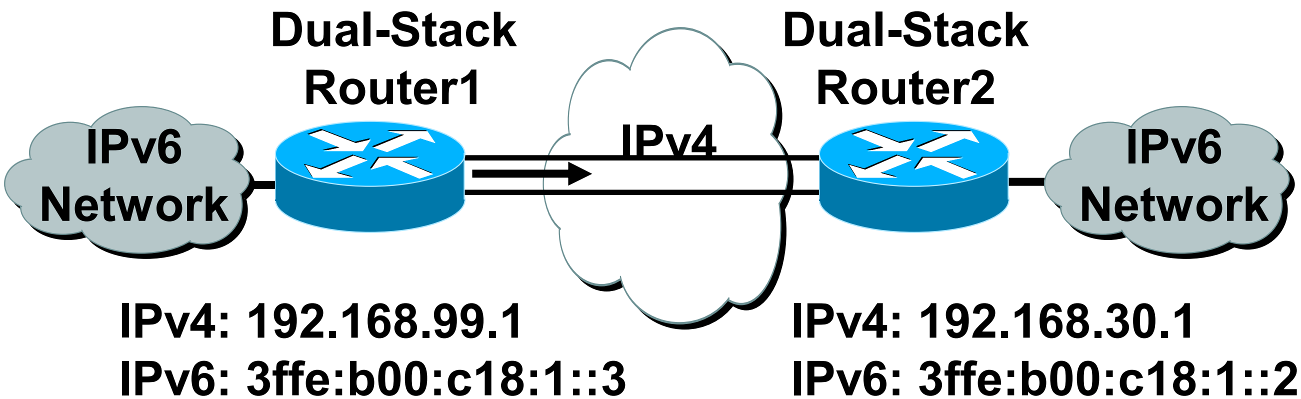
- **Many techniques are available to establish a tunnel:**
  - **Manually configured**
    - **Manual Tunnel (RFC 2893)**
    - **GRE (RFC 2473)**
  - **Semi-automated**
    - **Tunnel broker**
  - **Automatic**
    - **Compatible IPv4 (RFC 2893): Deprecated**
    - **6to4 (RFC 3056)**
    - **6over4: Deprecated**
    - **ISATAP**

IPv6 over IPv4 Tunnels



- Tunneling is encapsulating the IPv6 packet in the IPv4 packet
- Tunneling can be used by routers and hosts

Manually Configured Tunnel (RFC 2893)




```
router1#

interface Tunnel0
 ipv6 address 3ffe:b00:c18:1::3/64
 tunnel source 192.168.99.1
 tunnel destination 192.168.30.1
 tunnel mode ipv6ip
```

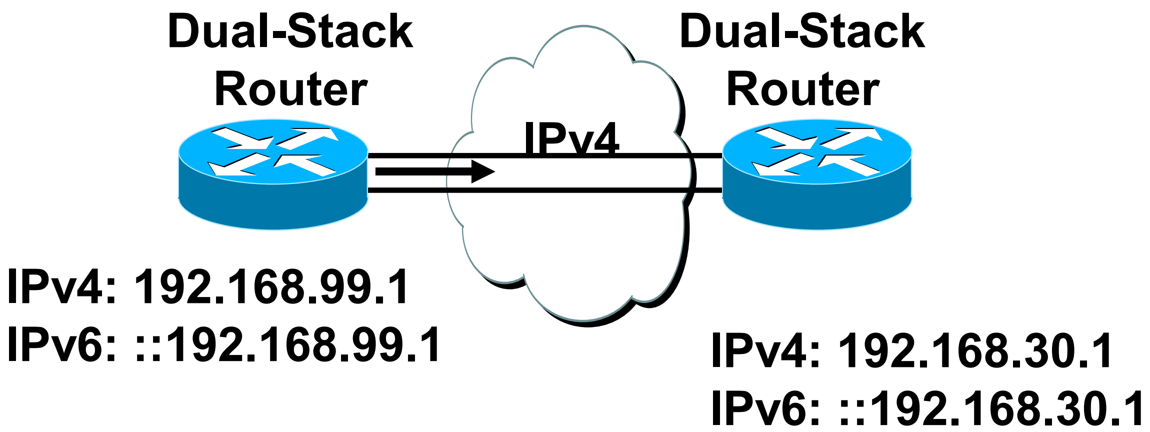
```
router2#

interface Tunnel0
 ipv6 address 3ffe:b00:c18:1::2/64
 tunnel source 192.168.30.1
 tunnel destination 192.168.99.1
 tunnel mode ipv6ip
```

- Manually Configured tunnels require:

  Dual stack end points

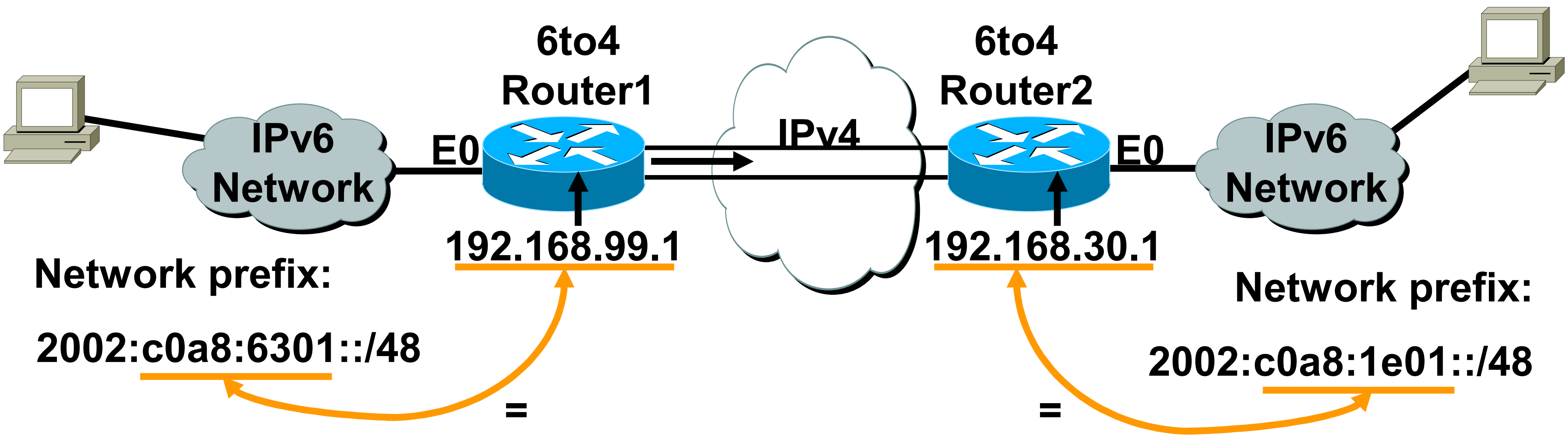
  Both IPv4 and IPv6 addresses configured at each end

IPv4 Compatible Tunnel (RFC 2893)



- **IPv4-compatible addresses are easy way to autotunnel, but it:**
  - **May be deprecated soon**

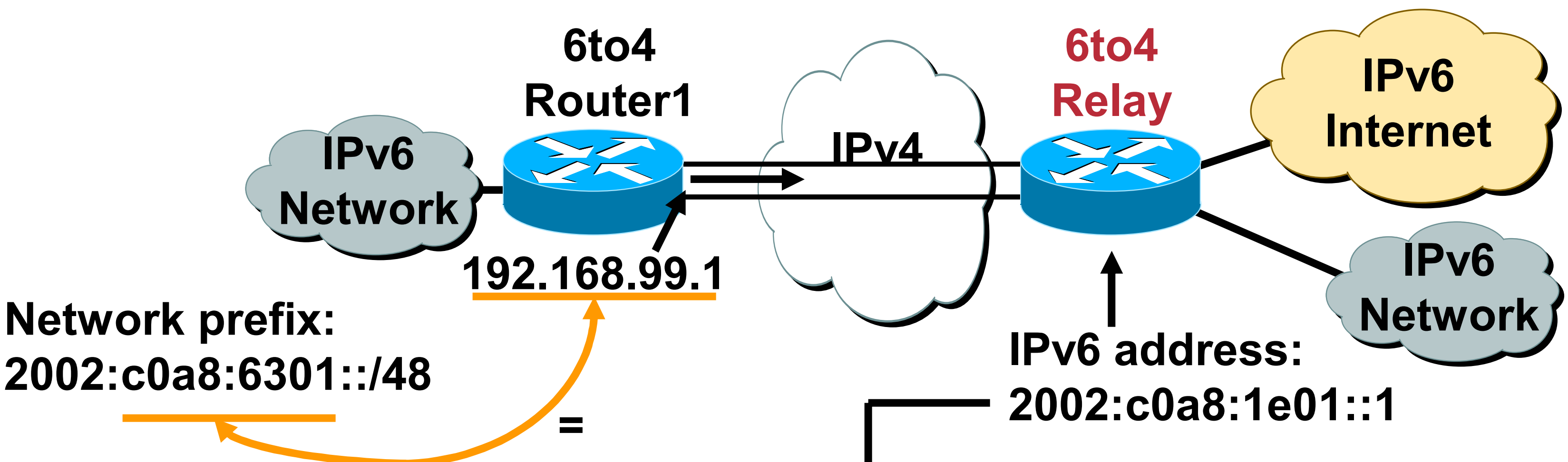
6to4 Tunnel (RFC 3056)



- **6to4 Tunnel:**
  - Is an automatic tunnel method
  - Gives a prefix to the attached IPv6 network
  - 2002::/16 assigned to 6to4
  - Requires one global IPv4 address on each Ingress/Egress site

```
router2#
interface Loopback0
 ip address 192.168.30.1 255.255.255.0
 ipv6 address 2002:c0a8:1e01:1::/64 eui-64
interface Tunnel0
 no ip address
 ipv6 unnumbered Ethernet0
 tunnel source Loopback0
 tunnel mode ipv6ip 6to4

ipv6 route 2002::/16 Tunnel0
```

6to4 Relay



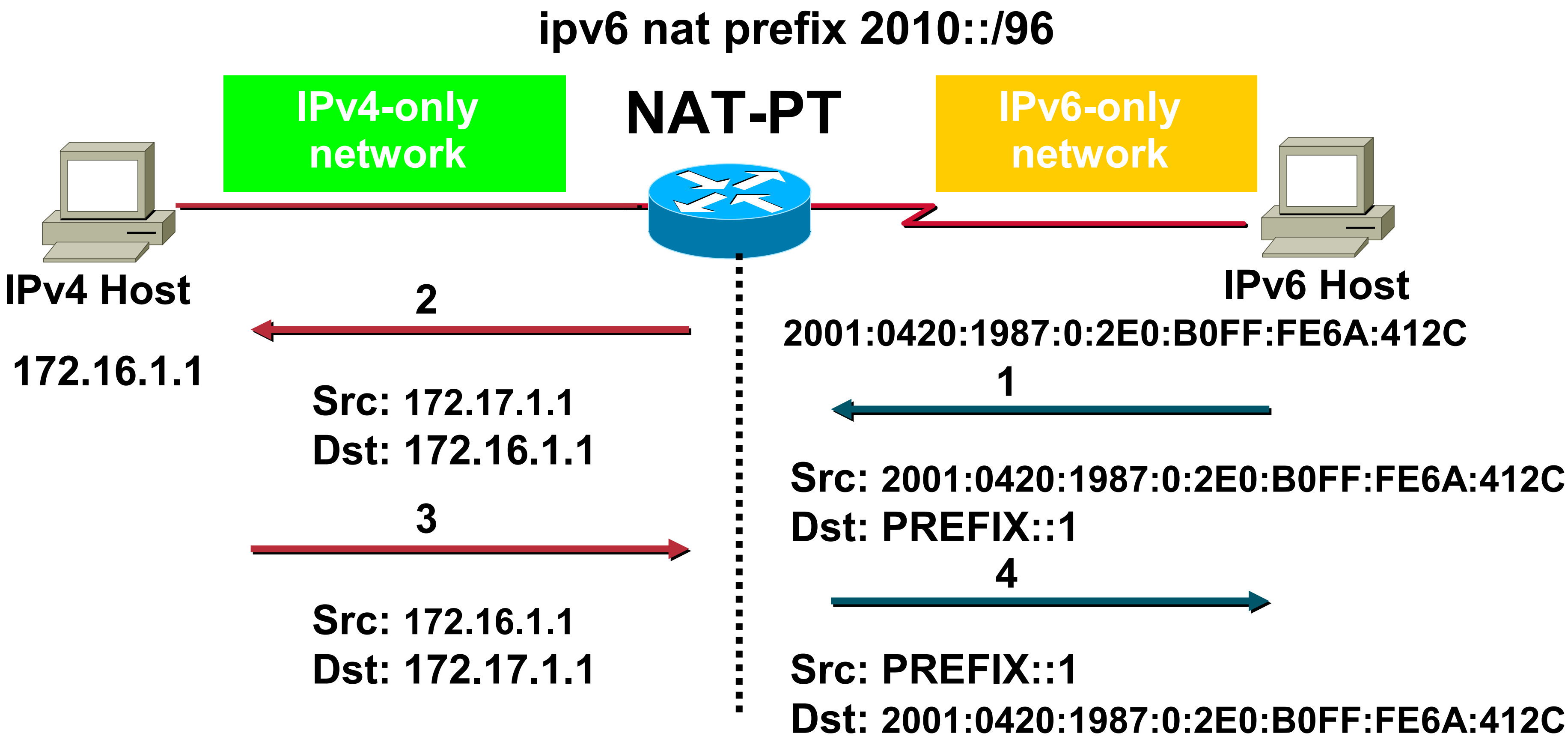

```
router1#
interface Loopback0
 ip address 192.168.99.1 255.255.255.0
 ipv6 address 2002:c0a8:6301:1::/64 eui-64
interface Tunnel0
 no ip address
 ipv6 unnumbered Ethernet0
 tunnel source Loopback0
 tunnel mode ipv6ip 6to4

ipv6 route 2002::/16 Tunnel0
ipv6 route ::/0 2002:c0a8:1e01::1
```

- **6to4 relay:**
  - Is a gateway to the rest of the IPv6 Internet
  - Default router
  - Anycast address (RFC 3068) for multiple 6to4 Relay

IPv6-IPv4 Communication Mechanisms

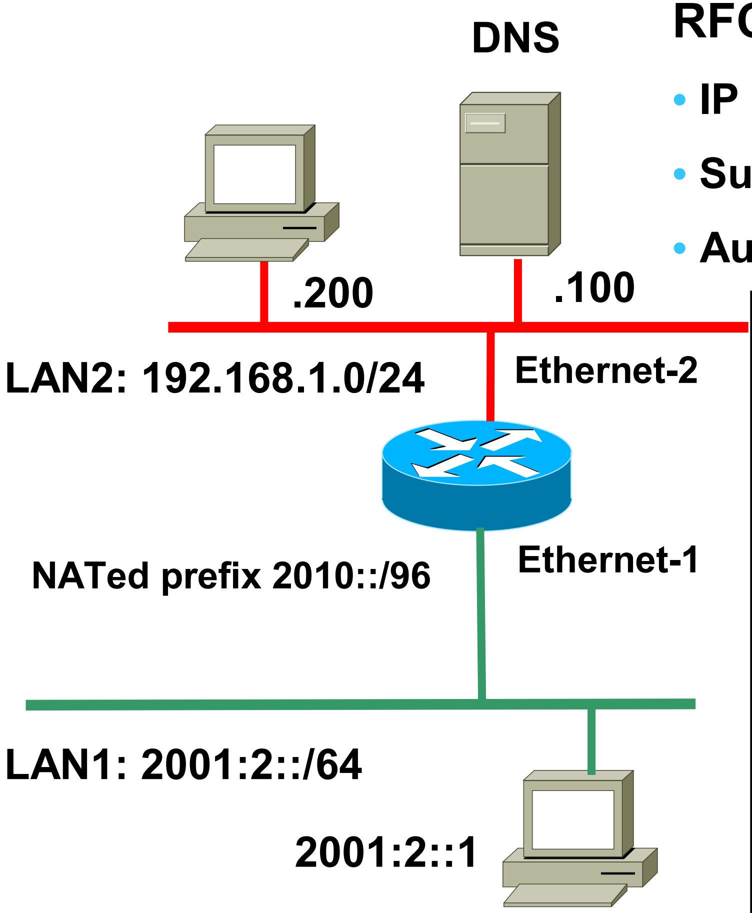
- Translation
  - NAT-PT (RFC 2766)
  - TCP-UDP Relay (RFC 3142)
- DSTM (Dual Stack Transition Mechanism)
- API
  - BIS (Bump-In-the-Stack) (RFC 2767)
  - BIA (Bump-In-the-API)
- ALG
  - SOCKS-based Gateway (RFC 3089)
  - NAT-PT (RFC 2766)

NAT-PT Overview



PREFIX is a 96-bit field that allows routing back to the NAT-PT device

Configuring Cisco IOS NAT-PT



Network Address Translation-Protocol Translation RFC 2766

- IP Header and Address translation
- Support for ICMP and DNS embedded translation
- Auto-aliasing of NAT-PT IPv4 Pool Addresses

```
interface ethernet-1
   ipv6 address 2001:2::10/64
   ipv6 nat prefix 2010::/96
   ipv6 nat
!
interface ethernet-2
   ip address 192.168.1.1 255.255.255.0
   ipv6 nat
!
ipv6 nat v4v6 source 192.168.1.100 2010::1
!
ipv6 nat v6v4 source route-map map1 pool v4pool1
ipv6 nat v6v4 pool v4pool1 192.168.2.1 192.168.2.10
prefix-length 24
!
route-map map1 permit 10
 match interface Ethernet-1
```

Agenda

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IPv6 @Cisco Systems

- Co-chair of IETF IPv6 WG and NGtrans WG
- Well Known Cisco 6Bone router
  - ~ 70 tunnels with other companies
  - acts as 6to4 Relay
  - Official Cisco IPv6 prefix registered to ARIN (2001:0420::/35)
- ‘Founding Member’ of the IPv6 Forum
- Official CCO IPv6 page is www.cisco.com/ipv6
  - Cisco IPv6 Statement of Direction published last June
  - Cisco IOS IPv6 EFT available for free over 3 years
  - ~around 500 sites running Worldwide
- Cisco IOS 12.2(2)T offers official IPv6 support
  - including Cisco IOS IPv6 training & Worldwide TAC

Cisco IOS Roadmap: The Confluence of IPv4/IPv6

Cisco IOS Release	Market Target
Phase I IOS 12.2(2)T Done	Early Adopter Deployment
Phase II On-Going	Production Backbone Deployment
Phase III CY 2002 and later	Enhanced IPv6 Services

Cisco IOS Upgrade = Free IPv6

How is Cisco IOS IPv6 Roadmap defined?

Cisco IOS IPv6 Phase I

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Cisco IOS Release	IPv6 Features Supported
Phase I **Early Adopters** Cisco IOS 12.2(2)T, (4)T Any router able to run 12.2T, from Cisco 800 to Cisco 7500 IP Plus, Enterprise and SP images	IPv6 Basic specification (RFC 2460) ICMPv6, Neighbor Discovery Stateless auto-configuration RIPv6 (RFC 2080) Multi-Protocol Extensions for BGP4 (RFC 2545 & 2858) Configured and Automatic Tunnels 6to4 Tunnel Standard Access List IPv6 over Ethernet (10/100/1000Mb/s), FDDI, Cisco HDLC, ATM and FR PVC, PPP (Serial, POS, ISDN) Ping, Traceroute, Telnet, TFTP

Done

Cisco IOS IPv6 Phase II

Cisco IOS Release	IPv6 Features Under Development
Phase II Backbone Deployment On-Going 12.2(8)T 12.0(21)ST1	i/IS-ISv6 CEFv6/dCEFv6 IPv6 Access (Encap/AAA/Dialer Pool), NAT-PT Extended Access Control List IPv6 over IPv4 GRE Tunnels IPv6 Provider Edge router (6PE) over MPLS DNS AAAA client, Static ND cache entry Link-Local Address for BGP Peering CDP, SSH, IPv6 MIB Phase I Sustaining

Extensive Platform Support

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Check latest release number & availability with your local Cisco team

Cisco IOS 12.2T

Cisco 800 series Routers

Cisco 1400 series Routers

Cisco 1600 series Routers

Cisco 1700 series Routers

Cisco 2500 series Routers [12.2(4)T]

Cisco 2600 series Routers

Cisco 3600 series Routers

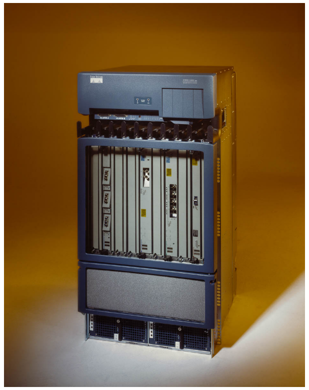
Cisco 3700 series Routers

Cisco 4500/4700 series Routers [12.2(2)T only]

Cisco 7100 series Routers

Cisco 7200 series Routers

Cisco 7500 series Routers



Cisco IOS 12.0ST

Cisco 12000 series Routers

Cisco IOS 12.2S

Cisco 7100 series Routers

Cisco 7200 series Routers

Cisco 7400 series Routers

Cisco 7500 series Routers

Cisco 7600 series Routers

Catalyst 6500 series

Cisco IOS Cable Routers

Cisco ubr7100, ubr7200,

IPv6 over IPv4 Tunnels only

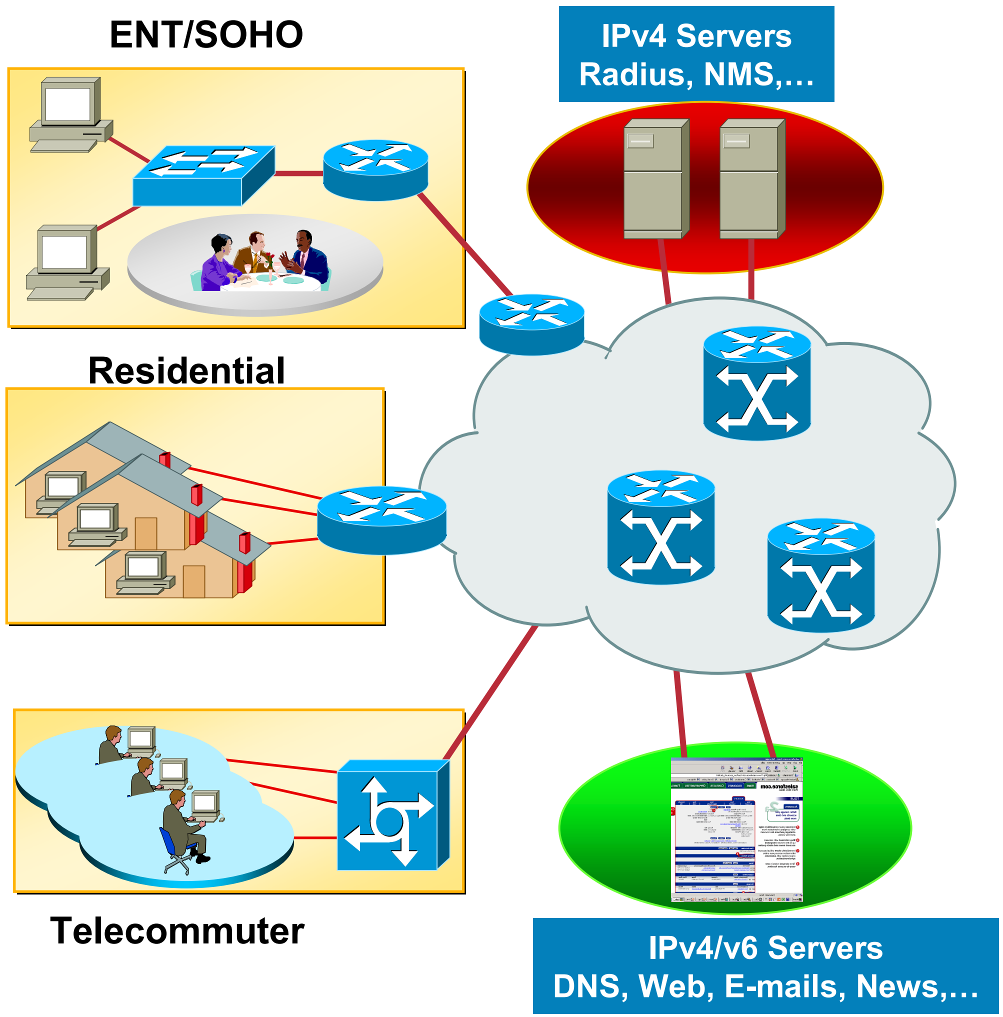
Cisco IOS 12.2B

Cisco 7200, 7400

Cisco IOS IPv6 EFT only

AS5300, 5400

Cisco IOS IPv6 Dialer Pool/AAA



- Solutions to deploy IPv6 over Dial and DSL access
- On DSL, complete choice of encapsulations
  - ATM RFC 1483 Routed
  - RBE for ATM RFC 1483 Bridged
  - PPPoA
  - PPPoE
- IPv6 prefix pools
- IPv6 AAA attributes
  - IPv6 prefix
  - IPv6 route
  - IPv6 ACL {In, Out}
- Proxy RA

Cisco IOS IPv6 Phase III

Cisco IOS Release	Evaluation of IPv6 Phase III Features
Phase III Enhanced Protocols Target date: CY 2002 And Later	**Routing:** OSPFv3 & E-IGRP **Enhanced Services:** Mobile IPv6, IPSec, IPv6 Multicast, IPv6 QoS **Management:** Netflow IPv6 record, SNMP over IPv6, MIB's enhancements **Tunnels**: IPv6 over IPv6, IPv4 over IPv6 tunnels, ISATAP **IETF IPv6 Enhancements**: eg. R.A. extensions, ICMPv6 prefix delegation, **Hardware Acceleration**: in-progress **Encapsulation**: Add enhanced support for DPT, Cable and DSL

Agenda

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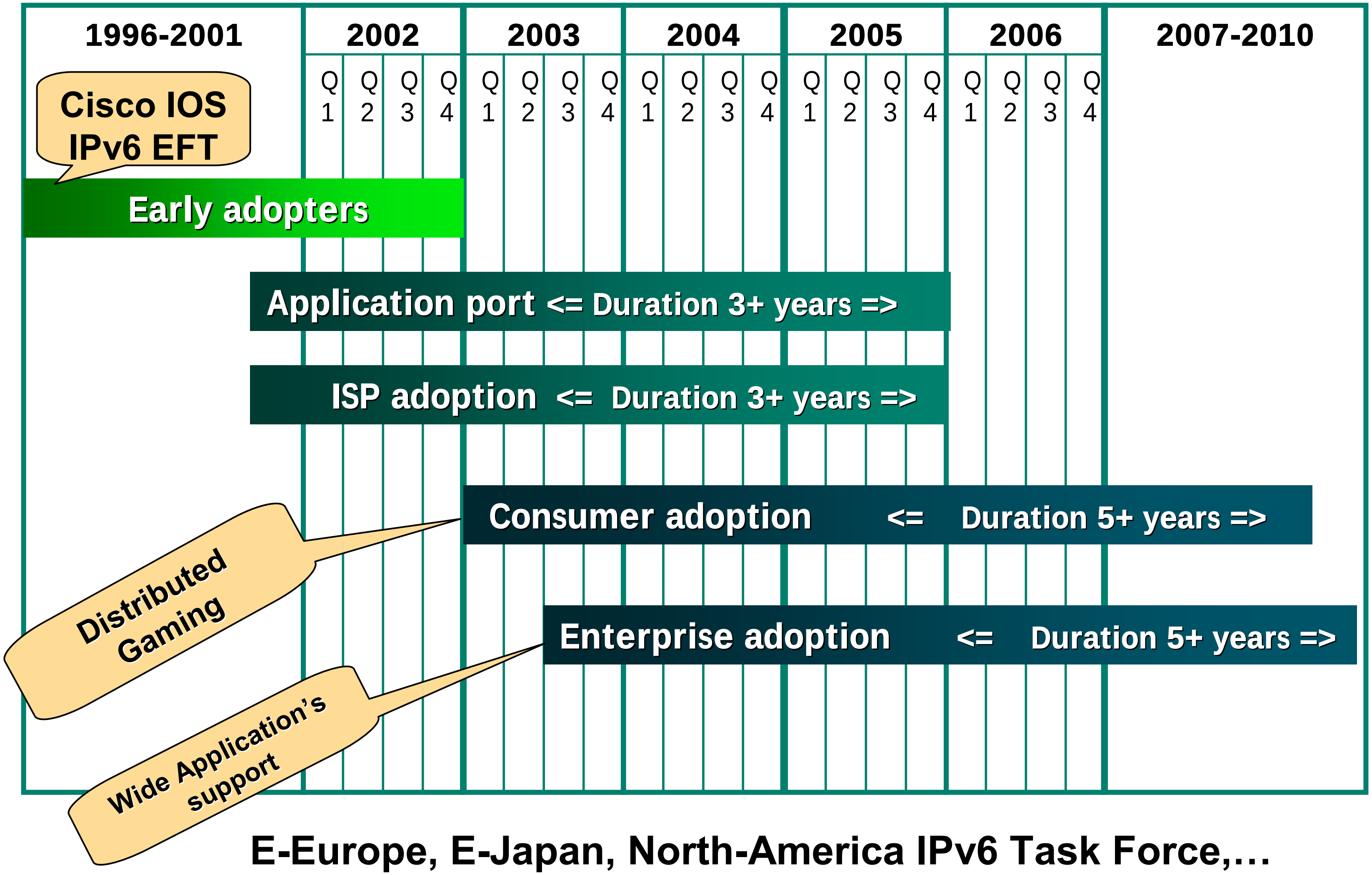
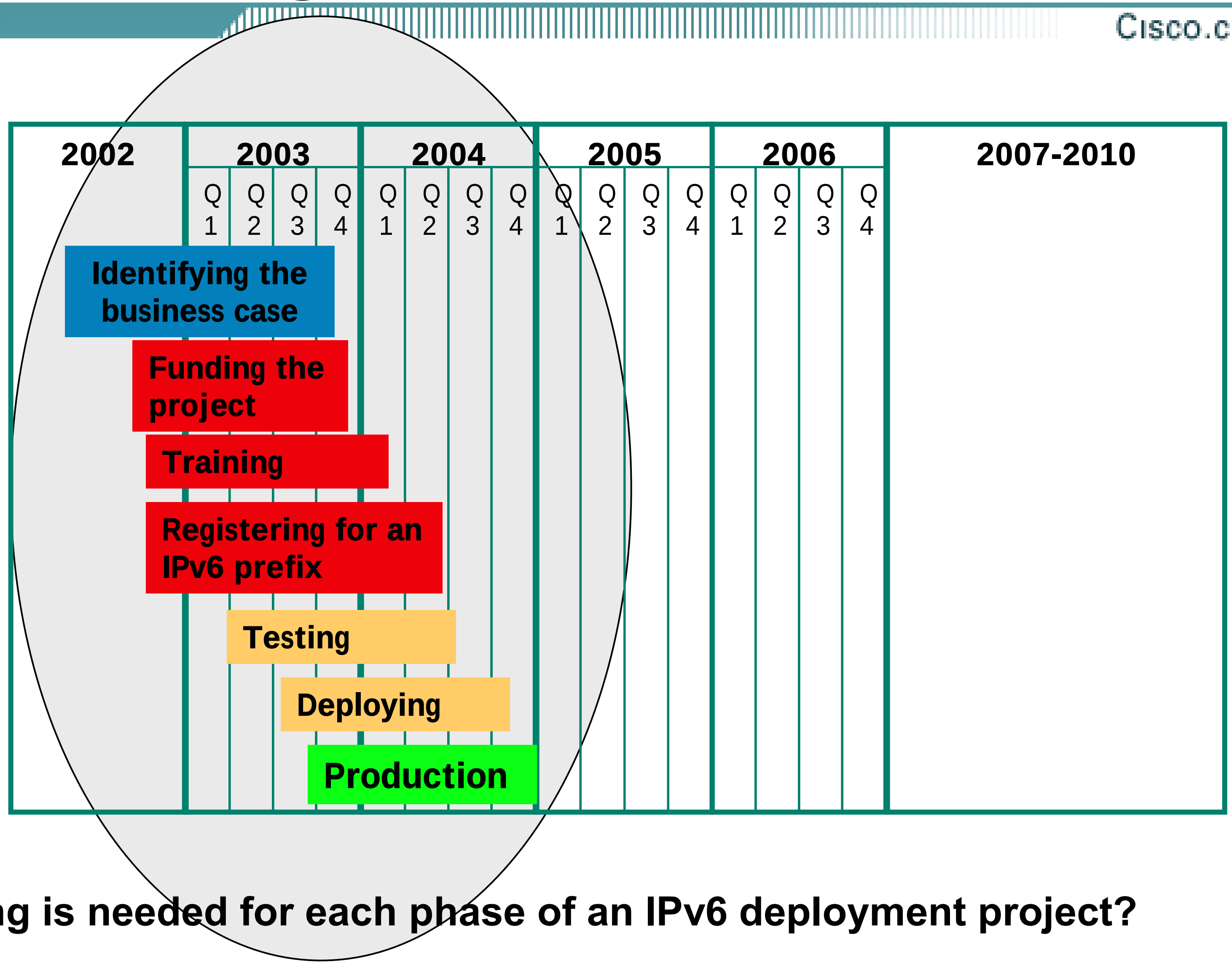
IPv6 – Looking at the Crystal Ball



E-Europe, E-Japan, North-America IPv6 Task Force,…

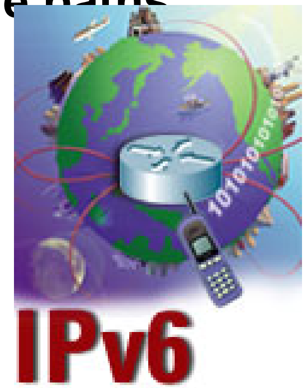
IPv6 – Working out the Timeline



How long is needed for each phase of an IPv6 deployment project?

IPv6 Deployment Scenarios

- Many ways to deliver IPv6 services to End Users
  - End-to-end IPv6 traffic forwarding is the Key feature
  - Minimize operational upgrade costs
- Service Providers and Enterprises may have different deployment needs
  - Incremental Upgrade/Deployment
  - ISP’s differentiate Core and Edge infrastructures upgrade
  - Enterprise Campus and WAN may have separate upgrade paths
- IPv6 over IPv4 tunnels
- Dedicated Data Link layers for native IPv6
- Dual stack Networks
  - IPv6 over MPLS or IPv4-IPv6 Dual Stack Routers



IPv6 over IPv4 Tunnels

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- 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
    - All of the above are supported on Cisco IOS 12.2T
- Leverages 6Bone experience
- No impact on Core infrastructure
    - Either IPv4 or MPLS

Native IPv6 over Dedicated Data Links

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- Native IPv6 links over dedicated infrastructures

    ATM PVC, dWDM Lambda, Frame Relay PVC, Serial, Sonet/SDH, Ethernet

    All of the above are supported on Cisco IOS 12.2T as well as Cisco 12000 & 7600 Internet Series Routers (Cisco IOS 12.0ST/12.2S)

- No impact on existing IPv4 infrastructures

    Only upgrade the appropriate network paths

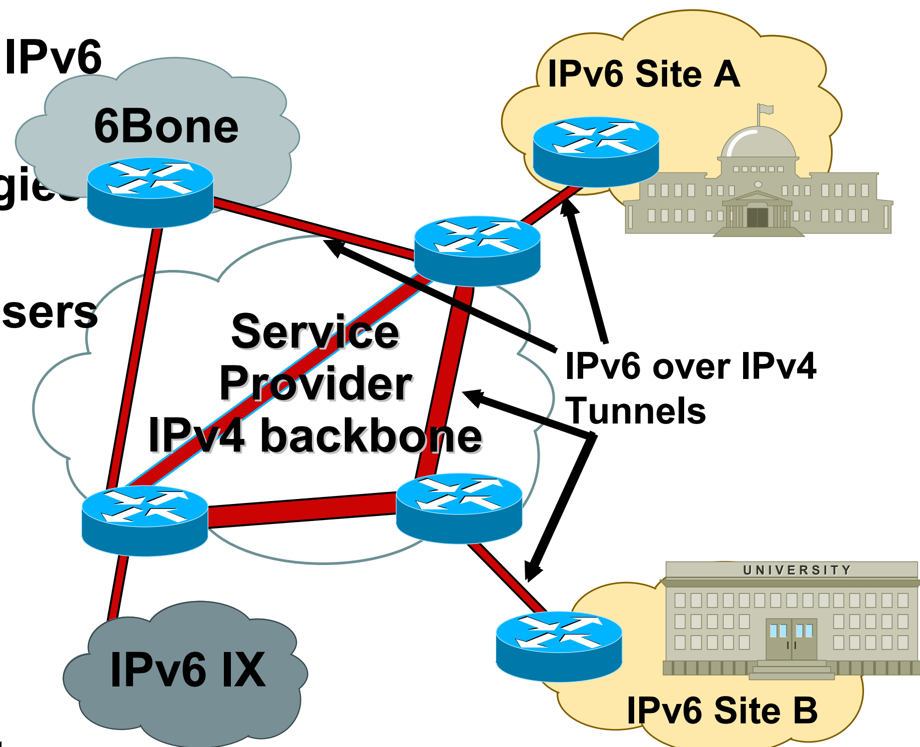
    IPv4 traffic (and revenues) can be separated from IPv6

- Network Management done through IPv4

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



Dual Stack IPv4-IPv6 Infrastructure

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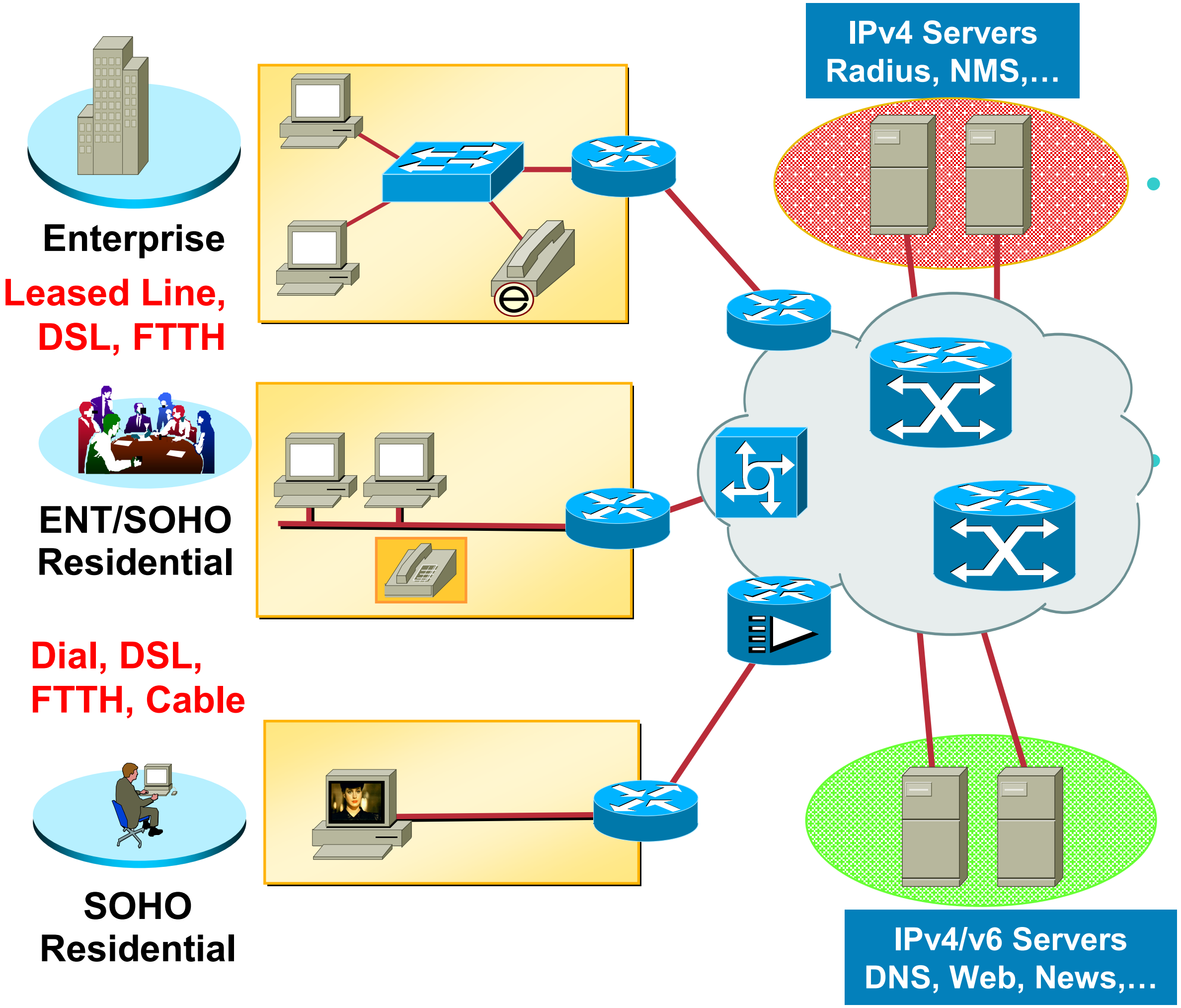
- It is generally a long term goal when IPv6 traffic and users will be rapidly increasing
- May be easier on network's portion such as Campus or Access networks
- Cisco IOS is multi-protocols from the beginning but the network design phase has to be well planned
  - Memory size to handle the growth for both IPv4 & IPv6 routing tables
  - IGP options & its management: Integrated versus "Ships in the Night"
  - Full network upgrade impact
- IPv4 and IPv6 Control & Data planes should not impact each other
  - Feedback, requirements & experiments are welcome

Dual Stack IPv4-IPv6 Case Study



- **Campus scenario**

  Upgrade all layer 3 devices to allow IPv6 hosts deployment anywhere, similar to IPX/IP environment

- **ISP**

  Access technologies may have IPv4 dependencies, eg. for User's management

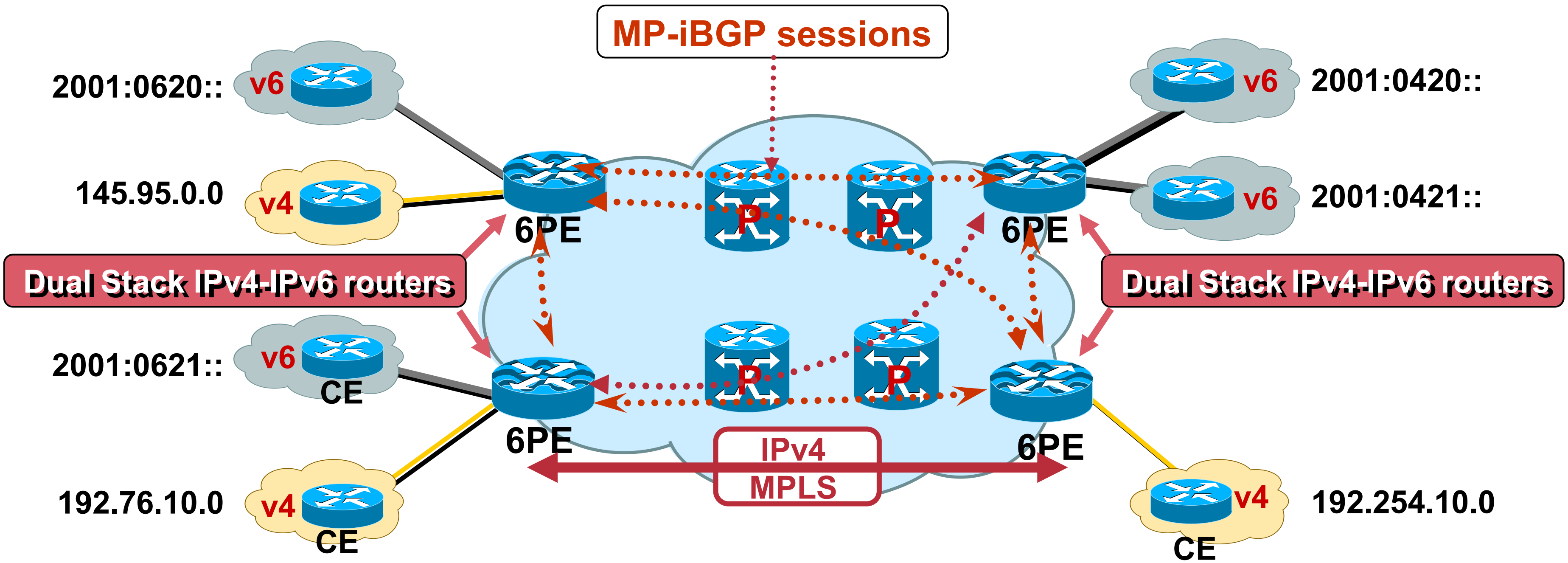
  Transparent IPv4-IPv6 access services

  Core may not go dual-stack before sometimes to avoid a full network upgrade

IPv6 over MPLS Infrastructure

- 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

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

3GPP/UMTS Release 5: a 6PE application

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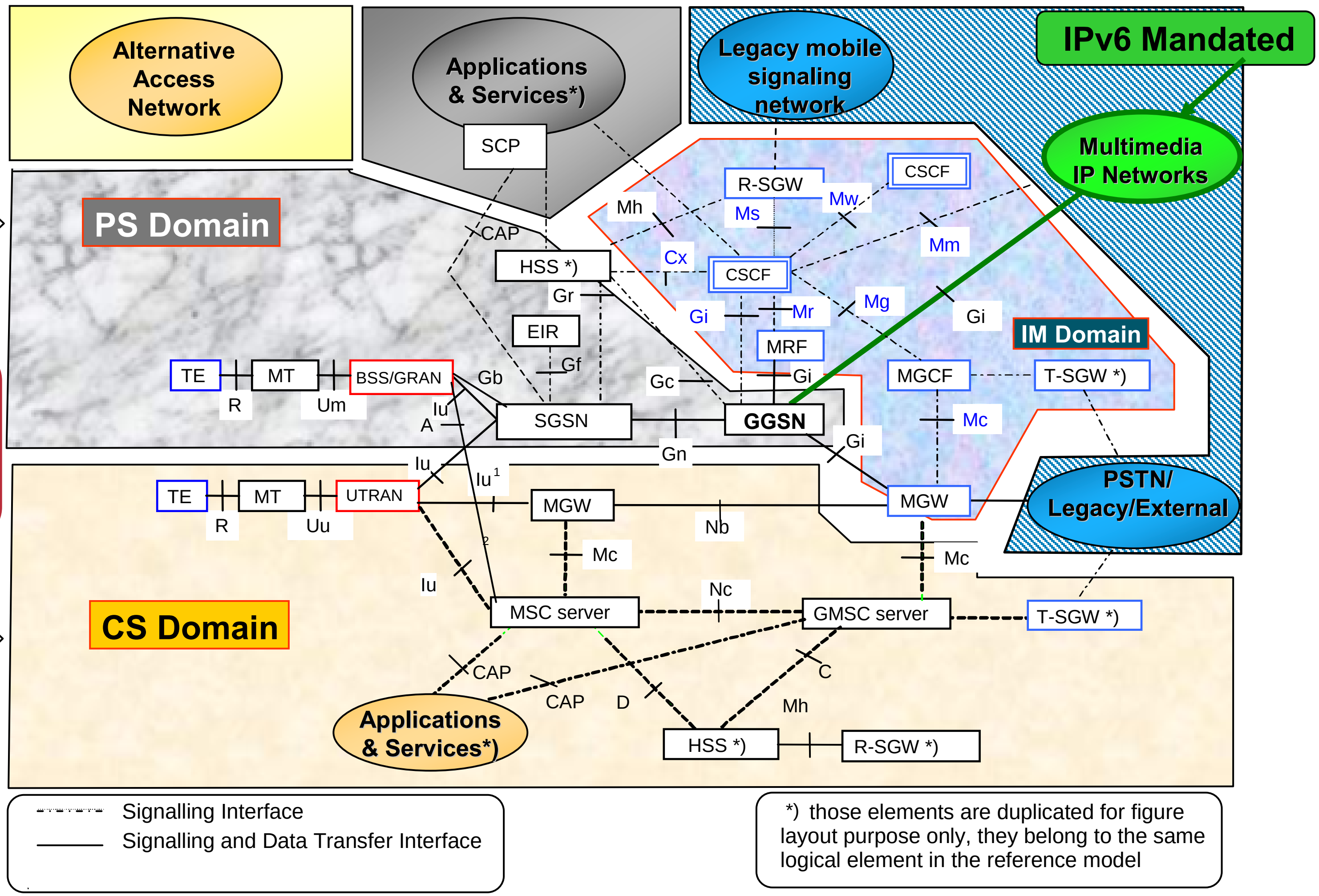
GPRS Access Network

MPLS offers ATM + IP + IPv6 switching

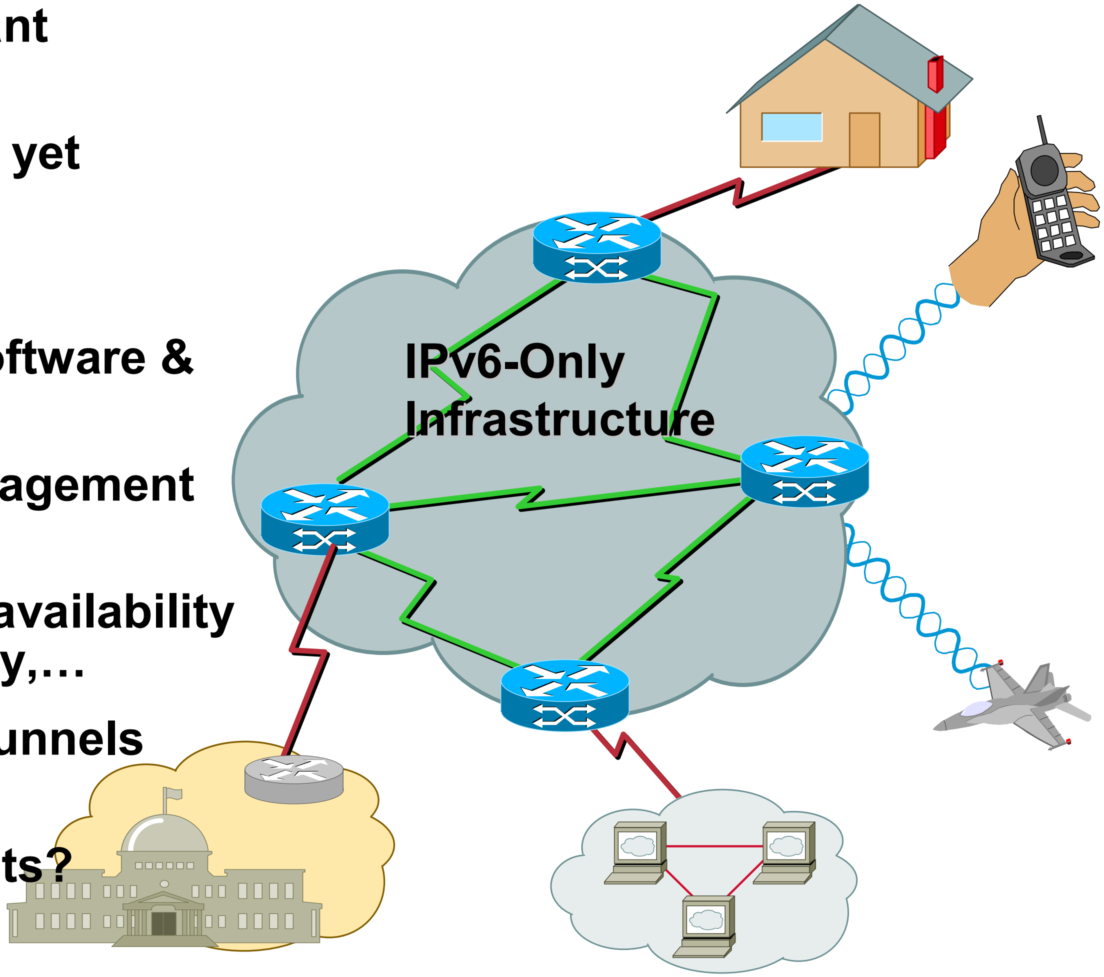
MS Circuit Switch Access Network



IM Domain is now a sub-set of the PS Domain

Native IPv6-only Infrastructure?

- **Application's 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?



IPv6 Deployment Phases

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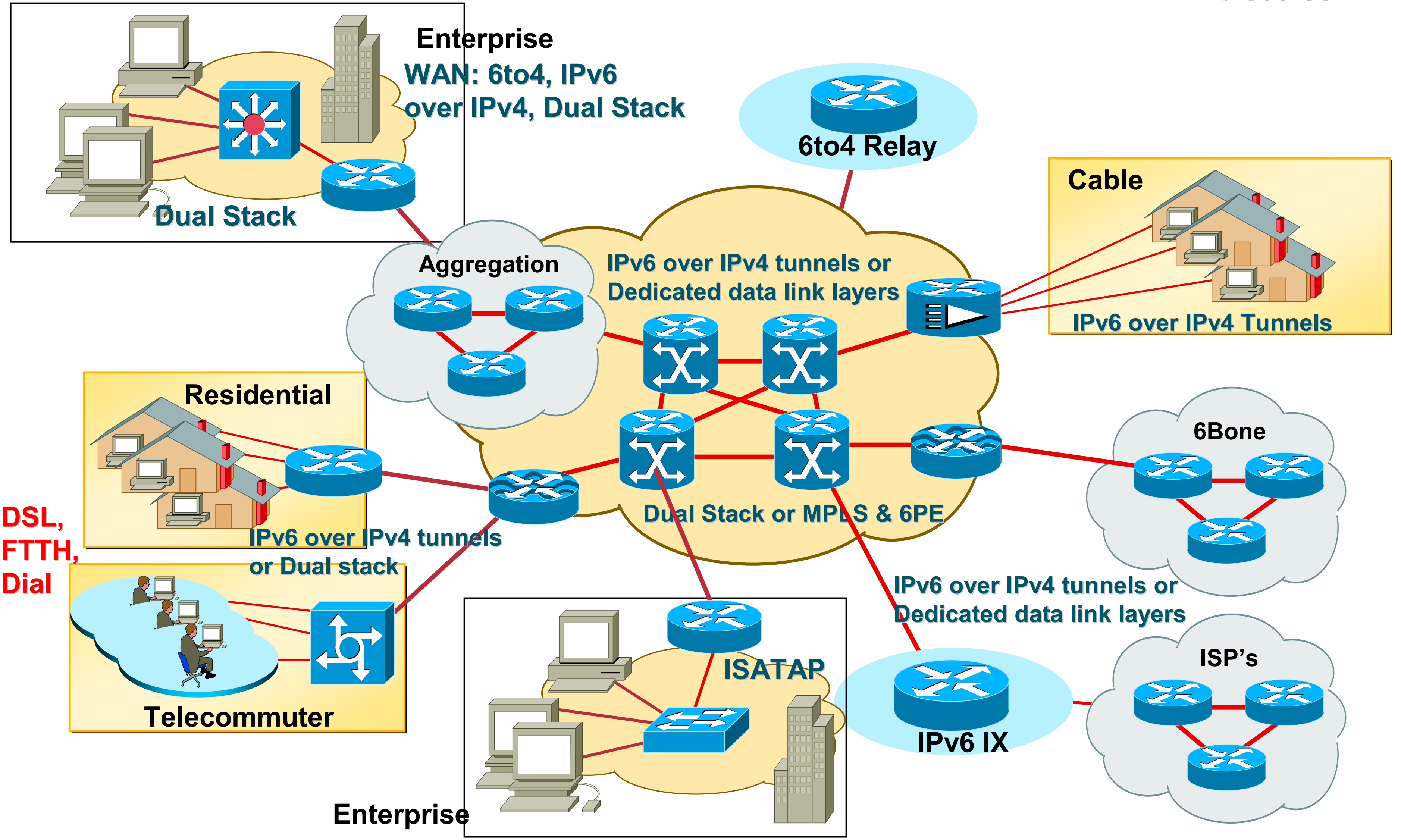
Phases	Benefits
IPv6 Tunnels over IPv4	Low cost, low risk to offer IPv6 services. No infrastructure change. Has to evolve when many IPv6 clients get connected
Dedicated Data Link layers for Native IPv6	Natural evolution when connecting many IPv6 customers. Require a physical infrastructure to share between IPv4 and IPv6 but allow separate operations
MPLS 6PE	Low cost, low risk , it requires MPLS and MP-BGP4. No need to upgrade the Core devices , keep all MPLS features (TE, IPv4-VPN)
Dual stack	Requires a major upgrade. Valid on Campus or Access networks as IPv6 hosts may be located anywhere
IPv6-Only	Requires upgrading all devices. Valid when IPv6 traffic will become preponderant

Moving IPv6 to Production, running Cisco IOS



..a lot to do still..

Though IPv6 today has all the functional capability of IPv4:

- **Implementations are not as advanced**
  (e.g., with respect to performance, multicast support, compactness, instrumentation, etc.)
- **Deployment has only just begun**
- **Much work to be done moving application, middleware, and management software to IPv6**
- **Much training work to be done**
  (application developers, network administrators, sales staff,…)
- **Some of the advanced features of IPv6 still need specification, implementation, and deployment work**

IPv6 Forum

- +100 companies

  Cisco is a founding member

- www.ipv6forum.com
- Mission is to promote IPv6 not to specify it (IETF)
- Held 'IPv6 summit' around the World

IPv6—Conclusion

IPv6 Ready for Production Deployment?

- Core IPv6 specifications are well-tested & stable

  Some of the advanced features of IPv6 still need specification, implementation, and deployment work

- Application, middleware and Scalable Deployment scenario are IPv6 Focus and Challenge.

- Plan for IPv6 integration and IPv4-IPv6 co-existence

  Training, applications inventory, and IPv6 deployment planning

- Cisco is committed to deliver advanced IPv6 capabilities to the Internet industry

  By Listening Customer's Requirements as Experience is Key.

  See http://www.cisco.com/ipv6

Questions?

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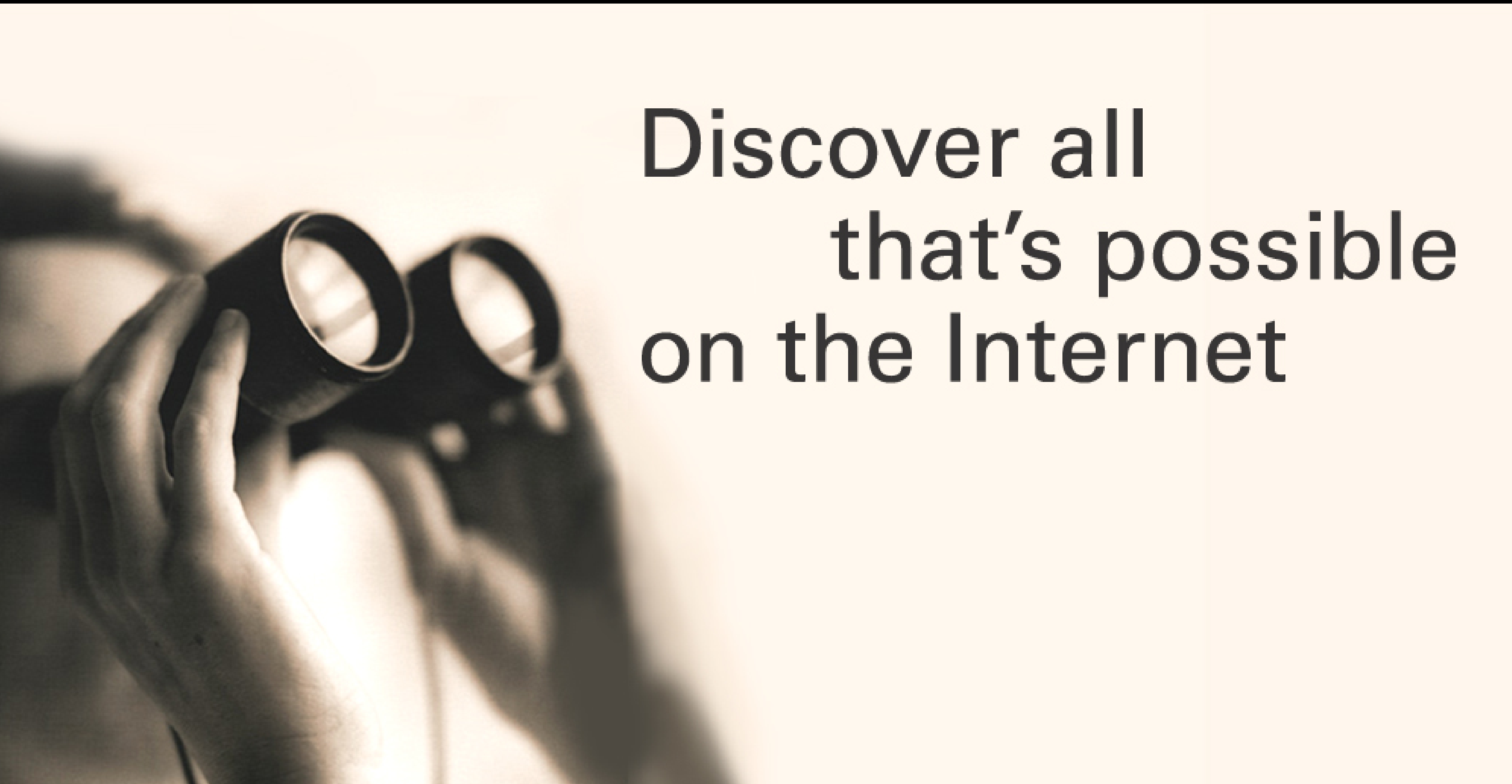
Discover all
that's possible
on the Internet