IPv6 Addressing & Routing Protocols

ISP/IXP Workshops

Topics

- Addressing plans for IPv6

- Configuring IPv6 in IOS

- IPv6 Routing Protocols

Addressing

Where to get IPv6 addresses

- Your upstream ISP

- Africa

    AfriNIC – http://www.afrinic.net

- Asia and the Pacific

    APNIC – http://www.apnic.net

- North America

    ARIN – http://www.arin.net

- Latin America and the Caribbean

    LACNIC – http://www.lacnic.net

- Europe and Middle East

    RIPE NCC – http://www.ripe.net/info/ncc

Internet Registry Regions

Getting IPv6 address space

- Become a member of your Regional Internet Registry and get your own allocation

  - Require a plan for a year ahead

  - General allocation policies are outlined in RFC2050, more specific details for IPv6 are on the individual RIR website

    or

- Take part of upstream ISP's PA space

    or

- Use 6to4

- There is plenty of IPv6 address space

  - The RIRs require high quality documentation

Getting IPv6 address space

- **From the RIR**

  Receive a /32 (or larger if you have more than 65k /48 assignments)

- **From your upstream ISP**

  Get one /48 from your upstream ISP

  More than one /48 if you have more than 65k subnets

- **Use 6to4**

  Take a single public IPv4 /32 address

  2002:<ipv4 /32 address>::/48 becomes your IPv6 address block, giving 65k subnets

  Requires a 6to4 gateway

Addressing Plans – ISP Infrastructure

- ISPs should receive /32 from their RIR

- Address block for router loop-back interfaces
    - Generally number all loopbacks out of **one** /64
    - /128 per loopback

- Address block for infrastructure
    - /48 allows 65k subnets
    - /48 per PoP or region (for large networks)
    - /48 for whole backbone (for small to medium networks)
    - Summarise between sites if it makes sense

Addressing Plans – ISP Infrastructure

- ## What about LANs?

  /64 per LAN

- ## What about Point-to-Point links?

  Expectation is that /64 is used

  People have used /126s

  Mobile IPv6 Home Agent discovery won't work

  People have used /112s

  Leaves final 16 bits free for node IDs

  See RFC3627 for more discussion

Addressing Plans – Customer

- ## Customers get **one** /48

  - Unless they have more than 65k subnets in which case they get a second /48 (and so on)

  - (Still on going RIR policy discussion about giving "small" customers a /56 and single LAN end-sites a /64)

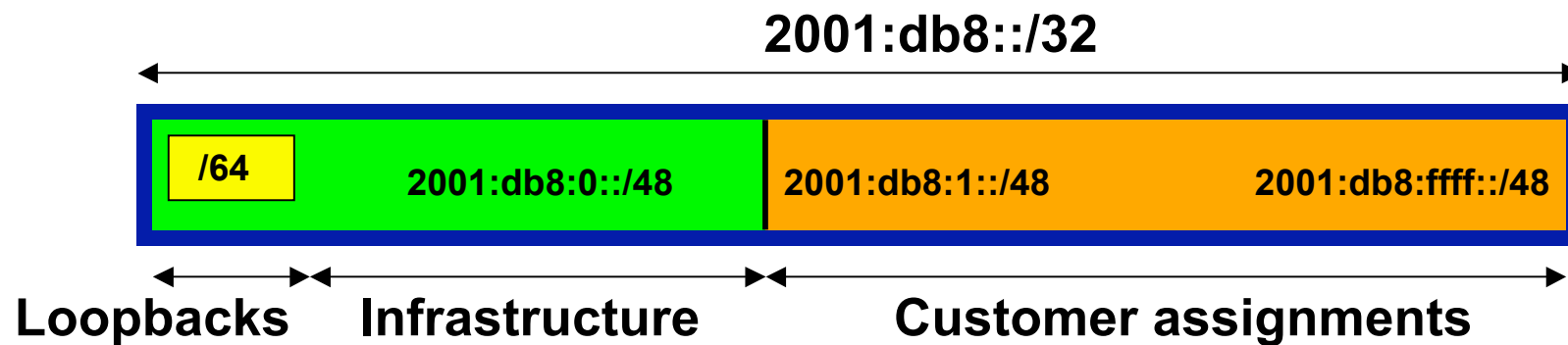- ## Should not be reserved or assigned on a per PoP basis

  - ISP iBGP carries customer nets

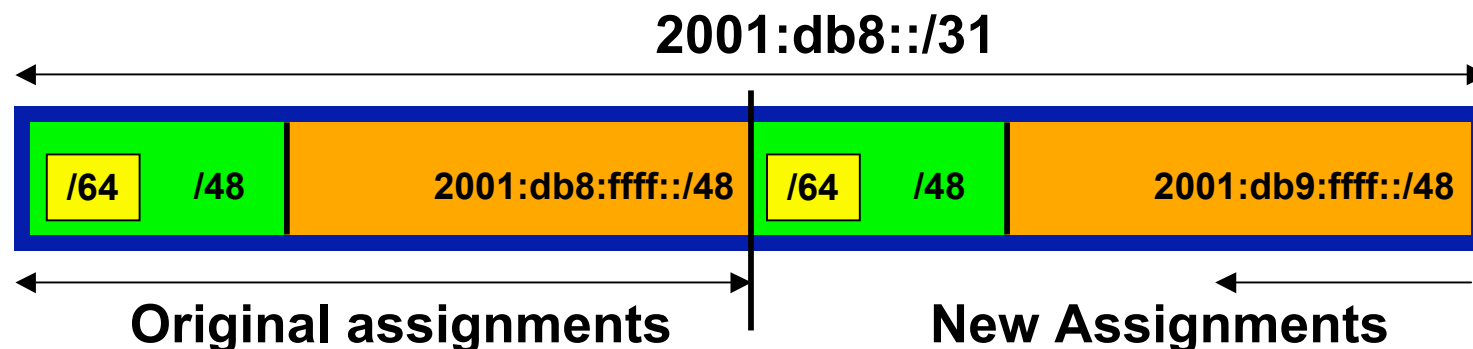 - Aggregation within the iBGP not required and usually not desirable

  - Aggregation in eBGP is very necessary

Addressing Plans – ISP Infrastructure

- ## Phase One

2001:db8::/32

/64	**2001:db8:0::/48**	**2001:db8:1::/48**	**2001:db8:ffff::/48**

Loopbacks   **Infrastructure**   **Customer assignments**

- ## Phase Two – second /32

2001:db8::/31

/64	/48	**2001:db8:ffff::/48**	/64	/48	**2001:db9:ffff::/48**

Original assignments   **New Assignments**

Addressing Plans
Planning

- Registries will usually allocate the next block to be contiguous with the first allocation

    Minimum allocation is /32

    Very likely that subsequent allocation will make this up to a /31

    So plan accordingly

Addressing Plans (contd)

- **Document infrastructure allocation**

  Eases operation, debugging and management

- **Document customer allocation**

  Customers get /48 each

  Prefix contained in iBGP

  Eases operation, debugging and management

  Submit network object to RIR Database

Addressing Tools

- Examples of IP address tools (which support IPv6 too):

IPAT	http://nethead.de/index.php/ipat
ipv6gen	http://techie.devnull.cz/ipv6/ipv6gen/
sipcalc	http://www.routemeister.net/projects/sipcalc/
freeipdb	http://home.globalcrossing.net/~freeipdb/

Initial IPv6 Configuration for IOS

IPv6 Configuration

- To enable IPv6 the following global command should be entered:

  `Router(config)# ipv6 unicast-routing`

  Also enable IPv6 CEF (not on by default):

  `Router(config)# ipv6 cef`

  Also disable IPv6 Source Routing (enabled by default):

  `Router(config)# no ipv6 source-routing`

IPv6 Configuration

- To configure a global or unique-local IPv6 address the following interface command should be entered:

    `Router(config-if)# ipv6 address X:X..X:X/prefix`

- To configure an EUI-64 based IPv6 address the following interface command should be entered:

    `Router(config-if)# ipv6 address X:X::/prefix eui-64`

    This is not useful on a router and is **not recommended**

IPv6 Configuration

- Link-local address:

    Enabling IPv6 on an interface using:

    ```
    Router(config-if)# ipv6 enable
    ```

    will result in a link-local IPv6 address being constructed automatically

    FE80:: is concatenated with the Interface ID to give:

    FE80::interface-id

- Configuring an IPv6 address (whether global or unique-local) will also result in a link-local IPv6 address being created

IPv6 Configuration

```
rtr# conf t
rtr(config)# ipv6 unicast-routing
rtr(config)# ipv6 cef
rtr(config)# int eth 0/0
rtr(config-int)# ipv6 enable
rtr(config-int)# ^Z

rtr#sh ipv6 interface eth 0/0
Ethernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::A8BB:CCFF:FE00:1E00
  No global unicast address is configured
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:1E00
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
```

IPv6 Configuration – EUI64

```
rtr#sh ipv6 interface eth 0/0
Ethernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::A8BB:CCFF:FE00:1E00
  Global unicast address(es):
    2001:DB8::A8BB:CCFF:FE00:1E00, subnet is 2001:DB8::/64 [EUI]
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:1E00
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND advertised reachable time is 0 milliseconds
  ND advertised retransmit interval is 0 milliseconds
  ND router advertisements are sent every 200 seconds
  ND router advertisements live for 1800 seconds
  Hosts use stateless autoconfig for addresses.
```

IPv6 Configuration – Static

```
rtr#sh ipv6 int fast 0/1
FastEthernet0/1 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::21D:70FF:FEBD:4CA1
  Global unicast address(es):
    2001:db8::2, subnet is 2001:db8::/64
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF08:2
    FF02::1:FFBD:4CA1
 ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND advertised reachable time is 0 milliseconds
  ND advertised retransmit interval is 0 milliseconds
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  Hosts use stateless autoconfig for addresses.
```

Routing Protocols
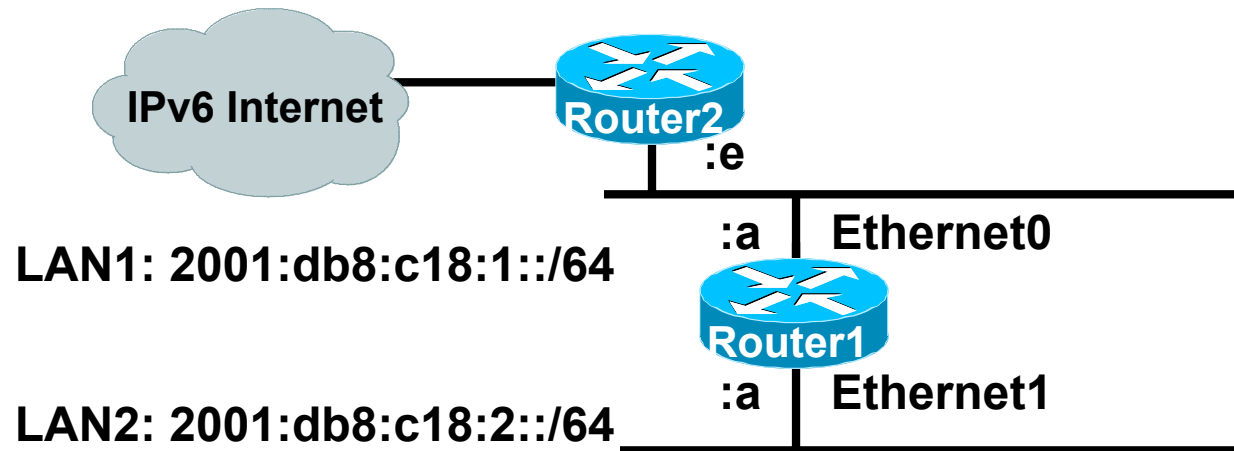
Static Routing

- Syntax is:

  ipv6 route ipv6-prefix/prefix-length {ipv6-address | interface-type interface-number} [administrative-distance]

- Static Route

  ```
  ipv6 route 2001:db8::/64 2001:db8:0:CC00::1 150
  ```

  Routes packets for network 2001:db8::/64 to a networking device at 2001:db8:0:CC00::1 with an administrative distance of 150

Default Routing Example

IPv6 Internet

Router2

:e

LAN1: 2001:db8:c18:1::/64

:a | Ethernet0

Router1

LAN2: 2001:db8:c18:2::/64

:a | Ethernet1

```
ipv6 unicast-routing
!
interface Ethernet0
 ipv6 address 2001:db8:c18:1::a/64
!
interface Ethernet1
 ipv6 address 2001:db8:c18:2::a/64
!
ipv6 route ::/0 2001:db8:c18:1::e
```

**Default Route
to Router2**

Dynamic Routing Protocols in IPv6

- Dynamic Routing in IPv6 is unchanged from IPv4:

    IPv6 has 2 types of routing protocols: IGP and EGP

    IPv6 still uses the longest-prefix match routing algorithm

- IGP

    RIPng (RFC 2080)

    Cisco EIGRP for IPv6

    OSPFv3 (RFC 5340)

    Integrated IS-ISv6 (RFC 5308)

- EGP

    MP-BGP4 (RFC 4760 and RFC 2545)

Configuring Routing Protocols

- Dynamic routing protocols require router-id

  Router-id is a 32 bit integer

  IOS auto-generates these from loopback interface address if configured, else highest IPv4 address on the router

  Most ISPs will deploy IPv6 dual stack – so router-id will be automatically created

- Early adopters choosing to deploy IPv6 in the total absence of any IPv4 addressing need to be aware:

  Router-id needs to be manually configured:

  ```
  ipv6 router ospf 100
    router-id 10.1.1.4
  ```

RIPng

- For the ISP industry, simply don't go here

- ISPs do not use RIP in any form unless there is absolutely no alternative

  - And there usually is

- RIPng was used in the early days of the IPv6 test network

  - Sensible routing protocols such as OSPF and BGP rapidly replaced RIPng when they became available

EIGRP for IPv6

- Cisco EIGRP has had IPv6 protocol support added

    Just another protocol module (IP, IPX, AppleTalk) with three new TLVs:

    IPv6_REQUEST_TYPE (0X0401)

    IPv6_METRIC_TYPE (0X0402)

    IPv6_EXTERIOR_TYPE (0X0403)

    Router-ID is still 32-bit, protocol is still 88

- Uses similar CLI to existing IPv4 protocol support

- Easy deployment path for existing IPv4 EIGRP users

- In IOS Release 12.4 onwards
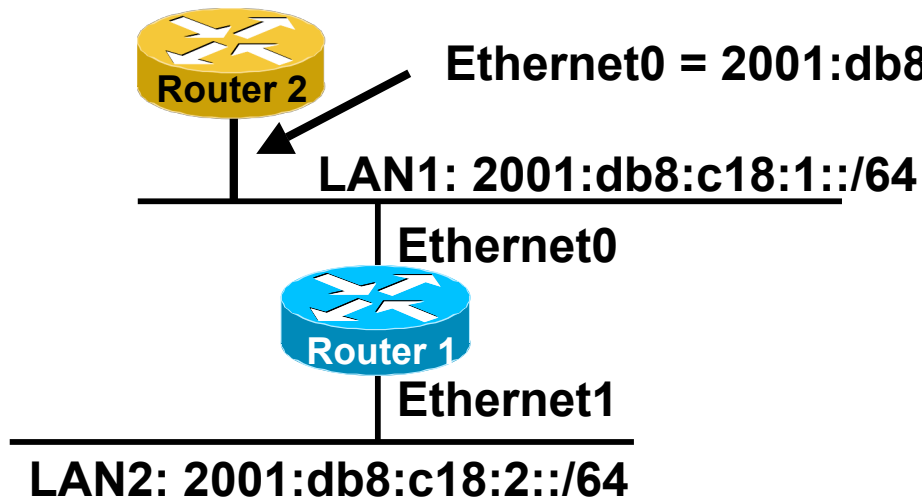
EIGRP for IPv6

- Some differences:

    Hellos are sourced from the link-local address and destined to FF02::A (all EIGRP routers). This means that neighbors do not have to share the same global prefix (with the exception of explicitly specified neighbours where traffic is unicasted).

    Automatic summarisation is disabled by default for IPv6 (unlike IPv4)

    No split-horizon in the case of EIGRP for IPv6 (because IPv6 supports multiple prefixes per interface)

EIGRP for IPv6—Configuration & Display

Router 2

Ethernet0 = 2001:db8:c18:1:260:3eff:fe47:1530

LAN1: 2001:db8:c18:1::/64

Ethernet0

Router 1

Ethernet1

LAN2: 2001:db8:c18:2::/64

```
Router2#
ipv6 router eigrp 100
 Router-id 10.10.10.1

interface Ethernet0
 ipv6 address 2001:db8:c18:1::/64 eui-64
 ipv6 enable
 ipv6 eigrp 100
```

```
Router1#show ipv6 eigrp neighbor
IPv6-EIGRP neighbors for process 100
```

H	Address	Interface	Hold (sec)	Uptime	SRTT (ms)	RTO	Q Cnt	Seq Num
0	FE80::260:3eff:fe47:1530	E0	14	00:01:43	1	4500	0	1

```
Router1#show ipv6 eigrp topology all-links
IPv6-EIGRP Topology Table for AS(100)/ID(10.10.10.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
     r - reply Status, s - sia Status
P 2001:db8:c18:1::/64, 1 successors, FD is 28160, serno 1
    via Connected, Ethernet0
    via FE80::260:3eff:fe47:1530 (30720/28160), Ethernet0
```

Neighbour Identified by Link-Local Address

OSPFv3 overview

- OSPFv3 is OSPF for IPv6 (RFC 5340)

- Based on OSPFv2, with enhancements

- Distributes IPv6 prefixes

- Runs directly over IPv6

- Ships-in-the-night with OSPFv2

Differences from OSPFv2

- Runs over a link, not a subnet
    - Multiple instances per link

- Topology not IPv6 specific
    - Router ID
    - Link ID

- Standard authentication mechanisms

- Uses link local addresses

- Generalized flooding scope

- Two new LSA types

OSPFv3 configuration example

```
Router1#
 interface Ethernet0
  ipv6 address 2001:db8:1:1::1/64
  ipv6 ospf 1 area 0

 interface Ethernet1
  ipv6 address 2001:db8:2:2::2/64
  ipv6 ospf 1 area 1

 ipv6 router ospf 1
  router-id 1.1.1.1
```


Area 0

Router2

LAN1: 2001:db8:1:1::/64

Eth0

Router1

Eth1

LAN2: 2001:db8:2:2::/64

Area 1
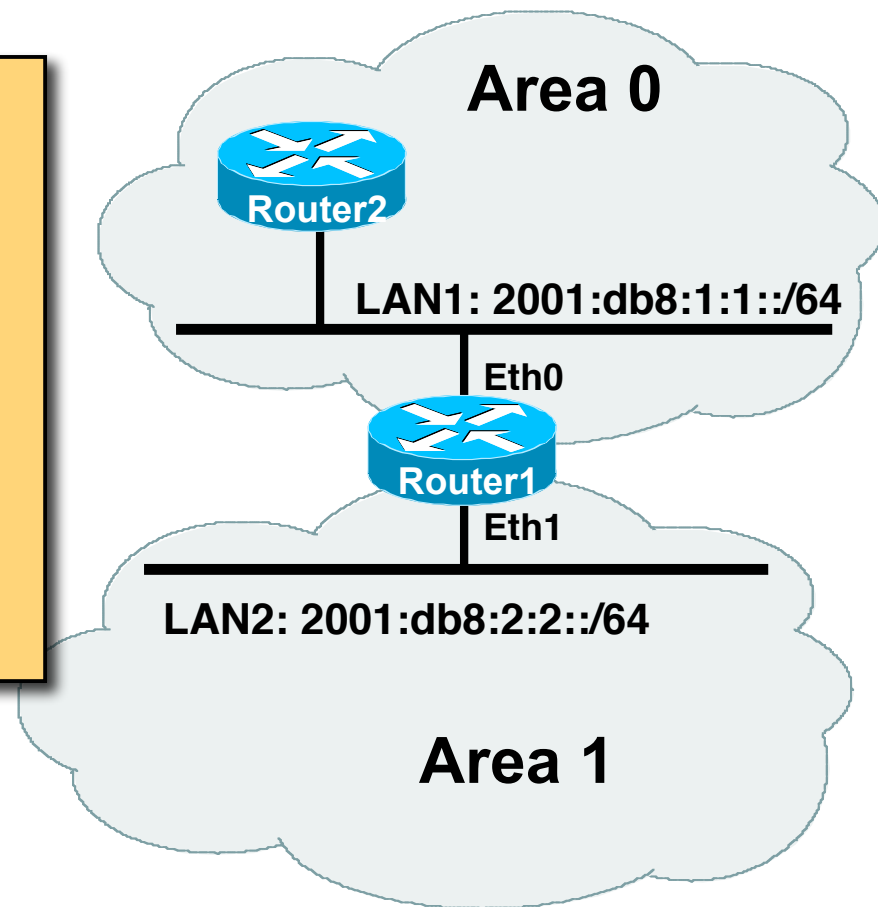
IS-IS Standards History

- IETF ISIS for Internets Working Group

- ISO 10589 specifies OSI IS-IS routing protocol for CLNS traffic

    Tag/Length/Value (TLV) options to enhance the protocol

    A Link State protocol with a 2 level hierarchical architecture.

- RFC 1195 added IP support, also known as Integrated IS-IS (I/IS-IS)

    I/IS-IS runs on top of the Data Link Layer

    Requires CLNP to be configured

- RFC5308 adds IPv6 address family support to IS-IS

- RFC5120 defines Multi-Topology concept for IS-IS

    Permits IPv4 and IPv6 topologies which are not identical

IS-IS for IPv6

- 2 Tag/Length/Values added to introduce IPv6 routing

- IPv6 Reachability TLV (0xEC)

    External bit

    Equivalent to IP Internal/External Reachability TLV's

- IPv6 Interface Address TLV (0xE8)

    For Hello PDUs, must contain the Link-Local address

    For LSP, must only contain the non-Link Local address

- IPv6 NLPID (0x8E) is advertised by IPv6 enabled routers

Cisco IOS IS-IS dual IP configuration

LAN1: 2001:db8:1::45c/64

Ethernet-1

Router1

Ethernet-2

LAN2: 2001:db8:2::45a/64
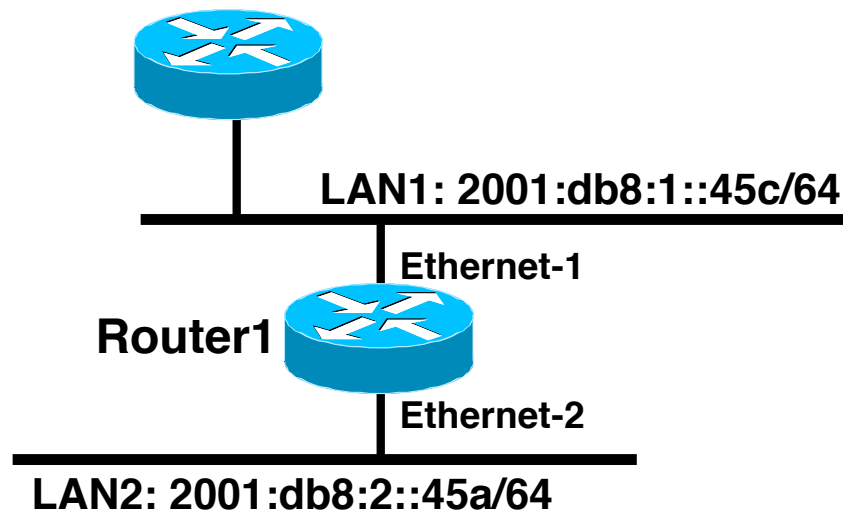
**Dual IPv4/IPv6 configuration.
Redistributing both IPv6 static routes
and IPv4 static routes.**

```
Router1#
interface ethernet-1
 ip address 10.1.1.1 255.255.255.0
 ipv6 address 2001:db8:1::45c/64
 ip router isis
 ipv6 router isis

interface ethernet-2
 ip address 10.2.1.1 255.255.255.0
 ipv6 address 2001:db8:2::45a/64
 ip router isis
 ipv6 router isis

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

Multi-Topology IS-IS extensions

- New TLVs attributes for Multi-Topology extensions.

    Multi-topology TLV: contains one or more multi-topology ID in which the router participates. It is theoretically possible to advertise an infinite number of topologies. This TLV is included in IIH and the first fragment of a LSP.

    MT Intermediate Systems TLV: this TLV appears as many times as the number of topologies a node supports. A MT ID is added to the extended IS reachability TLV type 22.

    Multi-Topology Reachable IPv4 Prefixes TLV: this TLV appears as many times as the number of IPv4 announced by an IS for a give n MT ID. Its structure is aligned with the extended IS Reachability TLV Type 236 and add a MT ID.

    Multi-Topology Reachable IPv6 Prefixes TLV: this TLV appears as many times as the number of IPv6 announced by an IS for a given MT ID. Its structure is aligned with the extended IS Reachability TLV Type 236 and add a MT ID.
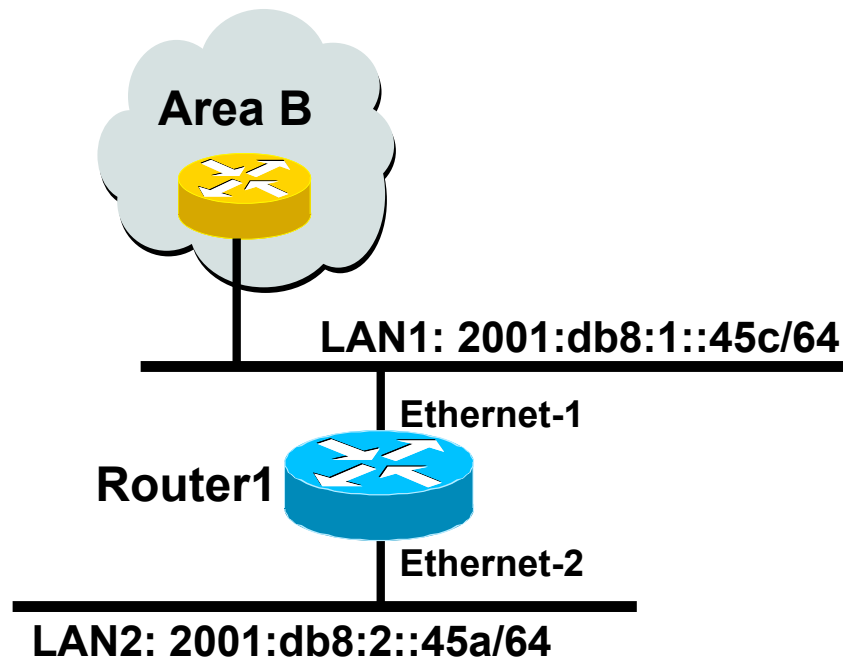
- Multi-Topology ID Values

    Multi-Topology ID (MT ID) standardized and in use in Cisco IOS:

    MT ID #0 – "standard" topology for IPv4/CLNS

    MT ID #2 – IPv6 Routing Topology.

Multi-Topology ISIS configuration example

Area B

LAN1: 2001:db8:1::45c/64

Ethernet-1

Router1

Ethernet-2

LAN2: 2001:db8:2::45a/64

- The optional keyword `transition` may be used for transitioning existing IS-IS IPv6 single SPF mode to MT IS-IS

- Wide metric is mandated for Multi-Topology to work

```
Router1#
interface ethernet-1
 ip address 10.1.1.1 255.255.255.0
 ipv6 address 2001:db8:1::45c/64
 ip router isis
 ipv6 router isis
 isis ipv6 metric 20

interface ethernet-2
 ip address 10.2.1.1 255.255.255.0
 ipv6 address 2001:db8:2::45a/64
 ip router isis
 ipv6 router isis
 isis ipv6 metric 20

router isis
 net 49.0000.0100.0000.0000.0500
 metric-style wide
 !
 address-family ipv6
  multi-topology
 exit-address-family
```

Multi-Protocol BGP for IPv6 – RFC2545

- IPv6 specific extensions

  Scoped addresses: Next-hop contains a global IPv6 address and/or potentially a link-local address

  NEXT_HOP and NLRI are expressed as IPv6 addresses and prefix

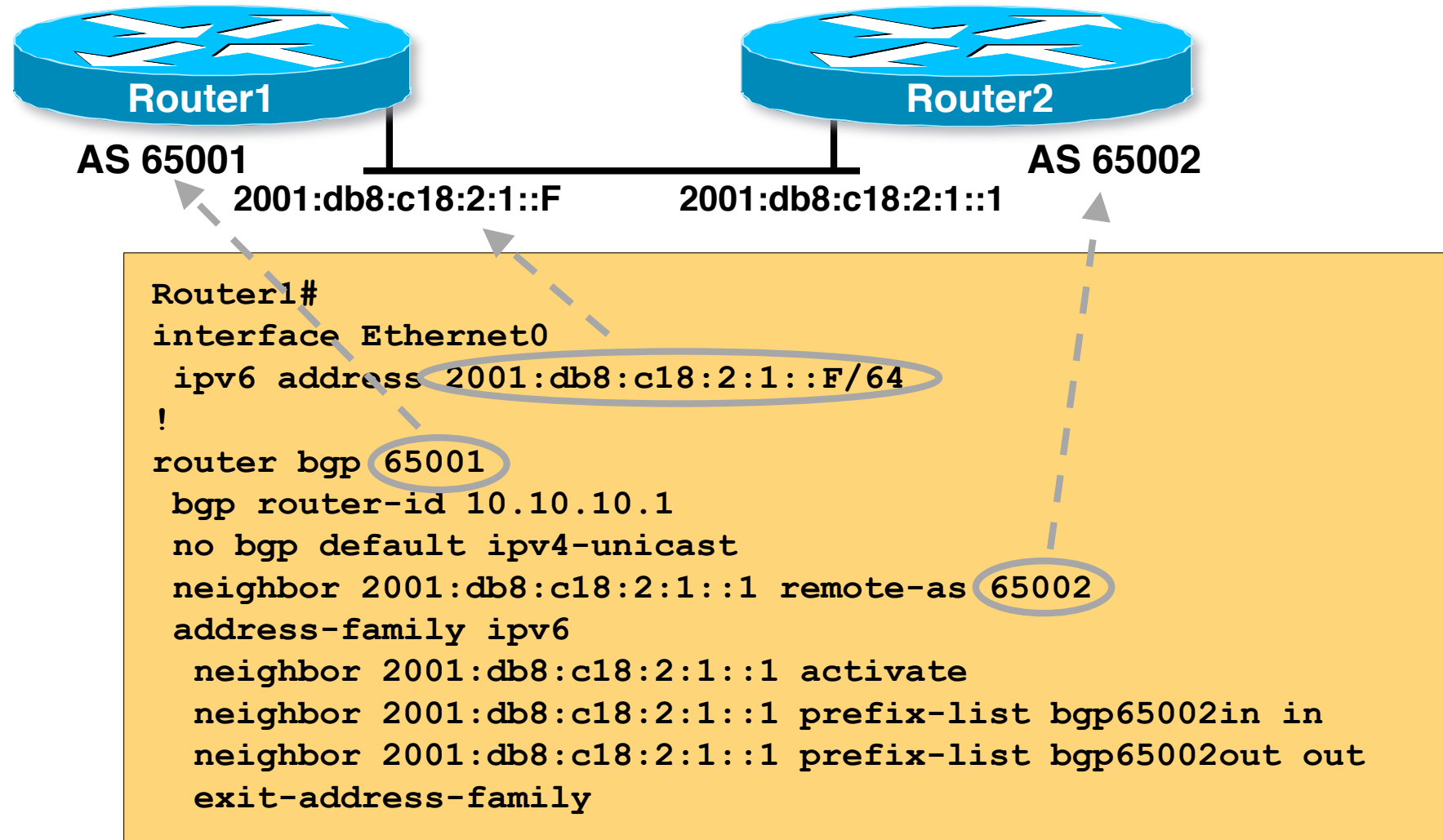 Address Family Information (AFI) = 2 (IPv6)

  Sub-AFI = 1 (NLRI is used for unicast)

  Sub-AFI = 2 (NLRI is used for multicast RPF check)

  Sub-AFI = 3 (NLRI is used for both unicast and multicast RPF check)

  Sub-AFI = 4 (label)

A Simple MP-BGP Session

Router1

AS 65001

2001:db8:c18:2:1::F

Router2

AS 65002

2001:db8:c18:2:1::1

```
Router1#
interface Ethernet0
 ipv6 address 2001:db8:c18:2:1::F/64
!
router bgp 65001
 bgp router-id 10.10.10.1
 no bgp default ipv4-unicast
 neighbor 2001:db8:c18:2:1::1 remote-as 65002
 address-family ipv6
  neighbor 2001:db8:c18:2:1::1 activate
  neighbor 2001:db8:c18:2:1::1 prefix-list bgp65002in in
  neighbor 2001:db8:c18:2:1::1 prefix-list bgp65002out out
  exit-address-family
```

Routing Protocols for IPv6 Summary

- Support for IPv6 in the major routing protocols

- More details for OSPF, ISIS and BGP in following presentations

IPv6 Addressing & Routing Protocols

ISP/IXP Workshops