Address Space Management

Transitioning to IPv6

IPv4 vs. IPv6

	Internet Protocol version 4 (IPv4)	Internet Protocol version 6 (IPv6)
Developed	1981	1998 IETF (Internet Engineering Task Force)
Address Length	32 bits	128 bits
Binary Value	11000000.10101000. 11001001.01110001	1010010100100100.0111001011010011. 0010110010000000.1101110100000010. 0000000000101001.1110110001111010. 0000000000101011.1110101001110011
Address Format	Decimal Notation 192.168.201.113	Hexadecimal Notation A524:72D3:2C80:DD02: 0029:EC7A:002B:EA73
Number of Addresses	$2^{32} \approx 4{,}294{,}467{,}295$	$2^{128} \approx 3.4 \times 10^{38}$

IPv6 Advanced Features

Larger address space:

- Global reachability and flexibility
- Aggregation
- Multihoming
- Autoconfiguration
- Plug-and-play
- End-to-end without NAT
- Renumbering

Mobility and security:

- Mobile IP RFC-compliant
- IPsec mandatory (or native) for IPv6

Simpler header:

- Routing efficiency
- Performance and forwarding rate scalability
- No broadcasts
- No checksums
- Extension headers
- Flow labels

Transition richness:

- Dual stack
- 6to4 and manual tunnels
- Translation (NAT-PT)

IPv6 Address Representation

Format:

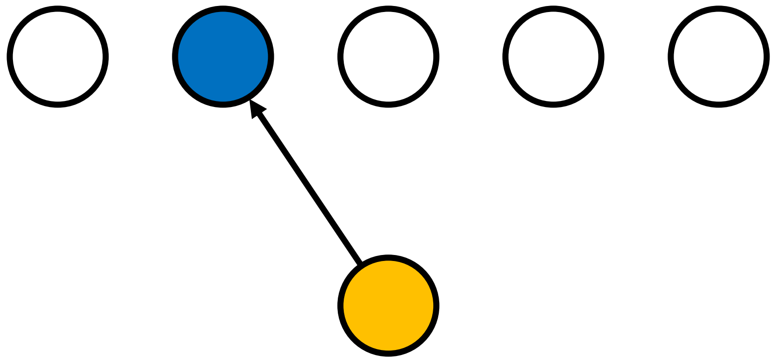
- **x:x:x:x:x:x:x:x, where x is a 16-bit hexadecimal field**
  - **Case-insensitive for hexadecimal A, B, C, D, E, and F**
- Leading zeros in a field are optional. (Ex: 09C0 = 9C0; 0000 = 0)
- Successive fields of zeros can be represented as :: only once per address

Examples:

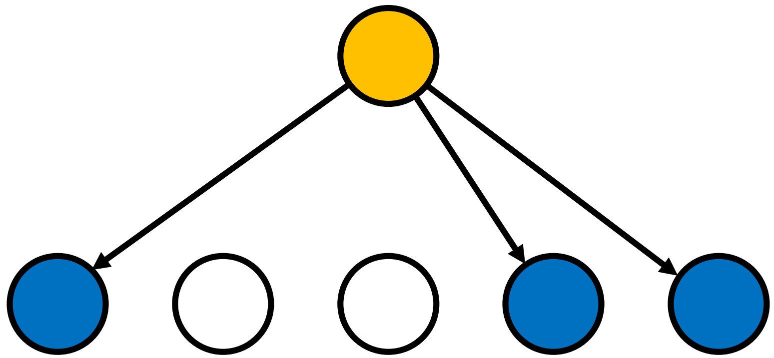
- **2031:0000:130F:0000:0000:09C0:876A:130B**
  - Can be represented as 2031:0:130f::9c0:876a:130b
  - Cannot be represented as 2031::130f::9c0:876a:130b
- **FF01:0:0:0:0:0:0:1 → FF01::1**
- **0:0:0:0:0:0:0:1 → ::1**
- **0:0:0:0:0:0:0:0 → ::**

IPv6 Address Types

- **Unicast:**
  - One-to-One
  - Address is for a single interface
  - IPv6 has several types (for example, global, reserved, link-local, and site-local)

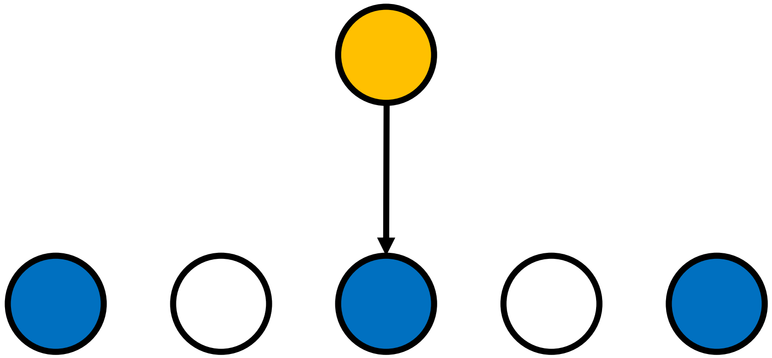


- **Multicast:**
  - One-to-Many
  - Enables more efficient use of the network
  - Uses a larger address range **(FF00::/8)**



IPv6 Address Types (Cont.)

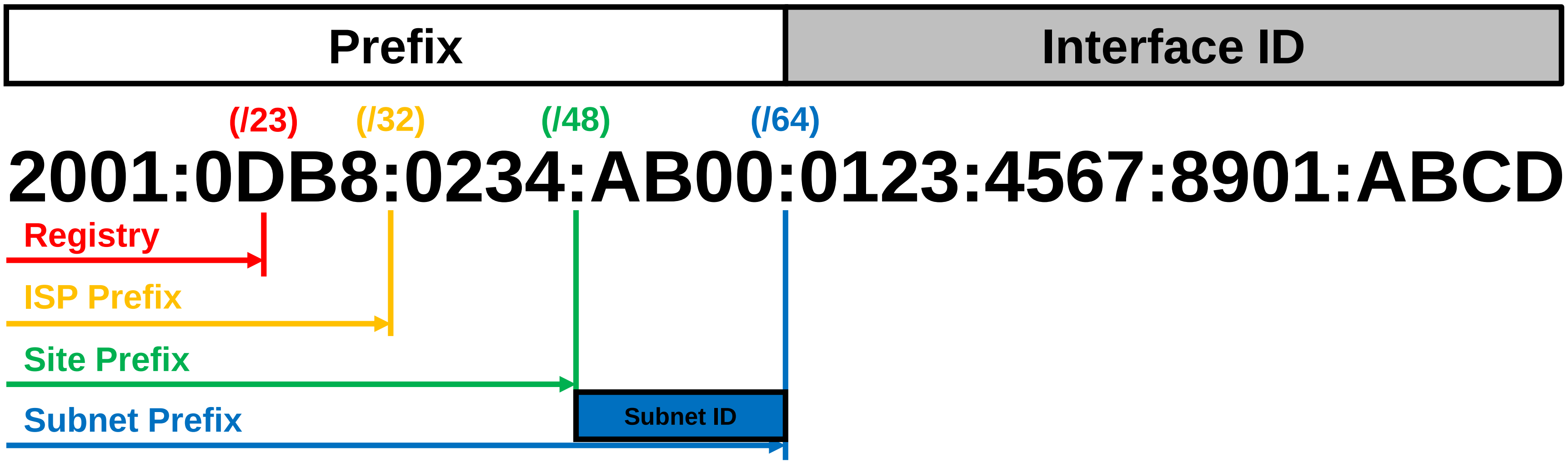
- **Anycast:**
  - One-to-Nearest (allocated from unicast address space)
  - Multiple devices share the same “anycast” address
  - A packet sent to an anycast address is delivered to the “nearest” interface (node) having this address
  - Suitable for load balancing and content delivery services



IPv6 Unicast Addressing

- **Types of IPv6 unicast addresses:**
  - Global unicast: similar to public IPv4 address (starts with **2000::/3**)
  - Reserved: used by the IETF
  - Link-local: used only to communicate with devices on the same local link (starts with **FE80::/10**)
  - Unique-local (**FC00::/7**): similar to private address in IPv4 (or Site-local in the past, starts with **FEC0::/10**)
  - Loopback (::1): similar to 127.0.0.1 in IPv4
  - Unspecified (::): similar to 0.0.0.0 in IPv4
- **A single interface may be assigned multiple IPv6 addresses of any type:** unicast, anycast, or multicast.
- **IPv6 addressing rules are covered by multiple RFCs.**
  - Architecture defined by RFC 4291

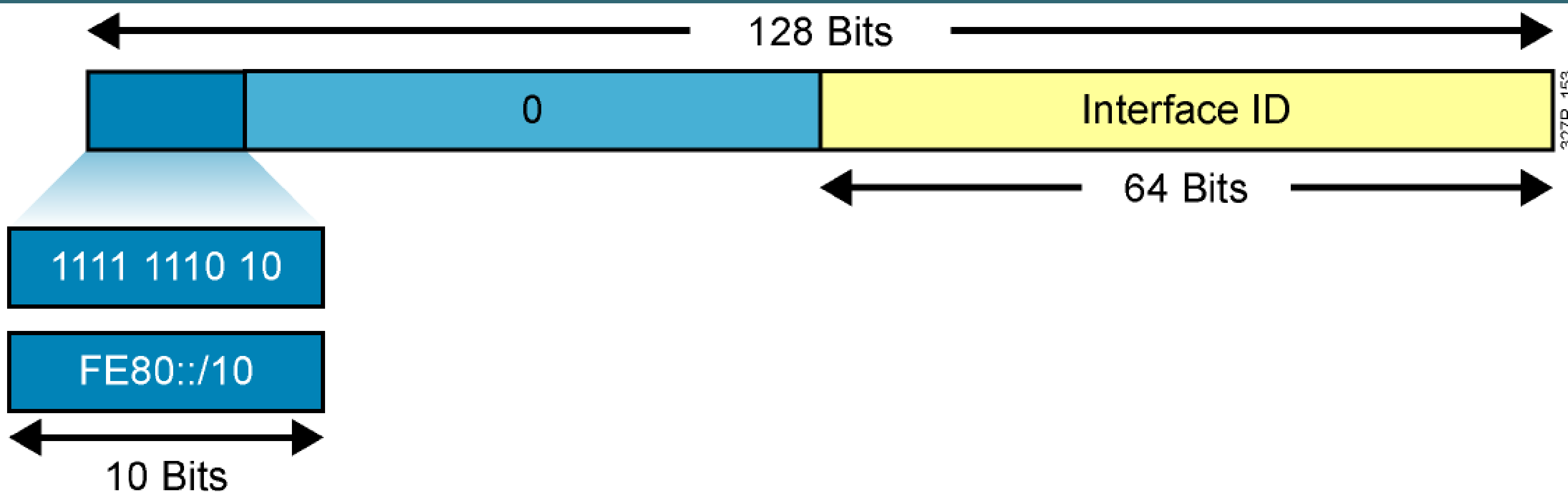
IPv6 Global Unicast (and Anycast) Addresses



IPv6 has the same address format for global unicast and for anycast addresses.

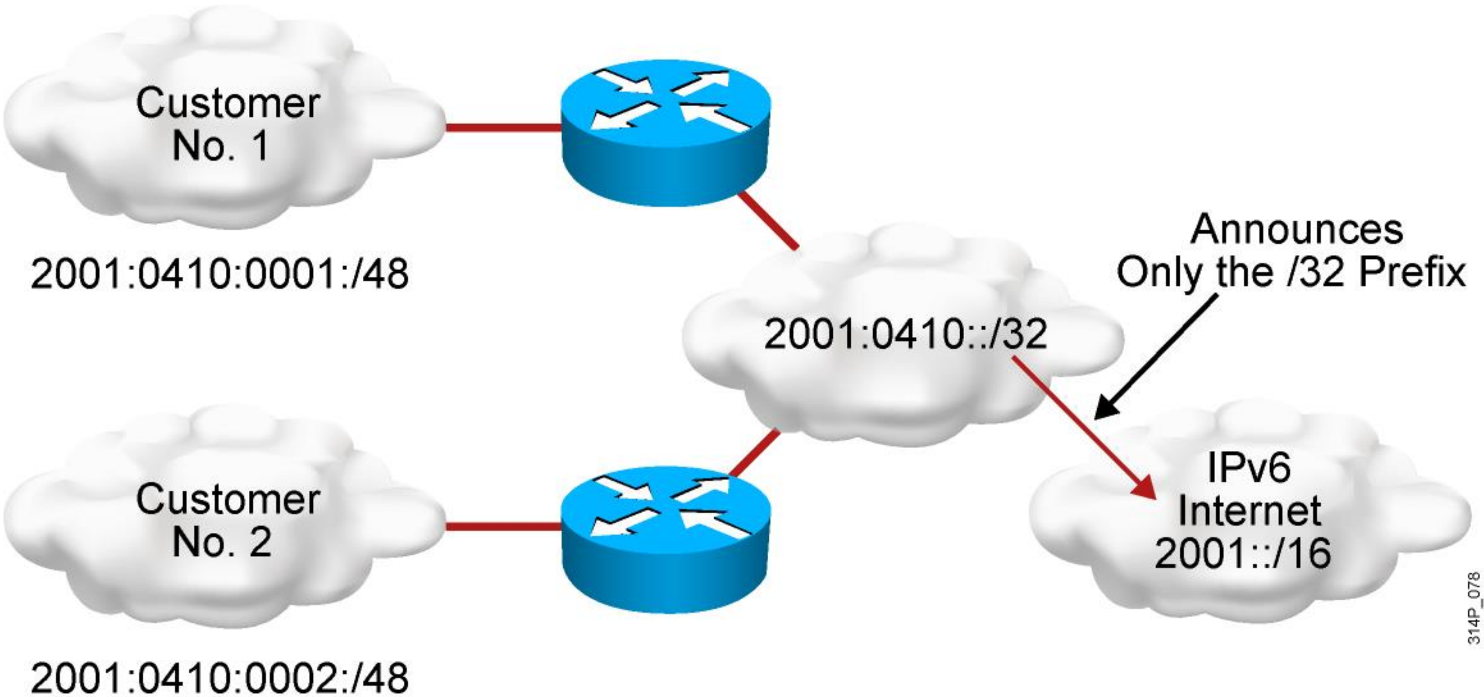
- Uses a global routing prefix—a structure that enables aggregation upward, eventually to the ISP.
- A single interface may be assigned multiple addresses of any type (unicast, anycast, multicast).
- Every IPv6-enabled interface contains at least one loopback (::1/128) and one link-local address.
- Optionally, every interface can have multiple unique local and global addresses.

Link-Local Addresses



- Link-local addresses have a scope limited to the link and are dynamically created on all IPv6 interfaces by using a specific link-local prefix **FE80::/10** and a 64-bit interface identifier.
- Link-local addresses are used for automatic address configuration, neighbor discovery, and router discovery. Link-local addresses are also used by many routing protocols.
- Link-local addresses can serve as a way to connect devices on the same local network without needing global addresses.
- When communicating with a link-local address, you must specify the outgoing interface because every interface is connected to **FE80::/10**.

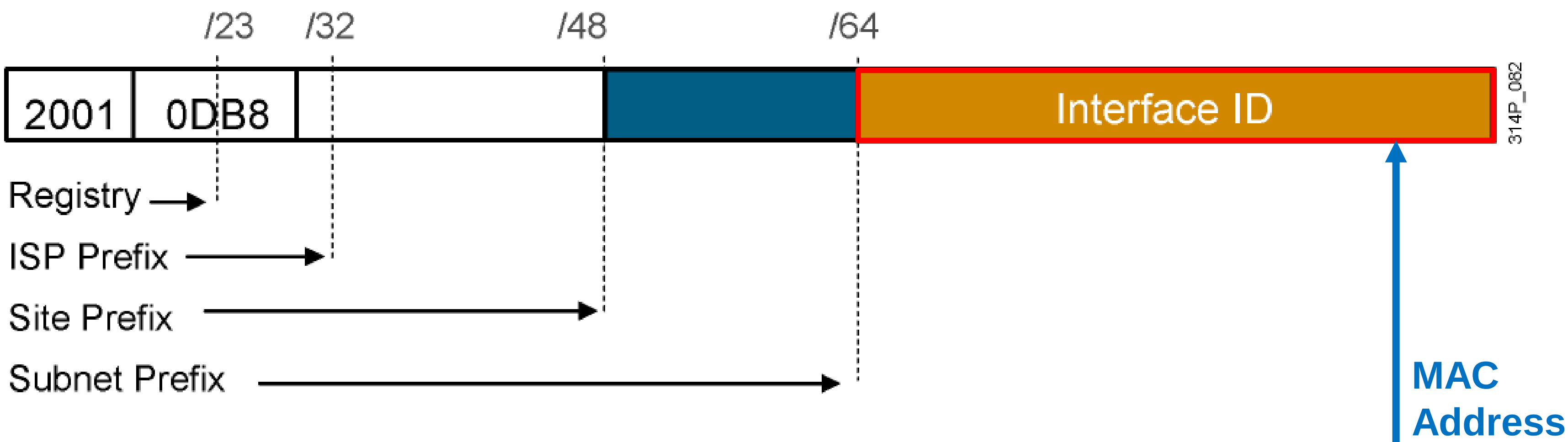
Larger Address Space Enables Address Aggregation



Address aggregation provides the following benefits:

- Aggregation of prefixes announced in the global routing table
- Efficient and scalable routing
- Improved bandwidth and functionality for user traffic

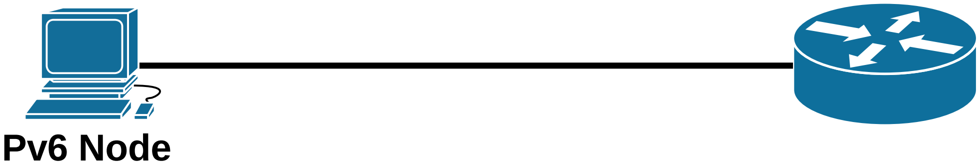
Assigning IPv6 Global Unicast Addresses



- **Static assignment**
  - Manual interface ID assignment
  - EUI-64 interface ID assignment
- **Dynamic assignment**
  - Stateless autoconfiguration
  - DHCPv6 (stateful autoconfiguration)

IPv6 EUI-64 Interface Identifier (64-bit Extended Unique Identifier)

Ethernet MAC: 05-36-E8-BB-14-CB
Link-local IPv6 address:
fe80::736:e8ff:febb:14cb

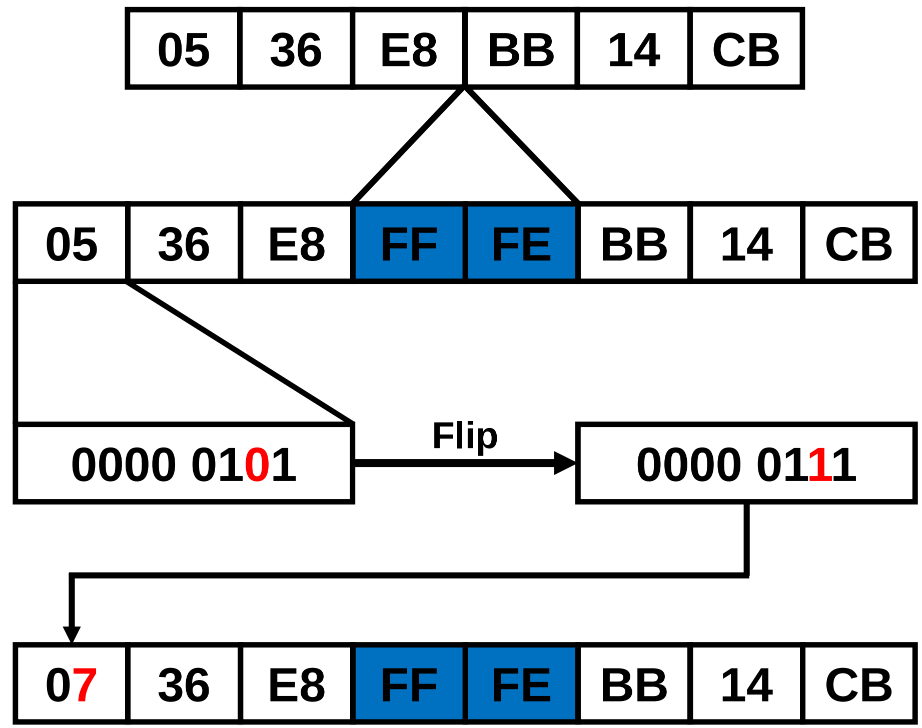


48-bit MAC address of the interface

1. Insert 0xFFFE into the center of the MAC Address

2. Flip the 7th bit of the MAC address (Universal/Local bit)

3. Interface ID is generated with 64-bit length (modified EUI-64)



→ Link-local IPv6 address: fe80::736:e8ff:febb:14cb

Duplicate Address Detection (DAD)

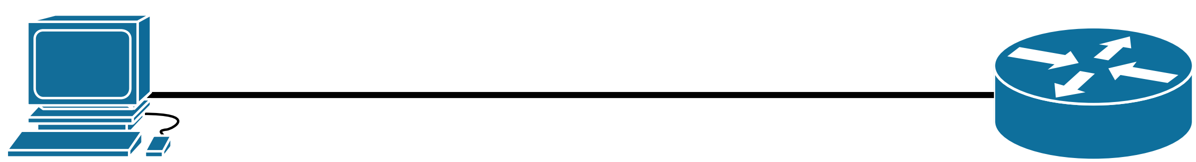
Once the IPv6 node has a link-local address, it needs to ensure that no other node on the segment is using that address.

Neighbor Solicitation (NS) → **Solicited Node Multicast Address**

Source	Destination
::	ff02::1:ffbb:14cb

Not received = unique address
Received = duplicate address

Neighbor Advertisement (NA)?



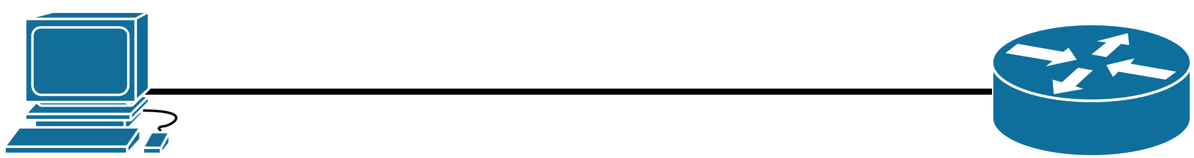
IPv6 Node
Ethernet MAC: 05-36-E8-BB-14-CB
Link-local IPv6 address: fe80::736:e8ff:febb:14cb

Solicited Node Multicast Address: ff02::1:ffxx:xxxx → **ff02::1:ffbb:14cb**

Stateless Address Autoconfiguration (SLAAC)

Router Solicitation (RS) → **All Routers Multicast Address (FF02::2)**

Source	Destination
fe80::736:e8ff:febb:14cb	ff02::2

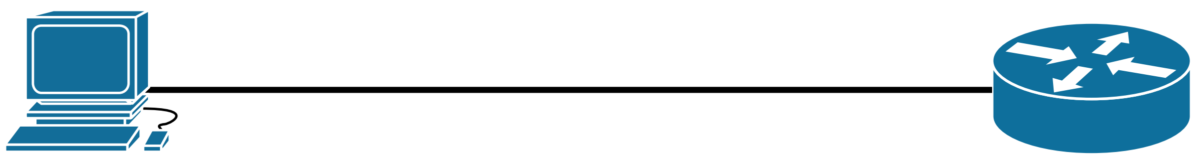


IPv6 Node
Ethernet MAC: 05-36-E8-BB-14-CB
Link-local IPv6 address: fe80::736:e8ff:febb:14cb

Stateless Address Autoconfiguration (Cont.)

Router Advertisement (RA)
Here is the prefix for this link + other information

Destination	Source
fe80::736:e8ff:febb:14cb	link-local of router
Prefix: 2001:db8:66:6::/64 + other information	



IPv6 Node

Ethernet MAC: 05-36-E8-BB-14-CB
Link-local IPv6 address: fe80::736:e8ff:febb:14cb
Global Unicast Address: 2001:db8:66:6::736:e8ff:febb:14cb/64

Stateless Address Autoconfiguration (Cont.)

Router Advertisement (RA) Message:

- Default gateway (source IPv6 address of RA)
- Prefix (network address) + prefix-length
- Optional:
  - DNS addresses
  - Domain name
- Flags
  - A (Autonomous Flag - default ON): use prefix in RA to configure address using SLAAC
  - O (Other Configuration Flag - OFF): get DNS/Domain name from stateless DHCPv6
  - M (Managed Configuration Flag - OFF): use stateful DHCPv6 (similar to DHCP for IPv4)

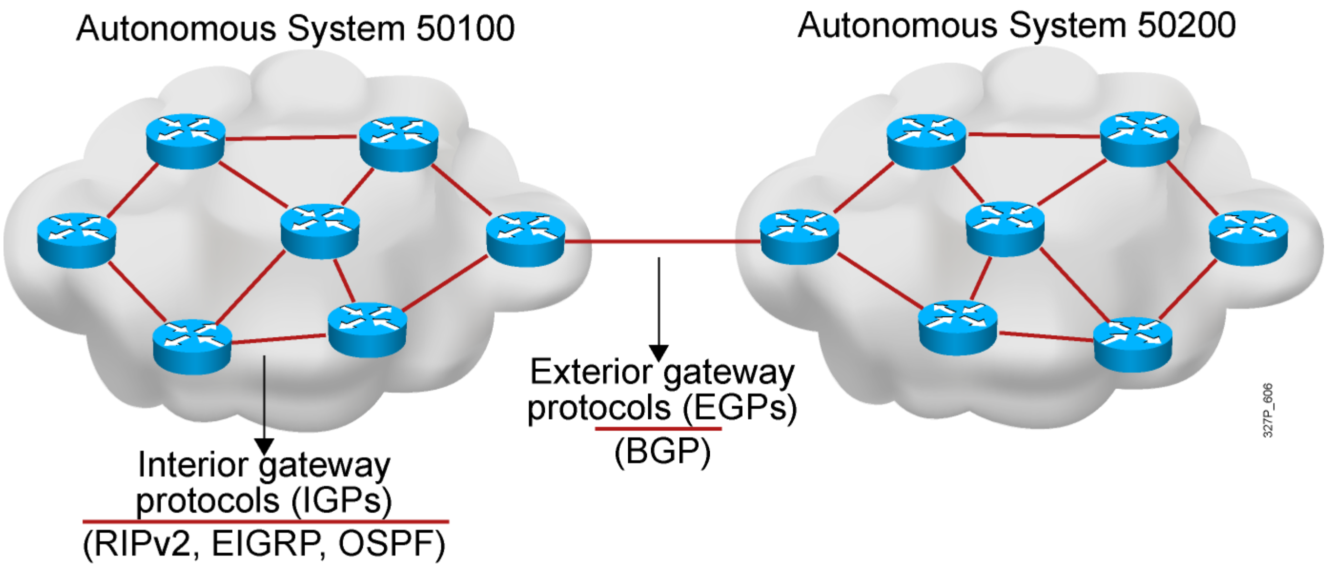
DHCPv6 (Stateful Autoconfiguration)

DHCPv6 is an updated version of DHCP for IPv4:

- Supports new addressing
- Enables more control than stateless autoconfiguration
- Can be used for renumbering
- Can be used for automatic domain name registration of hosts using dynamic DNS

IPv6 Routing Protocols

- **IPv6 routing types:**
  - Static
  - RIPng (RFC 2080)
  - OSPFv3 (RFC 2740)
  - IS-IS for IPv6
  - MP-BGP4 (RFC 2545/2858)
  - EIGRP for IPv6



- **The “ipv6 unicast-routing” command is required to enable IPv6 before any routing protocol is configured.**

RIPng (RIP Next Generation)

Similar IPv4 features:

- Distance vector, radius of 15 hops, split horizon, and poison reverse
- Based on RIPv2

Updated features for IPv6:

- Named RIPng
- IPv6 prefix, next-hop IPv6 address, uses IPv6 for transport
- Uses the multicast group **FF02::9**, the all-rip-routers multicast group, as the destination address for RIP updates
- Uses UDP port 521

OSPF Version 3 (OSPFv3)

Similar to IPv4

- Same mechanisms, but a major rewrite of the internals of the protocol

Updated features for IPv6

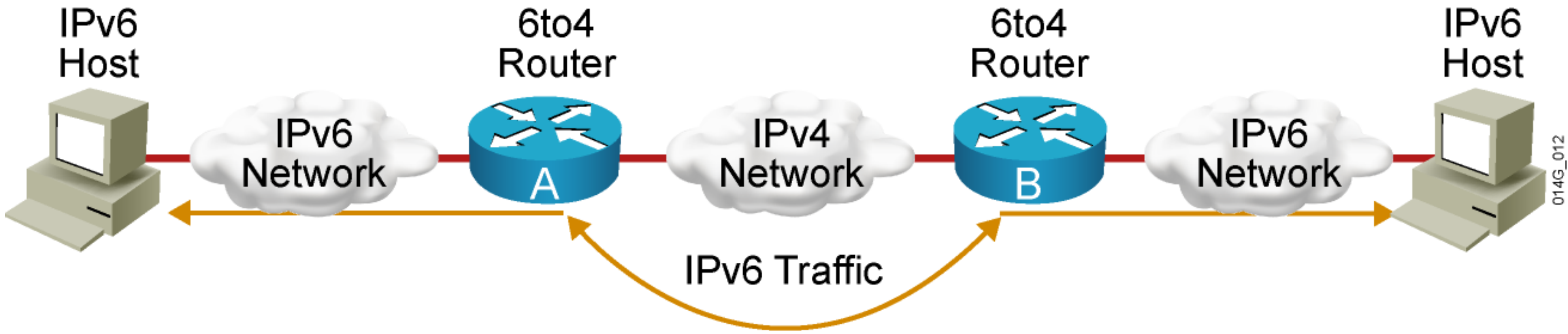
- Every IPv4-specific semantic removed
- Carry IPv6 addresses
- Link-local addresses used as source
- IPv6 transport
- OSPF for IPv6 currently an IETF proposed standard

OSPFv3 Differences from OSPFv2

OSPFv3 protocol processing is per link, not per subnet

- IPv6 connects interfaces to links. An OSPF interface now connects to a link instead of to a subnet.
- Multiple IPv6 subnets can be assigned to a single link.
- Two nodes can talk directly over a single link, even though they do not share a common subnet.
- The terms "network" and "subnet" are being replaced with "link".
- AllSPFRouters multicast address is **FF02::5**, and the AllDRouters multicast address is **FF02::6**.

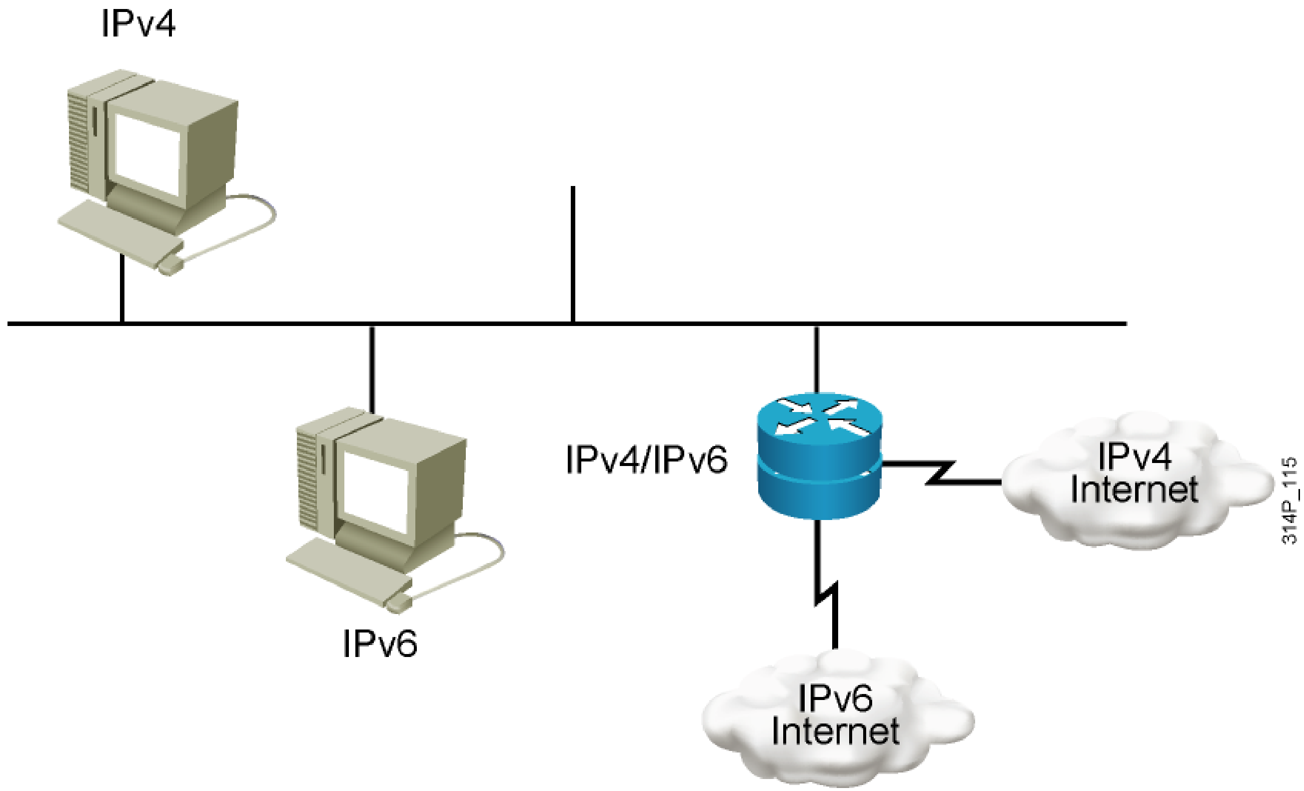
IPv4-to-IPv6 Transition



Transition richness means:

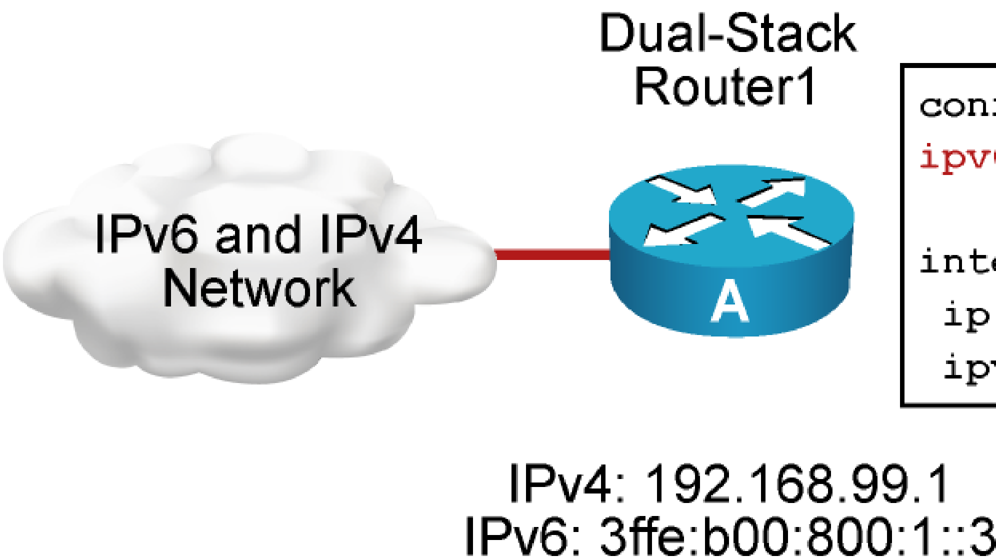
- **No fixed day to convert; no need to convert all at once**
- **Different transition mechanisms are available:**
  - Dual stack
  - Manual IPv6-over-IPv4 tunnel
  - Dynamic 6to4 tunnel
  - ISATAP tunnel
  - Teredo tunnel
- **Different compatibility mechanisms:**
  - Proxying and translation (NAT-PT)

Cisco IOS Dual Stack



- Coexistence of both IPv6 and IPv4 on the same infrastructure
- Dual stack is an integration method in which a node has implementation and connectivity to both an IPv4 and IPv6 network.

Cisco IOS Dual Stack (Cont.)

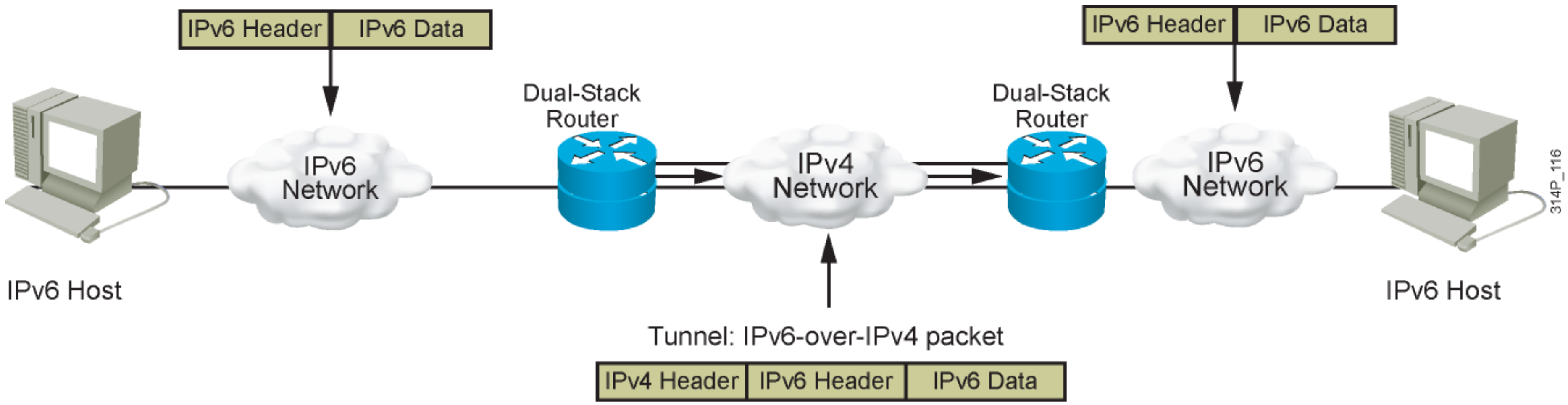



```
conf t
ipv6 unicast-routing

interface ethernet0
 ip address 192.168.99.1 255.255.255.0
 ipv6 address 3ffe:b00:c18:1::3/127
```

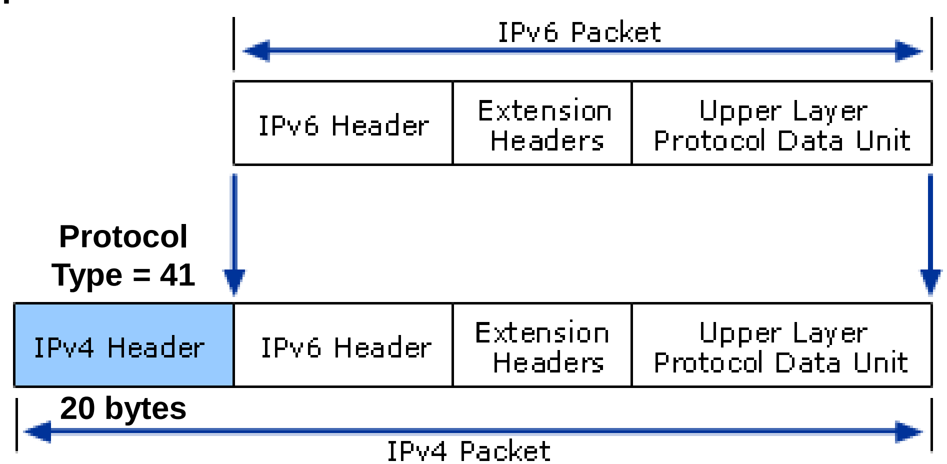
- When both IPv4 and IPv6 are configured on an interface, the interface is considered dual-stacked.

IPv6 Tunneling



Tunneling is an integration method in which an IPv6 packet is encapsulated within another protocol, such as IPv4. This method of encapsulation is IPv4.

- Includes a 20-byte IPv4 header with no options and an IPv6 header and payload
- Requires dual-stack routers



Enabling IPv6 on Cisco Routers

RouterX(config)#

```
ipv6 unicast-routing
```

- **Enables IPv6 traffic forwarding**

RouterX(config-if)#

ipv6 address ***ipv6prefix/prefix-length*** **eui-64**

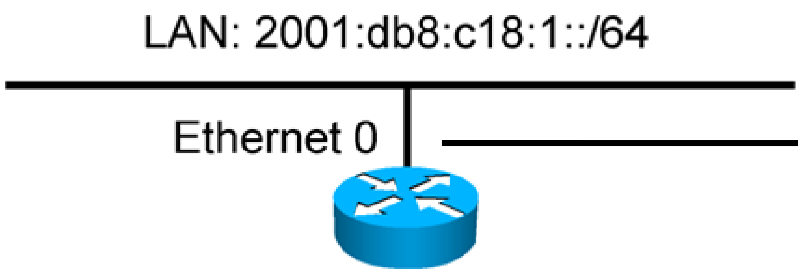
- **Configures the interface IPv6 addresses**

RouterX(config-if)#

ipv6 address ***ipv6-address/prefix-length***

- **Or manual assignment**

IPv6 Address Configuration Example



MAC address: c201.0763.0000

EUI-64
?

Interface ID: c001:07ff:fe63:0000

```
ipv6 unicast-routing
interface Ethernet 0
 ipv6 address 2001:db8:c18:1::/64 eui-64
```

```
RouterX#show ipv6 interface Ethernet 0
Ethernet0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::C001:7FF:FE63:0
  Global unicast address(es):
    2001:DB8:C18:1::C001:7FF:FE63:0, subnet is 2001:DB8:C18:1::/64 [EUI]
  Joined group address(es):
    FF02::1:FF63:0 → Solicited Node Multicast Address
    FF02::1 → All Nodes Multicast Address
    FF02::2 → All Routers Multicast Address
  MTU is 1500 bytes
```

Configuring and Verifying RIPng for IPv6

RouterX(config)#

```
ipv6 router rip tag
```

- **Creates and enters RIP router configuration mode**

RouterX(config-if)#

```
ipv6 rip tag enable
```

- **Configures RIP on an interface**

```
show ipv6 rip
```

- **Displays the status of the various RIP processes**

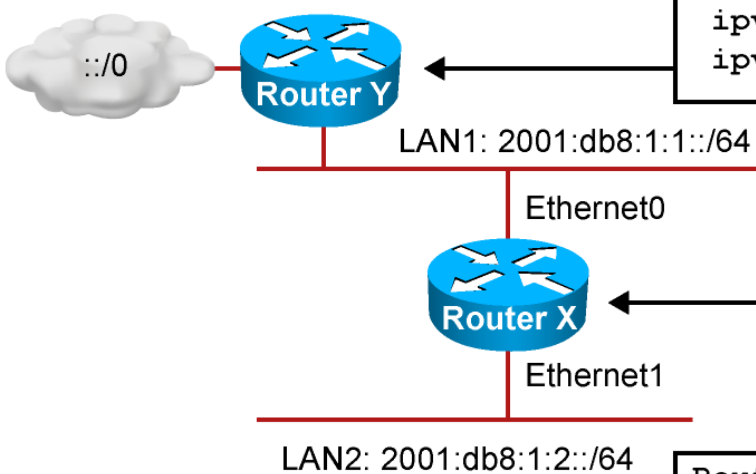
```
show ipv6 route rip
```

- **Shows RIP routes in the IPv6 route table**

RIPng for IPv6 Configuration Example

```
RouterY#
ipv6 unicast-routing
ipv6 router rip RT0

interface Ethernet0
 ipv6 address 2001:db8:1:1::/64 eui-64
 ipv6 rip RT0 enable
```




```
RouterX#
ipv6 unicast-routing
ipv6 router rip RT0

interface Ethernet0
 ipv6 address 2001:db8:1:1::/64 eui-64
 ipv6 rip RT0 enable

interface Ethernet1
 ipv6 address 2001:db8:1:2::/64 eui-64
 ipv6 rip RT0 enable
```

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Configuring OSPFv3 in Cisco IOS Software

- **Similar to OSPFv2**
  - Prefixes existing interface and EXEC mode commands with “ipv6”
- **Interfaces configured directly**
  - Replaces network command
- **“Native” IPv6 router mode**
  - Not a submode of router ospf command

Configuring OSPFv3 in Cisco IOS Software (cont.)

Enabling OSPFv3 Globally

```
ipv6 unicast-routing
ipv6 router ospf 1
 router-id 2.2.2.2
```

Enabling OSPFv3 on an Interface

```
interface Ethernet0/0
 ipv6 address 3FFE:FFFF:1::1/64
 ipv6 ospf 1 area 0
```

OSPFv3 Configuration Example

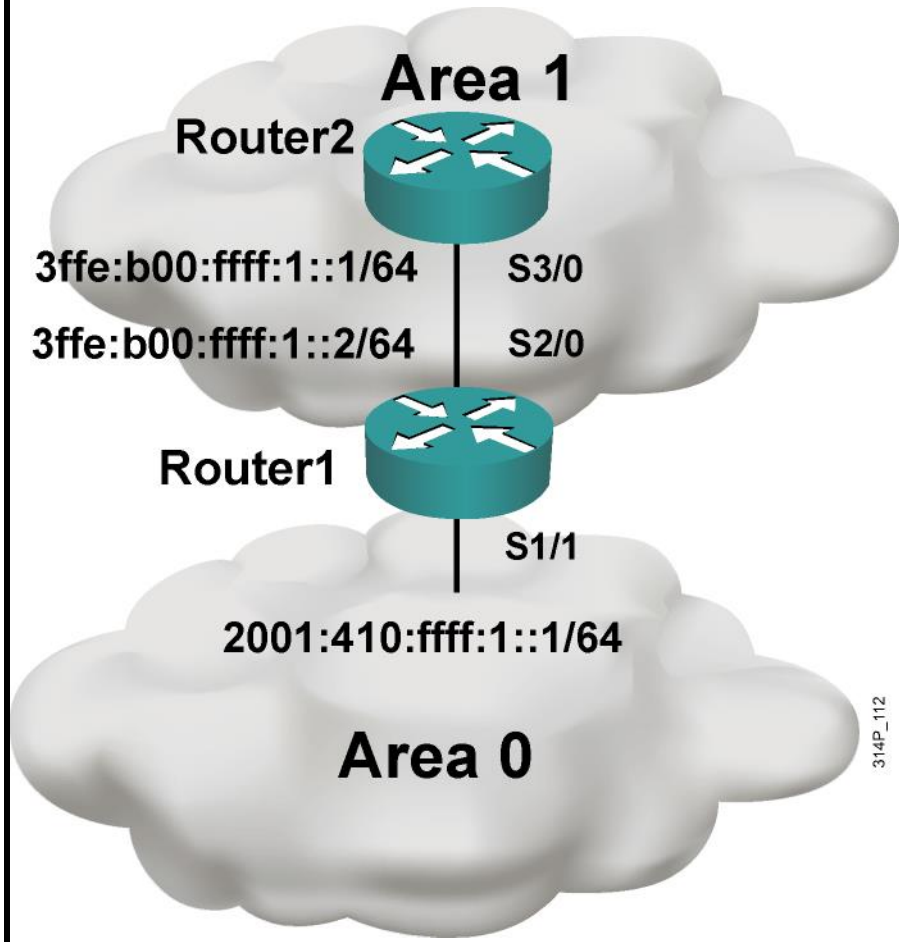
```
Router1#
interface S1/1
 ipv6 address 2001:410:FFFF:1::1/64
 ipv6 ospf 100 area 0

interface S2/0
 ipv6 address 3FFE:B00:FFFF:1::2/64
 ipv6 ospf 100 area 1

 ipv6 router ospf 100
   router-id 10.1.1.3


Router2#
interface S3/0
 ipv6 address 3FFE:B00:FFFF:1::1/64
 ipv6 ospf 100 area 1

ipv6 router ospf 100
   router-id 10.1.1.4
```



Configuring EIGRP for IPv6

Enabling EIGRP for IPv6 Globally

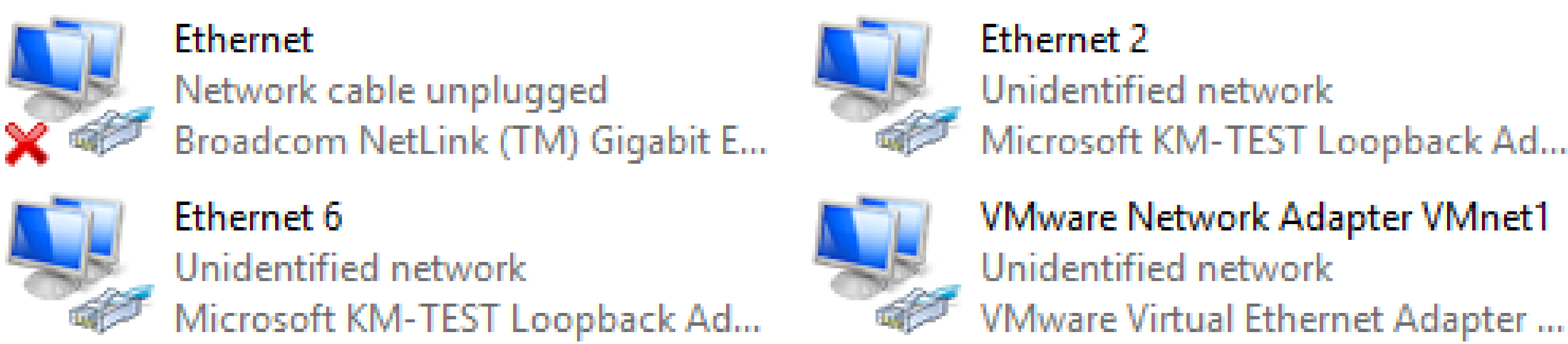
```
ipv6 unicast-routing
ipv6 router eigrp 100
  eigrp router-id 2.2.2.2
  no shutdown
```

Enabling EIGRP for IPv6 on an Interface

```
interface Ethernet0/0
 ipv6 address 3FFE:FFFF:1::1/64
 ipv6 eigrp 100
```

IPv6 on Windows XP

```
C:\> netsh interface ipv6 install
C:\> netsh
netsh> interface ipv6
netsh interface ipv6> show address
netsh interface ipv6> add    address 2 2009::1
netsh interface ipv6> delete address 2 2009::1
C:\>
```



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