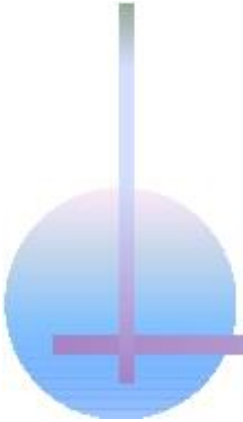


Module 08 IPv6

IPv6의 필요성

1) 스마트폰 등 IP를 요구하는 다양한 기기의 등장으로 IPv4 주소 고갈

2) 보안 취약성 해소

3) 멀티미디어/실시간 트래픽 처리 능력 개선

IPv6 주요특징

- Larger address space: Global reach capability, flexibility, aggregation, multihoming, autoconfiguration, “plug-and-play,” renumbering
- Simpler header: Routing code streamlined, simpler processing in hardware
- Security and mobility: Built into the standard, not as extensions
- Transition richness: Several mechanisms available, including “dual-stacking”

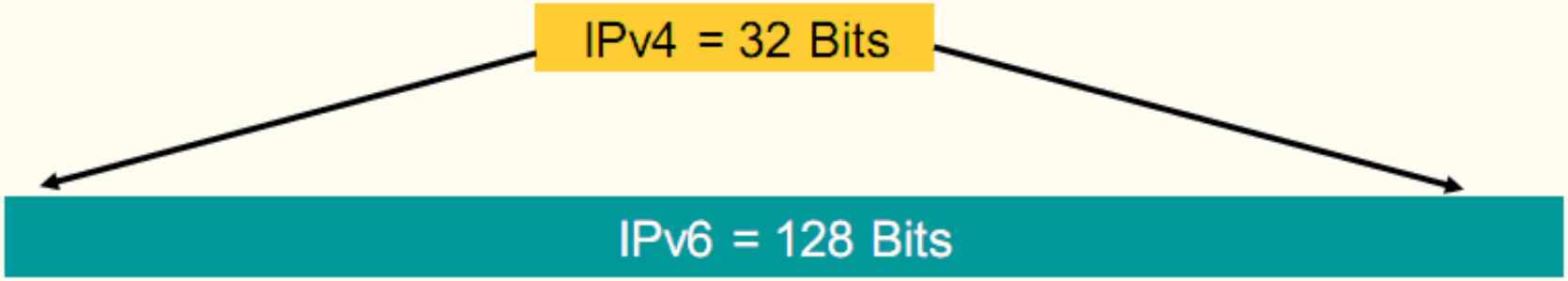
넓은 주소공간

IPv4:

- 32 bits
- = 4,294,967,296 possible addressable nodes

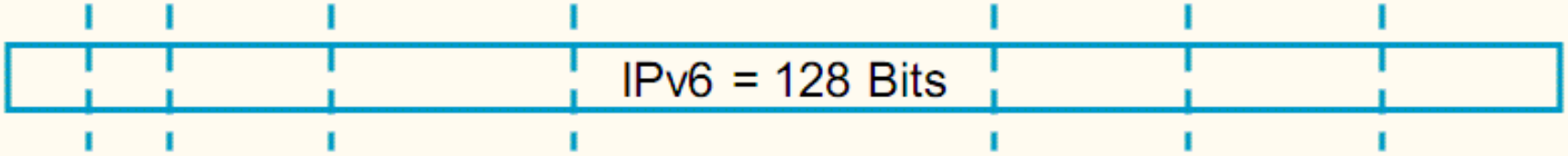
IPv6:

- 128 bits: 4 times larger in bits
- = ~3.4 * 1038 possible addressable nodes
- = 340,282,366,920,938,463,463,374,607,431,768,211,456



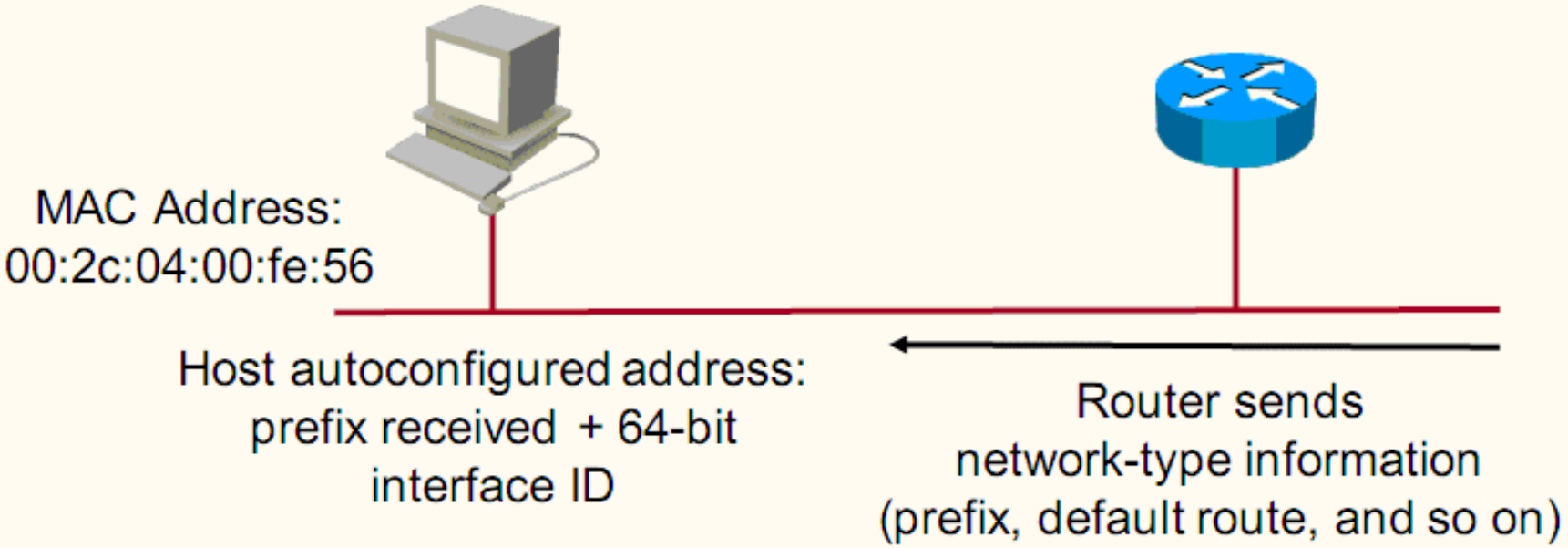
주소의 계층적 구조

- Multiple levels of hierarchy inside the address space allow better segmentation of the network to follow organizational structure (/48 or /56 given to end users)
- More flexibility, more privacy, new functionalities



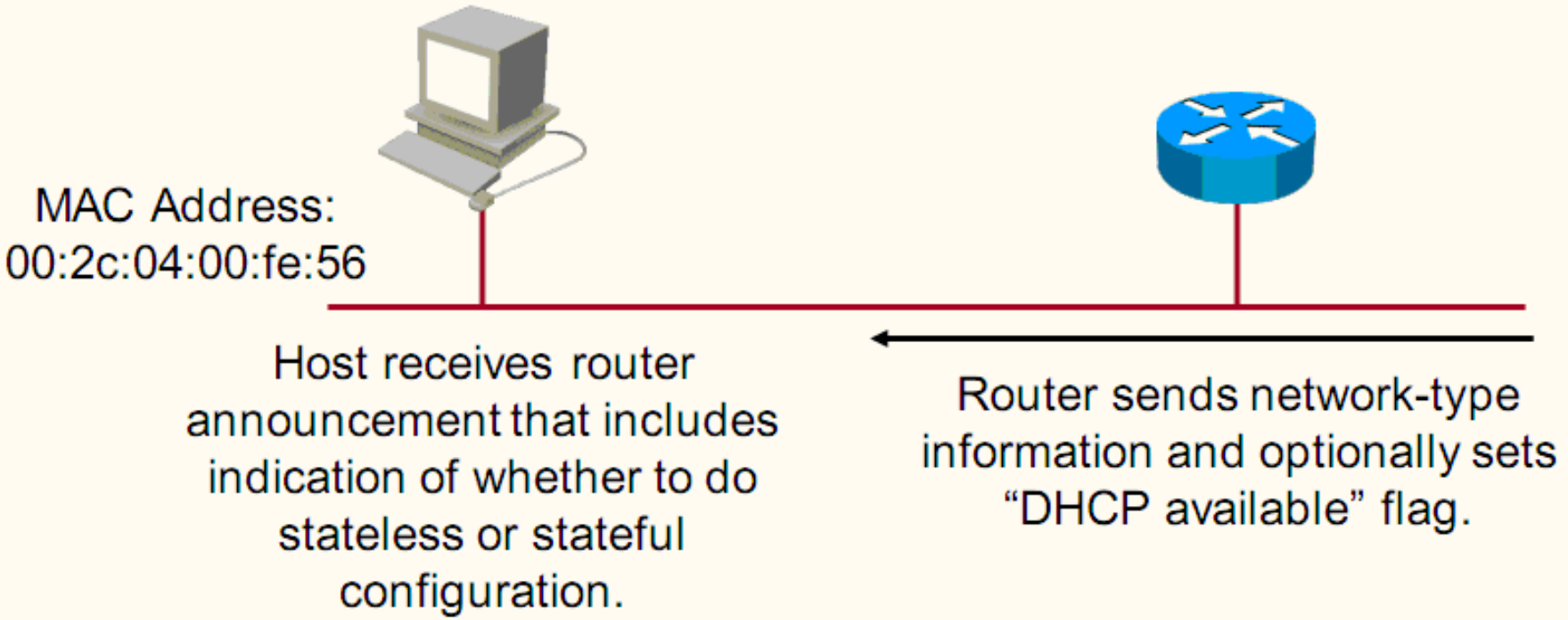
Stateless Autoconfiguration(비상태보존형 자동설정)

- Often uses Layer 2 identifier (derived from OUI)
- Autoconfiguration with no collisions
- "Plug-and-play"
- Suitable for embedded networks for industrial use (dispersed seismic sensors, etc.), but lack of capability to communicate DNS settings



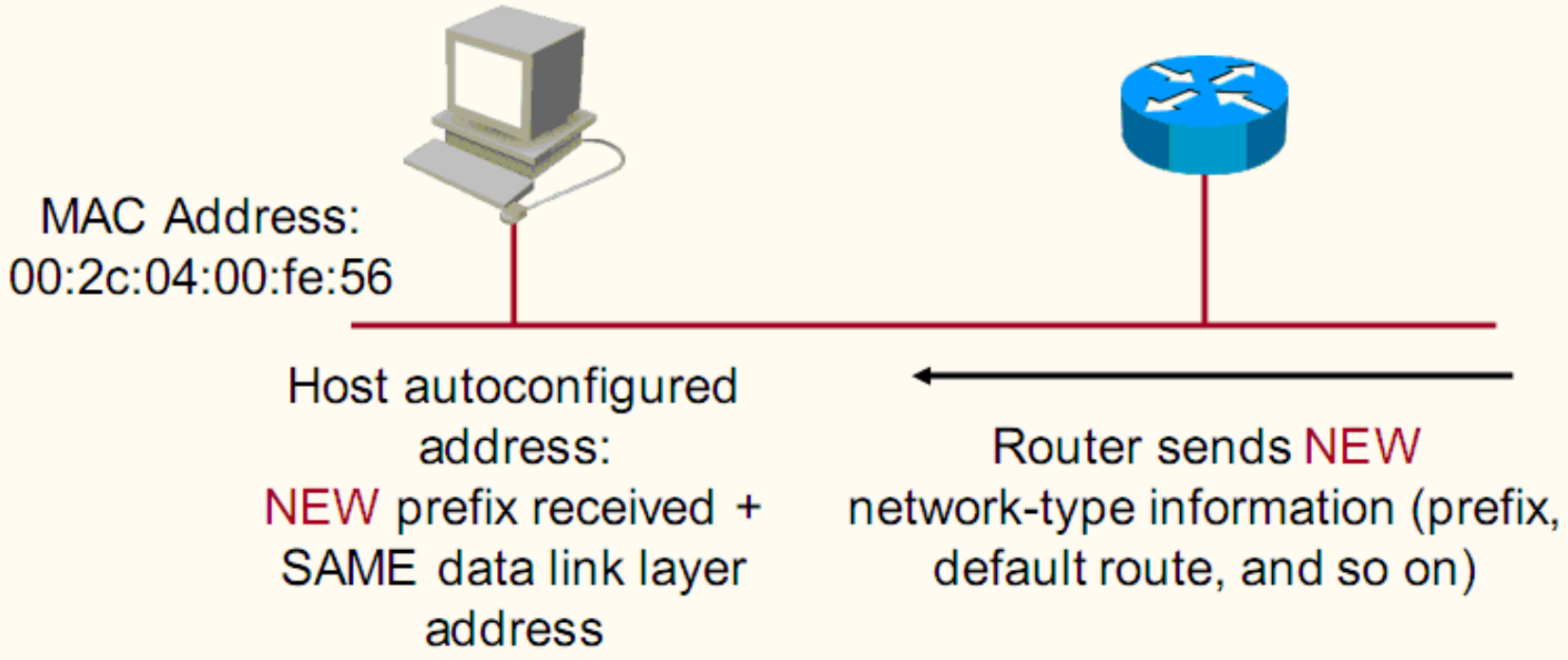
Stateful Autoconfiguration (상태보존형 자동설정)

- Router announcement can indicate to hosts whether or not additional configuration parameters are available via stateful configuration (DHCPv6), such ans DNS, IP options, and so on.



Renumbering(주소 재지정)

- Renumbering, using autoconfiguration and multiple addresses
- Old address still held for a time for possible incoming traffic; new address is used for outgoing connections first

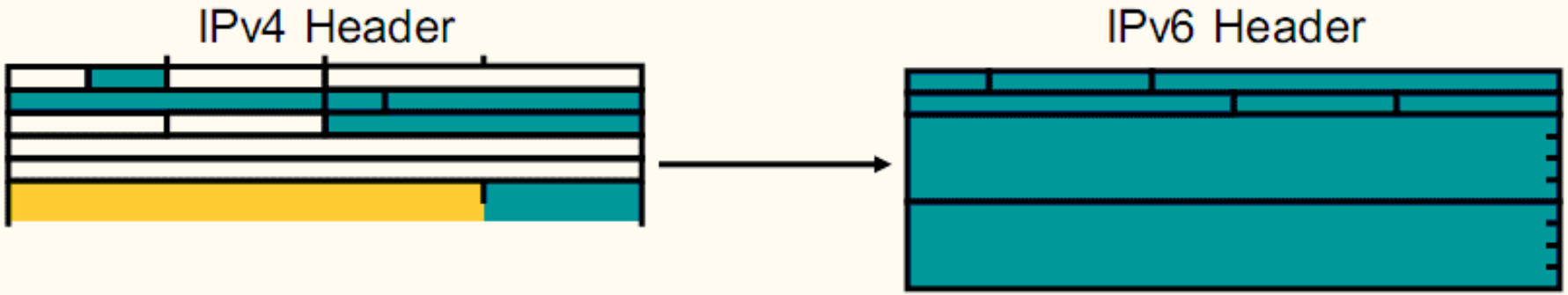


Multicast 사용

- Broadcasts in IPv4:
  - Interrupt all computers on the LAN, even if the destination is only one or two computers
  - Can completely bring down a network (“broadcast storm”)
- No broadcast in IPv6:
  - Replaced by scoped multicast
- Multicast:
  - Enables efficient use of the network
  - Has much larger address range

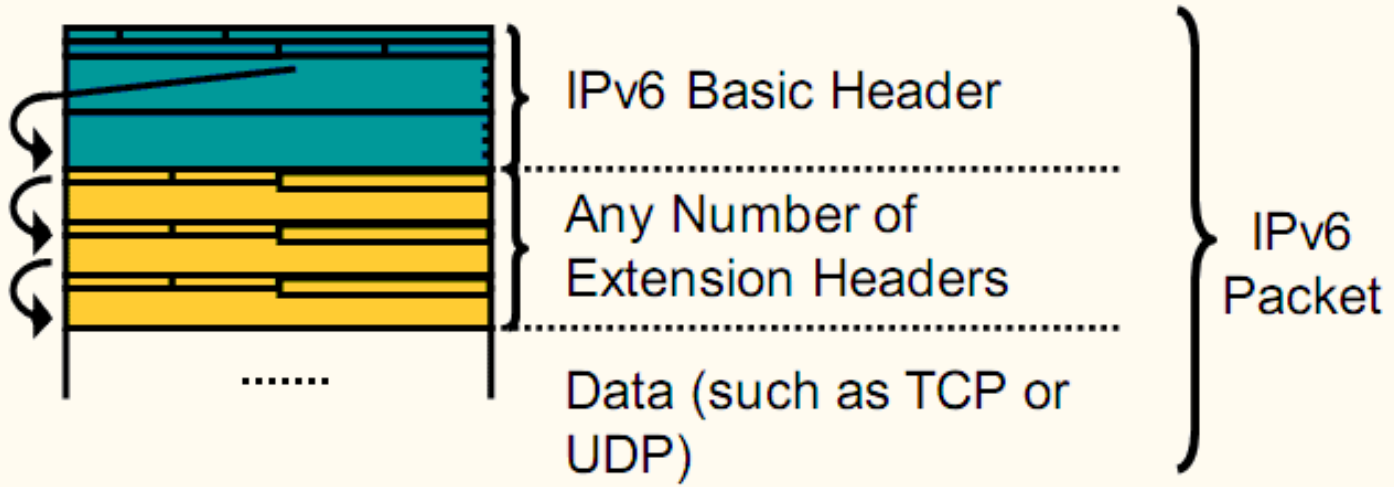
단순하고 효율적인 헤더

- 64-bit aligned fields and fewer fields
- Hardware-based, efficient processing
- Improved routing efficiency, performance, and forwarding rate scalability



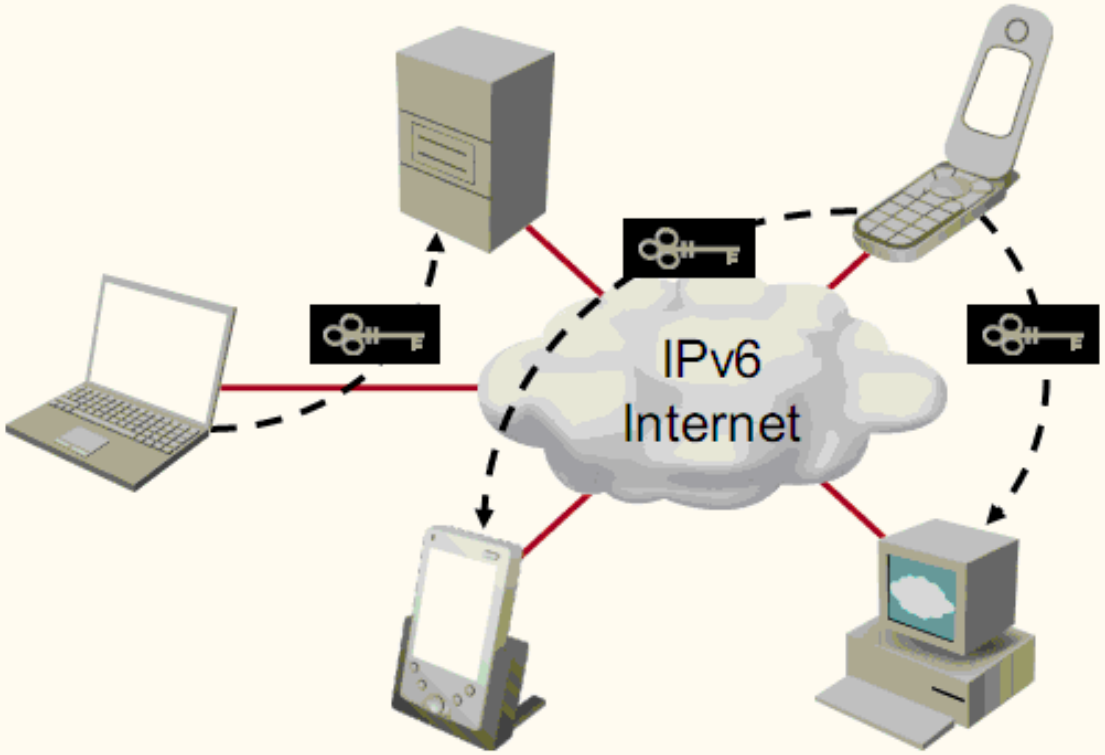
Extension Headers (확장 헤더)

- Flexible extension headers
- More efficient handling of IP options
- Faster forwarding rate and end-node processing



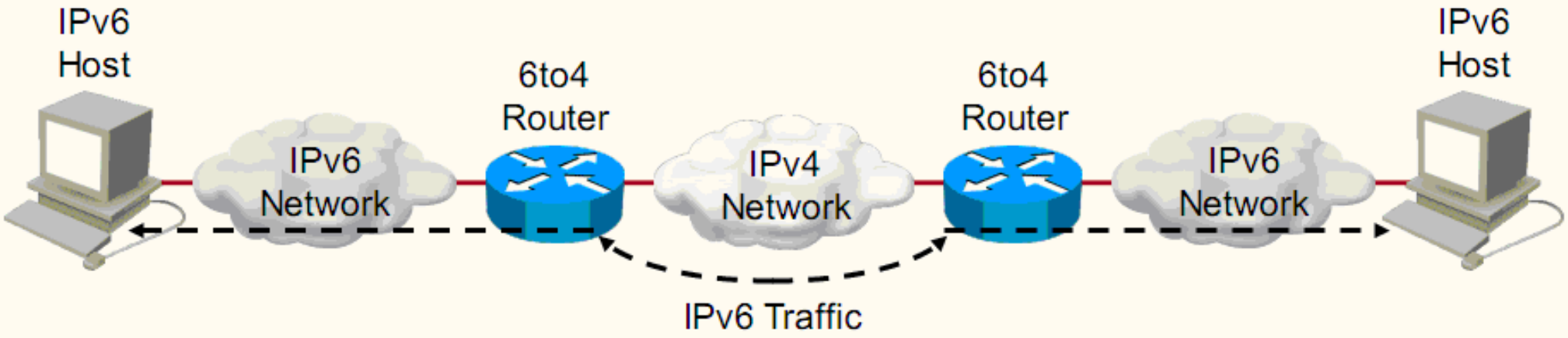
Security (보안성)

- End-to-end network security (integrity, authentication, confidentiality)
- Inherent (built-in) with IPv6—usable by any node



Transition Richness (IPv4에서 IPv6 변환)

- No fixed day to convert, no need to convert all at once
- Different transition mechanisms available:
  - Smooth integration of IPv4 and IPv6
- Different compatibility mechanisms:
  - Communication between IPv4 and IPv6 nodes



IPv6 vs IPv4 Technology 비교

IP Service	IPv4 Solution	IPv6 Solution
Addressing Range	32-bit, Network Address Translation	128-bit, multiple scopes
Autoconfiguration	DHCP	Stateless, Stateful (DHCPv6)
Security	IPsec	IPsec-mandated, works end-to-end
Mobility	Mobile IP	Mobile IP with optimized routing
QoS	Differentiated service, integrated service	Differentiated service, integrated service
IP Multicast	IGMP, PIM, Multicast BGP	MLD, PIM, multicast BGP, scope identifier

IPv6 address 표기법

Address Representation: Format

- x:x:x:x:x:x:x:x, where x is a 16-bit hexadecimal field:
  - Example: 2001:0DB8:010F:0001:0000:0000:0000:0ACD
  - Case-insensitive
- Leading zeros in a field are optional:
  - Example: 2001:DB8:10F:1:0:0:0:ACD
- Successive fields of 0 are represented as "::", but only once in an address:
  - Example: 2001:DB8:10F:1::ACD

IPv6 address 표기법

Address Representation: Example

- Full address:
  - 2001:0DB8:0000:0000:FFFF:0000:0000:0ADC
- Correct representations:
  - 2001:DB8::FFFF:0:0:ADC
  - 2001:DB8:0:0:FFFF::AD
- Incorrect representation:
  - 2001:DB8::OFF::AD

IPv6 address 표기법

Address Representation: Further Examples

Full Address	Correct Representation
FF02:0:0:0:0:0:0:1	FF02::1
FF15:0:0:0:0:0:1:c001	FF15::1:C001
0:0:0:0:0:0:0:1	::1
0:0:0:0:0:0:0:0	::

IPv6 address 표기법

URL

http://2001:DB8:1003::F:8080/index.html

- Is 8080 part of the address or a port number?

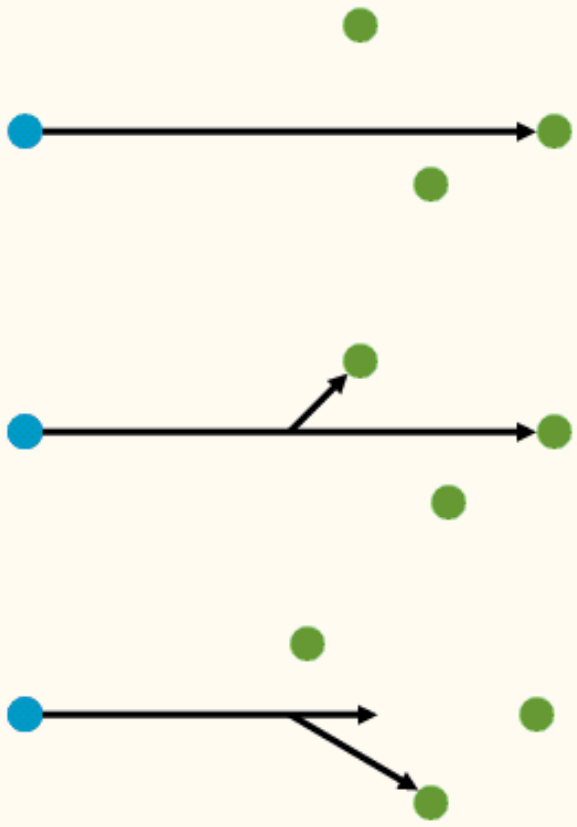
In a URL, the address is enclosed in brackets:

- Example: http://[2001:DB8:1003::F]:8080/index.html
- Not a new concept: works with IPv4 addresses
- Cumbersome for users
- Mostly for diagnostic purposes
- Use FQDNs whenever possible

Address 형태

Address Types

- Unicast
- Multicast
- Anycast
- No broadcast in IPv6



Unicast

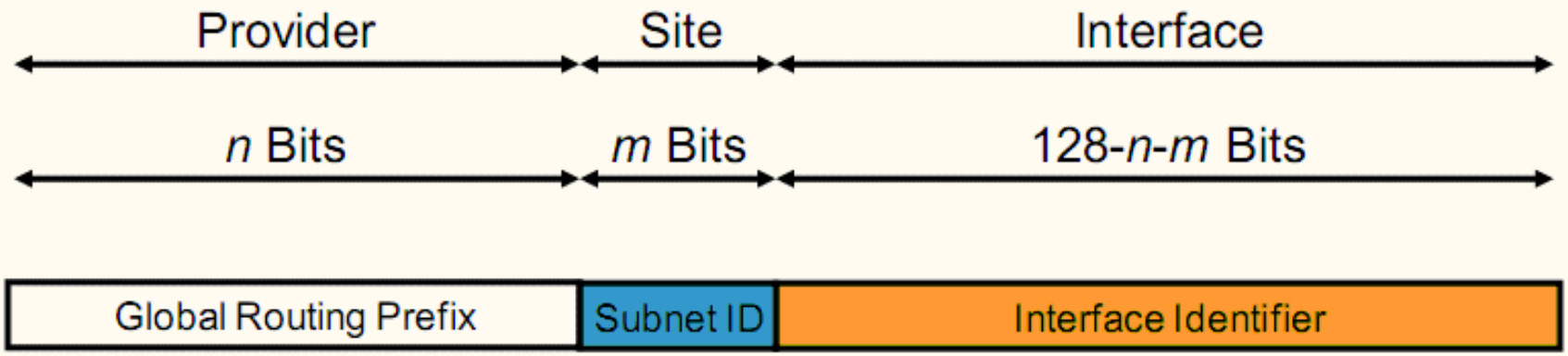
Unicast

- Unicast addresses are used in a one-to-one context.
- IPv6 unicast addresses:
  - Global unicast addresses
  - Link-local addresses
  - Unique local addresses
  - Special-purpose unicast:
    - Unspecified
    - Loopback
    - IPv4-mapped

Global Unicast 주소

Global Unicast Addresses

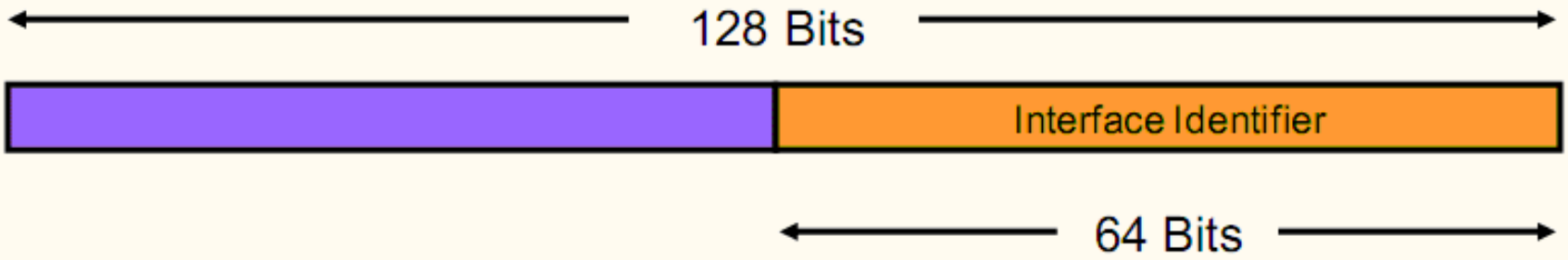
- Global unicast addresses are addresses for generic use of IPv6
- Interface identifier should be kept at 64 bits



Interface Identifiers

Interface Identifiers

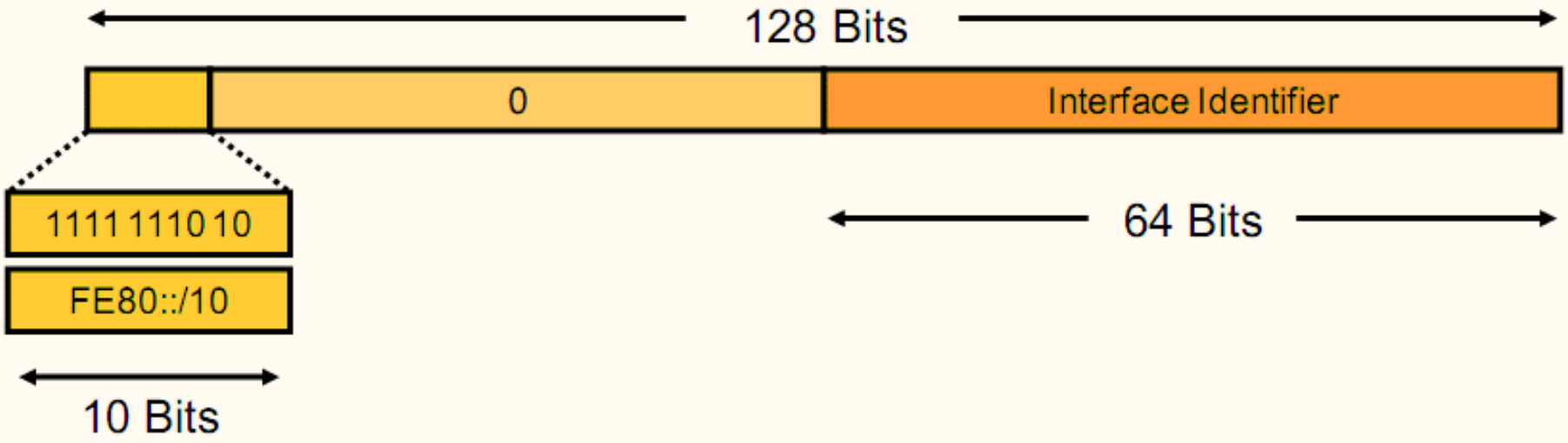
- Used to identify interfaces on a link:
  - Must be unique on that link
  - Can be globally unique
- Unicast addresses should have a 64-bit interface ID:
  - Except for unicast addresses that start with binary 000
  - Interface ID constructed in modified EUI-64 format



Link-Local 주소

Link-Local Addresses

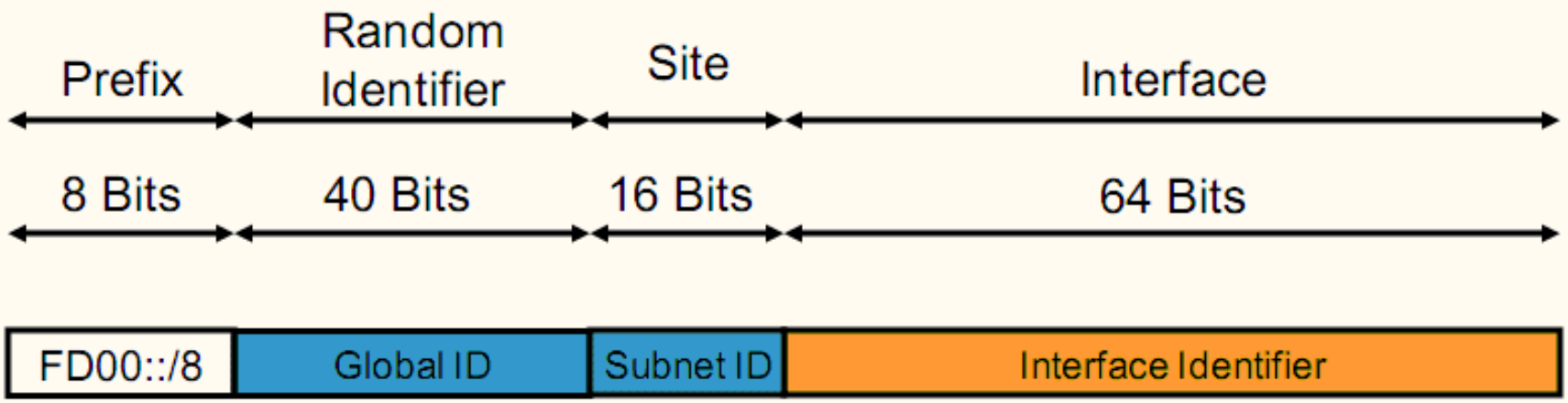
- Have a scope limited to the link
- Are automatically configured with the interface ID
- When used, must be paired with outgoing interface information



Unique Local Unicast 주소

Unique Local Unicast Addresses (RFC 4193)

- FC00::/7
  - FC00::/8 planned to be globally managed
  - FD00::/8 assigned locally by network administration
- For network in which only internal IPv6 communication is required
- Not routable on the Internet



Unspecified and Loopback 주소

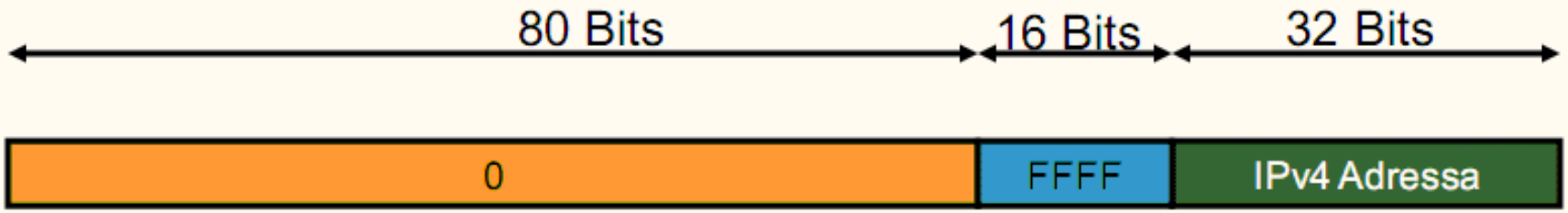
Unspecified and Loopback Addresses

- Unspecified address:
  - 0:0:0:0:0:0:0:0
  - Used as a placeholder when no address is available (initial DHCP request, DAD)
- Loopback address:
  - 0:0:0:0:0:0:0:1
  - Same as 127.0.0.1 in IPv4
  - Identifies self

IPv4-Mapped 변환 주소

IPv4-Mapped Addresses

- Used to represent the addresses of IPv4 nodes as IPv6 addresses
- Used for next-hop representation in 6PE and 6VPE
- Used in network stacks when both address families are processed internally as IPv6 (e.g., Linux)



0:0:0:0:0:FFFF:192.0.2.100

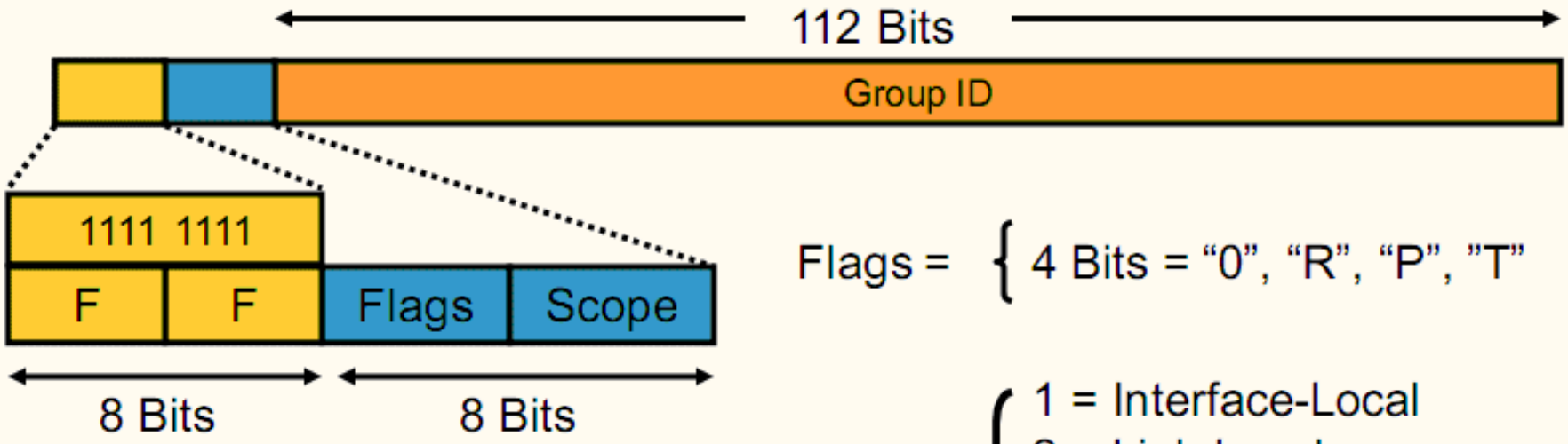
= ::FFFF:192.0.2.100

= ::FFFF:C000:0246

Multicast 주소

Multicast Addresses

- Multicast is used in the context of one to many.
- Explicit multicast scope is a new concept in IPv6.



Flags = { 4 Bits = “0”, “R”, “P”, ”T”

Scope = {
1 = Interface-Local
2 = Link-Local
3 = Subnet-Local
4 = Admin-Local
5 = Site-Local
8 = Organization
E = Global

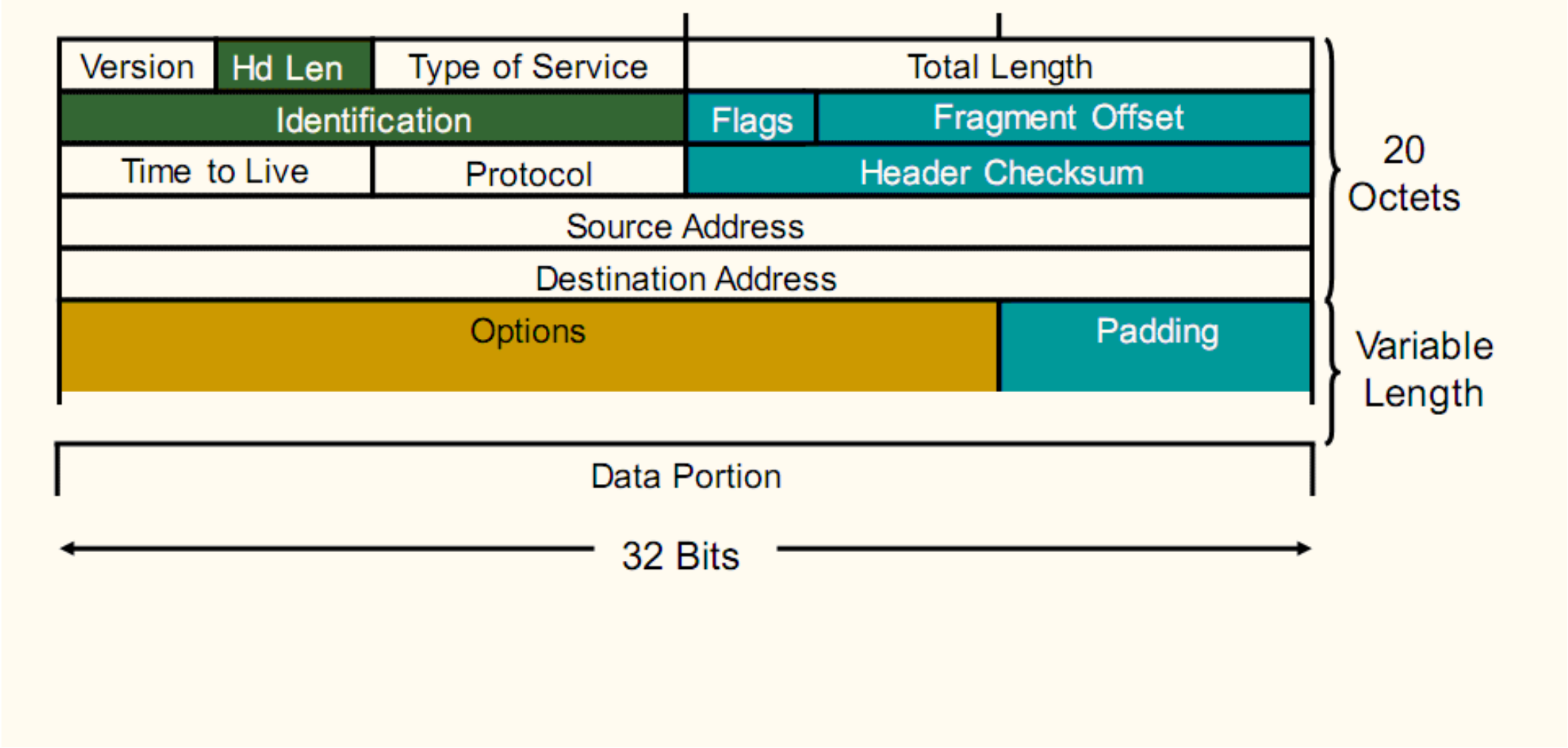
예약된 Multicast 주소

Multicast Assigned Addresses (RFC 2375)

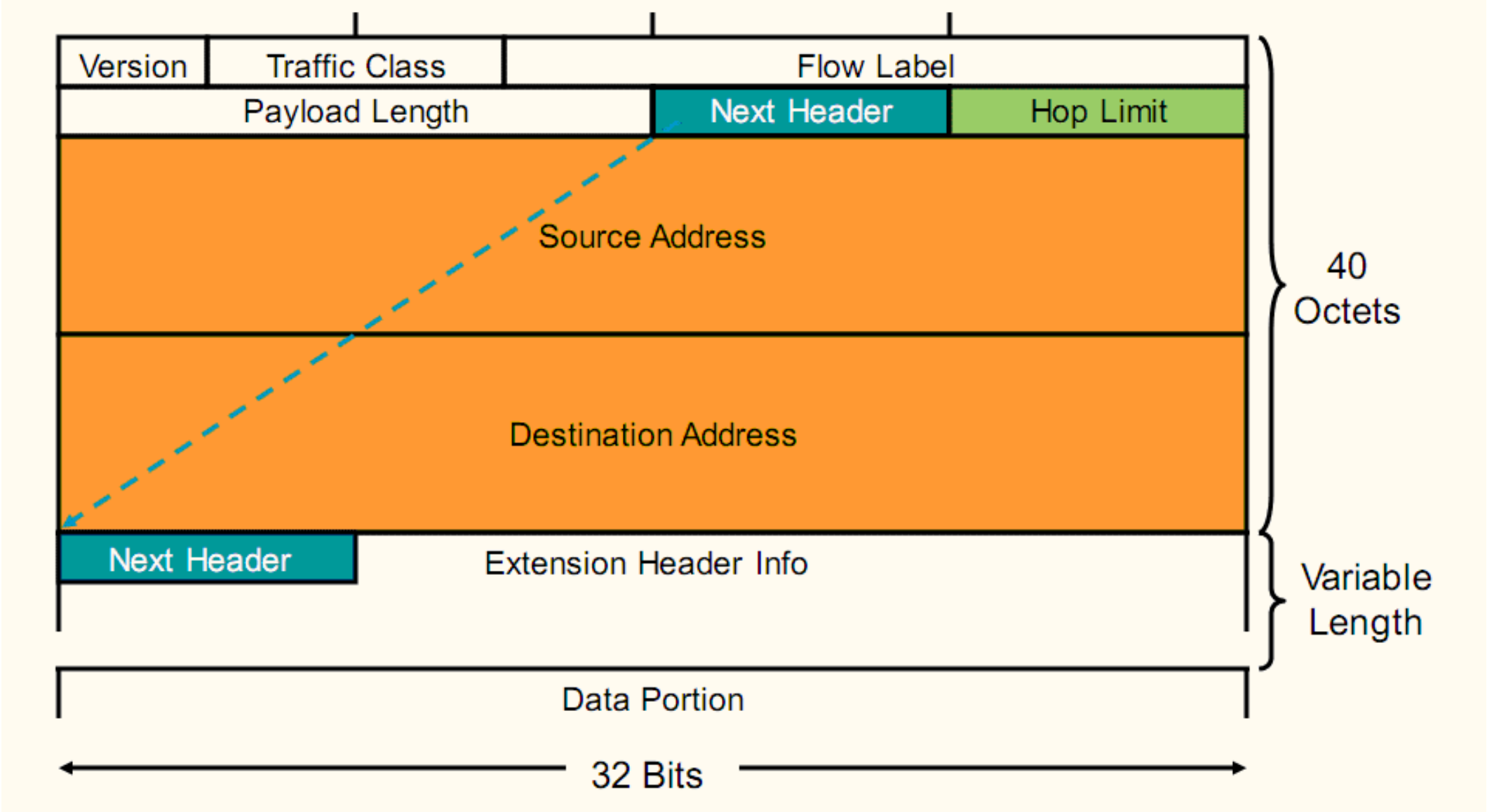
- FF0X:: is reserved (X is from the range from 0 to F).
- Inside this range, the following addresses are assigned:

Address	Meaning	Scope
FF02::1	All nodes	Link-local
FF02::2	All routers	Link-local
FF02::9	All RIP routers	Link-local
FF02::1:FFXX:XXXX	Solicited-node	Link-local
FF05::101	All NTP servers	Site-local
FF05::1:3	All DHCP servers	Site-local
FF0X::127	CISCO-RP-ANNOUNCE	Any scope
FF0X::128	CISCO-RP-DISCOVERY	Any scope

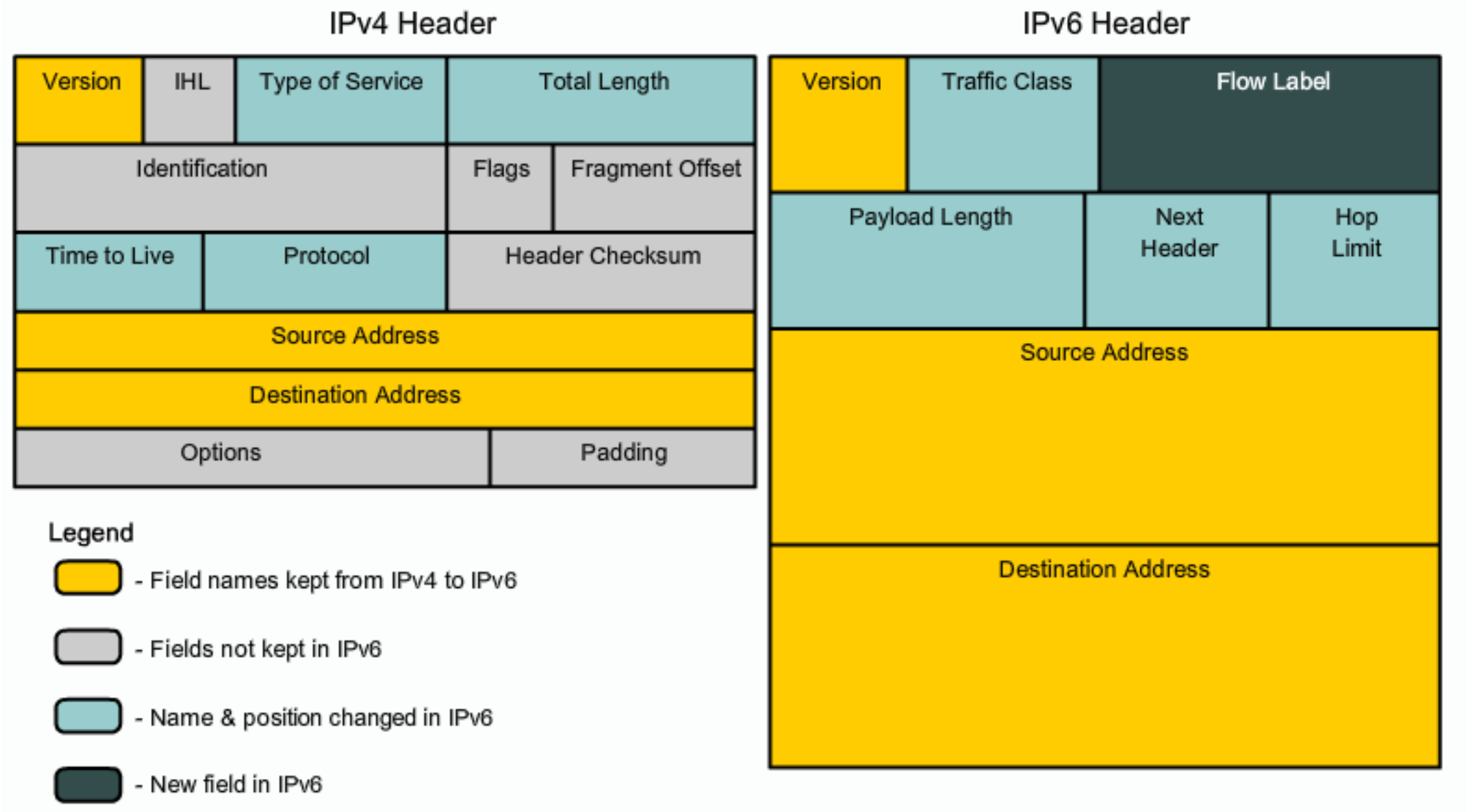
IPv4 Header 형태



IPv6 Header 형태



IPv4 and IPv6 Header 비교



Cisco Router에서 IPv6 활성화

To enable IPv6 on Cisco IOS routers, enable IPv6 unicast packet forwarding:

```
router(config)#
ipv6 unicast-routing
```

- Enable IPv6 traffic forwarding

Enabling IPv6 on Cisco Catalyst switches might require changing the switch database management template.

```
switch(config)#
sdm prefer dual-ipv4-and-ipv6 default
```

- Enable IPv6 TCAM support (advance IP Services feature set is required)

IPv6 Address 설정

The **ipv6 address** command:

- Enables IPv6 on the interface
- Configures the interface IPv6 address

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

- Enables IPv6 support on an interface when no explicit address has been configured

```
router(config-if)#
ipv6 address <ipv6prefix>/<prefixlength> [eui-64]
```

- Configures an IPv6 address on an interface and starts sending out route advertisements for the configured prefix

IPv6 Address 설정

```
router(config-if)#
ipv6 unnumbered <interface>
```

- Assigns address from another interface

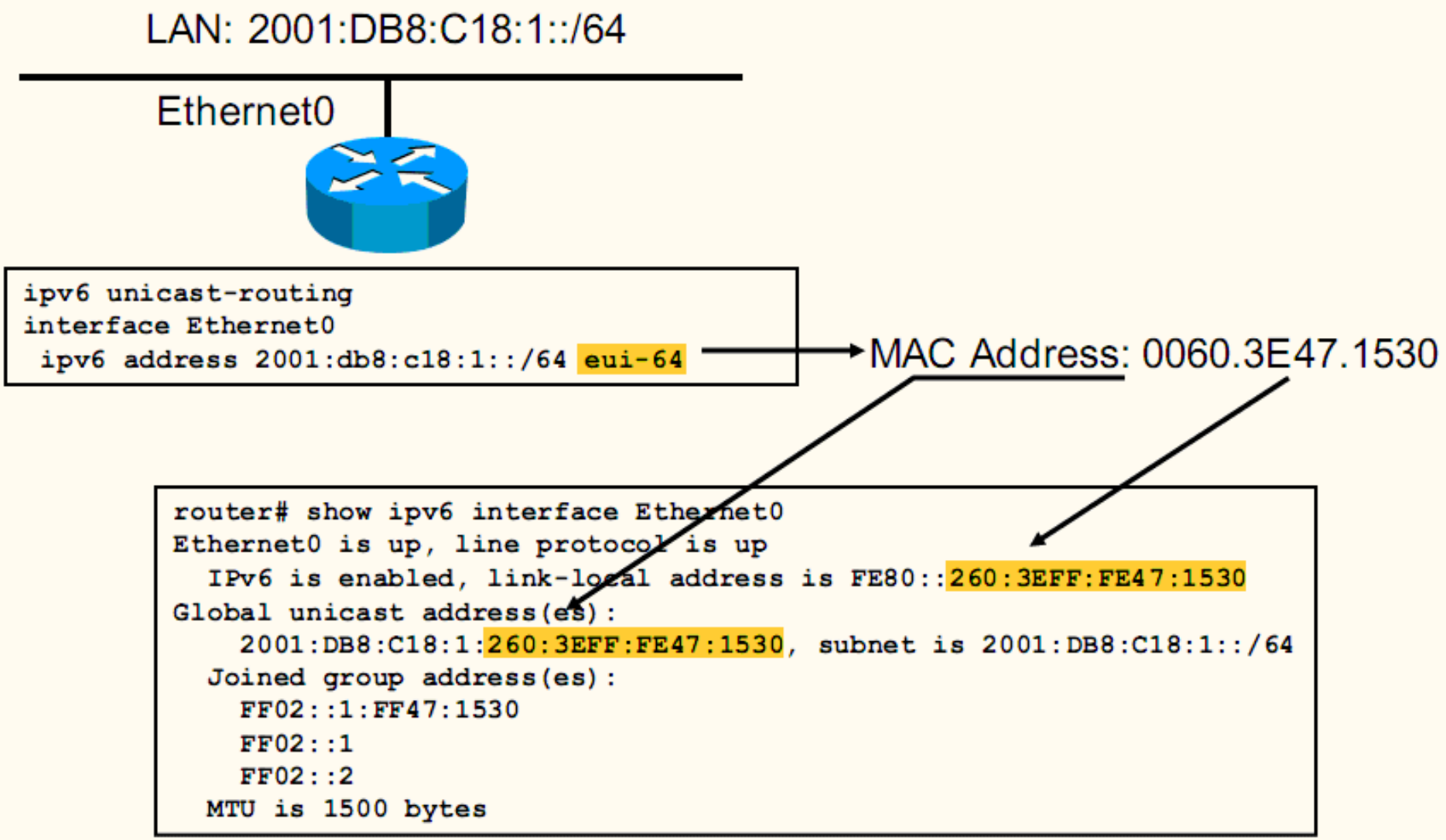
```
router(config-if)#
ipv6 address <fe80::suffix> link-local
```

- Configures link local address to an arbitrary value

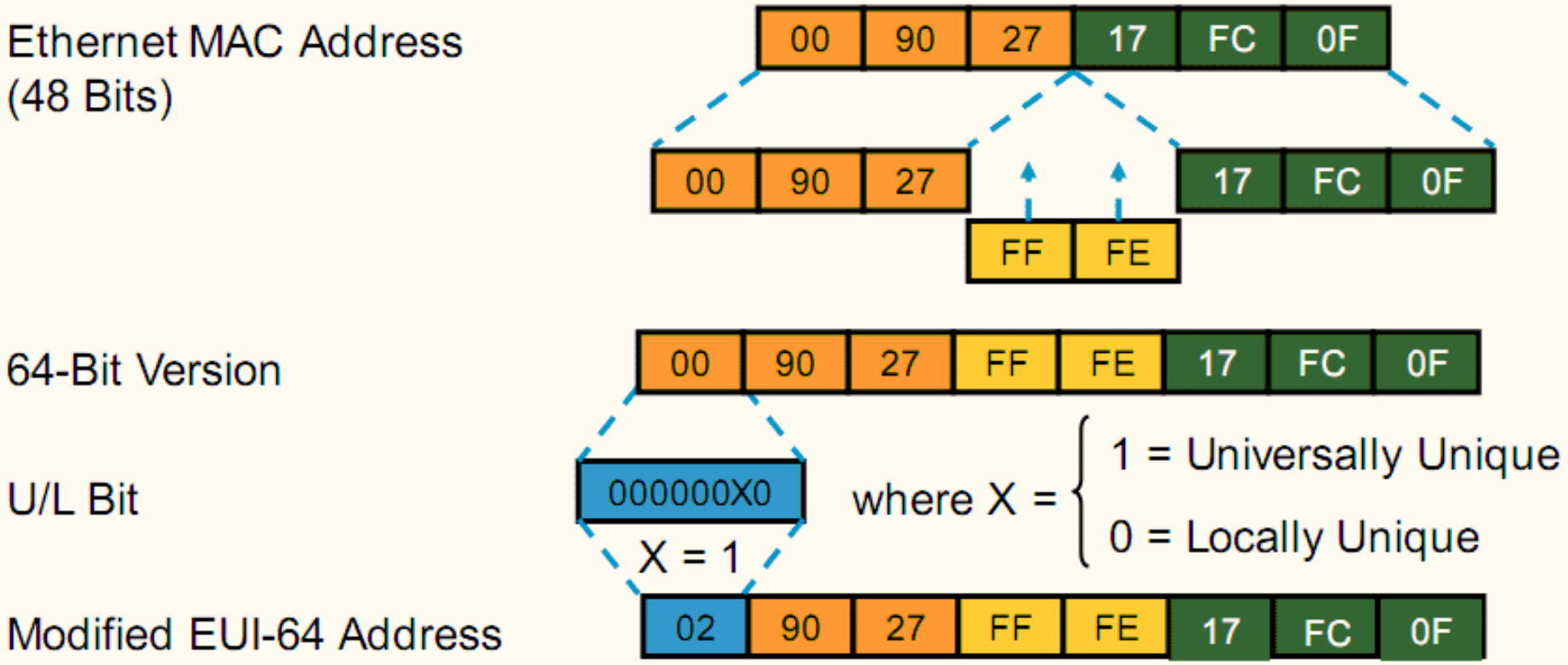
```
router(config-if)#
ipv6 address autoconfig [default]
```

- Configures stateless autoconfiguration on the interface
- Default route is added, based on route advertisement information, if the **default** keyword is added.

IPv6 Address 설정



Modified EUI-64 Format



A modified EUI-64 address is formed by inserting "FFFE" and complementing a bit that identifies the uniqueness of the MAC address.

Cisco IOS show 명령어

- Send IPv6 ICMP echo request to the default router:

```
router# ping 2001:DB8:C18:1:260:3EFF:FE47:1530

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001:DB8:C18:1:260:3EFF:FE47:1530, timeout
is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

- Display the neighbor discovery cache on the router:

```
router# show ipv6 neighbors

IPv6 Address                              Age Link-layer Addr State Interface
FE80:: 260:3EFF:FE47:1530                  26 0060.3e47.1530  REACH Ethernet0
2001:DB8:C18:1:260:3EFF:FE47:1530           0 0060.3e47.1530  REACH Ethernet0
```

RIPng for IPv6 개요

RIPng has the same main features as RIP for IPv4:

- Distance vector routing protocol
- Maximum radius of 15 hops
- Routing loop prevention using split horizon and poison reverse
- Uses UDP port 521 for communication
- Periodic routing updates and same timer values
- Derived from RIPv2, but not compatible due to IPv6-specific messages

RIPng for IPv6 개요

Updated RIPng Features for IPv6

- Able to carry IPv6 prefixes, next-hop IPv6 link-local address, next-hop interface.
- Uses the all-RIP-routers multicast group, FF02::9, as the destination address for RIP updates.
- Uses IPv6 for transport.
- Enabled per-interface, not per-network:
  - Enabled and used on the interface.
  - The network command deprecated.
- Several instances allowed on the router (up to four).

Cisco IOS RIPng 설정

router(config)#

```
ipv6 router rip tag
```

- Creates and enters RIP router submode

router(config-rtr)#

```
redistribute static | bgp | rip tag
```

- Redistributes routes from other routing processes

router(config-if)#

```
ipv6 rip tag enable
```

- Configures RIP on an interface

router(config-if)#

```
ipv6 rip tag default-information originate
```

- Originates the default route (::/0) from an interface

Cisco IOS RIPng 설정

Cisco IOS RIPng Commands

```
router#
show ipv6 rip
```

- Displays status of the various RIP processes

```
router#
show ipv6 rip database
```

- Displays the RIP database

```
router#
show ipv6 route rip
```

- Shows RIP routes in the IPv6 route table

```
router#
debug ipv6 rip
```

- Displays RIP packets sent and received

OSPF for IPv6 개요

- Router ID is no longer based on an IPv4 address of the router:
  - It is configured in the routing process
  - It is still a 32-bit number, written in four octets
  - It is used to sign routing updates
- Adjacencies and next-hop attributes use link-local addresses (exception: virtual links).
- IPv6 is used for transport of the LSA.
- Enabled per-link, not per-network.
- OSPFv3 requires Cisco Express Forwarding.

OSPF for IPv6 개요

- Router ID, area ID, and link-state ID remain 32 bits:
  - Not derived from an IPv4 address
- Router LSA and network LSA do not contain IPv4 addresses, these are only 32-bit identifiers.
- LSAs now have a flooding scope defining a radius:
  - Link-local
  - Area
  - Autonomous system
- Handling and forwarding of unknown LSAs is supported—to handle future OSPF extensions.
- Uses IPv6 link-local multicast addresses:
  - FF02::5 OSPF routers
  - FF02::6 OSPF-designated routers

OSPF for IPv6 개요

- Two LSAs have been renamed:
  - Interarea Prefix LSAs (Type 3)
  - Interarea Router LSAs (Type 4)
- Two new LSAs have been added to OSPFv3:
  - Link LSAs (Type 8)
  - Intra-Area Prefix LSAs (Type 9)

Cisco IOS OSPFv3 설정 확인

```
router#
show ipv6 ospf [process-id][area-id] interface [int]
```

- Displays OSPF-related interface information

```
router#
show ipv6 ospf [process-id] [area-id]
```

- Displays general information about OSPF processes

```
router(config-if)#
clear ipv6 ospf [process-id] {process |force-spf |
redistribution | counters [neighbor [neighbor-interface]]}
```

- Triggers SPF recalculations

EIGRP for IPv6 개요

- Advanced distance vector mechanism with some features common to link-state protocols
- Uses protocol-dependent modules to support multiple protocols:
  - IPv4
  - IPX
  - AppleTalk
- Easy to configure
- Fast convergence
- Supports IPv6 as a separate routing context

Cisco IOS EIGRP for IPv6 설정

```
router(config)#
```

```
ipv6 router eigrp as-number
```

- Creates and enters EIGRP router submode

```
router(config-rtr)#
```

```
no shutdown
```

- Starts EIGRP for IPv6 without changing interface

```
router(config-rtr)#
```

```
default-information originate [route-map route-map]
```

- Advertises default route, with an optional route map

```
router(config-rtr)#
```

```
maximum-paths number
```

- Configures maximum number of paths to the same destination that will be installed in the routing table

Cisco IOS EIGRP for IPv6 설정

```
router(config-if)#
ipv6 eigrp as-number
```

- Configures EIGRP for IPv6 on an interface

```
router(config-if)#
ipv6 summary-address eigrp as-number prefix/mask [AD]
```

- Configures summarization on an interface

```
router(config-if)#
no ipv6 split-horizon eigrp as-number
```

- Disables split horizon on an interface

```
router(config-if)#
ipv6 bandwidth-percent eigrp as-number percent
```

- Configures the percentage of bandwidth EIGRP uses

Cisco IOS EIGRP for IPv6 설정 확인

```
router#
show ipv6 eigrp topology
```

- Displays entries in the EIGRP IPv6 topology table

```
router#
show ipv6 eigrp neighbors
```

- Displays the neighbors discovered by EIGRP for IPv6

```
router#
show ipv6 route eigrp
```

- Shows EIGRP routes in the IPv6 routing table

```
router#
debug ipv6 eigrp
```

- Displays information about EIGRP for IPv6 protocol