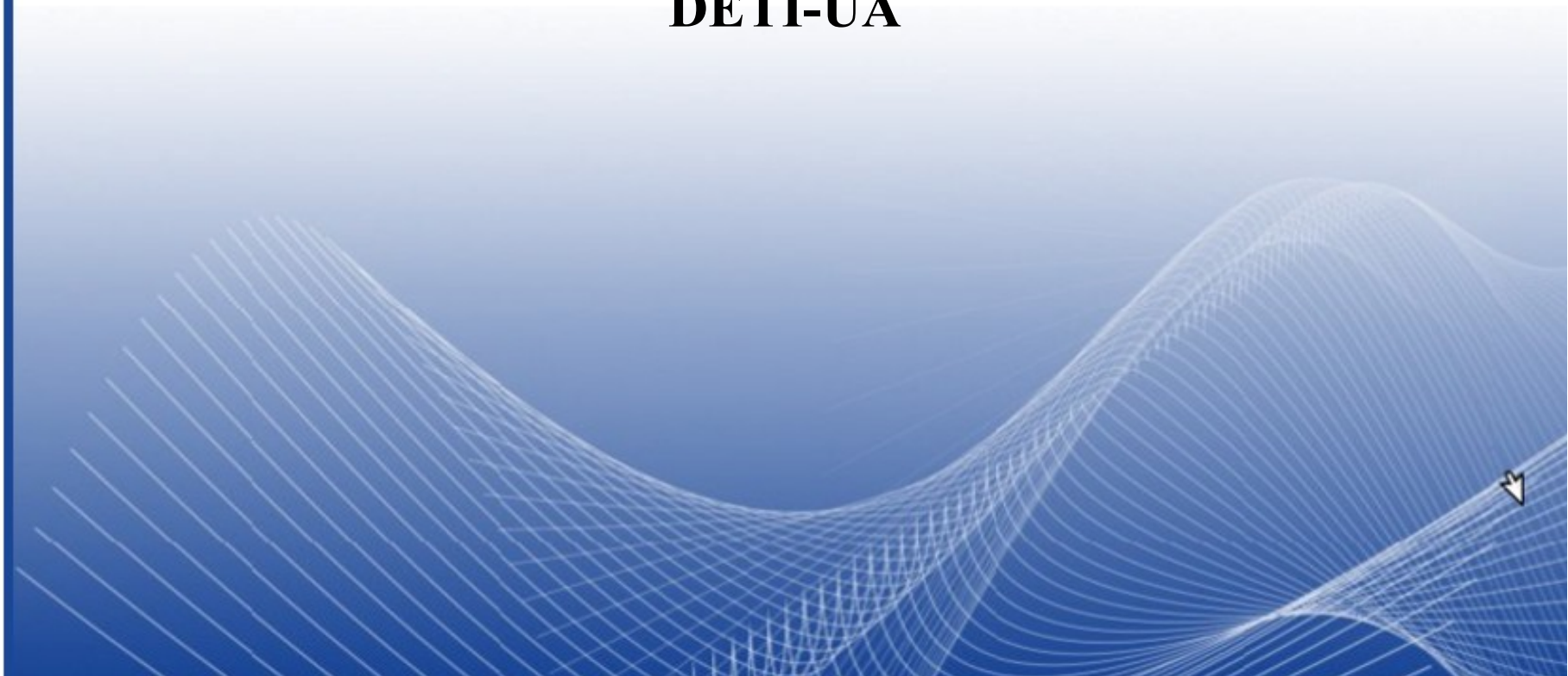
Camada de Rede (Protocolo IPv6)

Redes e Serviços

Licenciatura em Engenharia Informática
DETI-UA



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IPv6 Background

- ETF IPv6 WG began to work on a solution to solve addressing growth issues in early 1990s
- Reasons to late deployment
  - Classless Inter-Domain Routing (CIDR) and Network address translation (NAT) were developed
  - Investments on field equipments (not IPv6 aware) had to reach the predicted “return of investment”
  - Massive re-equipment price

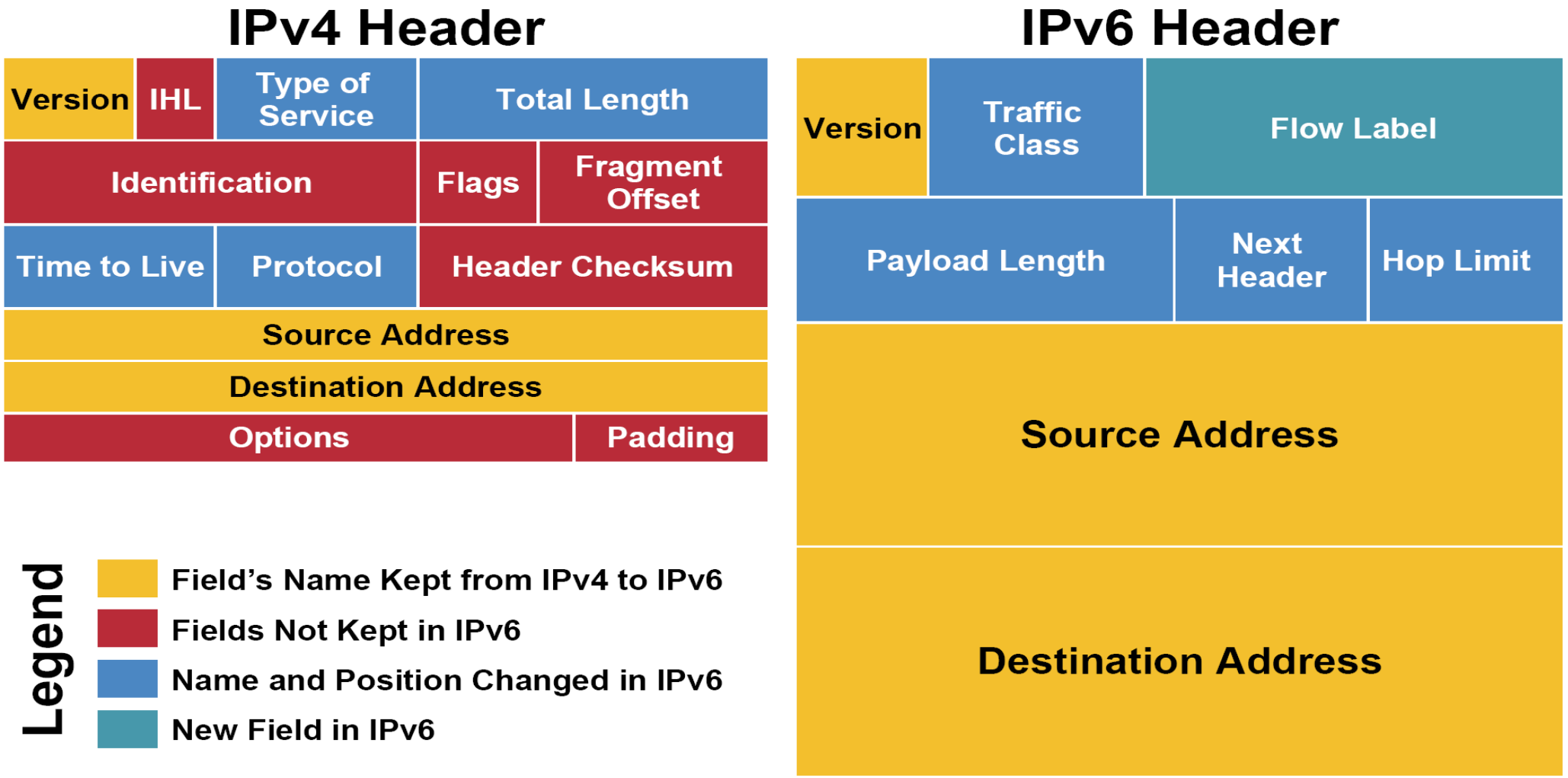
IPv6 Features

- Larger address space enabling:
  - Global reachability, flexibility, aggregation, multihoming, autoconfiguration, “plug and play” and renumbering
- Simpler header enabling:
- Routing efficiency, performance and forwarding rate scalability
- Improved option support

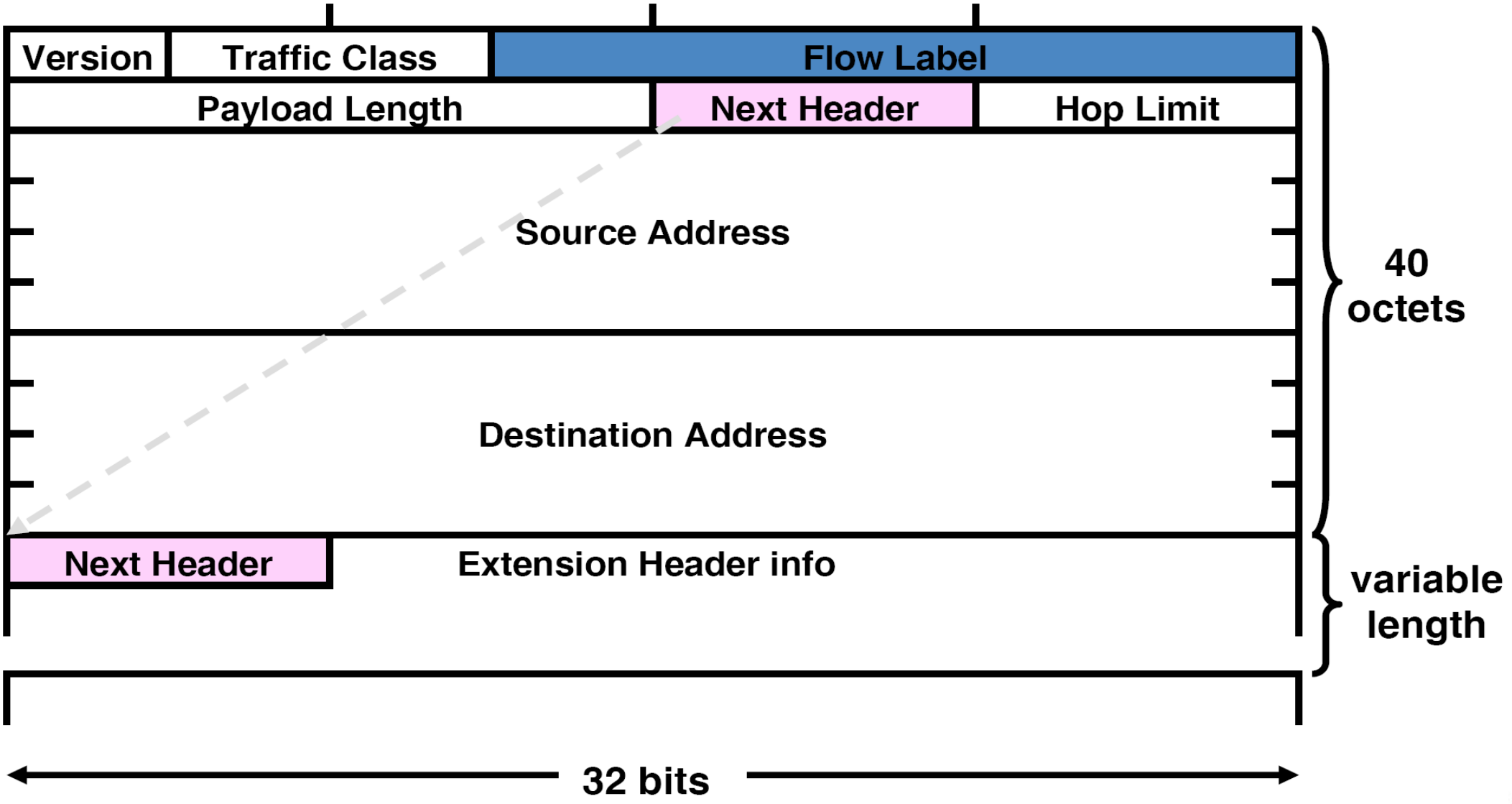
IPv6 Addressing

- IPv4: 4bytes/32 bits
  - ~ 4,294,967,296 possible addresses
- IPv6: 16bytes/128 bits
  - 340,282,366,920,938,463,463,374,607,431,768,211,456 possible addresses
- Representation
  - 16-bit hexadecimal numbers
    - Hex numbers are not case sensitive
  - Numbers are separated by (:)
    - Abbreviations are possible
      - Leading zeros in contiguous block could be represented by (::)
      - Example:
      - 2001:0db8:0000:130F:0000:0000:087C:140B = 2001:0db8:0:130F::87C:140B
      - Double colon only appears once in the address
  - Address's prefix is represented as: prefix/mask_number_of_bits

IPv4 vs. IPv6 Headers



IPv6 Header Format



IPv6 Addressing Model

- Interface have multiple addresses
- Addresses have scope:
  - Link Local
    - Valid within the same LAN or link
  - Unique Local
    - Valid within the same private domain
    - Can not be used in Internet
  - Global
- Addresses have lifetime
  - Valid and preferred lifetime

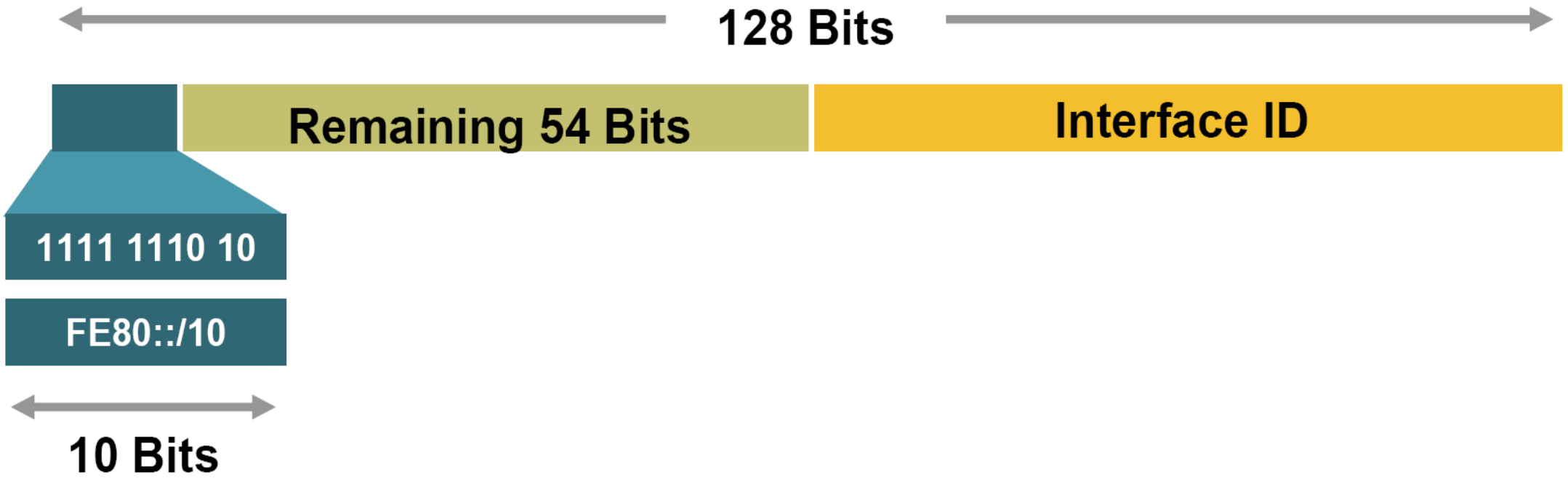
Types of IPv6 Addresses

- Unicast
  - Address of a single interface.
  - One-to-one delivery to single interface
- Multicast
  - Address of a set of interfaces.
  - One-to-many delivery to all interfaces in the set
- Anycast
  - Address of a set of interfaces.
  - One-to-one-of-many delivery to a single interface in the set that is closest
- No more broadcast addresses

IPv6 Addressing

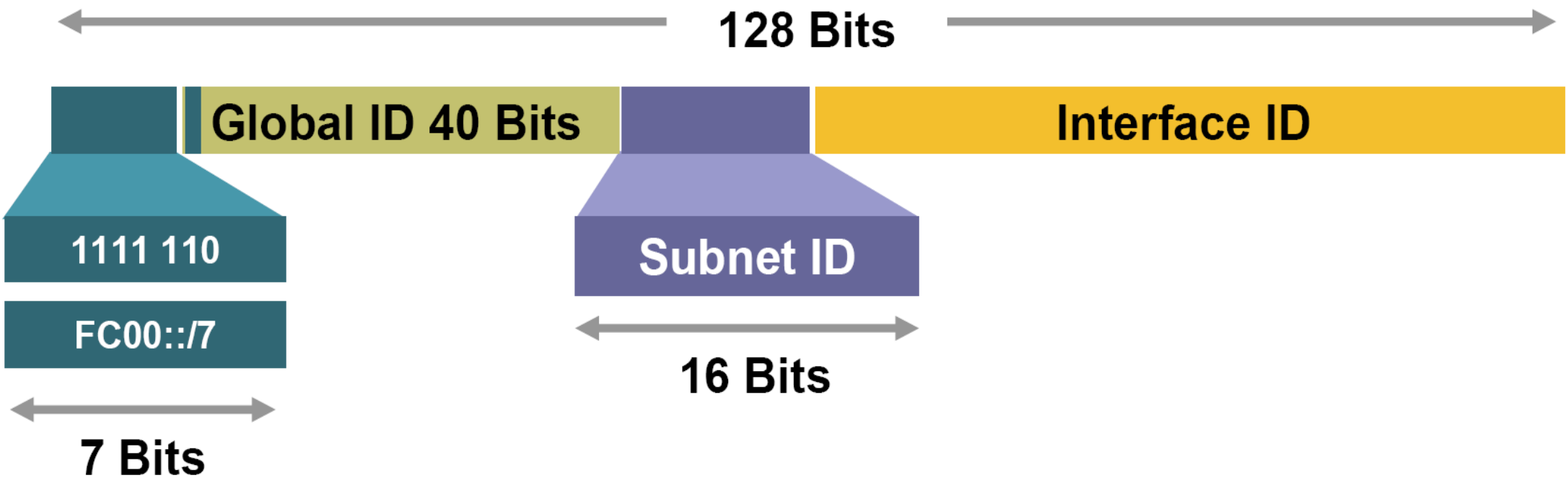
Type	Binary	Hexadecimal
Global Unicast Address	0010	2
Link-Local Unicast Address	1111 1110 10	FE80::/10
Unique-Local Unicast Address	1111 1100 1111 1101	FC00::/8 FD00::/8
Multicast Address	1111 1111	FF00::/16

Link-Local Address



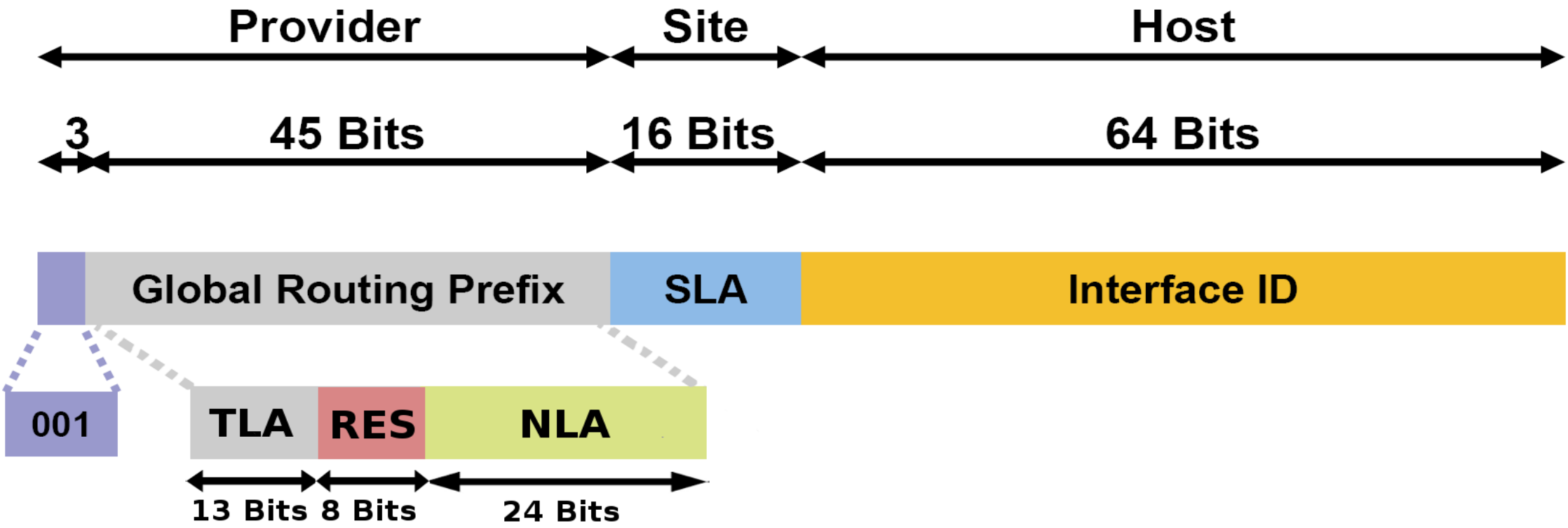
- Used For:
  - Mandatory address for local communication between two IPv6 devices
  - Next-Hop calculation in Routing Protocols
- Automatically assigned as soon as IPv6 is enabled
- Remaining 54 bits could be Zero or any manual configured value

Unique-Local Address



- Used For:
  - Local communications
  - Inter-site VPNs
- Can be routed only within the same Autonomous System
  - Can not be used on the Internet

Global Unicast Addresses



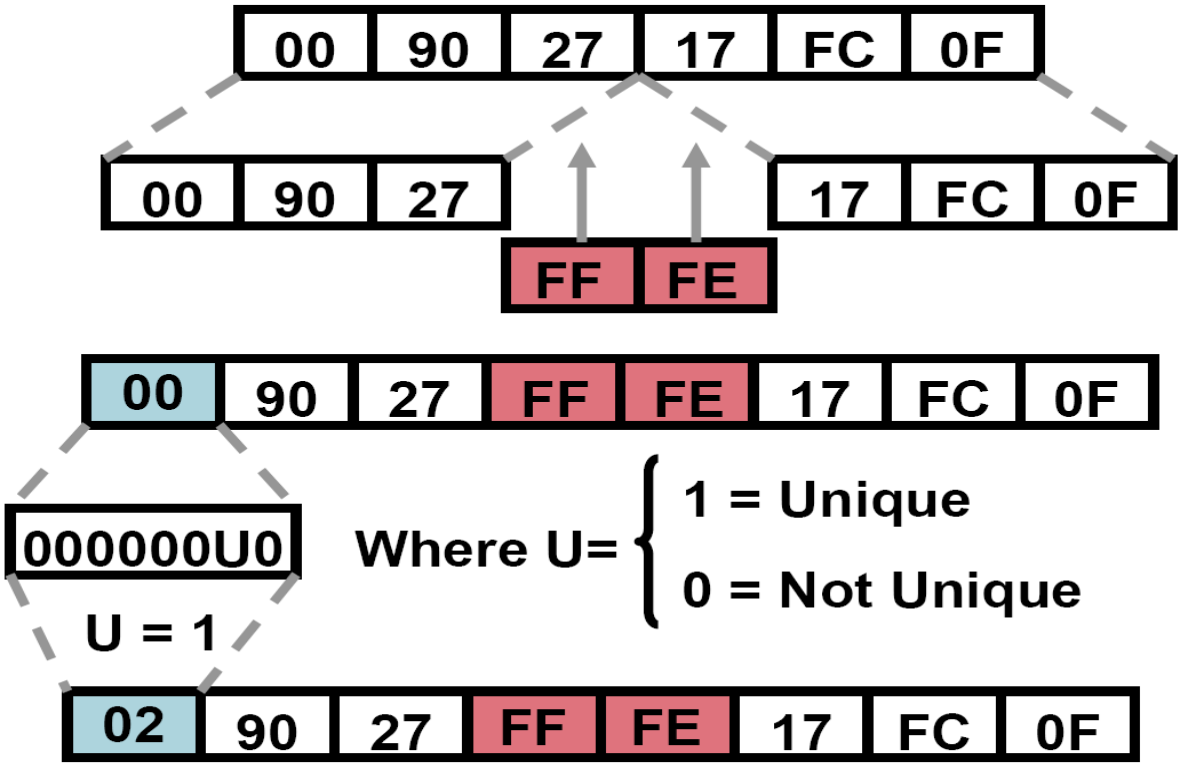
- LA, NLA and SLA used for hierarchical addressing
  - TLA - Top-Level Aggregation
  - RES – Reserved (must be zero)
  - NLA - Next-Level Aggregation Identifier
  - SLA - Site-Level Aggregation Identifier

IPv6 Interface Identifier

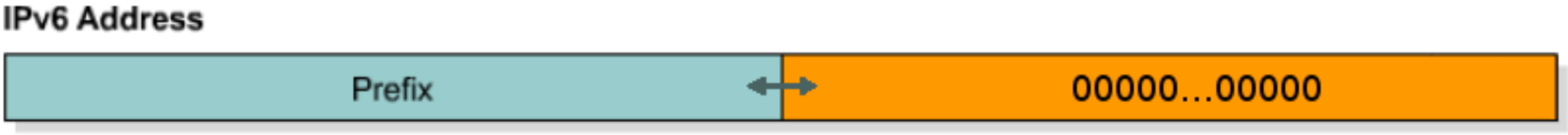
- Lowest-Order 64-Bit field of any address:
  - Auto-configured from a 64-bit EUI-64, or expanded from a 48-bit MAC address (e.g. Ethernet address)
  - Auto-generated pseudo-random number
  - Assigned via DHCP
  - Manually configured

MAC to Interface ID (EUI-64 format)

- Stateless auto-configuration
- Expands the 48 bit MAC address to 64 bits by inserting FFFE into the middle 16 bits
- To make sure that the chosen address is from a unique Ethernet MAC address
  - "u"bit is set to 1 for global scope
  - "u"bit is set to 0 for local scope



Anycast Address



- Address that is assigned to a set of interfaces
  - Typically belong to different nodes
- A packet sent to an Anycast address is delivered to the closest interface (determined by routing and timings)
- Anycast addresses can be used only by routers, not hosts
- Must not be used as the source address of an IPv6 packet
- Nodes to which the anycast address is assigned must be explicitly configured to recognize that the address is an Anycast address

Multicast Addresses

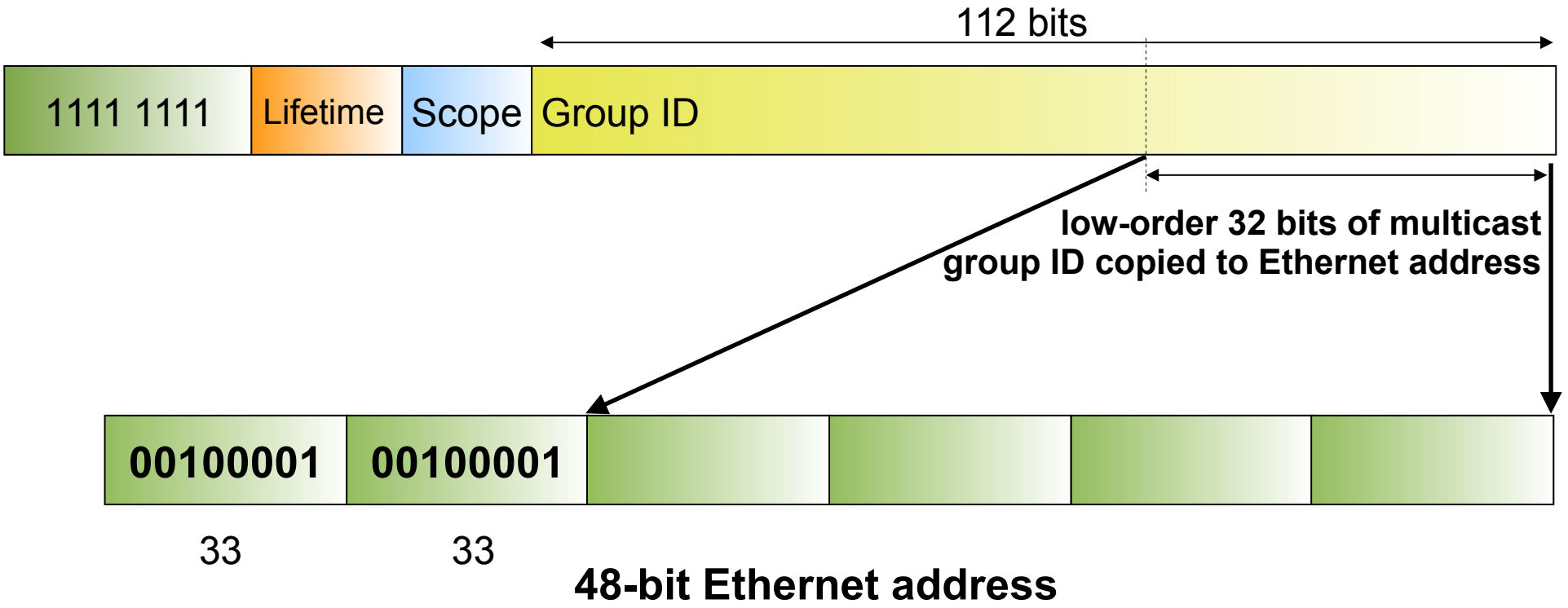
8-bit	4-bit	4-bit	112-bit
1111 1111	Lifetime	Scope	Group-ID

Lifetime	
0	If Permanent
1	If Temporary

Scope	
1	Node
2	Link
5	Site
8	Organization
E	Global

- Multicast addresses have a prefix FF00::/8
- The second byte defines the lifetime and scope of the multicast address.

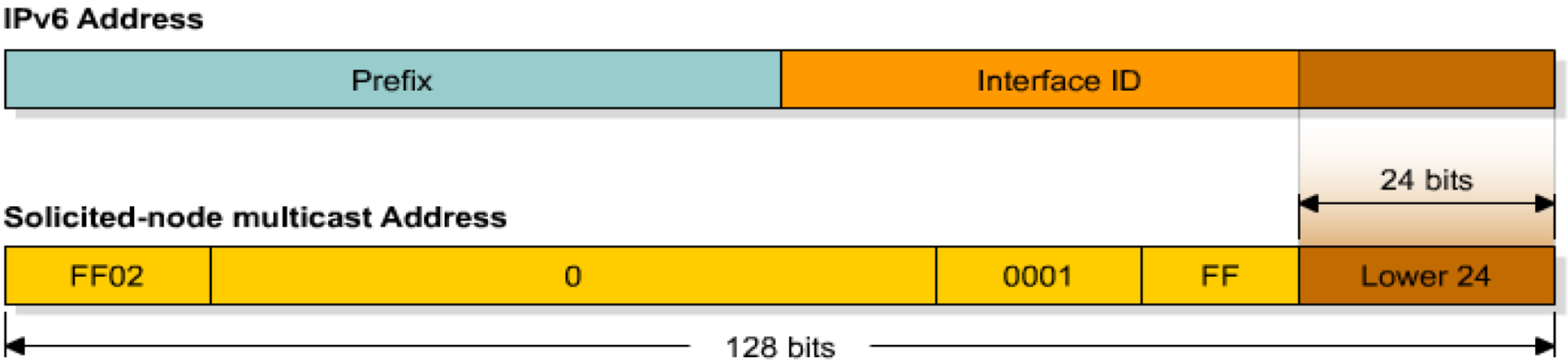
Mapping a IPv6 Multicast Address to Ethernet Address



Common Multicast Addresses

- Node Scope
  - FF01:::1 All Nodes Address (Node scope)
  - FF01:::2 All Routers Address (Node scope)
- Link Scope
  - FF02::1 All Nodes Address (Node scope)
  - FF02::2 All Routers Address
  - FF02::4 DVMRP Routers
  - FF02::5 OSPF IGP
  - FF02::6 OSPF IGP Designated Routers
  - FF02::9 RIP Routers
  - FF02::B Mobile-Agents
  - FF02::D All PIM Routers
  - FF02::E RSVP-ENCAPSULATION
  - FF02::16 All MLDv2-capable routers
  - FF02:::1:2 All DHCP agents

Solicited-Node Multicast Address



- For each unicast and anycast address configured there is a corresponding solicited-node multicast
- FF02::1:FF:<interface ID's lower 24 bits>
- This address has link local significance only
- Used in “Neighbour Solicitation Messages”
  - MAC/Physical addresses resolution
  - Duplicate Address Detection (DAD)
    - Random or assigned interface IDs may result in equal global/link addresses

Physical Addresses Resolution

- In IPv6 ARP does not exist anymore.
- ARP table is now called **NDP table**
  - NDP: Neighbor Discovery Protocol
  - Maintains a list of known neighbors (IPv6 addresses and MAC addresses).
- Uses ICMPv6 “Neighbor Solicitation” and “Neighbor Advertisement” messages.
  - To resolve an address a Neighbor Solicitation message is sent to the Solicited-Node multicast address of the target machine (IPv6 address).
  - Response is sent in unicast using a Neighbor Advertisement message.

ICMPv6

- Internet Control Message Protocol version 6 (ICMPv6) is the implementation ICMP for IPv6
  - RFC 4443
  - ICMPv6 is an integral part of IPv6.
- Have the same functionalities of ICMP, plus:
  - Replaces and enhances ARP,
    - ICMPv6 implements a Neighbor Discovery Protocol (NDP),
  - Hosts use it to discover routers and perform auto configuration of addresses,
  - Used to perform Duplicate Address Detection (DAD),
  - Used to test reachability of neighbors.

Neighbor Discovery

- Neighbor discovery uses ICMPv6 messages, originated from node on link local with hop limit of 255
- Consists of IPv6 header, ICMPv6 header, neighbor discovery header, and neighbor discovery options
- Five neighbor discovery messages
  - Router solicitation (ICMPv6 type 133)
  - Router advertisement (ICMPv6 type 134)
  - Neighbor solicitation (ICMPv6 type 135)
  - Neighbor advertisement (ICMPv6 type 136)
  - Redirect (ICMPV6 type 137)

Router Solicitation

- Host send to inquire about presence of a router on the link
- Send to all routers multicast address of FF02::2 (all routers multicast address)
- Source IP address is either link local address or unspecified IPv6 address

Router advertisement

- Sent out by routers periodically, or in response to a router solicitation
- Includes auto-configuration information
- Includes a "preference level" for each advertised router address
- Also includes a "lifetime" field

Neighbor Solicitation

- Send to discover link layer address of IPv6 node
- IPv6 header, source address is set to unicast address of sending node, or :: for DAD
- Destination address is set to
  - Unicast address for reachability
  - Solicited node multicast for address resolution and DAD

Neighbor Advertisement

- Response to neighbor solicitation message
- Also send to inform change of link layer address

Redirect

- Redirect is used by a router to signal the reroute of a packet to a better router

Auto-configuration

- Stateless
  - A node on the link can automatically configure global IPv6 addresses by appending its interface identifier (64 bits) to the prefixes (64 bits) included in the Router Advertisement messages
  - Additional/Other network information may be obtained
    - Additional fields in Router Advertisement messages,
    - Using a stateless DHCPv6 server.
- Stateful
  - Addresses are obtained using DHCPv6.

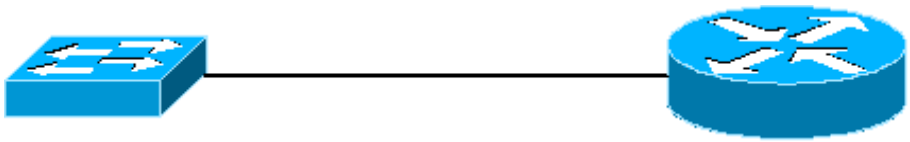
- The default gateway may send two configurable flags in Router Advertisements (RA)
  - Other flag bit: client can use DHCPv6 to retrieve other configuration parameters (e.g.: DNS server addresses)
  - Managed flag bit: client may use DHCPv6 to retrieve a Managed IPv6 address from a server

Multicast Listener Discovery (MLD)

- MLD permits the creation/management of multicast groups
- MLD is used by an IPv6 router to:
  - Discover the presence of multicast listeners on directly attached links
  - And to discover which multicast addresses are of interest to those neighboring nodes
  - Report interest in router specific multicast addresses
- Routers and hosts use MLD to report interest in respective Solicited-Node Multicast Addresses

- MLD will be studied later in detail.

IPv6 Start-up - Router



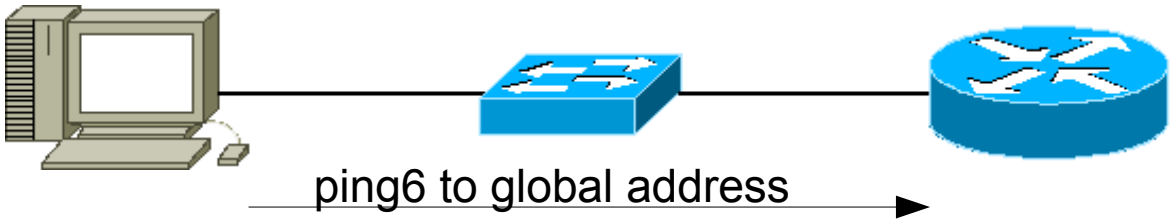
Multicast (all MLDv2-capable routers) ff02::16	**MLDv2 Report Message** (Multicast all routers)	**Null address ::**
Multicast (all MLDv2-capable routers) ff02::16	**MLDv2 Report Message** (Multicast solicited-node address)	**Null address ::**
Multicast solicited-node address ff02::1:ff+(address's last 24 bits)	**Neighbor Solicitation** (DAD link-local address)	**Null address ::**
Multicast (all hosts) ff02::1	**Neighbor Advertisement**	**Link-local address fe80::+(interface ID 64-bits)**
Multicast (all MLDv2-capable routers) ff02::16	**MLDv2 Report Message** (Multicast all routers)	**Link-local address fe80::+(interface ID 64-bits)**
Multicast (all MLDv2-capable routers) ff02::16	**MLDv2 Report Message** (Multicast solicited-node address)	**Link-local address fe80::+(interface ID 64-bits)**
Multicast solicited-node address ff02::1:ff+(address's last 24 bits)	**Neighbor Solicitation** (DAD global address)	**Null address ::**
Multicast (all hosts) ff02::1	**Router Advertisement**	**Link-local address fe80::+(interface ID 64-bits)**

Only if global address is configured

IPv6 Start-up – Terminal/Router Interaction

Null address **::**	**Neighbor Solicitation** (DAD link-local address)	**Multicast solicited-node address** **ff02::1:ff+(address's last 24 bits)**
Link-local address **fe80::+(interface ID 64-bits)**	**Router Solicitation**	**Multicast (all routers)** **ff02::2**
Null address **::**	**MLDv2 Report Message** ~~(Multicast solicited-node address)~~	**Multicast (all MLDv2-capable routers)** **ff02::16**
Multicast (all hosts) **ff02::1**	**Router Advertisement**	**Link-local address** **fe80::+(interface ID 64-bits)**
Null address **::**	**Neighbor Solicitation** (DAD global address)	**Multicast solicited-node address** **ff02::1:ff+(address's last 24 bits)**

Address Resolution and Ping6



Global address — **Neighbor Solicitation** (Target's IPv6 address) → **Multicast solicited-node address ff02::1:ff+(address's last 24 bits)**

Global address ← **Neighbor Advertisement** (MAC address) — **Global address**

Global address — **ICMPv6 Echo Request** → **Global address**

Global address ← **ICMPv6 Echo Reply** — **Global address**

Global/link-local address — **Neighbor Solicitation** (IPv6 address) → **Global/link-local address**

Global/link-local address ← **Global/link-local address**

To verify the reachability of a neighbor after physical address of a neighbor is identified

IPv6 Subnetting/Aggregation

- In IPv6 the same principles of IPv4 subnetting and aggregation are still valid.
  - Using the TLA, NLA and SLA bits of the IPv6 addresses.
  - Example: network 2001:A:A:/48 can be divided in 2^16 sub-networks with identifiers 2001:A:A:****:/64
- By standard, the maximum mask size is /64, however it is possible to subnet also the host part of the IPv6 address.
  - Usage of mask /120 to protect the network from NDP Table Exhaustion attacks.
    - With mask /120 the maximum size of the NDP table is limited to 2^8.
    - More “large” masks also work.
  - Some tools/services may break.
  - Requires manual, DHCPv6 address configuration or modified auto-configuration mechanisms.