Structure of IPv6 Addresses and Networks (1/5)

- IPv6 addresses have a length of 128 bits (16 bytes)
  - Therefore, $2^{128} \approx 3,4 * 10^{38}$ addresses can be represented
- The introduction is useful because of the limited address space of IPv4
- Problem: The decimal notation is confusing
  - For this reason, IPv6 addresses are represented in hexadecimal format
    - Groups of 4 bits are represented as a hexadecimal number
  - Goups of 4 hexadecimal numbers are merged into blocks
  - The blocks are separated by colons
    Example: `2001:0db8:85a3:08d3:1319:8a2e:0370:7344`

- The last 4 bytes (32 bits) of an IPv6 address may also be written in decimal notation
- This is useful to embed the IPv4 address space into the IPv6 address space
  $\Longrightarrow$ see slide 47

RFC 4291 (2006) *IP Version 6 Addressing Architecture*

Structure of IPv6 Addresses and Networks (2/5)

- Rules for simplification (RFC 5952):
  - Leading zeros within a block may be omitted
  - Successive blocks with value 0 (= 0000), may be omitted **exactly 1 time within an IPv6 address**
    - If blocks are omitted, this is indicated by 2 consecutive colons
  - If several groups of null blocks exist, it is recommended to shorten the group with the most null blocks
- Example:
  - The IPv6 address of `j.root-servers.net` is:
    2001:0503:0c27:0000:0000:0000:0002:0030
    $\Longrightarrow$ 2001:503:c27::2:30

Notation of IPv6 addresses (URLs)

- IPv6 addresses are enclosed in square brackets
- Port numbers are appended outside the brackets
  `http://[2001:500:1::803f:235]:8080/`
- This prevents the port number from being interpreted as part of the IPv6 address

Structure of IPv6 Addresses and Networks (3/5)

- IPv6 addresses consist of 2 parts

64 Bits	64 Bits
Network Prefix	Interface Identifier
2001:638:208:ef34	:0:ff:fe00:65

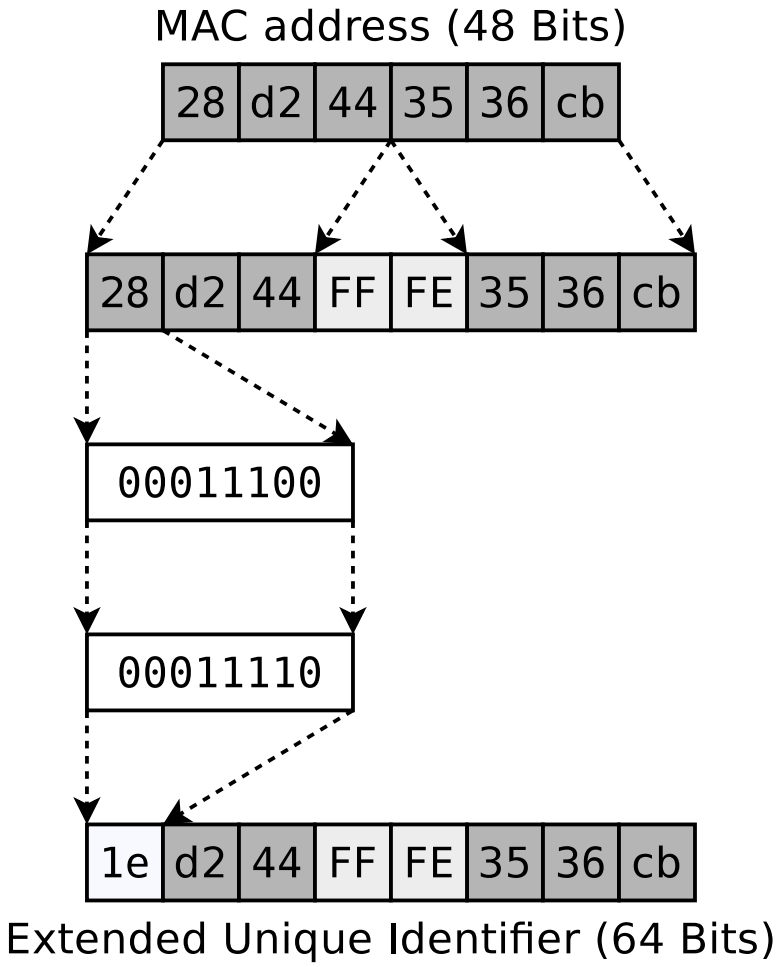
1. **Prefix** (Network Prefix)
   - Identifies the network
2. **Interface identifier** (Interface ID)
   - Identifies a network device in a network
   - Can be manually set, assigned via DHCPv6 or calculated from the MAC address of the network interface
   - If the interface identifier is calculated from the MAC address, it is called **Extended Unique Identifier** (EUI)
     - When this is done, the MAC address (48 bits) is converted into a 64-bit address $\Longrightarrow$ **modified EUI-64 address format** (see slide 45)

Some address spaces

`fe80::/10` $\Longrightarrow$ Link local addresses. They are only valid in the local network and are therefore not forwarded by Routers
`2000::/3` $\Longrightarrow$ (`2000...` until `3fff...`) Global unicast addresses. Routers forward them
`ff00::/8` $\Longrightarrow$ All addresses `ff...` are multicast addresses. Since IPv6 has no broadcast addresses, multicast addresses implement the broadcast functionality. The addresses `ff01::1` and `ff02::1` address all nodes in the local network and the addresses `ff01::2`, `ff02::2` and `ff05::2` address all local Routers
`2001:db8::/32` $\Longrightarrow$ Addresses only for documentation purposes

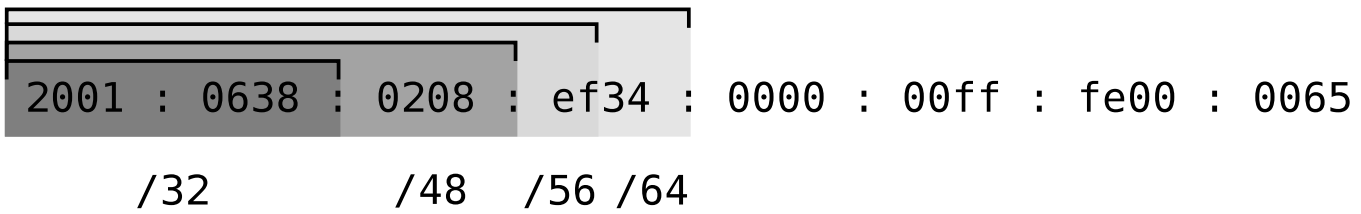
Structure of IPv6 Addresses and Networks (4/5)

- Converting a MAC address in the modified EUI-64 address format
  1. The MAC address is split into 2 parts of 24 bits
     - The 1st part becomes the first 24 bits
     - The 2nd part becomes the final 24 bits of the modified EUI-64 address
  2. The free 16 bits in the middle of the EUI-64 address have the following bit pattern: `1111 1111 1111 1110` (hex: `FFFE`)
  3. Finally, the value of the seventh bit from the left is inverted



Structure of IPv6 Addresses and Networks (5/5)

- (Sub-)netmasks do not exist in IPv6
  - The subdivision of address ranges into subnets is done by specifying the prefix length
- IPv6 networks are specified in CIDR notation
  - The address of a single device sometimes has `/128` attached
  - An example is the loopback address of IPv6: `::1/128`
    - All bits – except the last one – have value `0`
      (For IPv4, the loopback address is: `127.0.0.1`)
  - Internet Providers (ISPs) or operators of large networks get the first 32 or 48 bits assigned from a Regional Internet Registry (RIR)
    - The ISPs or network operators split this address space into subnets
    - End users usually get a `/64` or even a `/56` network assigned



- If a user gets a /56 network assigned, the 8 Bits between the Prefix and the Interface Identifier are the **Subnet Prefix**

Embedd IPv4 Addresses into IPv6 (*IPv4 mapped*)

- A globally routed (unicast) IPv4 address can be represented as an IPv6 address and thus integrated into the IPv6 address space
  - In literature, this approach is called *IPv4 mapped*
- The IPv4 address gets a 96 bytes long prefix:
  `0:0:0:0:0:FFFF::/96`

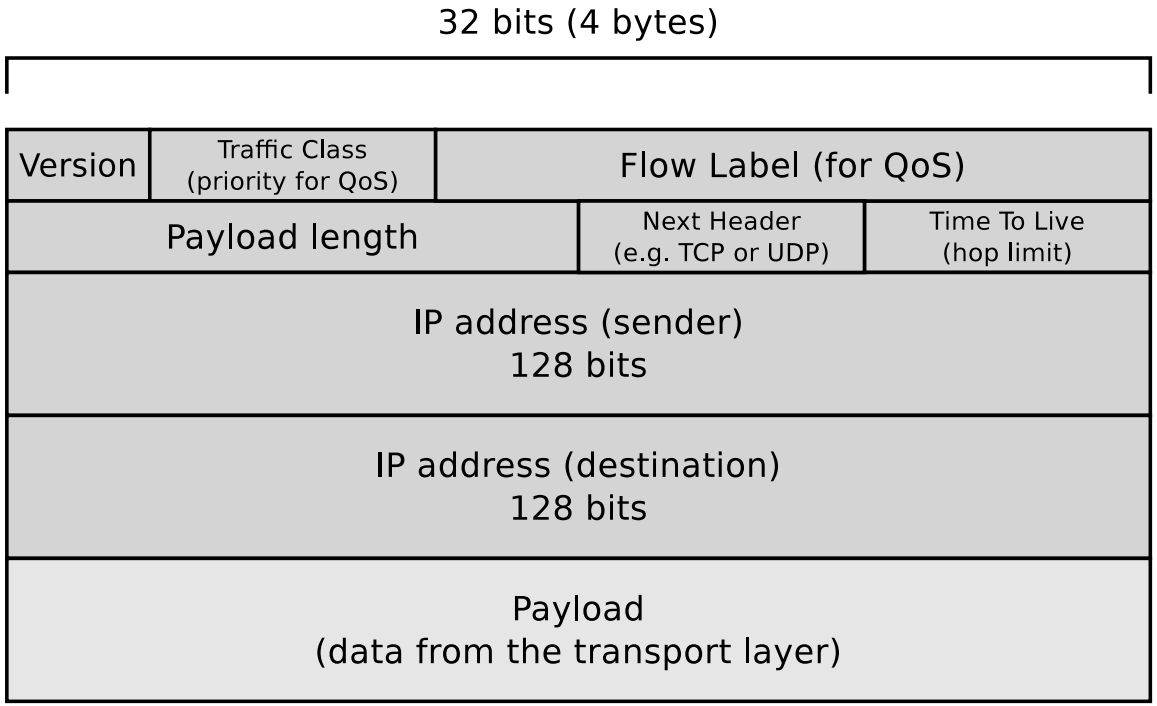
80 Bits					16 Bits	32 Bits
0000	0000	0000	0000	0000	FFFF	IPv4 address

- The IPv4 address may be represented in hexadecimal or decimal notation
- Example

IPv4 address:	`131.246.107.35`
IPv6 address:	`0:0:0:0:0:FFFF:83F6:6B23`
Shorter notation:	`::FFFF:83F6:6B23`
	`::FFFF:131.246.107.35`

Structure of IPv6 Packets

- The size of the IPv6 header is fixed (320 bits $\Longrightarrow$ 40 bytes)



- The field **next header** points to an extension header field or identifies the Transport Layer protocol (e.g. TCP = type 6 or UCP = type 17) which is carried in the payload of the packet

Concept: Simplified (reduced) package structure, but simple option to add additional (new) features with a chain of extension headers

Extension Headers

- **Hop-By-Hop Options** (type 0, RFC 2460)
  - Contains optional information that must be examined by every node along the delivery path of the packet
- **Routing** (type 43, RFC 2460)
  - Can be used to specify the route of the packet though the network
- **Fragment** (type 44, RFC 2460)
  - Contains parameters for the fragmentation of packets
- **Encapsulating Security Payload** (type 50, RFC 4303)
  - Contains encrypted data for secure communication
- **Authentication Header** (type 51, RFC 4302)
  - Contains information used to verify the authenticity parts of the packet
- **No Next Header** (type 59, RFC 2460)
  - Placeholder to indicates that that there is nothing following that header
- **Destination Options** (type 60, RFC 2460)
  - Options that need to be examined only by the destination network device of the packet