Computer Networks - IPv6

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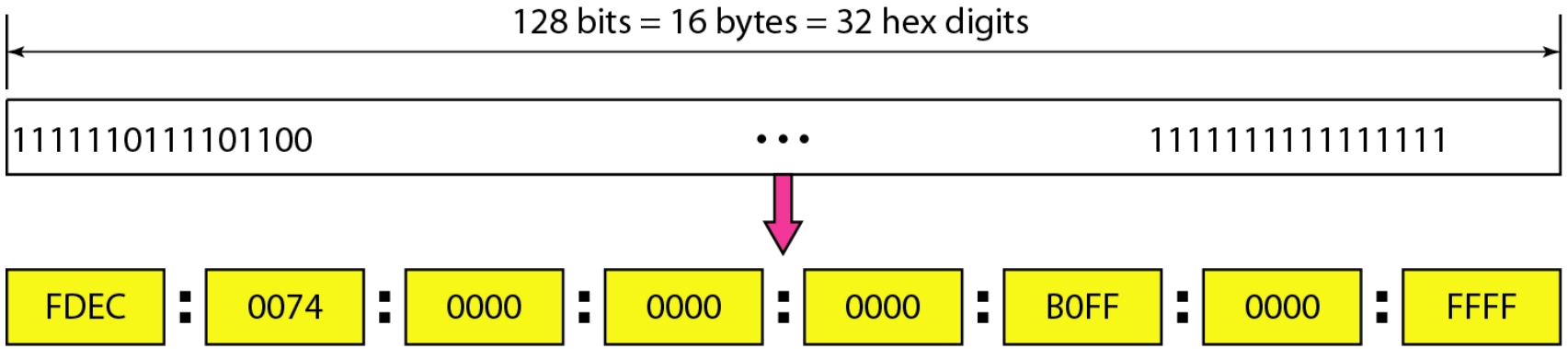
IPv6

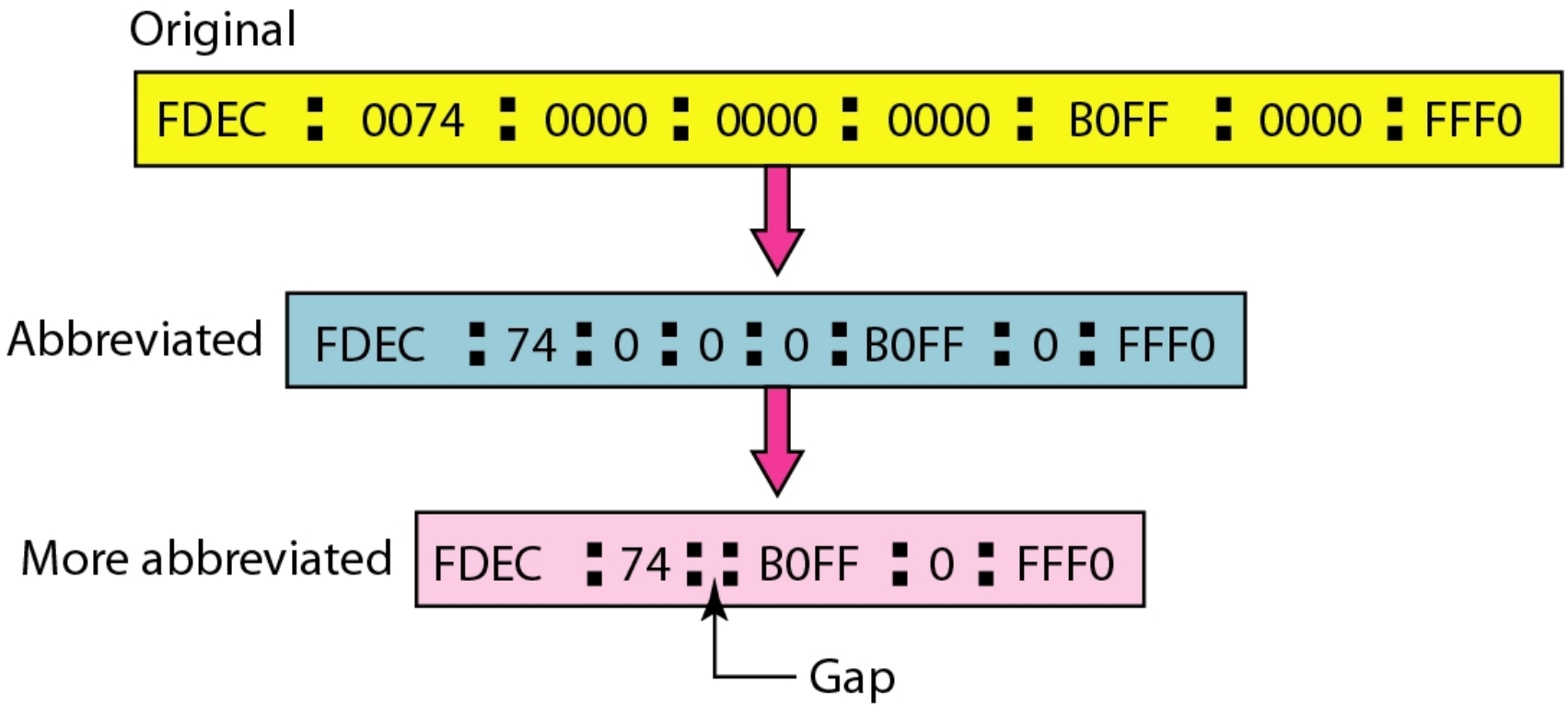
- Initial motivation: 32-bit address space not big enough
- Additional motivation:
  - Header format helps speed processing/forwarding
  - Header changes to facilitate QoS
- IPv6 datagram format:
  - Fixed-length 40 byte header
  - No fragmentation allowed

IPv6 Address in Binary and Hexadecimal Colon Notation



- Length - 128 bits or 16 bytes (octets)
- Dotted Decimal Notation for IPv6 - Too long
- 128 bits is divided into 8 sections of 16 bits (4 hex digits)

Abbreviated IPv6 Addresses



- Only leading zeros in a section can be omitted
- Consecutive sections consisting of zeros only can be replaced by a double colon - allowed only once per address

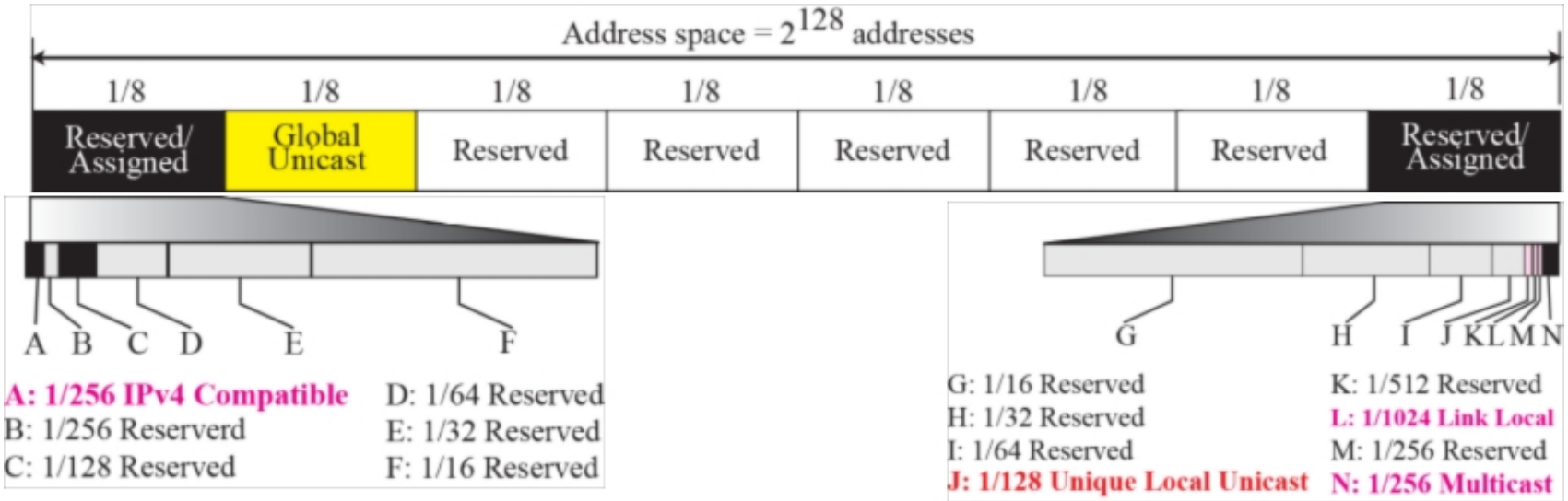
Mixed representation

- Colon Hex and Dotted Decimal
- Appropriate during the transition period - an IPv4 address is embedded in an IPv6 address (as the rightmost 32 bits)
- Example:
  - FDEC:14AB:2311:BBFE:AAAA:BBBB:130.24.24.18
  - ::130.24.24.18

IPv6 Address Types

- Unicast Addresses
  - Defines a single interface (computer or router)
- Anycast Addresses
  - Defines a group of computers that all share a single address
  - A packet with an anycast address is delivered to only one member of the group, the most reachable one
- Multicast Addresses
  - Defines a group of computers
  - Each member of the group receives a copy
- Broadcasting
  - IPv6 does not define broadcasting

Address Space Allocation



- IPv6 address space is divided into several blocks of varying size
- Eight sections of 2^{125} addresses
  - First section contains six variable sized blocks
  - Second section is used for Global Unicast Addresses
  - Next five sections are unassigned
  - Last section contains eight variable sized blocks

IPv6 Unicast Addresses

- The following types of addresses are IPv6 unicast addresses:
  - Global unicast addresses
  - Link-local addresses
  - Site-local addresses
  - Unique local IPv6 unicast addresses
  - Special addresses

Global Unicast Addresses I

- Used for unicast (one-to-one) communication between two hosts in the Internet
- CIDR notation for the block is 2000::/3
- Three Levels of Hierarchy

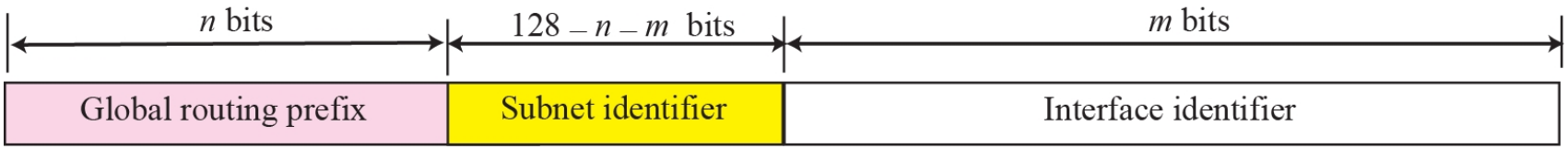


Table 26.2 *Recommended Length of Different Parts in Unicast Addressing*

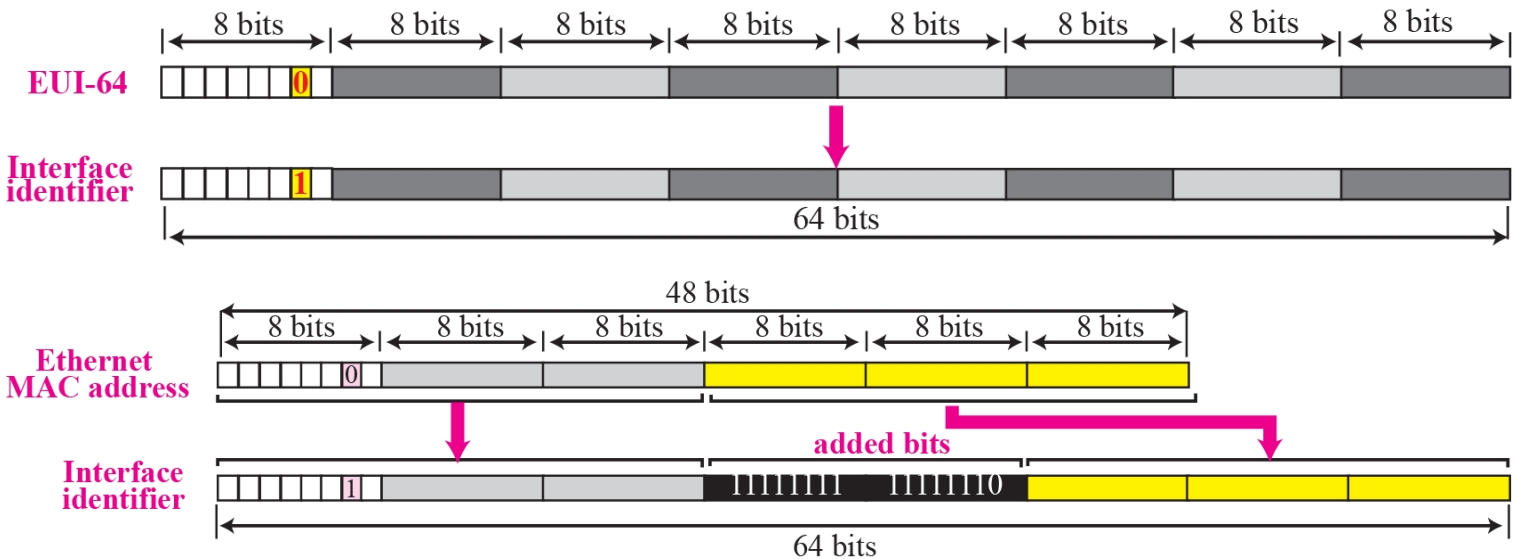
Block Assignment	*Length*
Global routing prefix (n)	48 bits
Subnet identifier ($128 - n - m$)	16 bits
Interface identifier (m)	64 bits

Global Unicast Addresses II

- Global Routing Prefix
  - First 48 bits
  - Used to route the packet through the Internet to the organization site such as ISP that owns the block
  - Up to 2^{45} (as first three bits is always 001) sites - a private organization or an ISP
- Subnet Identifier
  - Next 16 bits defines a subnet in an organization
  - Can have up to 2^{16} subnets

Global Unicast Addresses III

- Interface Identifier
  - Last 64 bits
  - A physical address whose length is less than 64 bits can be embedded as the whole or part of the interface identifier
  - Two common physical addressing scheme



IPv6 Unicast Address Scopes

- Link-local scope
  - Identifies all hosts within a single layer 2 domain
  - Called as link-local addresses
- Unique-local scope
  - Identifies all devices reachable within an administrative site or domain
  - Called as unique-local addresses (ULAs)
- Global scope
  - Identifies all devices reachable across the Internet
  - Called as global unicast addresses (GUAs)

Local-Use Unicast Addresses

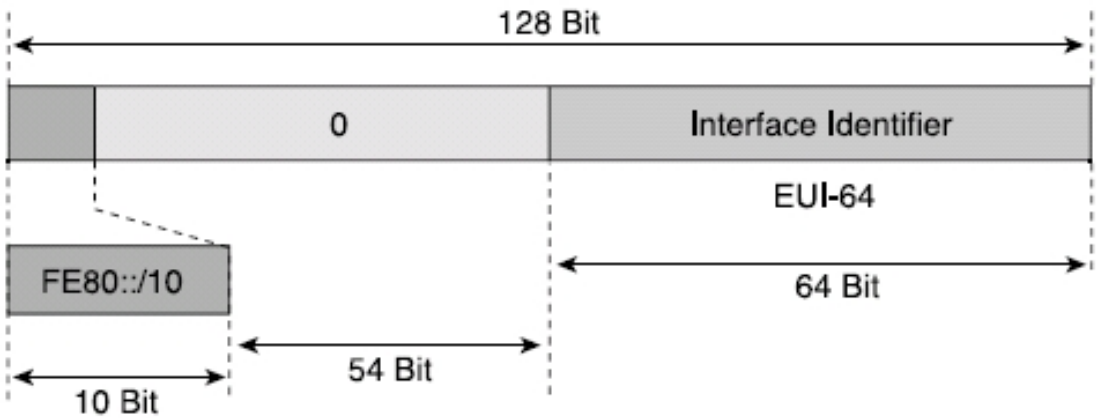
- Link-local addresses
  - Used between on-link neighbors and for Neighbor Discovery Processes
- Site-local addresses
  - Used between nodes communicating with other nodes in the same site

Link-local Unicast Address

- Equivalent to IPv4 link-local addresses defined in RFC 3927 that use the 169.254.0.0/16 prefix
- IPv4 link-local addresses are known as Automatic Private IP Addressing (APIPA) addresses for computers running current Microsoft Windows operating systems
- The scope of a link-local address is the local link
- A link-local address is required for Neighbor Discovery (NDP) processes and is always automatically configured, even in the absence of all other unicast addresses

Link-local Unicast Address

- Used only between nodes connected on the same local link
- When an IPv6 stack is enabled on a node, one link-local address is automatically assigned to each interface of the node at boot time
- IPv6 link-local prefix FE80::/10 is used and the interface identifier in Extended Unique Identifier 64 (EUI-64) format is appended as the address's low-order 64-bit
- Bits 11 through 64 are set to 0 (54-bit)
- Link-local addresses are only for local-link scope and must never be routed between subnets within a site



Link-local Unicast Address

- Because the low-order 64-bit of the link-local address is the interface identifier itself, the length of the link-local prefix is based on a 64-bit length (/64)
- In IPv6, a node having an aggregatable global unicast address on a local link uses the link-local address of its default IPv6 router rather than the router's aggregatable global unicast address
- If network renumbering must occur, meaning that the unicast aggregatable global prefix is changed to a new one, the default router can always be reached using the link-local address
- Link-local addresses of nodes and routers do not change during network renumbering

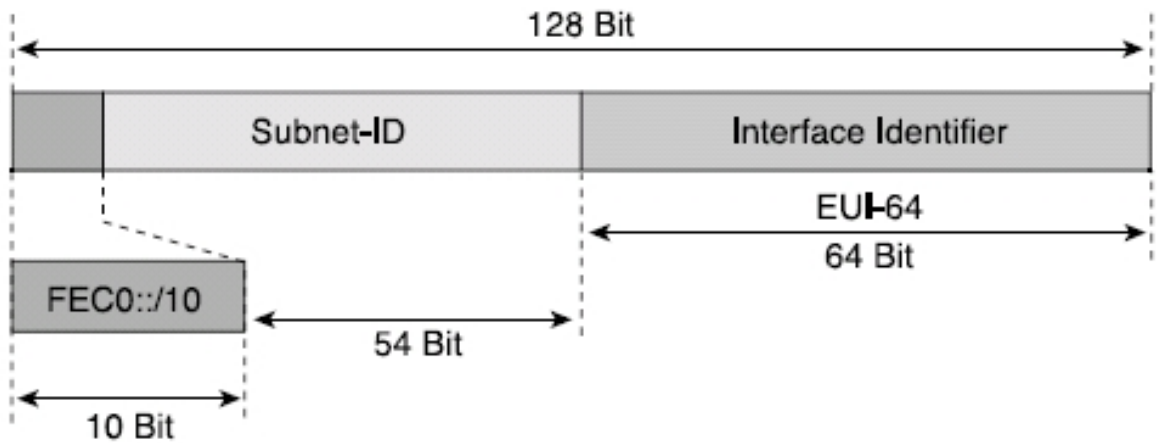
Site-Local Address

- Site-local addresses are equivalent to the IPv4 private address space (10.0.0.0/8, 172.16.0.0/12, and 192.168.0.0/16)
- Private intranets that do not have a direct, routed connection to the IPv6 Internet can use site-local addresses without conflicting with global unicast addresses
- Site-local addresses are not reachable from other sites, and routers must not forward site-local traffic outside the site
- Site-local addresses can be used in addition to global unicast addresses
- The scope of a site-local address is the site
- A site is an organization network or portion of an organization's network that has a defined geographical location (such as an office, an office complex, or a campus)

Site-Local Address

- Unlike link-local addresses, site-local addresses are not automatically configured and must be assigned either through stateless or stateful address configuration processes
- May be assigned to any nodes and routers within a site

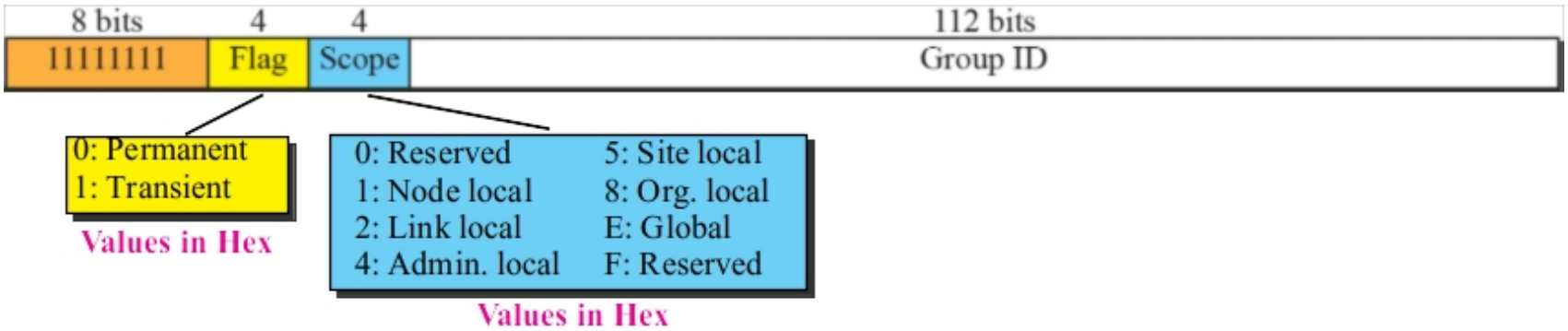
Representation	Value
Preferred format	FEC0:0000:0000:0000:0000:0000:0000:0000/10
Compressed format[1]	FEC0:0:0:0:0:0:0:0/10
Compressed format	FEC0::/10
Binary format	High-order 10-bit is set to 1111 1110 11



IPv6 Special Addresses

- Unspecified address
  - Unspecified address (0:0:0:0:0:0:0:0 or ::) is only used to indicate the absence of an address
  - Equivalent to the IPv4 unspecified address of 0.0.0.0
  - Used as a source address for packets attempting to verify the uniqueness of a tentative address
  - Never assigned to an interface or used as a destination address
- Loopback address
  - The loopback address (0:0:0:0:0:0:0:1 or ::1) is used to identify a loopback interface, enabling a node to send packets to itself
  - It is equivalent to the IPv4 loopback address of 127.0.0.1
  - Packets addressed to the loopback address must never be sent on a link or forwarded by an IPv6 router

Multicast address in IPv6

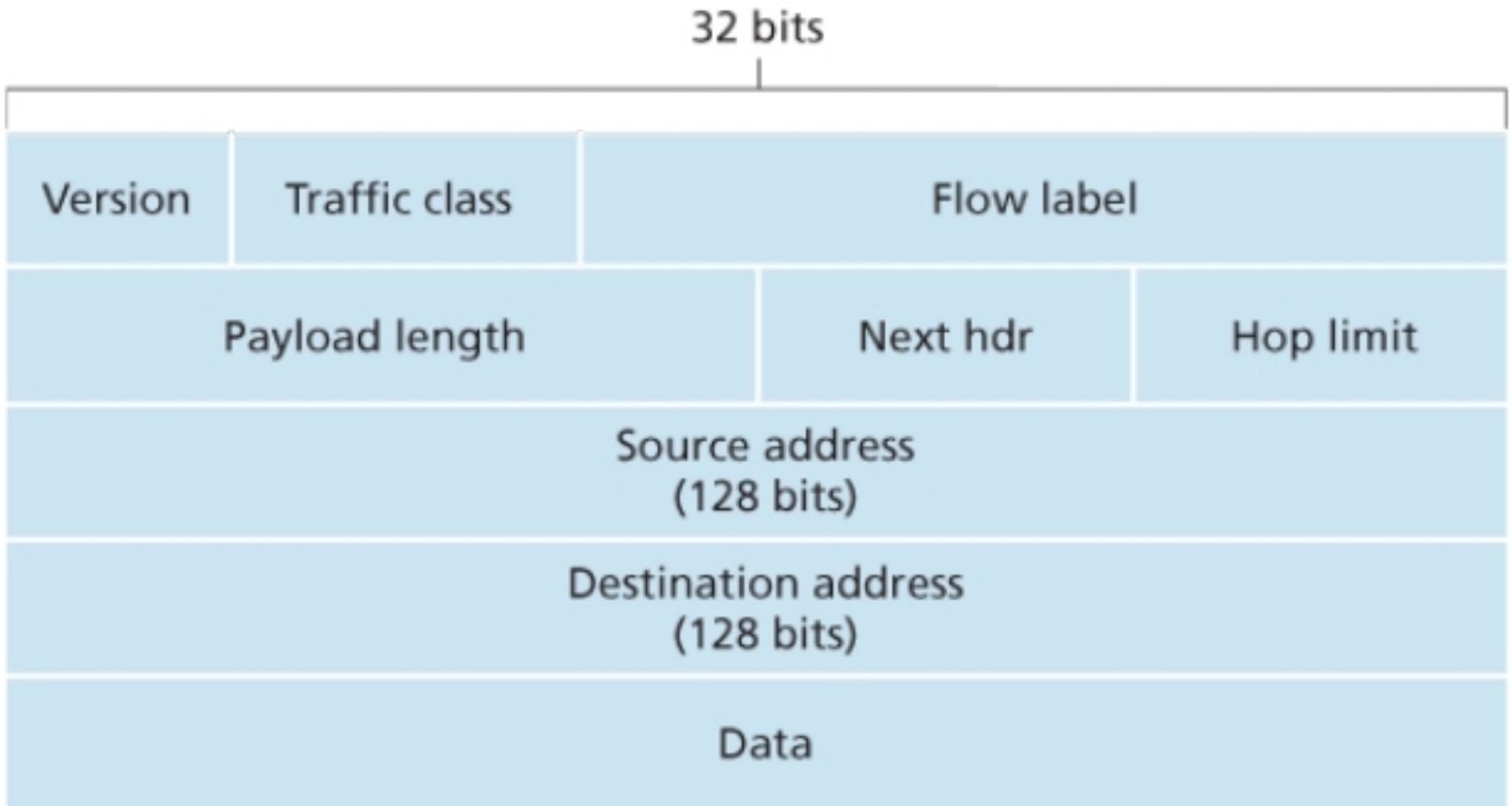


- Defines a group of hosts
- A packet sent to a multicast address is delivered to each member of the group
- Uses the prefix 11111111
- 4 bit flag defines the group address as either permanent or transient
  - A permanent group address is defined by the Internet authorities and can be accessed at all times
  - A transient group address, on the other hand, is used only temporarily, example: systems engaged in a teleconference
  - Third field defines the scope of the group address

Autoconfiguration

- When a host in IPv6 joins a network, it can configure itself
  - Creates a link local address for itself
    - Takes the 10-bit link local prefix (1111 1110 10)
    - Appends 54 zeros
    - Appends the 64-bit interface identifier
  - Tests the uniqueness of link local address
    - Sends a neighbor solicitation message and waits for neighbor advertisement message
    - If any host in the subnet is using this link local address, the process fails
    - Uses other means such as DHCP protocol
  - Gets a global unicast address
    - Sends a router solicitation message
    - Receives a router advertisement message that includes the global unicast prefix and the subnet prefix
    - Adds interface identifier to generate its global unicast address

IPv6 Header Fields I



- Version (4-bit): identifies the IP version number

IPv6 Header Fields II

- Traffic class (8-bit): like the TOS field in IPv4, can be used to give priority to certain datagrams within a flow
- Flow label (20-bit): identify a flow of datagrams
- Payload length (16-bit): number of bytes in the IPv6 datagram following the fixed-length, 40-byte datagram header
- Next header: identifies the protocol to which the contents (data field) of this datagram will be delivered (for example, to TCP or UDP)
- Hop limit: decremented by one by each router that forwards the datagram, discarded if the hop limit count reaches zero
- Source and destination addresses:
- Data: payload portion of the IPv6 datagram

Fields Absent in IPv6 Header

- Fragmentation/reassembly
  - IPv6 does not allow for fragmentation and reassembly at intermediate routers
  - If an IPv6 datagram received by a router is too large to be forwarded over the outgoing link, the router simply drops the datagram and sends a "Packet Too Big" ICMP error message back to the sender
  - The sender can then resend the data, using a smaller IP datagram size
  - Fragmentation and reassembly is a time-consuming operation; removing this functionality from the routers and placing it squarely in the end systems considerably speeds up IP forwarding within the network
- Header checksum
  - Need to be recomputed at every router in IPv4
  - Dropped in IPv6 to reduce processing time
- Options
  - Removed from IPv6 header
  - Available as next headers