Computer Networks - IPv6

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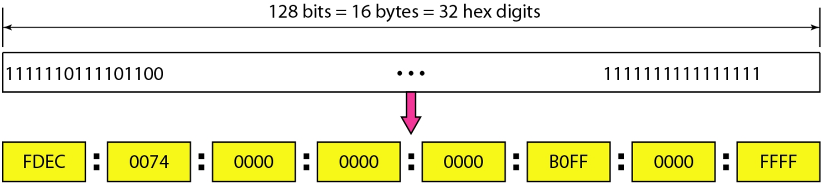
IPv6

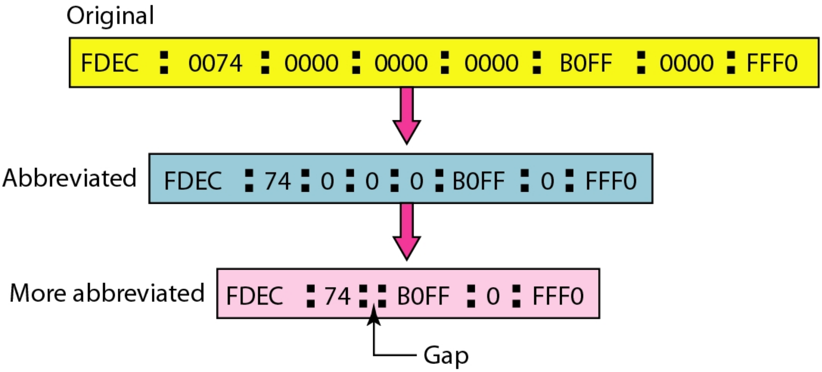
- Initial motivation: 32-bit address space not big enough
- Additional motivation:
    - Header format helps speed processing/forwarding
    - Header changes to facilitate QoS
- IPv6 datagram format:
    - Fixed-length 40 byte header
    - No fragmentation allowed

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

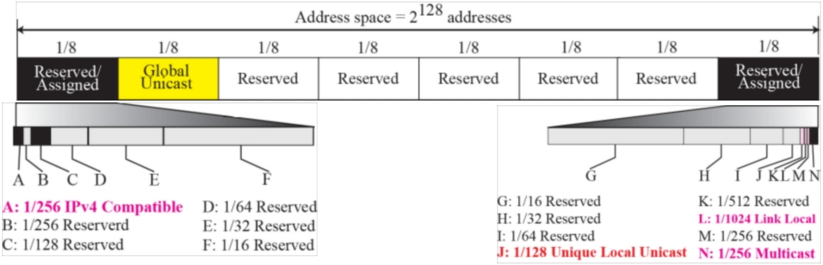
Mixed representation

- 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

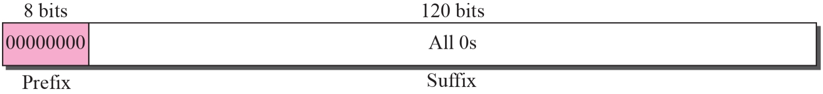
Type Prefixes for IPv6 Addresses

Table 26.1 *Prefixes for IPv6 Addresses*

	Block Prefix	*CIDR*	*Block Assignment*	*Fraction*
1	0000 0000	0000::/8	Reserved (IPv4 compatible)	1/256
	0000 0001	0100::/8	Reserved	1/256
	0000 001	0200::/7	Reserved	1/128
	0000 01	0400::/6	Reserved	1/64
	0000 1	0800::/5	Reserved	1/32
	0001	1000::/4	Reserved	1/16
2	**001**	**2000::/3**	**Global unicast**	**1/8**
3	010	4000::/3	Reserved	1/8
4	011	6000::/3	Reserved	1/8
5	100	8000::/3	Reserved	1/8
6	101	A000::/3	Reserved	1/8
7	110	C000::/3	Reserved	1/8
8	1110	E000::/4	Reserved	1/16
	1111 0	F000::/5	Reserved	1/32
	1111 10	F800::/6	Reserved	1/64
	1111 110	FC00::/7	Unique local unicast	1/128
	1111 1110 0	FE00::/9	Reserved	1/512
	1111 1110 10	FE80::/10	Link local addresses	1/1024
	1111 1110 11	FEC0::/10	Reserved	1/1024
	1111 1111	FF00::/8	Multicast addresses	1/256

IPv4 Compatible Address I

- Addresses that use the prefix (00000000) are reserved, but part of it is used to define some IPv4 compatible addresses
- CIDR notation, this block can be defined as 0000::/8
- Further divided into several subblocks
- Unspecified Address



  - Used as source address in query messages during bootstrap when a host does not know its own address
  - CIDR notation ::/128

IPv4 Compatible Address II

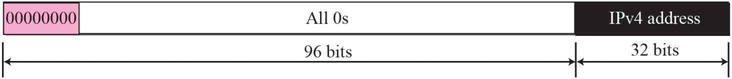
- Loopback Address

8 bits	120 bits
00000000	000000000000000000000000000000000000000000000000...............00000000001
Prefix	Suffix

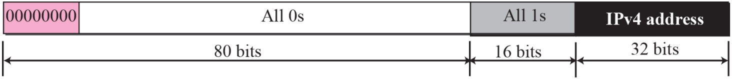
  - Used by a host to test itself without going into the network
  - Prefix 00000000 followed by 119 0s and one 1
  - The CIDR notation for this one-address single block is ::1/128
  - In IPv6 only one address is allocated as the loopback address

IPv4 Compatible Address III

- Embedded IPv4 Address Formats
  - Used during the transition from IPv4 to IPv6
  - A compatible address



    - 96 bits of zero followed by 32 bits of IPv4 address
    - Used for devices that are compatible with both IPv4 and IPv6
    - Example, the IPv4 address 2.13.17.14 becomes 0::2.13.17.14
  - A mapped address



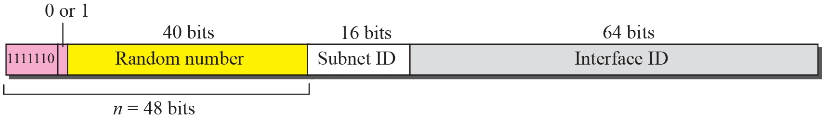
    - 80 bits of zero, followed by 16 bits of one, followed by the 32-bit IPv4 address
    - Used for mapping IPv4 devices that are not compatible with IPv6 into the IPv6 address space
    - Example: the IPv4 address 2.13.17.14 becomes 0::FFFF:2.13.17.14

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

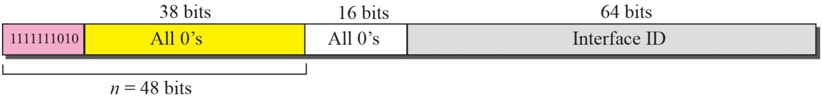
Unique Local Unicast Addresses in IPv6

- Two large blocks for private addressing: one at the site level and one at the link level



- A subblock in a unique local unicast block can be privately created and used by a site
- Packets carrying this type of address as the destination address is not routed in Internet
    - block identifier 1111 110
    - the next bit can be 0 or 1 to define how the address is selected (locally or by an authority)
    - Next 40 bits are selected by the site using a randomly generated number of length 40 bits

Link Local Unicast Addresses in IPv6



- Block identifier 1111111010
- Next 54 bits are set to zero
- Last 64 bits can be changed to define the interface for each computer

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

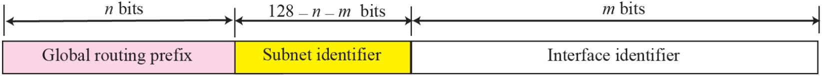


Table 26.2 *Recommended Length of Different Parts in Unicast Addressing*

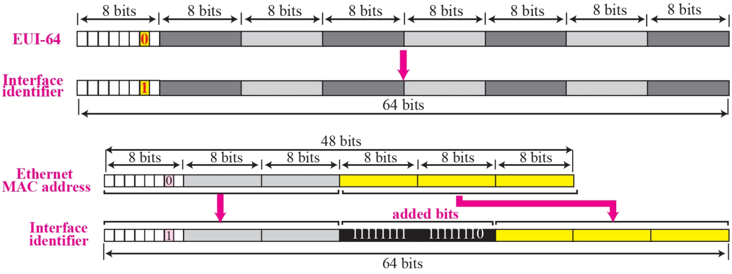
Block Assignment	*Length*
Global routing prefix (n)	48 bits
Subnet identifier ($128 - n - m$)	16 bits
Interface identifier (m)	64 bits

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

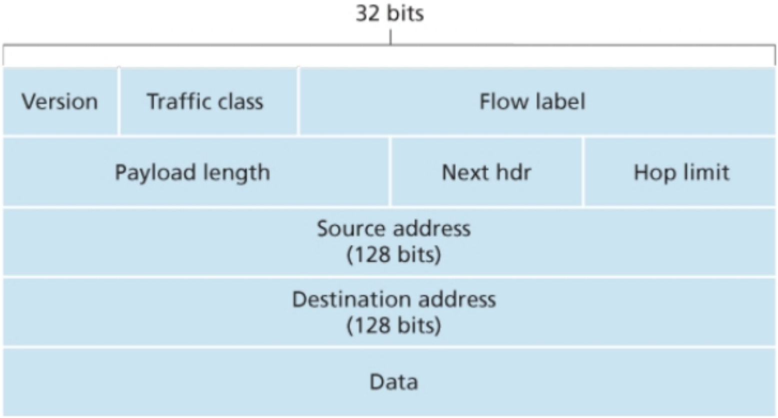
- Interface Identifier
  - Last 64 bits
  - A physical address whose length is less than 64 bits can be embedded as the whole or part of the interface identifier
  - Two common physical addressing scheme



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

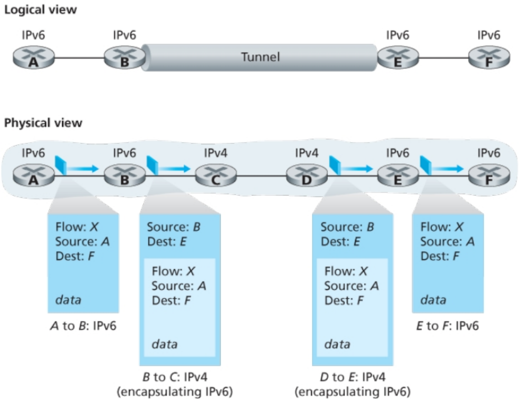
IPv6 Header Fields II

- 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

IPv4 to IPv6 Transition - Tunelling



- Not all routers can be upgraded simultaneously
  - no “flag days”
  - How will the network operate with mixed IPv4 and IPv6 routers?
- Tunneling: IPv6 carried as payload in IPv4 datagram among IPv4 routers