Data Communications and Networking Fourth Edition

Chapter 19

Network Layer: Logical Addressing

19-1 IPv4 ADDRESSES

An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet.

Topics discussed in this section:

Address Space
Notations
Classful Addressing
Classless Addressing
Network Address Translation (NAT)

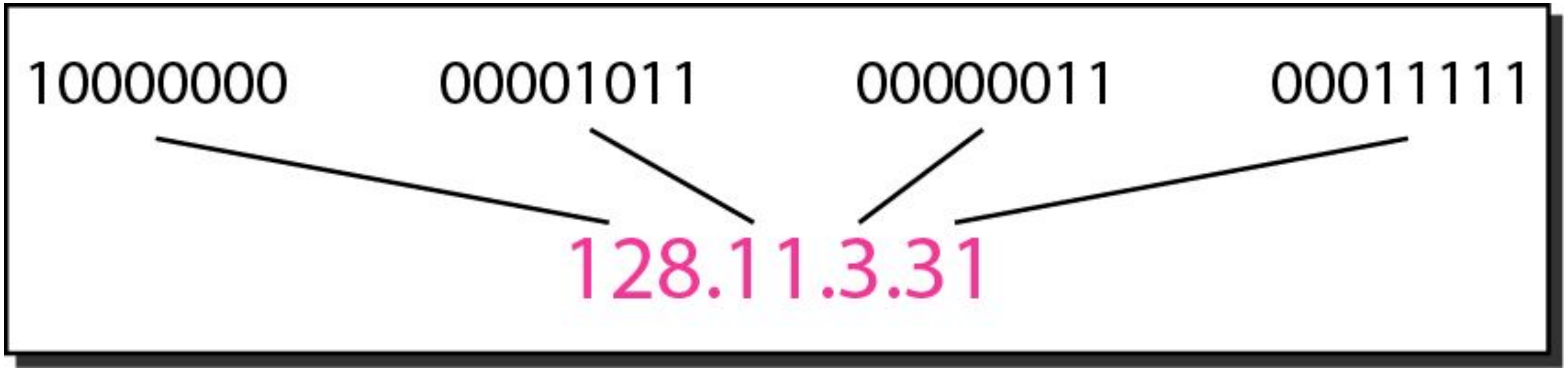
IPV4 Address

- An IPv4 address is 32 bits long.
- The IPv4 addresses are unique and universal.
- The address space of IPv4 is 2^{32} or 4,294,967,296

IPV4 Address

Notation

- **Binary Notation :**
  - The IPV4 address is displayed as 32 bits.
  - Each octet is often referred to as a byte.
- **Dotted-Decimal Notation**
  - To make the IPV4 address more compact and easier to read, Internet addresses are written in decimal form with a decimal point (dot) separating the byte.



Notation (cont'd)

Hexadecimal Notation

0111 0101   1001 0101   0001 1101   1110 1010

75   95   1D   EA

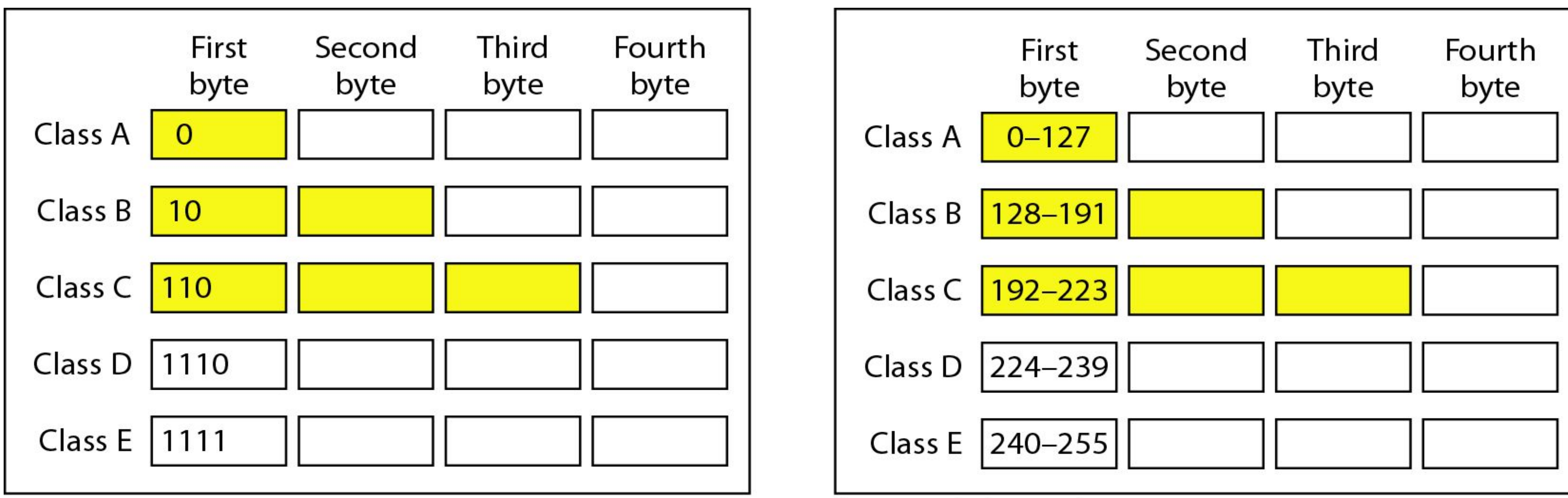
0x75951DEA

- 8 hexadecimal digits

- Used in network programming

Classful Addressing

- In classful addressing, the address space is divided into five classes: A, B, C, D, and E.
  - If the address is given in binary notation, the first few bits can tell us the class of the address.
  - If the address is given in decimal-dotted notation, the first byte defines the class.



a. Binary notation

b. Dotted-decimal notation

Classfull Addressing

- **Classful Addresses**
  - **Unicast Communication - A, B, C Class**

    (~must be delivered to specific computer)
  - **Multicast Communication – D Class**

    (~must be delivered to each member of the group)
  - **For reserve – E Class**

Classful Addressing

Classes and blocks

- One problem with classful addressing is that each class is divided into a fixed number of blocks with each block having a fixed size.

Table 19.1 *Number of blocks and block size in classful IPv4 addressing*

Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

Classful Addressing

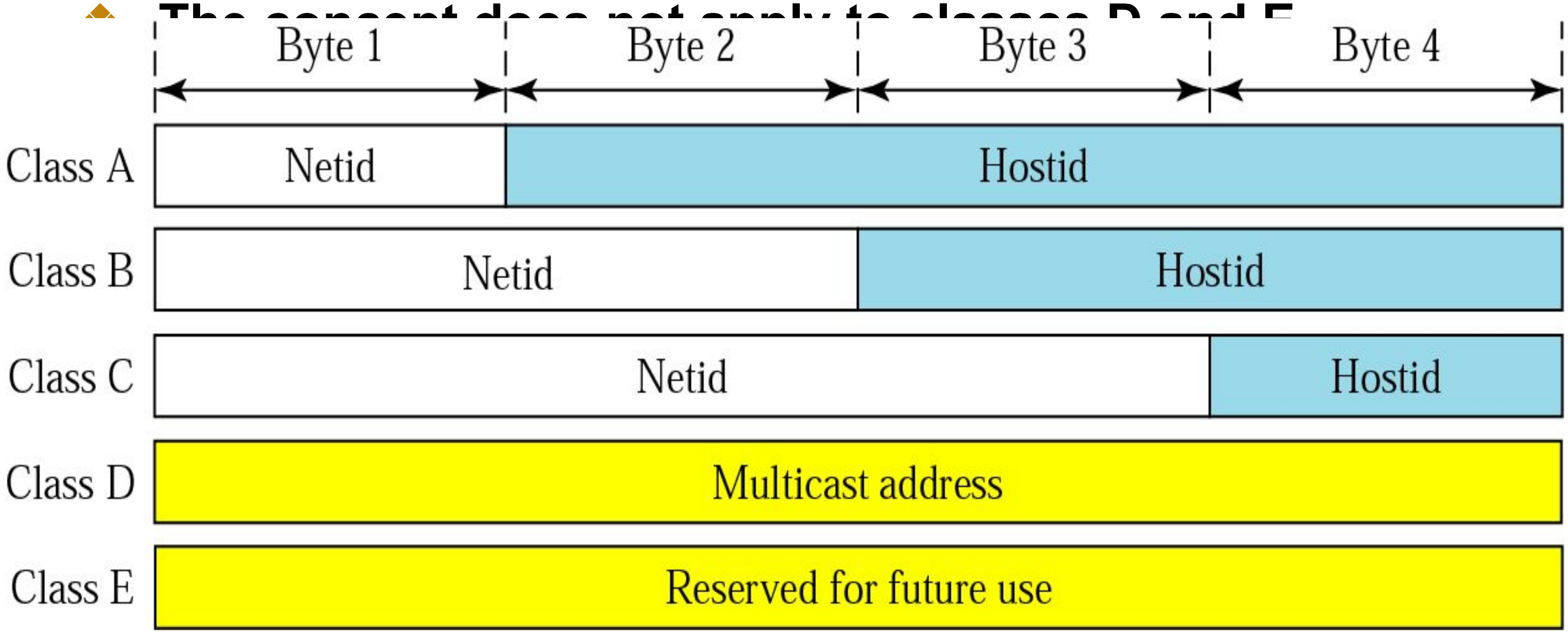
- Class A addresses were designed for large organizations
  - The most of the addresses were wasted and were not used.
- Class B addresses were designed for midsize organizations
  - Class B is also too large for many organizations.
- Class C addresses were designed for small organizations
  - Class C is too small for many organizations.
- Class D addresses were designed for multicasting
  - Each addresses in this class is used to define one group of hosts on the Internet.
- Class E addresses were reserved for future use.
  - Only a few used, resulting in another waste of addresses.

In classful addressing, a large part of the available addresses were wasted.

Classful Addressing

Netid and Hostid

- IP address in class A,B, or C is divided into netID and hostID.
  - netID defines a Network, and hostID defines a host in the networks.
- The concept does not apply to classes D and E



MASK

- **Mask**
  - When a router receives a packet with a destination address, it needs to route the packet.
  - The routing is based on the network address and subnetwork address.
    - The router outside the organization has a routing table with one column based on the network addresses;
    - The router inside the organization has a routing table based on the subnetwork addresses.
  - The mask is a 32-bit binary number, and the mask can help to find the network and subnetwork address.
    - The routers outside the organization use a Default Mask to find the network address and,
    - The routers inside the organization use a Subnet Mask to find the subnetwork address..

Default Mask

Default Mask

- A default mask is a 32-bit binary number, and the default mask for each class are as follows;   255.0.0.0, 255.255.0.0, 255.255.255.0.
- Default mask gives the network address when ANDed with an address in the block.
  - If the bit in the mask is 1, the corresponding bit in the address is retained in the output (no change)
  - If the mask is 0, a 0 bit in the output is the result.

Table 19.1 Default masks

Class	Binary	Dotted-Decimal	CIDR
A	11111111 00000000 00000000 00000000	255.0.0.0	/8
B	11111111 11111111 00000000 00000000	255.255.0.0	/16
C	11111111 11111111 11111111 00000000	255.255.255.0	/24

CIDR (Classless Inter-domain Routing)

Subnet Mask

- **Subnetting**
  - **A network is divided into several smaller networks with each subnetwork (or subnet) having its subnetwork address**
- **Subnet Mask :**
  - **We change some of the leftmost 0s in the default mask to make a subnet mask.**
  - **The number of subnets is determined by the number of extra 1s.**
    - **If the number of extra 1s in n, the number of subnets is 2^n.**
    - **If the number of subnets is N, the number of extra 1s is $\log_2 N$.**

255.255.0.0

Default Mask	11111111	11111111	00000000	00000000
			16	

255.255.224.0

Subnet Mask	11111111	11111111	111	00000	00000000
			3	13	

$2^n = 2^3 = 8$ subnets

Supernetting and Address depletion

- **Supernetting**
  - **Combining several class C addresses to create a larger range of addresses**
- **Address Depletion**
  - **The fast growth of the Internet led to the near depletion of the available addresses.**
  - **Classful addressing, which is almost obsolete, is replaced with classless addressing.**

Network Address

- **Network Addresses**
  - **The first address in a block is normally not assigned to any device;**
  - **It is used as the network address that represents the organization to the rest of the world.**

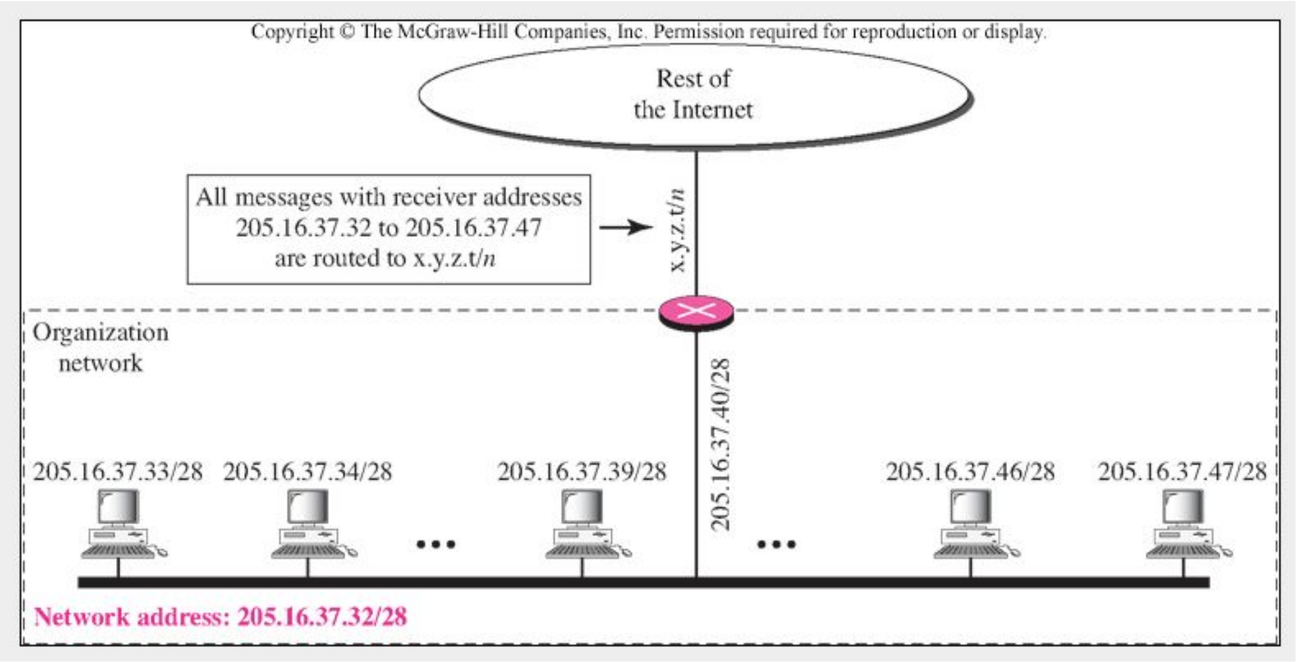


Figure 19.4 *A network configuration for the block 205.16.37.32/28*

Network Address

Hierarchy

- IP addresses have levels of hierarchy.
- For example, a telephone network has three levels of hierarchy.
  - The leftmost 3 digits define the area code, the next 3 digits define the exchange, the last 4 digits define the connection of the local loop to the central office.

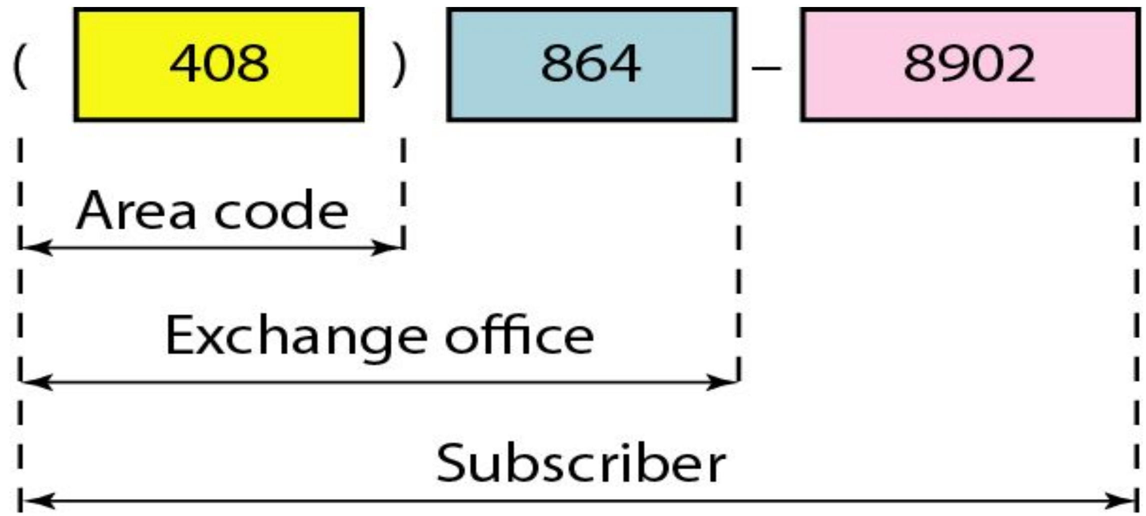
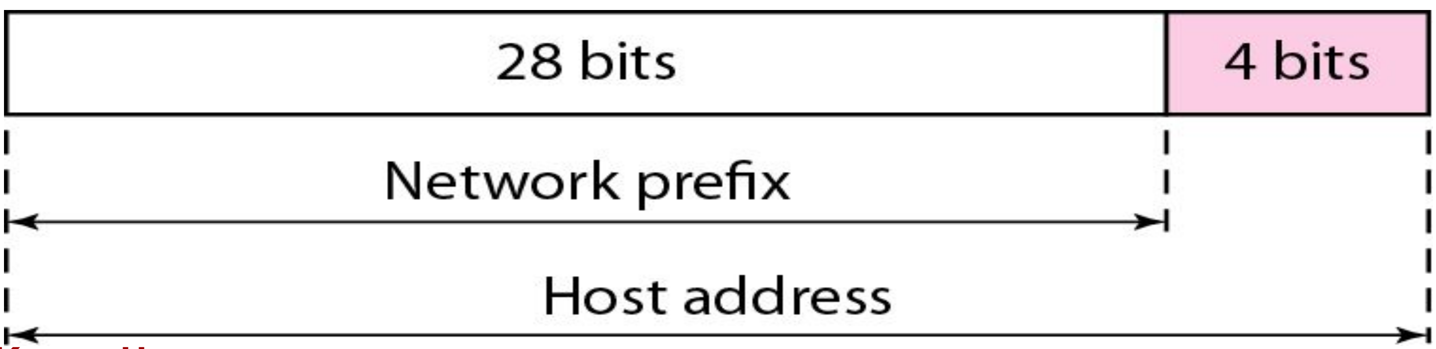


Figure 19.5 *Two levels of hierarchy in an IPv4 address*

Subnetting and Supernetting

- **Two-level Hierarchy : No Subnetting**
  - **Each IP address in the block can define only two-level of hierarchy when not subnetted.**
    - **the leftmost *n* bits (prefix) define the network;**
    - **the rightmost 32 − n bits define the host.**
  - **The part of the address that defines the network is called the Prefix;**
  - **The part that defines the host is called the Suffix.**
  - **The prefix is common to all addresses in the network; the suffix changes from one device to another.**

Figure 19.6 *A frame in a character-oriented protocol*



Subnetting and Supernetting

Three-Levels of Hierarchy : Subnetting

- Creating clusters of networks (called subnets)

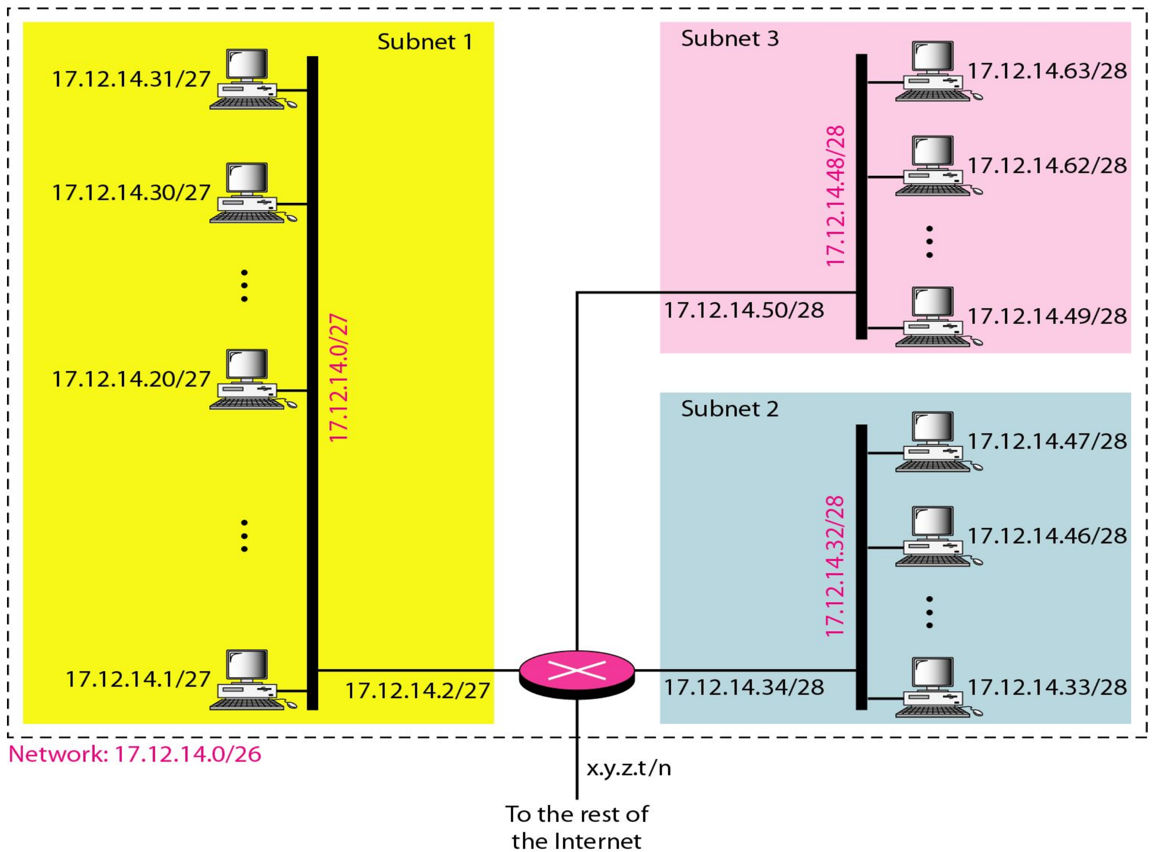


Figure 19.7 *Configuration and addresses in a subnetted network*

Subnetting and Supernetting

- We have three levels of hierarchy through subnetting.
  - The subnet prefix length can differ for the subnets.

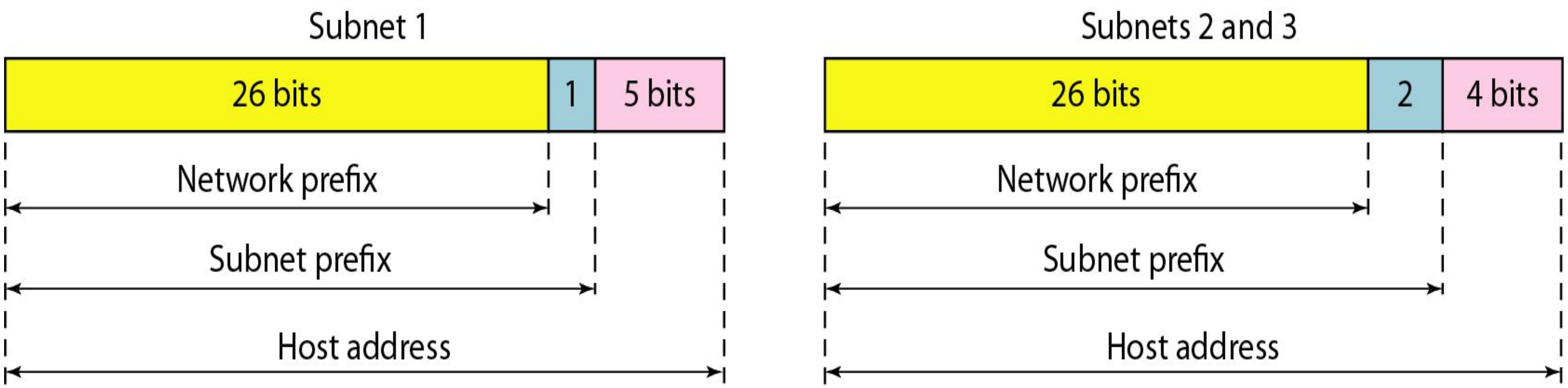
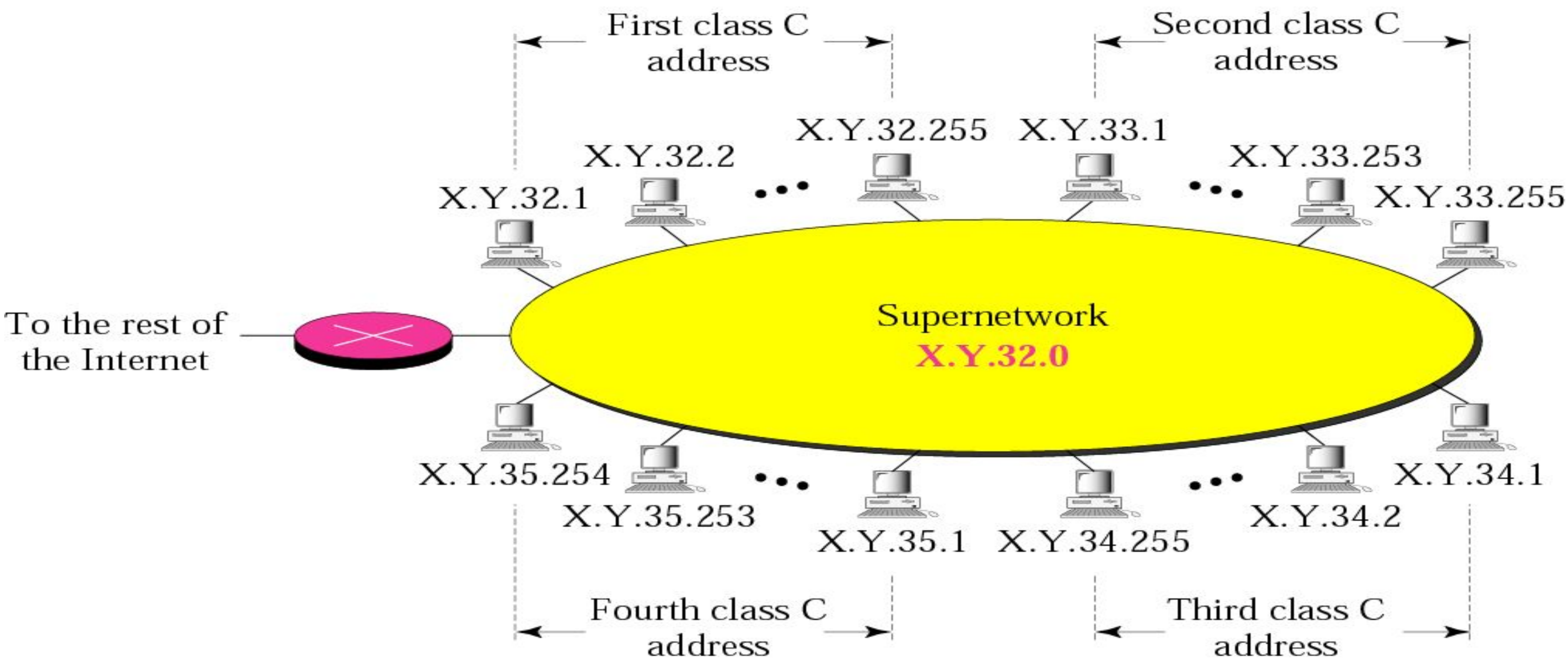


Figure 19.8 *Three-level hierarchy in an IPv4 address*

Supernetting

- A maximum number of Class C is 256 addresses,
- If organization needed more addresses, The Supernetting can combine several class C blocks to create a larger range of addresses.

  (The mask changes from /24 to /22)



Network Address Translation (NAT)

Network Address Translation (NAT)

- NAT enables a user to have a large set of address internally and one address, or a small set of addresses, externally.
- The Internet authorities have reserved 3 sets of addresses as private addresses.
  - Any organization can use an address out of this set without permission from the Internet authorities.
  - They are unique inside the organization, but they are not unique globally.
  - No router will forward this packet as the destination address.

Table 19.3 *Addresses for private networks*

Range			*Total*
10.0.0.0	to	10.255.255.255	2^{24}
172.16.0.0	to	172.31.255.255	2^{20}
192.168.0.0	to	192.168.255.255	2^{16}

Network Address Translation (NAT)

❑NAT Implementation

- ❖ The router that connects the network to the global address uses one private address and one global address.
- ❖ The private network is transparent to the rest of the Internet; the rest of the Internet sees only the NAT router with the address 200.24.5.8.

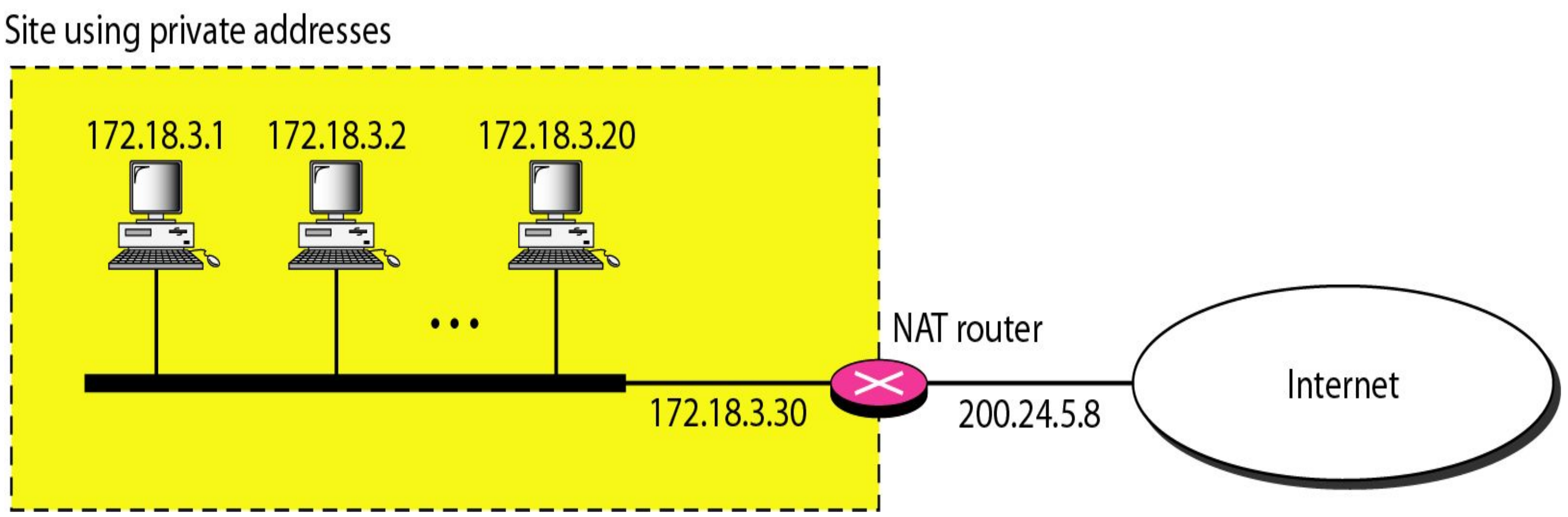


Figure 19.10 *A NAT implementation*

Network Address Translation (NAT)

❑Address translation

- All the outgoing packets go through the NAT router, which replaces the source address in the packet with the global NAT address.
- All incoming packets also pass through the NAT router, which replaces the destination addresses in the packet with the appropriate private address.

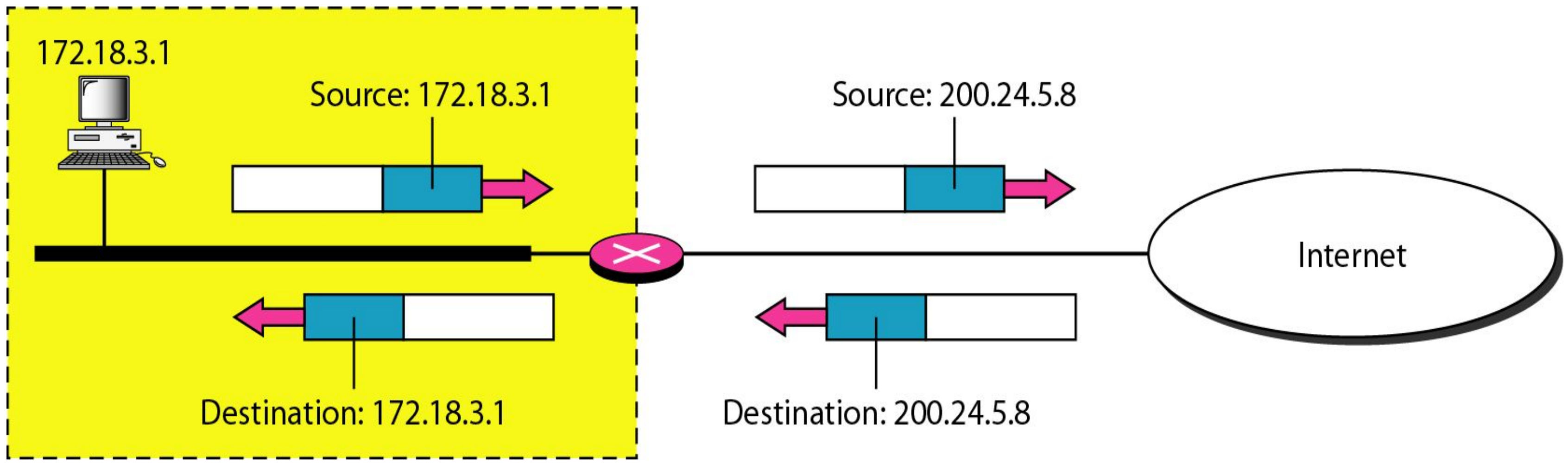


Figure 19.11 *Addresses in a NAT*

Network Address Translation (NAT)

Translation Table

- When the router translates the source address of the outgoing packet, it also makes note of the destination address – where the packet is going.
- When the response comes back from the destination, the router uses the source address of the packet to find the private address of the packet.

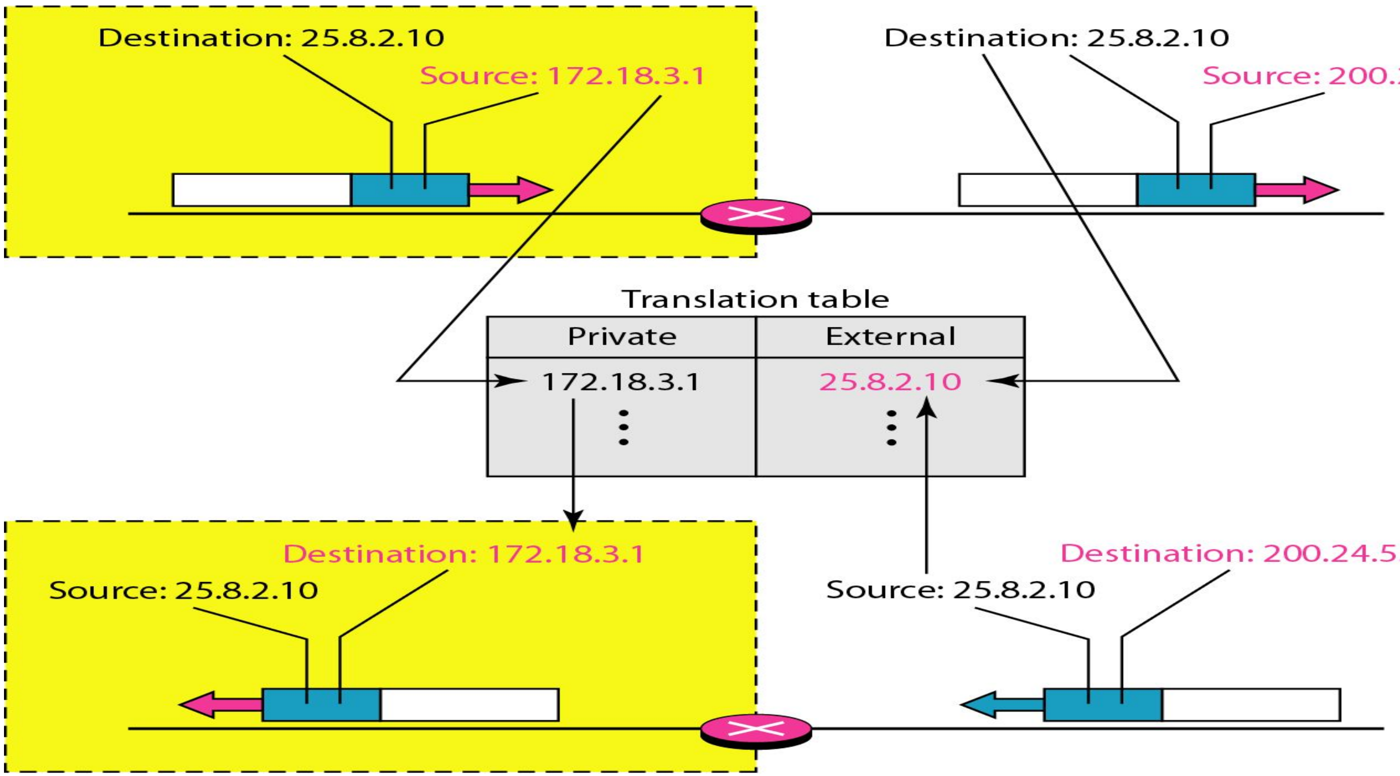


Figure 19.12 *NAT address translation*

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Network Address Translation (NAT)

- **Using both IP addresses and port numbers**

Table 19.4 ***Five-column translation table***

Private Address	*Private Port*	*External Address*	*External Port*	*Transport Protocol*
172.18.3.1	1400	25.8.3.2	80	TCP
172.18.3.2	1401	25.8.3.2	80	TCP
. . .	. . .	. . .	. . .	. . .

19-2 IPv6 ADDRESSES

Despite all short-term solutions, address depletion is still a long-term problem for the Internet. This and other problems in the IP protocol itself have been the motivation for IPv6.

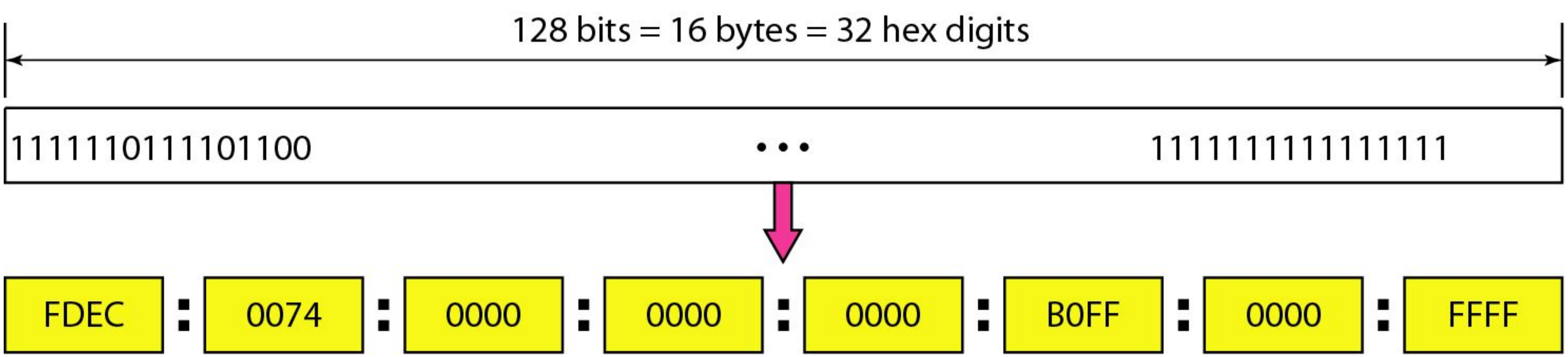
Topics discussed in this section:

Structure
Address Space

Structure - IPv6

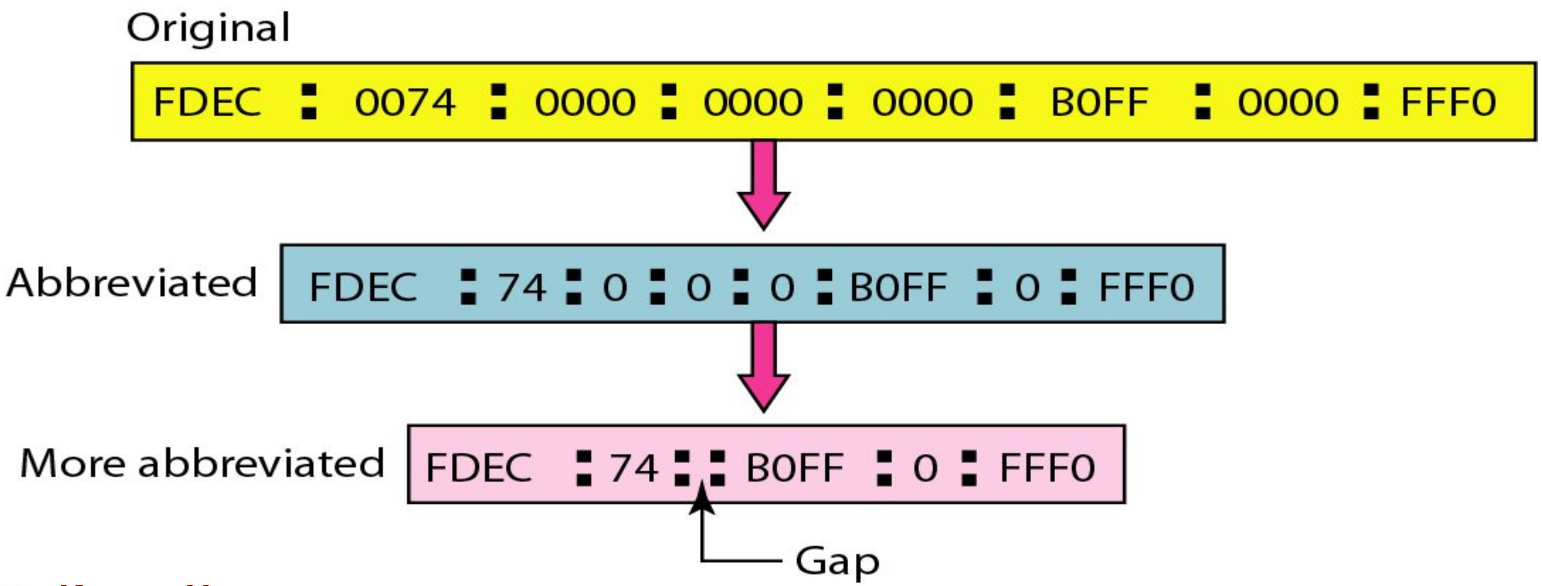
- An IPv6 address consists of 16 bytes (Octets); it is 128 bits long.

- Hexadeximal Colon Notation
  - In this notation, 128 bits is divided into eight sections, each 2 bytes in length.
  - Therefore, the address consists of 32 hexadecimal digits, with every four digits separated by a colon.



Abbreviation

- Although the IP address, even in hexadecimal format, is very long, many of the digits are zeros.
- The leading zeros of a section (four digits between two colons) can be omitted.
  - Only the leading zeros can be dropped, not the trailing zeros.



Address Space

- IPv6 has a much lager address space; 2^{128} addresses are available.

Summary (1)

- At the Network layer, a global identification system that uniquely identifies every host and router is necessary for delivery of packet from host to host.
- An IPv4 address is 32 bits long and uniquely and universally defines a host or router on the Internet.
- In classful addressing, the portion of the IP address that identifies the network is called the netid.
- In classful addressing, the portion of the IP address that identifies the host or router on the network is called the hosted.
- An IP address defines a device's connection to a network.
- There are five classes in IPv4 addresses. Classes A, B, and C differ in the number of hosts allowed per network. Class D is for multicasting and Class E is reserved.

Summary(2)

- The class of an address is easily determined by examination of the first byte.
- Addresses in classes A, B, or C are mostly used for unicast communication.
- Address in class D are used for multicast communication.
- Subnetting devides on large network into several smaller ones, adding an intermediate level of hierarchy in IP addressing.
- Supernetting combines several networks into one large one.
- In classless addressing, we can divided the address space into variable-length blocks.