Network Layer:
Logical Addressing

Introduction

The network layer is responsible for the delivery of individual packets from source to the destination host

Logical Addressing

A universal addressing system in which each host can be identified uniquely regardless of the underlying physical network

IPv4 Address

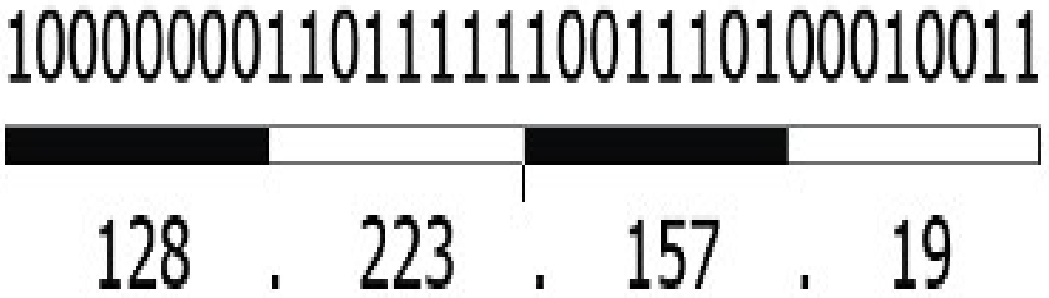
- 32-bit addresses that are *unique* and *universal*
- has **2^{32}** or **4,294,967,296** address space
- partitioned into four groups of eight bits (called **octets**)
- each octet is treated as independent unit
- RFC 791

IPv4 Address

- Notation
  - Binary notation

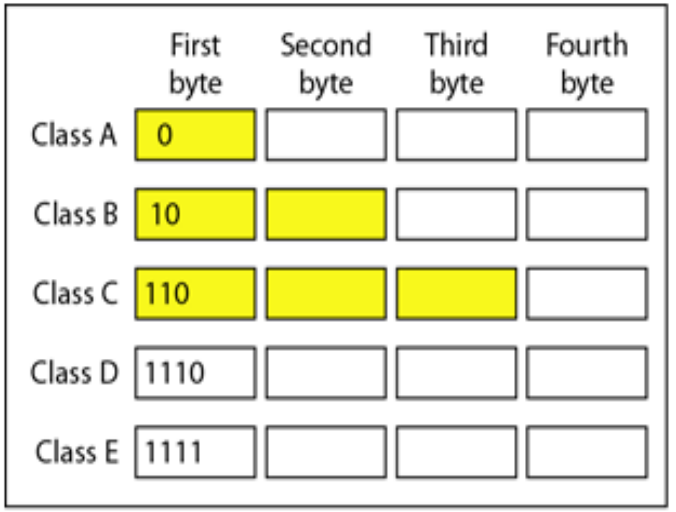
    10000000 11011111 10011101 00010011
  - Dotted-Decimal notation

    128.223.157.19

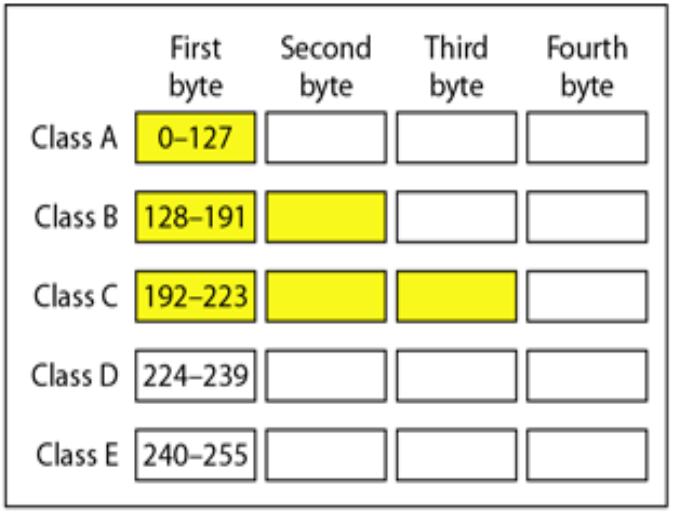


Classful Addressing

- Address space is divided into 5 classes: A, B, C, D and E
- Classification is determined by the value of the first four bits (bits 0 through 3)



a. Binary notation



b. Dotted-decimal notation

Classful Addressing (2)

- IP Address in Class A, B and C is divided:
  - **Network part** (netid) – identifies the network
  - **Host part** (hostid) – identifies the host or router on the network

- **Network mask** (netmask) – 32-bit number made of contiguous 1s followed by contiguous 0s

Classful Addressing (3)

- Class A
  - Starts with binary 0
  - Network part is next 7 bits, host part rest
  - 00000000 and 01111111 (127) is reserved
  - Range 1.x.x.x to 126.x.x.x
  - Netmask is 255.0.0.0
  - Designed for large organizations with large number of attached hosts or router

Classful Addressing (4)

- Class B
  - Starts with binary 10
  - Second octet also included in the network address
  - Range 128.x.x.x to 191.x.x.x
  - Netmask is 255.255.0.0
  - Designed for midsize organizations with tens of thousands of attached hosts or router

Classful Addressing (5)

- Class C
  - Starts with binary 110
  - Second and third octet also part of network address
  - Range 192.x.x.x to 223.x.x.x
  - Netmask is 255.255.255.0
  - Designed for small organizations with small number of attached hosts or router

Classful Addressing (6)

- Class D
  - Starts with 1110
  - Second, third and fourth octet part of the network address (no host part)
  - Range 224.x.x.x to 239.x.x.x
  - Used for multicasting
- Class E
  - Starts with 11110
  - Second, third and fourth octet part of the network address (no host part)
  - Range 240.x.x.x to 255.x.x.x
  - Reserved for future use

Classful Addressing (7)

IP Class	A	B	C	D	E
Format	N.H.H.H	N.N.H.H	N.N.N.H	N/A	N/A
High order bits	0	10	110	1110	11110
Address Range	1.x.x.x to 126.x.x.x	128.x.x.x to 191.x.x.x	192.x.x.x to 223.x.x.x	224.x.x.x to 239.x.x.x	240.x.x.x to 255.x.x.x
No of bits for network/host	7/24	14/16	21/8	Not for commercial use	N/A
Number of network (block)	128	16,384	2,097,152	1	1
Number of host	$2^{24} - 2 =$ 16777214	$2^{16} - 2 =$ 65534	$2^8 - 2 = 254$	(268,435,456)	(268,435,456)
Netmask	255.0.0.0	255.255.0.0	255.255.255.0		
Purpose	Few large organizations	Medium size organizations	Relatively small organizations	Multicast groups	Experimental

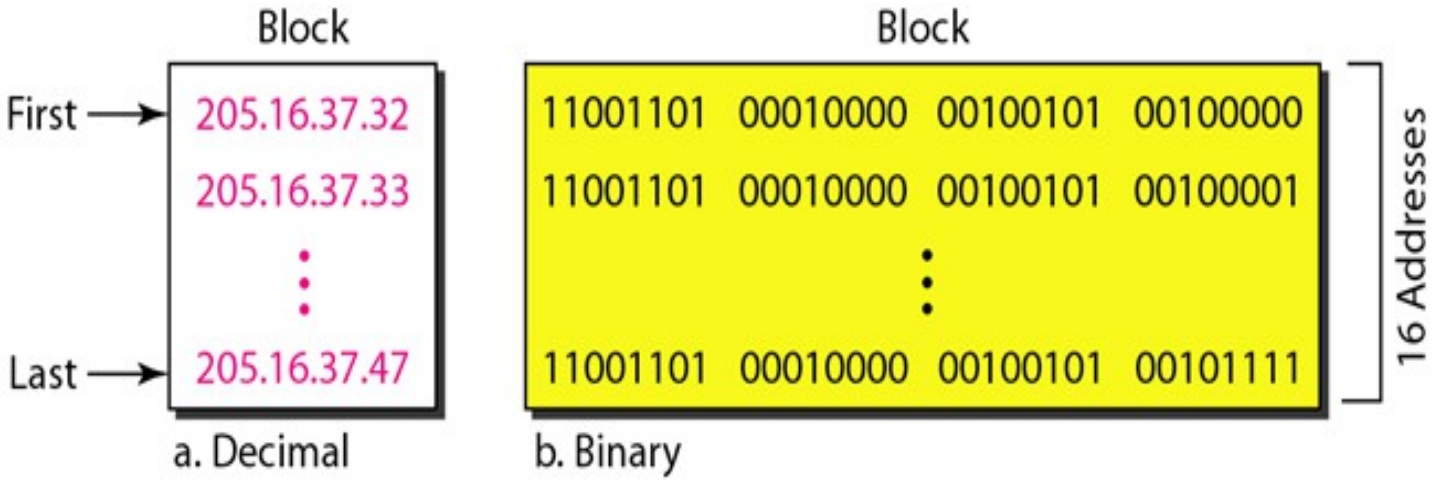
Subnetting/Supernetting

- **Subnetting**
  - Divide addresses (Class A and B) into several contiguous groups and assign each group to smaller groups (subnet) or share part of address with neighbors
- **Supernetting**
  - Combine several class C blocks to create larger range of addresses

Classless Addressing

- To overcome address depletion and give more organizations access to the Internet
- No classes, addresses are still granted in blocks (range of addresses)
- Restrictions:
  - The addresses in a block must be contiguous, one after another
  - The number of addresses in a block must be a power of 2
  - The first address must be evenly divisible by the number of addresses

Classless Addressing (2)



- Address is contiguous
- Number of address is a power of 2 ($16 = 2^4$)
- First address is divisible by 16
  - First address when converted to a decimal number is 3,440,387,360

Classless Addressing (3)

- Mask
  - 32-bit number where n leftmost bits are 1s and the 32-n rightmost bits are 0s
  - Any value from 0 to 32
  - **Classless Interdomain Routing** (CIDR) notation (/n notation)
- In IPv4 addressing, a block of addresses can be defined as *x.y.z.t/n* in which *x.y.z.t* defines one of the addresses and the ***/n*** defines the mask

Classless Addressing (4)

- The first address in the block can be found by setting the rightmost **32 – n** bits to 0s
- The last address in the block can be found by setting the rightmost **32 – n** bits to 1s
- The number of addresses in the block can be found using the formula $\mathbf{2^{32-n}}$

Classless Addressing (5)

- Question: A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28
  - What is the first address in the block?
  - What is the last address in the block?
  - Find the number of addresses in the block?

Classless Addressing (6)

- Binary representation is 11001101 00010000 00100101 00100111
- Set 32 – 28 rightmost bits to 0

  11001101 00010000 00100101 00100000 or **205.16.37.32**
- Set 32 – 28 rightmost bits to 1

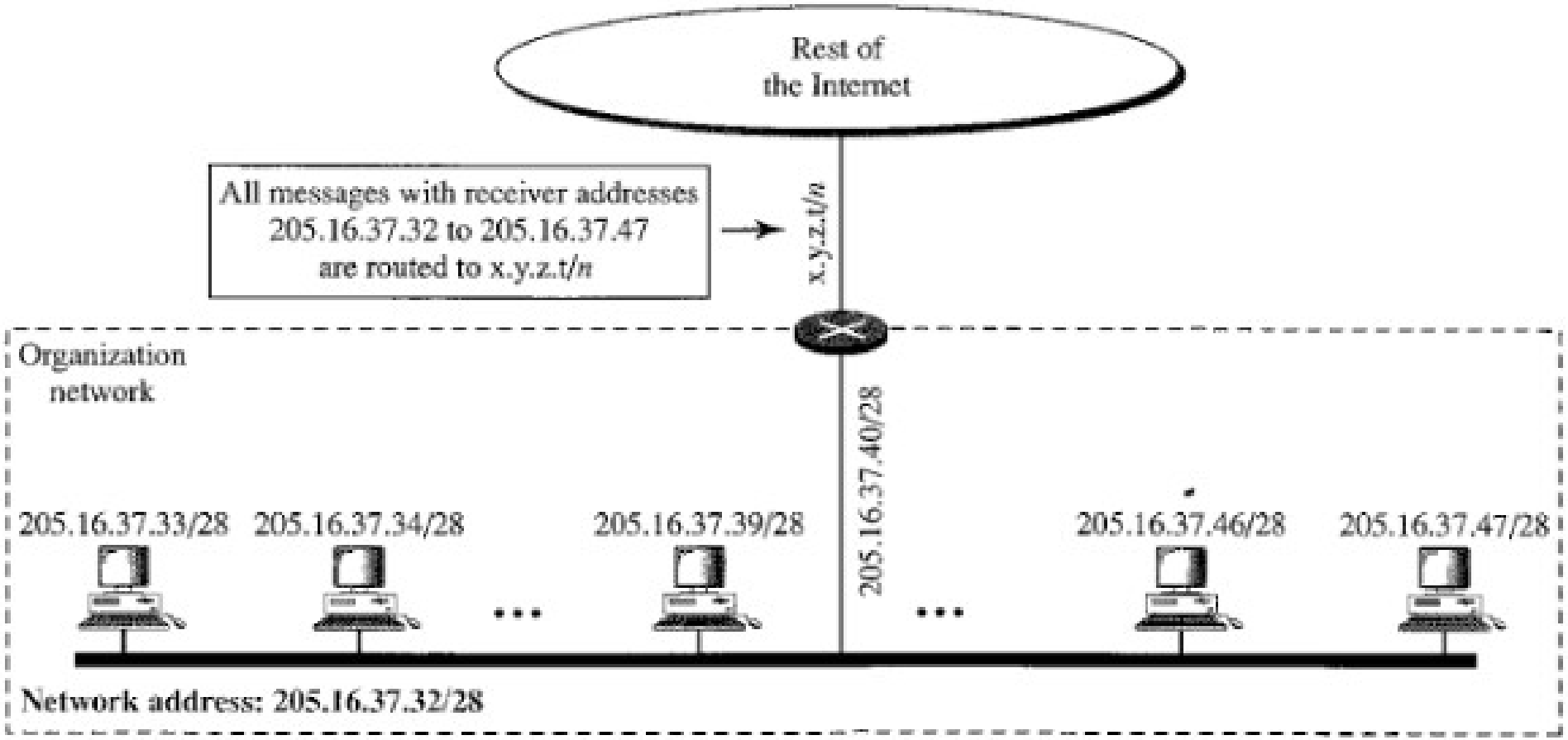
  11001101 00010000 00100101 00101111 or **205.16.37.47**
- Value of n is 28, so 2^{32-28}

  $2^4 = \mathbf{16}$

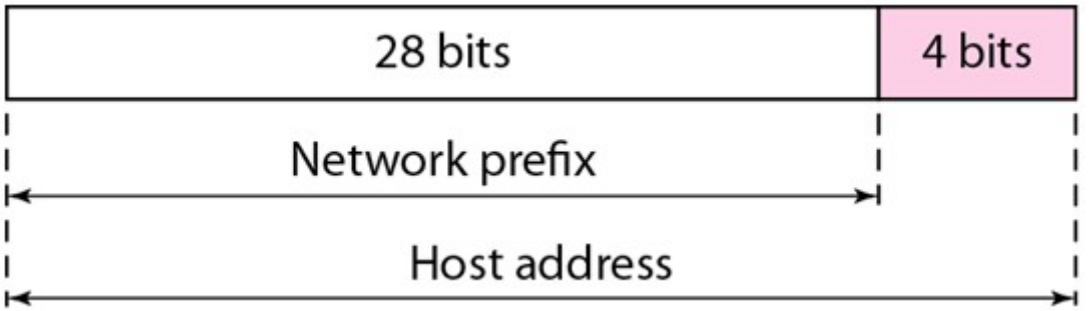
Network Address

- When organization is given a block of address, it is free to allocate the addresses to devices that need to be connected to the Internet
- The first address (normally) is treated as a special address and defines the organization to the rest of the world

Network Address (2)



Two-level Heirarchy: No Subnetting

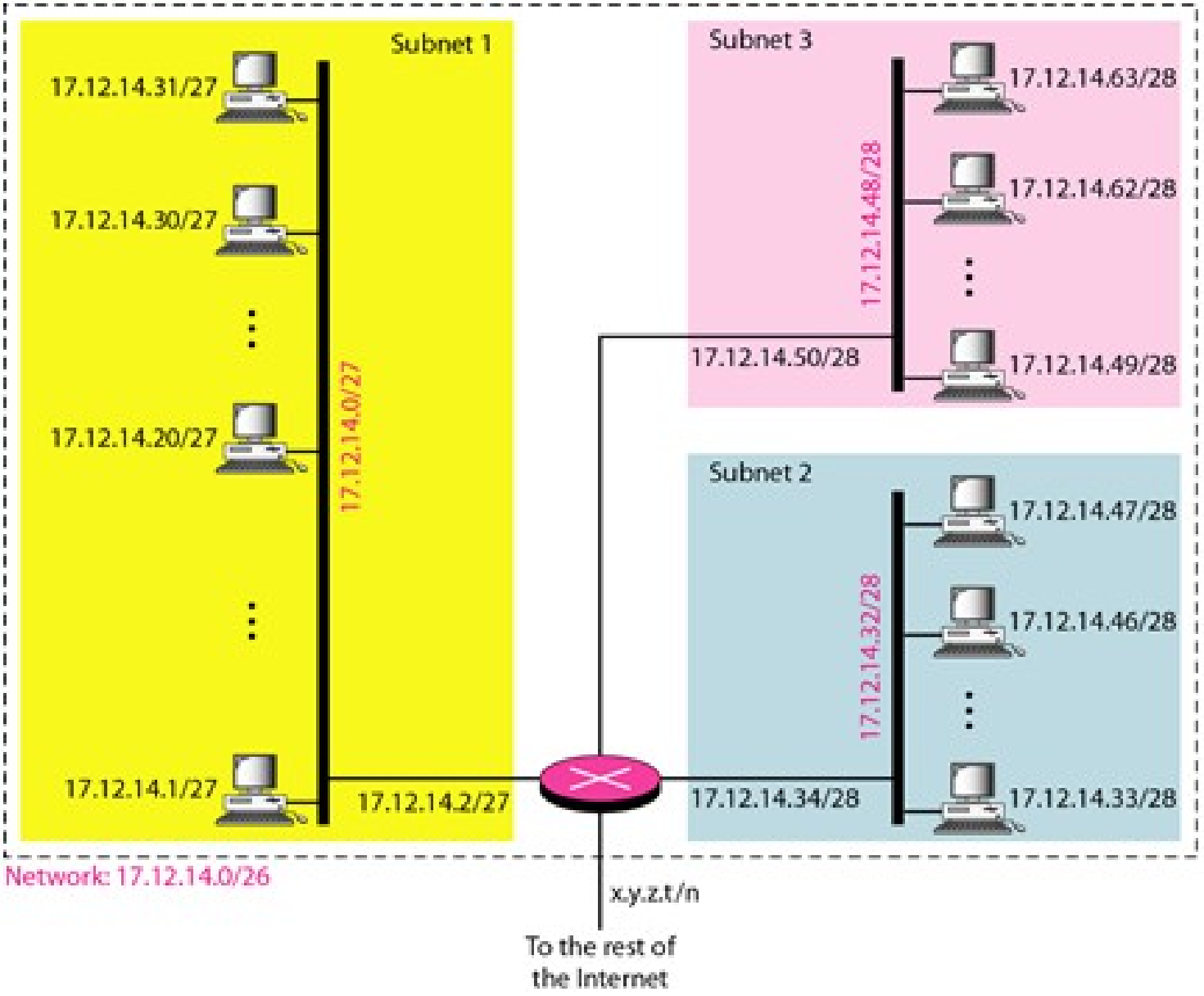


- **Prefix** – leftmost *n* bits that define the network
- **Suffix** – rightmost *32* – *n* bits define the hosts

Three-level Heirarchy: Subnetting

- Example: An organization is given the block 17.12.40.0/26 which contains 64 addresses. The organization has 3 offices and needs to divide addresses into 3 sub blocks of 32, 16 and 16 addresses
- New mask
  - First subnet must be $2^{32-n1} = 32$, n1 = 27
  - Second subnet must be $2^{32-n2} = 16$, n2 = 28
  - Third subnet must be $2^{32-n3} = 16$, n3 = 28

Three-level Heirarchy: Subnetting (2)



Three-level Heirarchy: Subnetting (3)

- In subnet 1, the address 17.12.14.29/27 can give the subnet address if /27 mask is used

  Host: 00010001 00001100 00001110 00011101

  Mask: 11111111 11111111 11111111 11100000 (/27)

  Subnet: 00010001 0001100 00001110 00000000 (17.12.14.0)

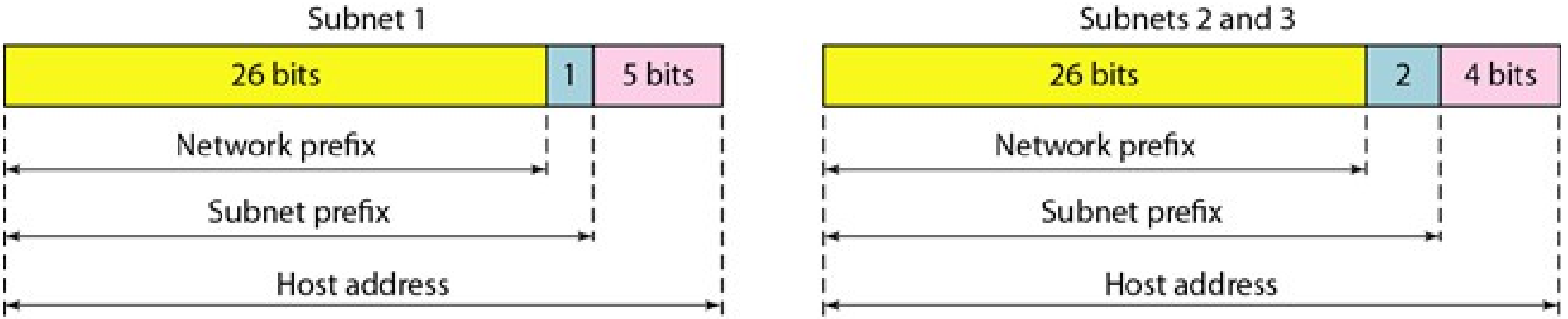
- In subnet 2, the address 17.12.14.45/28 can give the subnet address if /28 mask is used

  Host: 00010001 00001100 00001110 00101101

  Mask: 11111111 11111111 11111111 11110000 (/28)

  Subnet: 00010001 0001100 00001110 00100000 (17.12.14.32)

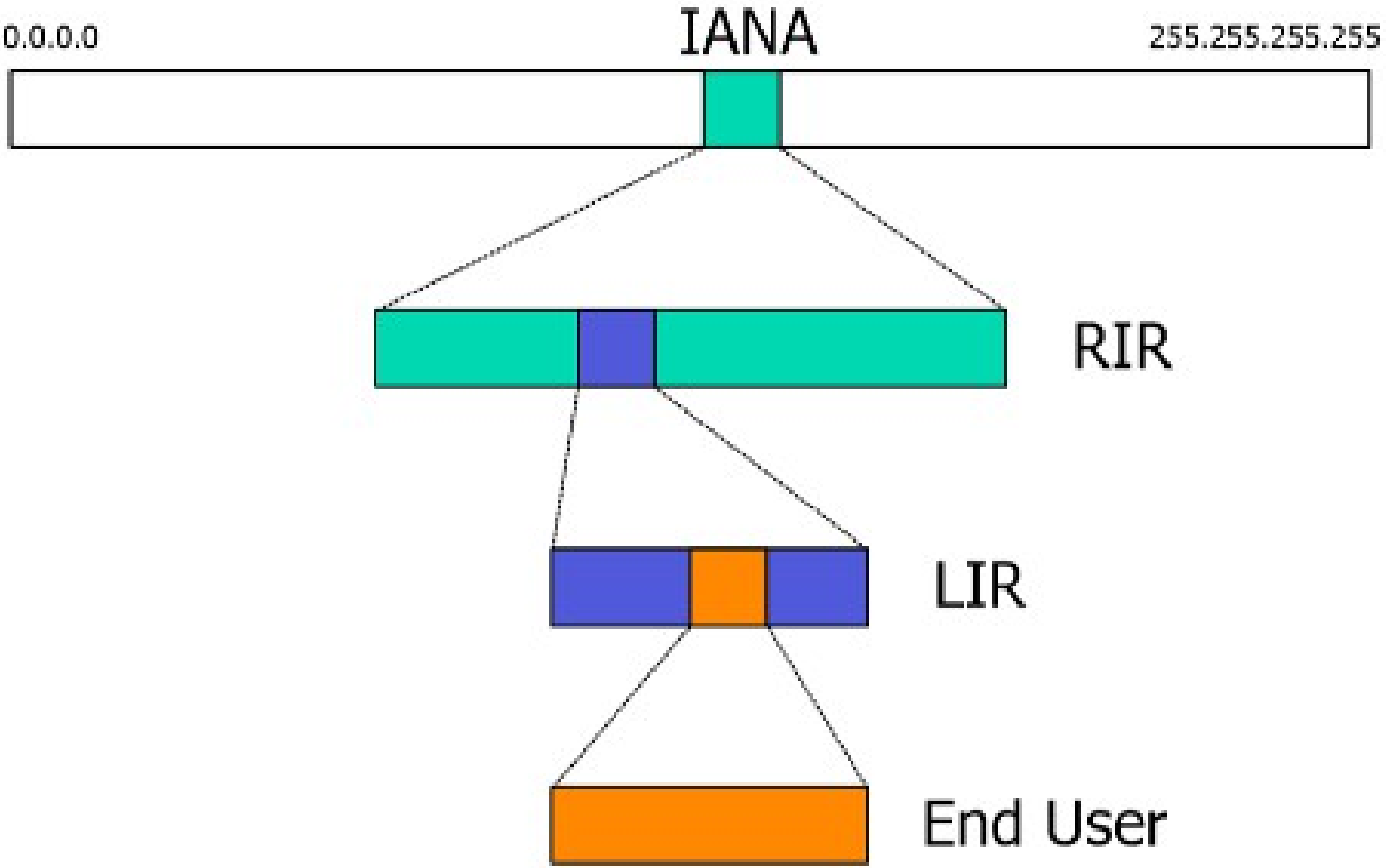
Three-level Heirarchy: Subnetting (4)



Address Allocation

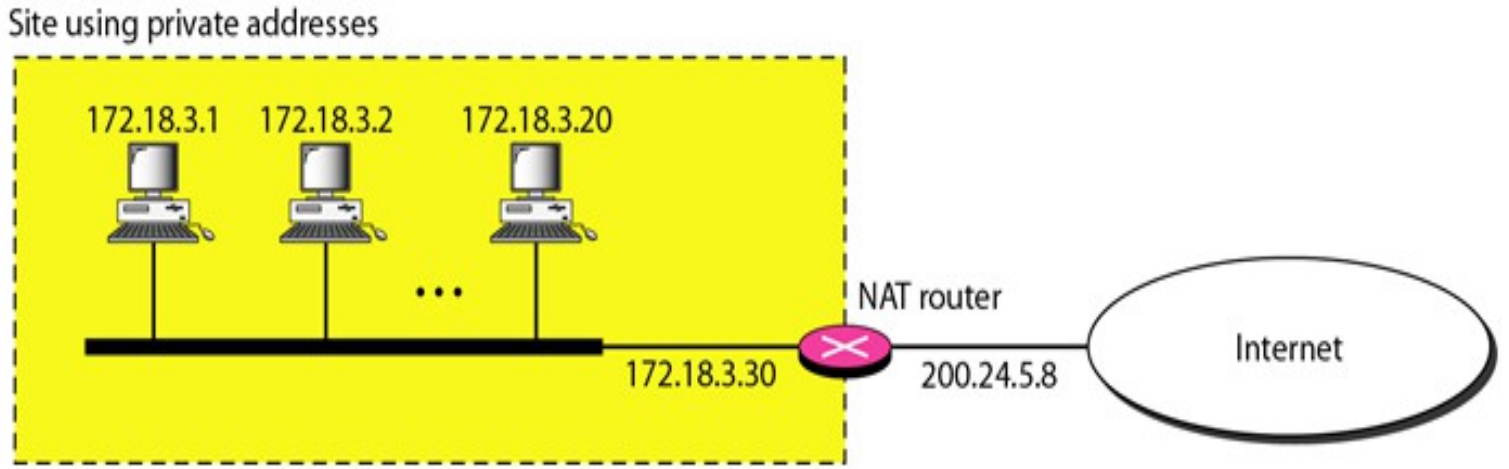
- **Internet Corporation for Assigned Names and Numbers** (ICANN) – global authority for address allocation
- **Internet Assigned Numbers Authority** (IANA)
  - Manages the DNS root, the .int and .arpa domains
  - Coordinates the global pool of IP and AS numbers, providing them to Regional Internet Registries
  - Manages internet protocol's numbering system

Address Allocation (2)



Network Address Translation

- Enables to have a large set of addresses internally and one address, or a small set of addresses externally
- RFC 3022

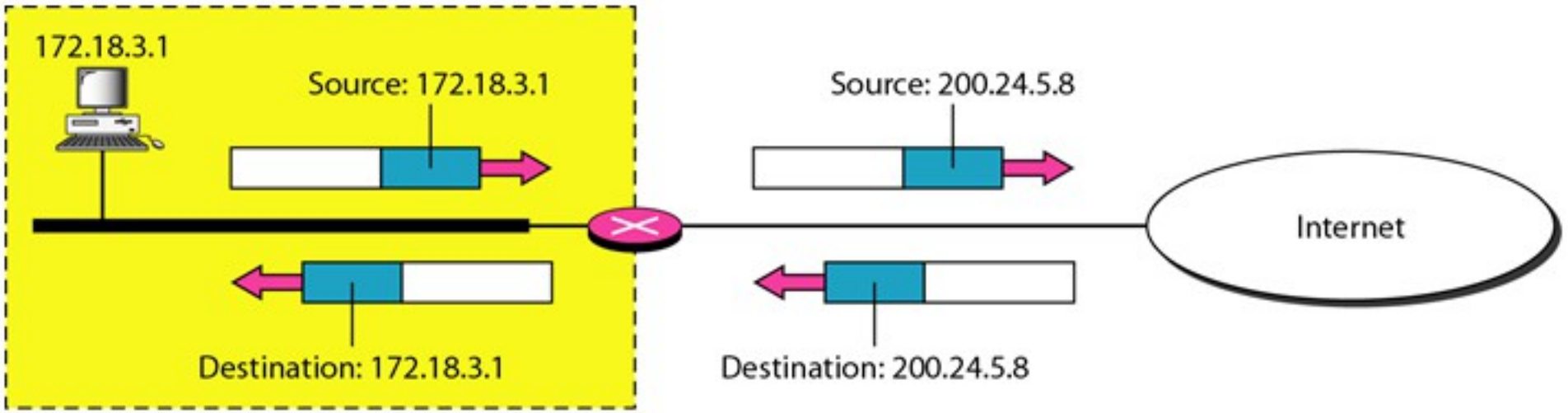


Network Address Translation (2)

- **Private Address** (RFC 1928 for IPv4) – reserved addresses for private network
  - Also known as *Network 10* address

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}

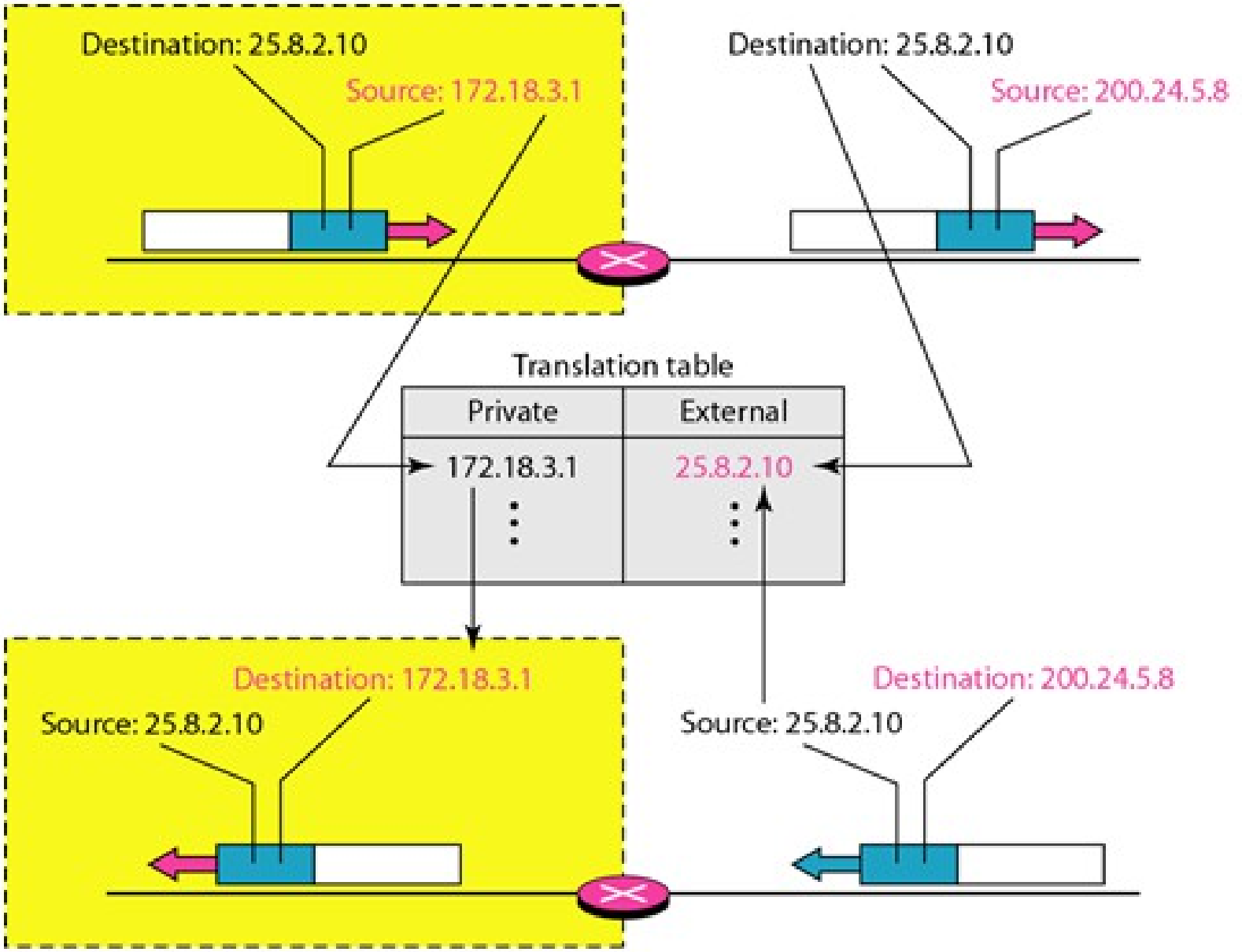
Network Address Translation (3)



Network Address Translation (4)

- Translation table
  - Using one IP Address
  - Using a pool of IP Addresses
  - Using both IP Addresses and Port Numbers

Network Address Translation (5)

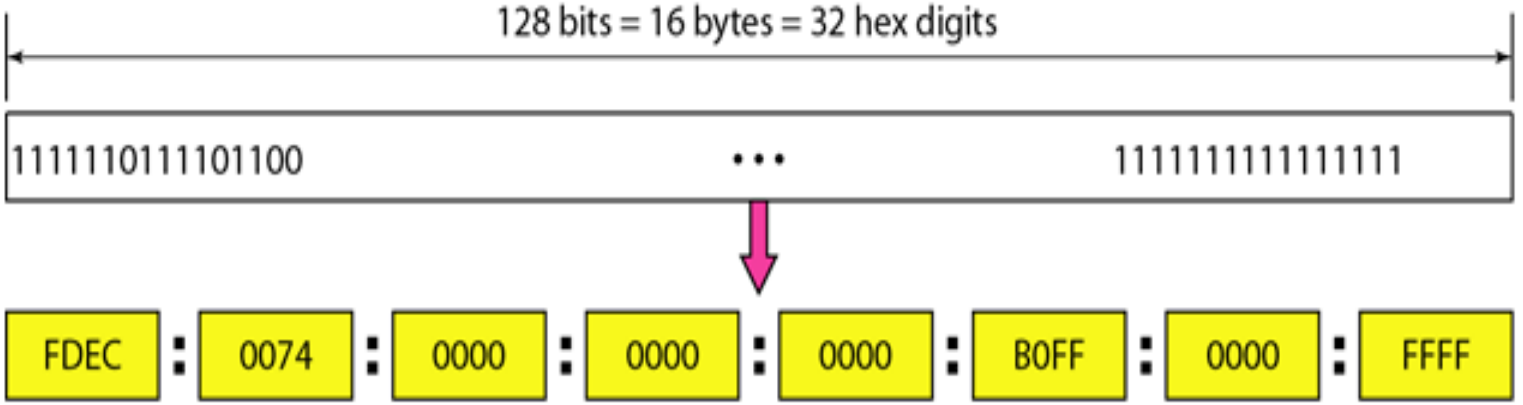


Network Address Translation (6)

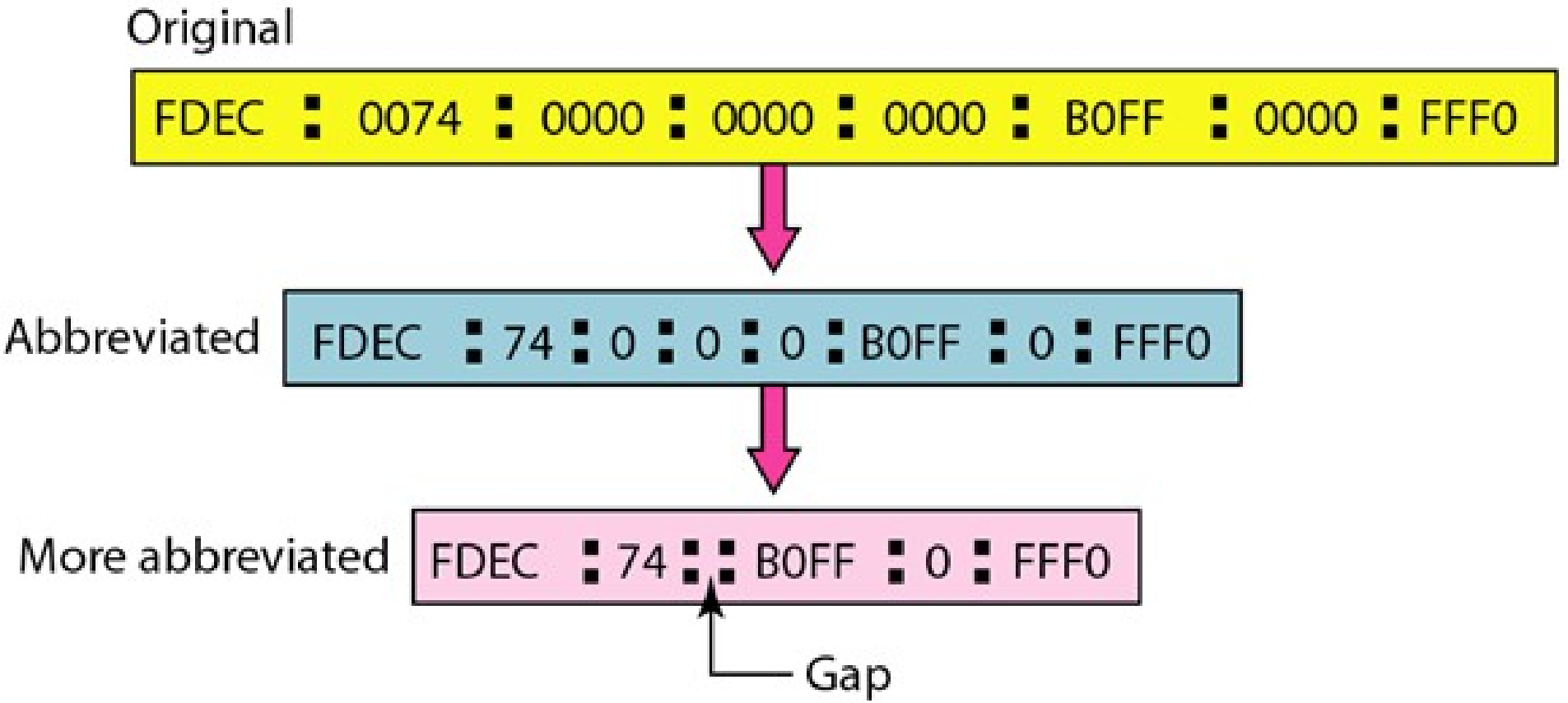
Private Address	*Private Port*	*External Address*	*External Port*	*Transport Protocol*
172.18.3.1	1400	25.8.3.2	80	TCP
172.18.3.2	1401	25.8.3.2	80	TCP
. . .	. . .	. . .	. . .	. . .

IPv6 Address

- 128-bit address (16 bytes/octets)
- RFC 2460
- Uses hexadecimal colon notation



IPv6 Address (2)



IPv6 Prefix

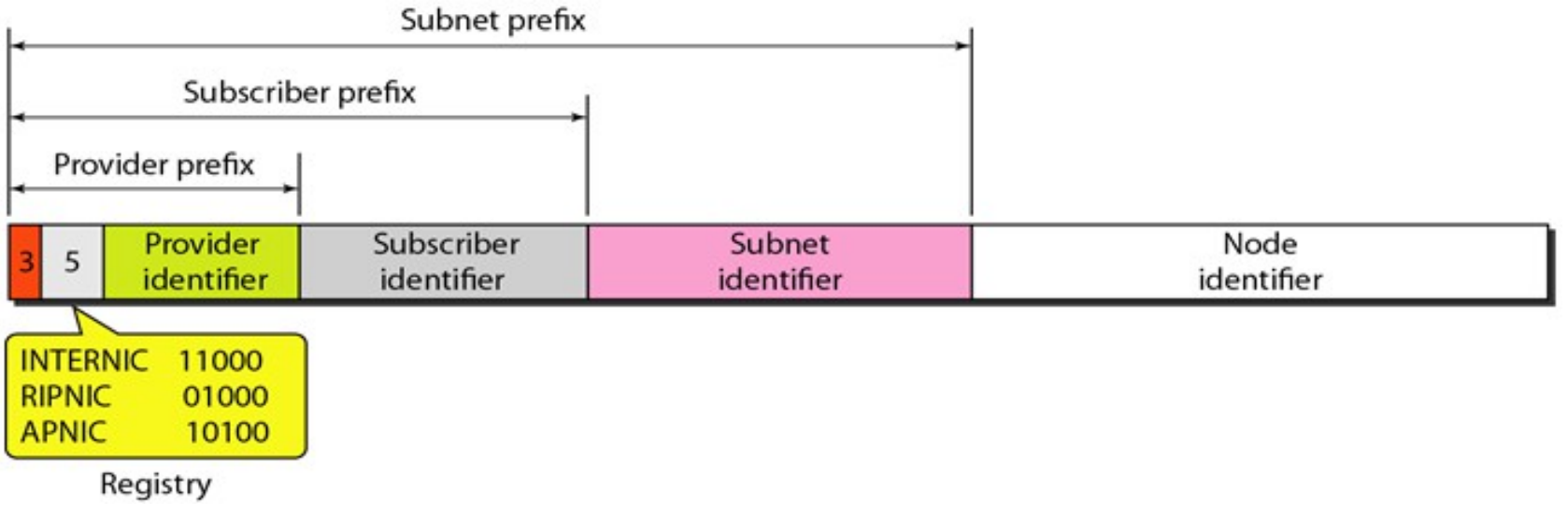
Type Prefix	*Type*	*Fraction*
0000 0000	Reserved	1/256
0000 0001	Unassigned	1/256
0000 001	ISO network addresses	1/128
0000 010	IPX (Novell) network addresses	1/128
0000 011	Unassigned	1/128
0000 1	Unassigned	1/32
0001	Reserved	1/16
001	Reserved	1/8
010	**Provider-based unicast addresses**	**1/8**

IPv6 Prefix (2)

Type Prefix	*Type*	*Fraction*
011	Unassigned	1/8
100	Geographic-based unicast addresses	1/8
101	Unassigned	1/8
110	Unassigned	1/8
1110	Unassigned	1/16
1111 0	Unassigned	1/32
1111 10	Unassigned	1/64
1111 110	Unassigned	1/128
1111 1110 0	Unassigned	1/512
1111 1110 10	Link local addresses	1/1024
1111 1110 11	Site local addresses	1/1024
1111 1111	Multicast addresses	1/256

Unicast Address

- Defines a single computer
- Two types
  - Geographically based
  - Provider-based



Unicast Address (2)

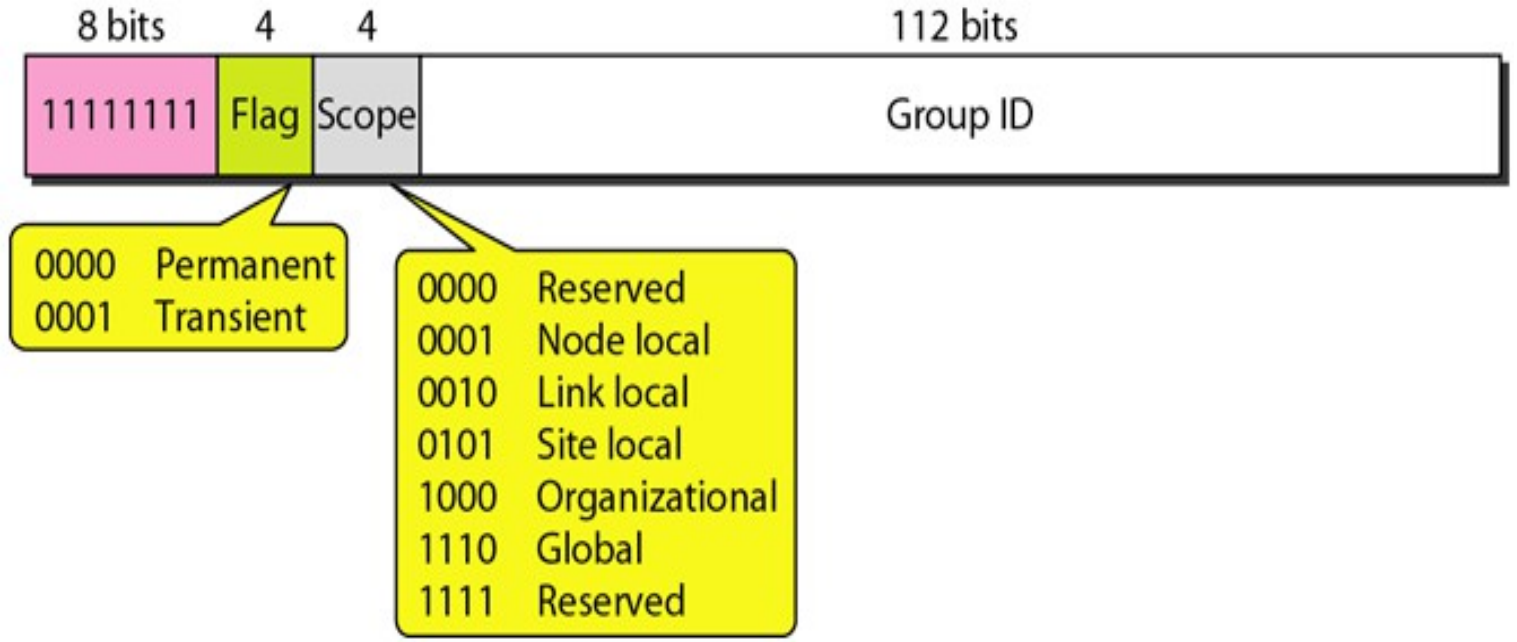
- **Type identifier** – 3-bit field that defines the address as a provider-based address
- **Registry identifier** – 5-bit field that indicates the agency that registered the address
- **Provider identifier** – variable-length field that identifies the provider for Internet access. (16-bit length recommended)

Unicast Address (3)

- **Subscriber identifier** – assigned to an organization when subscribed to the Internet through a provider (24-bit length recommended)
- **Subnet identifier** – defines a specific subnetwork under the territory of the subscriber (32-bit length recommended)
- **Node identifier** – identity of the node connected to a subnet (48-bit length recommended)

Multicast Address

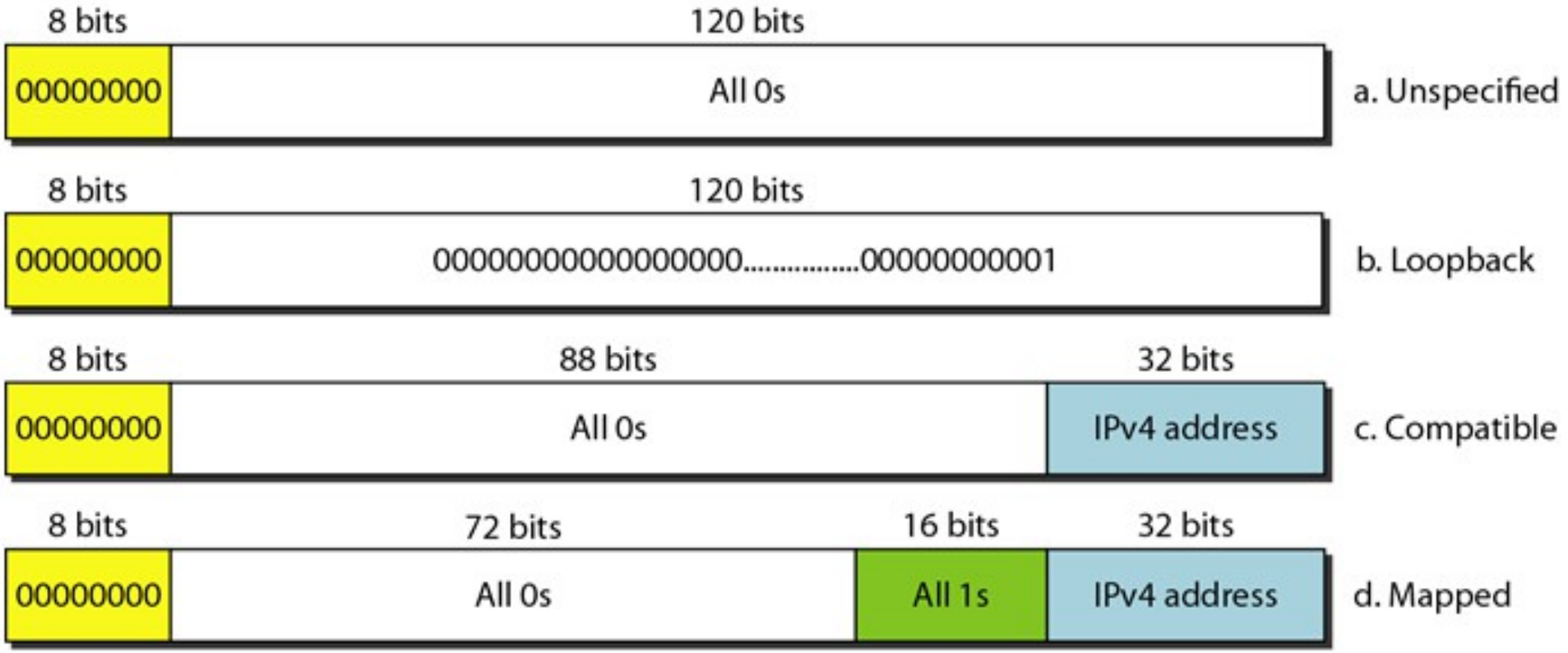
- Defines a group of hosts
- A packet sent to a multicast address must be delivered to each member of the group



Anycast Address

- Defines a group of nodes like multicast
- A packet destined for an anycast address is delivered to only one member of the anycast group, the nearest one.
- Possible use is to assign an anycast address to all routers of an ISP that covers a large logical area in the Internet

Reserved Address



Reserved Address (2)

- **Unspecified address** – used when a host does not know its own address and sends an inquiry to find its address
- **Loopback address** – used by a host to test itself without going into the network
- **Compatible address** – used when a computer using IPv6 wants to send a message to another computer using IPv6, but the message needs to pass through a part of the network that still operates in IPv4
- **Mapped address** – used when a computer that has migrated to IPv6 wants to send a packet to a computer still using IPv4

Local Address

- Used when organization wants to use IPv6 protocol without being connected to the global Internet
  - **Link local address** – used in an isolated subnet
  - **Site local address** – used in an isolated site with several subnets