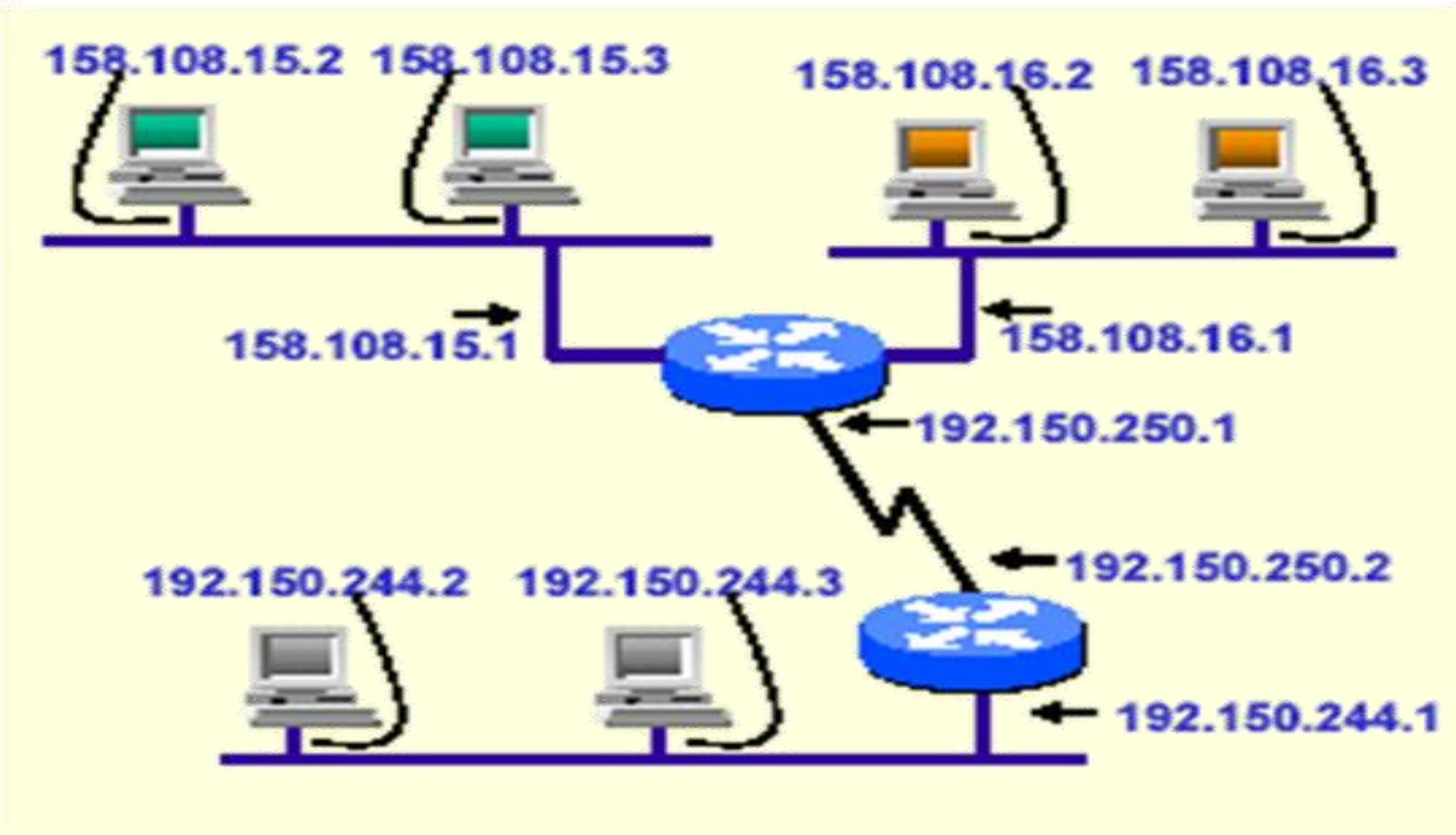
Logical address



- Communication at the network layer is host-to-host
- Length of address
- Space adresses (2^{length})
  - ✓ Total number of addresses used by the protocol
- IPv4 & IPv6

IPv4 ADDRESSES

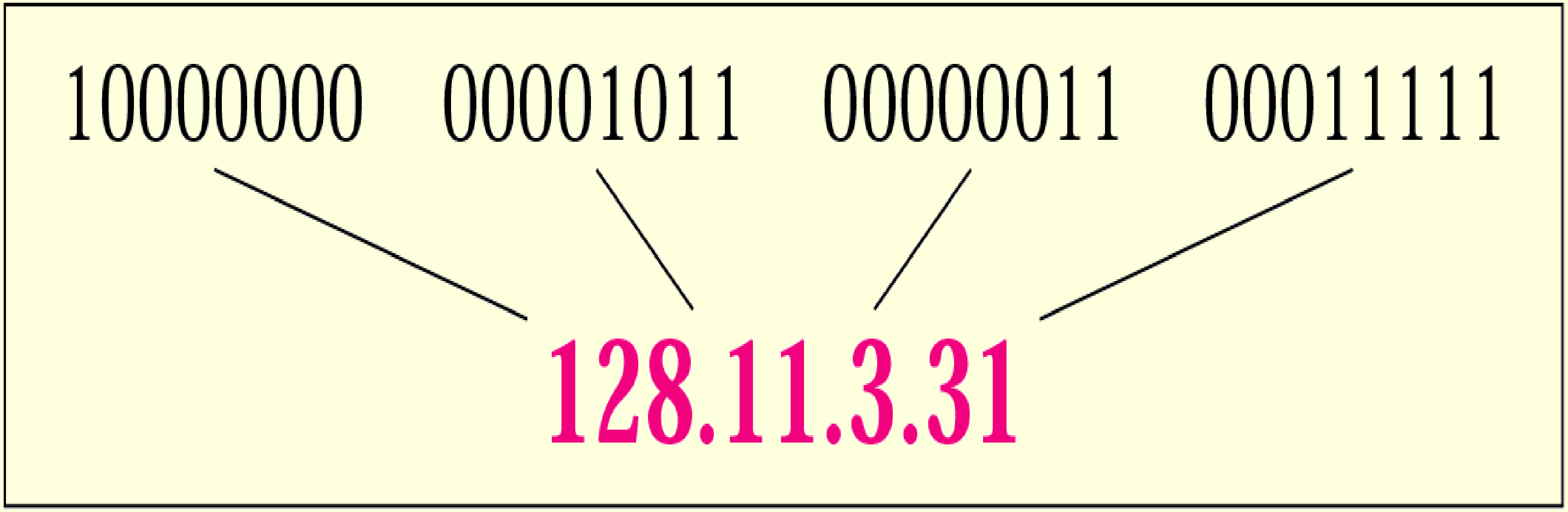
- Defines the connection of a device
- 32-bit address
- Space address (2^{32})
- M nodes ?
- Uniquely
- Universally

Notations

- ❑ Binary Notation
- Each octet is often referred to as a byte
- 23 bit or 4 byte
- 00000000 00000000 00000000 00000001 to 111111111   11111111 11111111 11111111

❑ Dotted-Decimal Notation

- 1 to 255



Example :

Change the following IP addresses from binary notation to dotted-decimal notation.

a. 10000001 00001011 00001011 11101111

b. 11111001 10011011 11111011 00001111

We replace each group of 8 bits with its equivalent decimal number and add dots for separation:

a. 129.11.11.239

b. 249.155.251.15

Example

Change the following IP addresses from dotted-decimal notation to binary notation.

a. 111.56.45.78

b. 75.45.34.78

We replace each decimal number with its binary equivalent:

a. 01101111 00111000 00101101 01001110
b. 01001011 00101101 00100010 01001110

Example :

Find the error, if any, in the following IPv4 addresses.

- 111.56.045.78
- 221.34.7.8.20
- 75.45.301.14
- 11100010.23.14.67

Classful Addressing

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

a. Binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0-127			
Class B	128-191			
Class C	192-223			
Class D	224–239			
Class E	240-255			

b. Dotted-decimal notation

Find the class of each address.

a. 00000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

c. 14.23.120.8

d. 252.5.15.111

Solution

a. The first bit is O. This is a class A address.

b. The first 2 bits are 1; the third bit is O. This is a class C address.

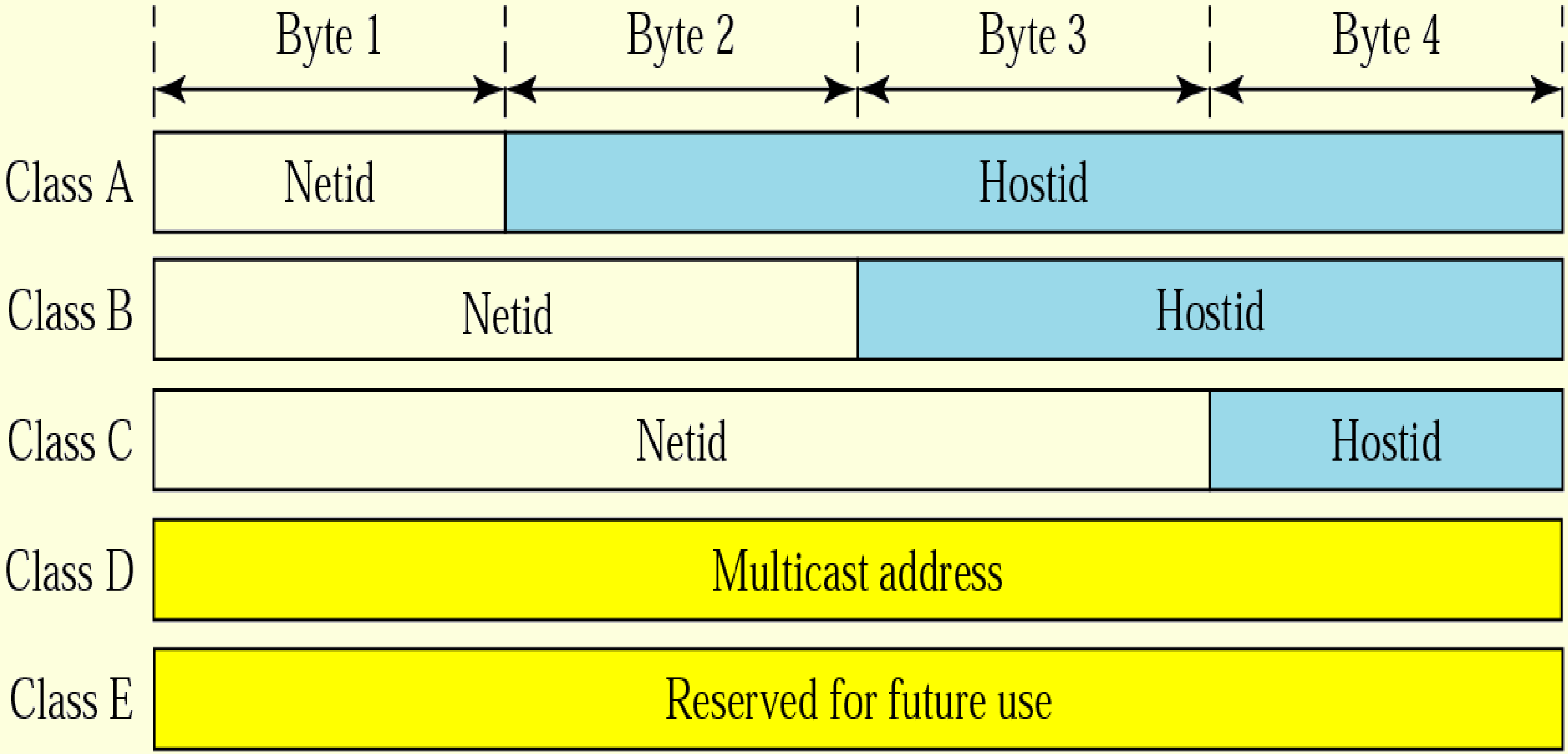
c. The first byte is 14 (between 0 and 127); the class is A.

d. The first byte is 252 (between 240 and 255); the class is E.

Classes and Blocks

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

Netid , Hostid & Mask



Subnetting & Supernetting

Classless Addressing

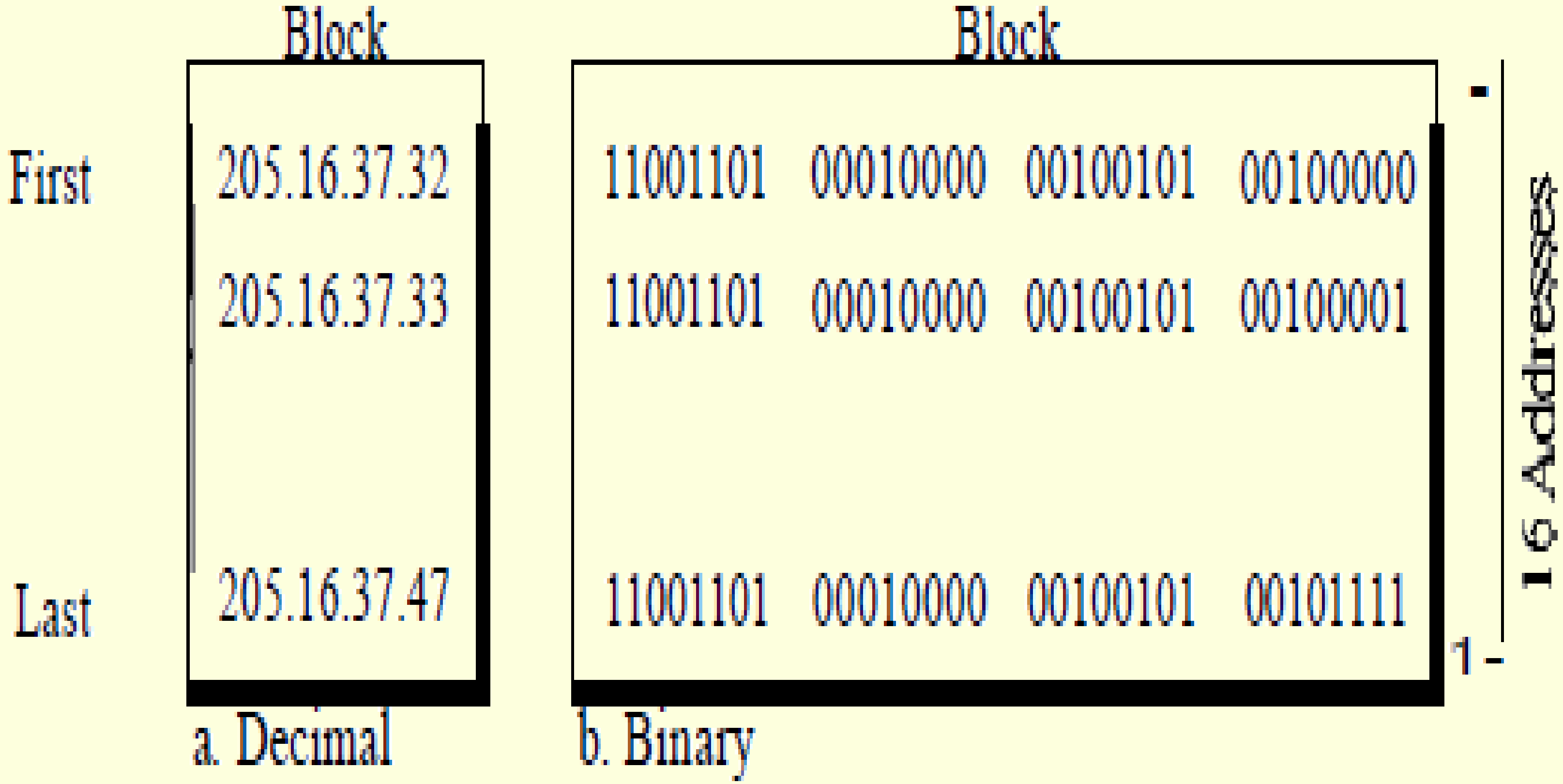
To overcome address depletion and give more organizations access to the Internet

Address Blocks

- Size of the block based on the nature and size of the entity
- Restriction :

1. The addresses in a block must be contiuous, one after another.
2. The number of addresses in a block must be a power of 2 (I, 2, 4, 8, ...).
3. The first address must be evenly divisible by the number of addresses.

Example


Block
Block
First
205.16.37.32
205.16.37.33
Last
205.16.37.47
11001101 00010000 00100101 00100000
11001101 00010000 00100101 00100001
11001101 00010000 00100101 00101111
16 Addresses
a. Decimal
b. Binary

Mask

Classless Interdomain Routing (CIDR) notation

x.y.z.t/n

First Address The first address in the block can be found by setting the 32 - *n* rightmost bits in the binary notation of the address to Os.

Example

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?

Solution

The binary representation of the given address is 11001101 00010000 00100101 00100 I 11. If we set 32 - 28 rightmost bits to 0, we get 11001101 000100000100101 0010000 or 205.16.37.32

Last Address The last address in the block can be found by setting the 32 – *n* rightmost bits in the binary notation of the address to ls.

Example :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 last address in the block?

Solution

The binary representation of the given address is 11001101 00010000000100101001001111. If weset 32 - 28 rightmost bits to 1, we get 11001101 00010000 001001010010 1111 or 205.16.37.47

Number of Addresses The number of addresses in the block is the difference between the last and first address. It can easily be found using the formula 2^{32-n}

Example :A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28. Find the number of addresses?

Solution :

The value of *n* is 28, which means that number of addresses is $2^{32-28} = 2^4$or 16.

Example :

Another way to find the first address, the last address, and the number of addresses is to represent the mask as a 32-bit binary (or 8-digit hexadecimal) number. This is particularly useful when we are writing a program to find these pieces of information. In Example 19.5 the /28 can be represented as 11111111 11111111 11111111 11110000 (twenty-eight Is and four Os). Find

a. The first address

h. The last address

c. The number of addresses

Solution

a. The first address can be found by ANDing the given addresses with the mask. ANDing here is done bit by bit. The result of ANDing 2 bits is 1 if both bits are Is; the result is 0 otherwise.

Address:	11001101	00010000	00100101	00100111
Mask:	11111111	11111111	11111111	11110000
First address:	11001101	00010000	00100101	00100000

b. The last address can be found by ORing the given addresses with the complement of the mask. ORing here is done bit by bit. The result of ORing 2 bits is 0 if both bits are Os; the result is 1 otherwise. The complement of a number is found by changing each 1 to 0 and each 0 to 1.

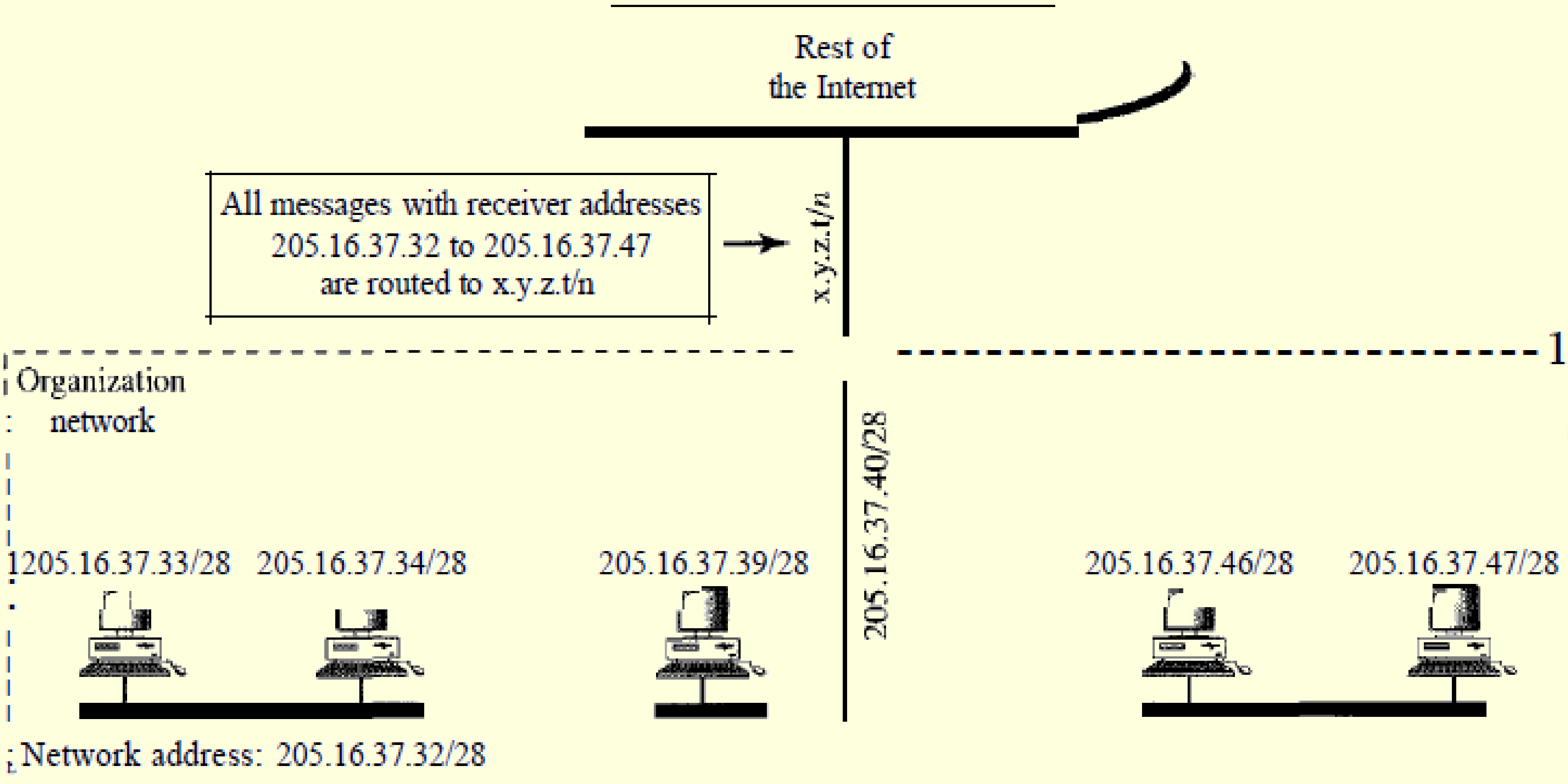
Address:	11001101	00010000	00100101	00100111
Mask complement:	0000000	0000000	0000000	0001111
Last address:	11001101	00010000	*00100101*	*00101111*

c. The number of addresses can be found by complementing the mask, interpreting it as a decimal number, and adding 1 to it.

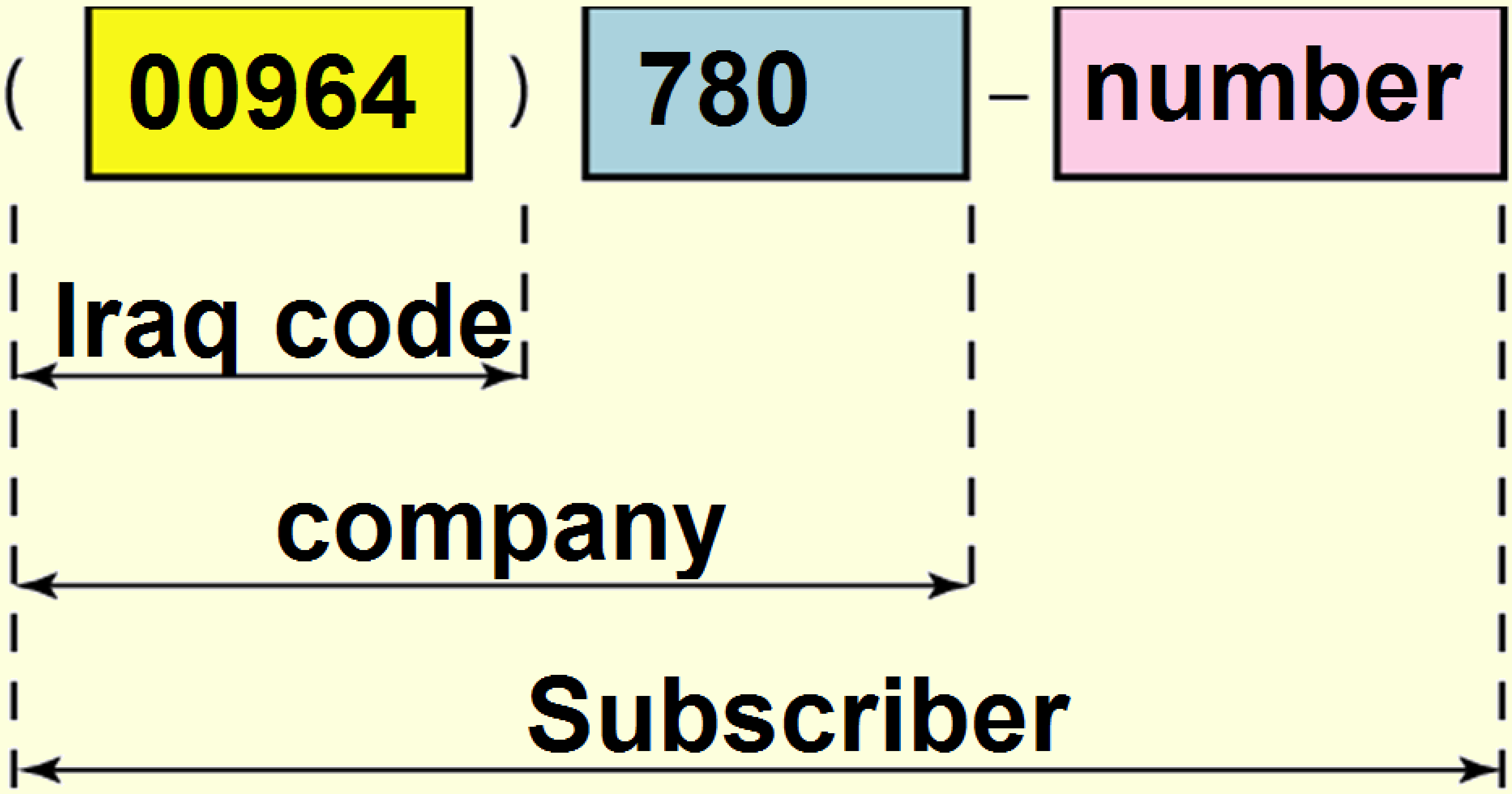
Mask complement:	00000000 0000000 0000000 0001111
Number of addresses:	15 + 1 = 16

Network Addresses

- A very important concept in IP addressing is the network address
- We can allocate the addresses of the block to devices that we needed
- First address normally called network address
- Network address defines the network to the rest of the world
- Router has two addresses

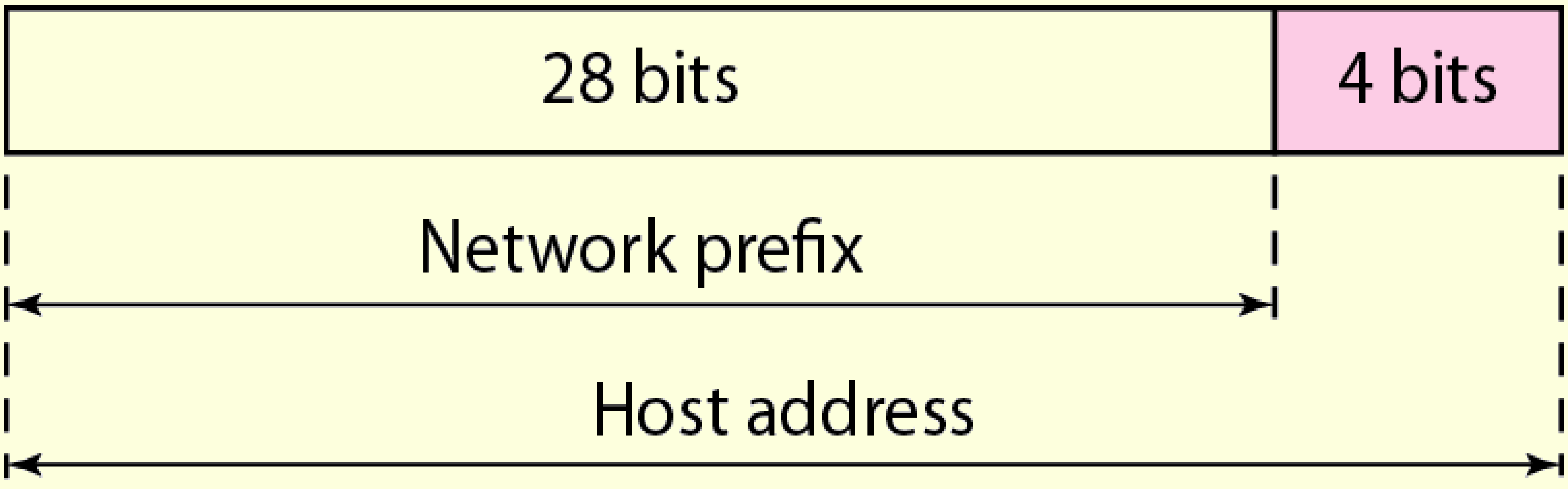

Rest of
the Internet
All messages with receiver addresses
205.16.37.32 to 205.16.37.47
are routed to x.y.z.t/n
x.y.z.t/n
Organization
network
205.16.37.33/28
205.16.37.34/28
205.16.37.39/28
205.16.37.40/28
205.16.37.46/28
205.16.37.47/28
Network address: 205.16.37.32/28

Hierarchy

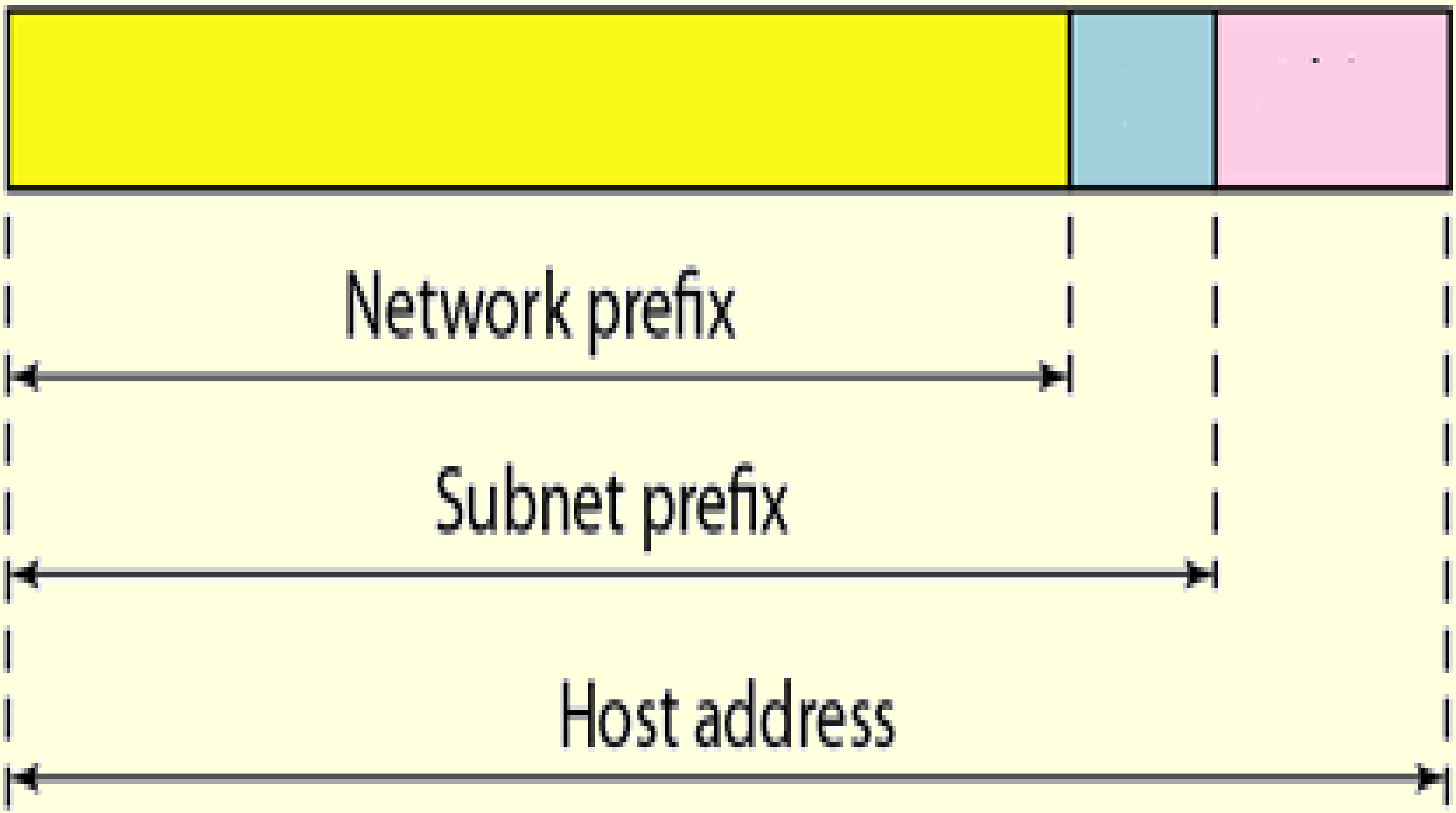


Two-Level Hierarchy: No Subnetting

- Netid & hostid
- Prefix & suffix
- Example :



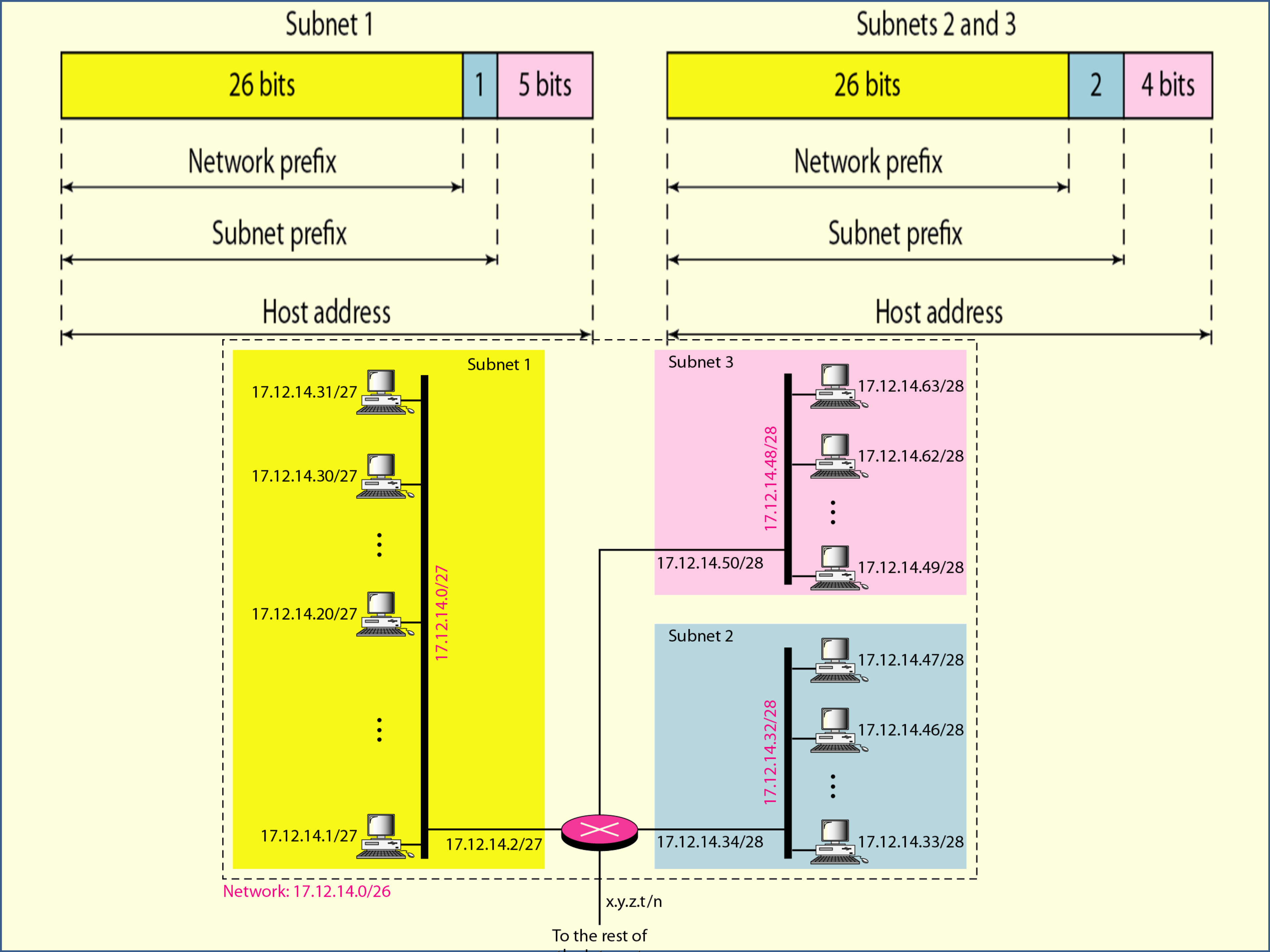
Three-Levels ofHierarchy: Subnetting



As an example, suppose an organization is given the block 17.12.40.0/26, which contains 64 addresses. The organization has three offices and needs to divide the addresses into three subblocks of 32, 16, and 16 addresses. We can find the new masks by using the following arguments:

1. Suppose the mask for the first subnet is n1, then 2^{32-n1} must be 32, which means that n1 =27.
2. Suppose the mask for the second subnet is n2, then 232- n2 must be 16, which means that n2 = 28.
3. Suppose the mask for the third subnet is n3, then 232- n3 must be 16, which means that n3 =28.

This means that we have the masks 27, 28, 28 with the organization mask being 26


Subnet 1
26 bits
1
5 bits
Network prefix
Subnet prefix
Host address
Subnets 2 and 3
26 bits
2
4 bits
Network prefix
Subnet prefix
Host address
Subnet 1
17.12.14.31/27
17.12.14.30/27
17.12.14.20/27
17.12.14.1/27
17.12.14.0/27
17.12.14.2/27
Subnet 3
17.12.14.63/28
17.12.14.62/28
17.12.14.49/28
17.12.14.48/28
17.12.14.50/28
Subnet 2
17.12.14.47/28
17.12.14.46/28
17.12.14.33/28
17.12.14.32/28
17.12.14.34/28
Network: 17.12.14.0/26
x.y.z.t/n
To the rest of

a. In subnet 1, the address 17.12.14.29/27 can give us the subnet address if we use the mask /27 because

Host:	00010001 00001100 00001110 00011101	
Mask:	/27	
Subnet:	00010001 00001100 00001110 00000000	(17.12.14.0)

b. In subnet 2, the address 17.12.14.45/28 can give us the subnet address if we use the mask /28 because

Host:	00010001 00001100 00001110 00101101	
Mask:	/28	
Subnet:	00010001 00001100 00001110 00100000	(17.12.14.32)

c. In subnet 3, the address 17.12.14.50/28 can give us the subnet address if we use the mask /28 because

Host:	00010001 00001100 00001110 00110010	
Mask:	/28	
Subnet:	00010001 00001100 00001110 00110000	(17.12.14.48)

More Levels of Hierarchy
ISP

Address Allocation

- Internet Corporation for Assigned Names and Addresses (ICANN)

- Address aggregation

An ISP is granted a block of addresses starting with 190.100.0.0/16 (65,536 addresses). The ISP needs to distribute these addresses to three groups of customers as follows:

a. The first group has 64 customers; each needs 256 addresses.

b. The second group has 128 customers; each needs 128 addresses.

c. The third group has 128 customers; each needs 64 addresses.

Design the subblocks and find out how many addresses are still available after these allocations.

Group 1

For this group, each customer needs 256 addresses. This means that 8 (log2 256) bits are needed to define each host. The prefix length is then 32 − 8 = 24. The addresses are

1st Customer:	*190.100.0.0/24*	*190.100.0.255/24*
2nd Customer:	*190.100.1.0/24*	*190.100.1.255/24*
. . .		
64th Customer:	*190.100.63.0/24*	*190.100.63.255/24*
Total = 64 × 256 = 16,384		

Group 2

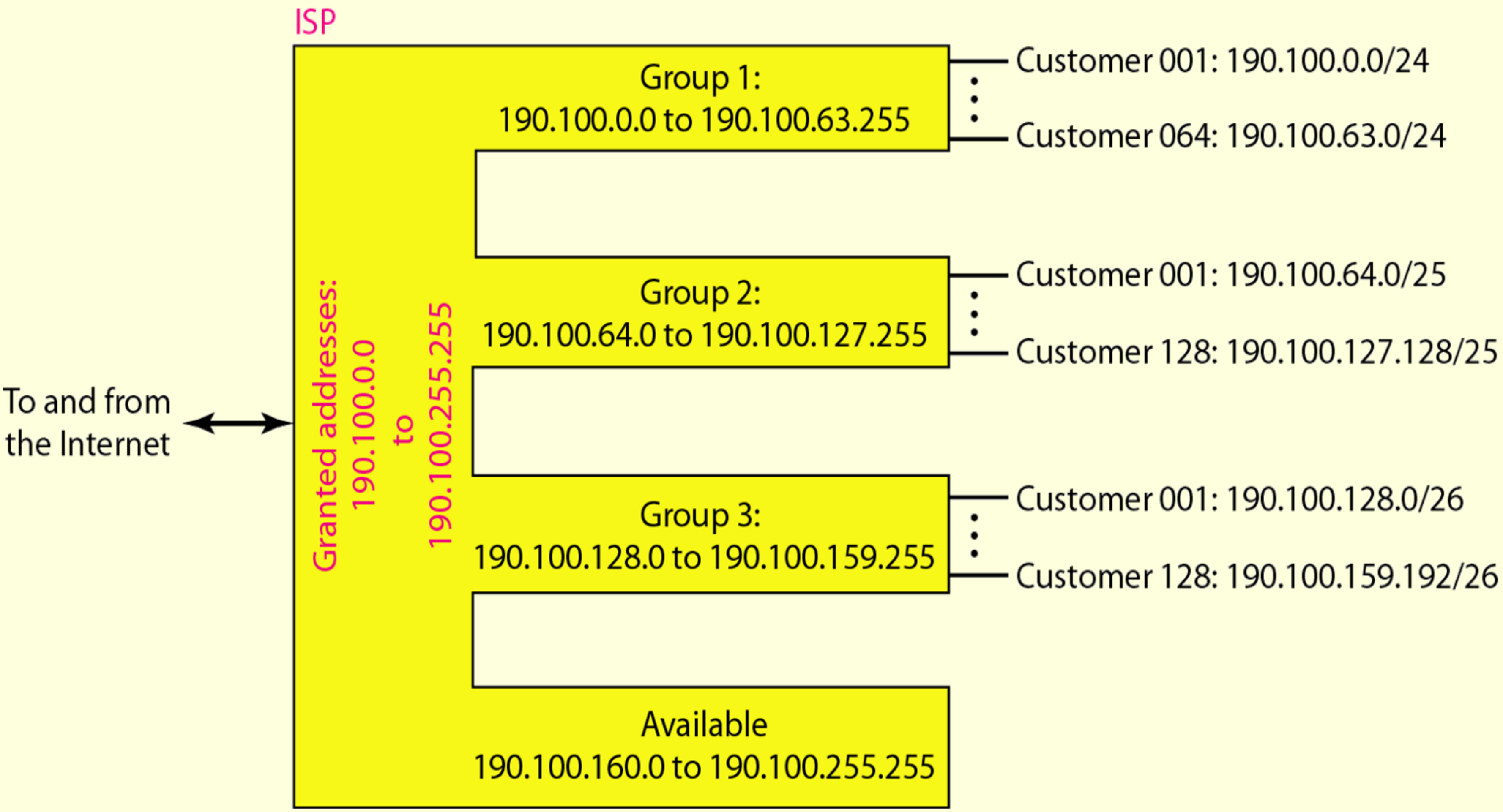
For this group, each customer needs 128 addresses. This means that 7 (log2 128) bits are needed to define each host. The prefix length is then $32 - 7 = 25$. The addresses are

1st Customer:	190.100.64.0/25	190.100.64.127/25
2nd Customer:	190.100.64.128/25	190.100.64.255/25
. . .		
128th Customer:	190.100.127.128/25	190.100.127.255/25
Total = $128 \times 128 = 16{,}384$		

Group 3

For this group, each customer needs 64 addresses. This means that 6 ($\log_2 64$) bits are needed to each host. The prefix length is then $32 - 6 = 26$. The addresses are

1st Customer:	190.100.128.0/26	190.100.128.63/26
2nd Customer:	190.100.128.64/26	190.100.128.127/26
. . .		
128th Customer:	190.100.159.192/26	190.100.159.255/26
Total = 128 × 64 = 8192		



Number of granted addresses to the ISP: 65,536
Number of allocated addresses by the ISP: 40,960
Number of available addresses: 24,576

Network Address Translation (NAT)

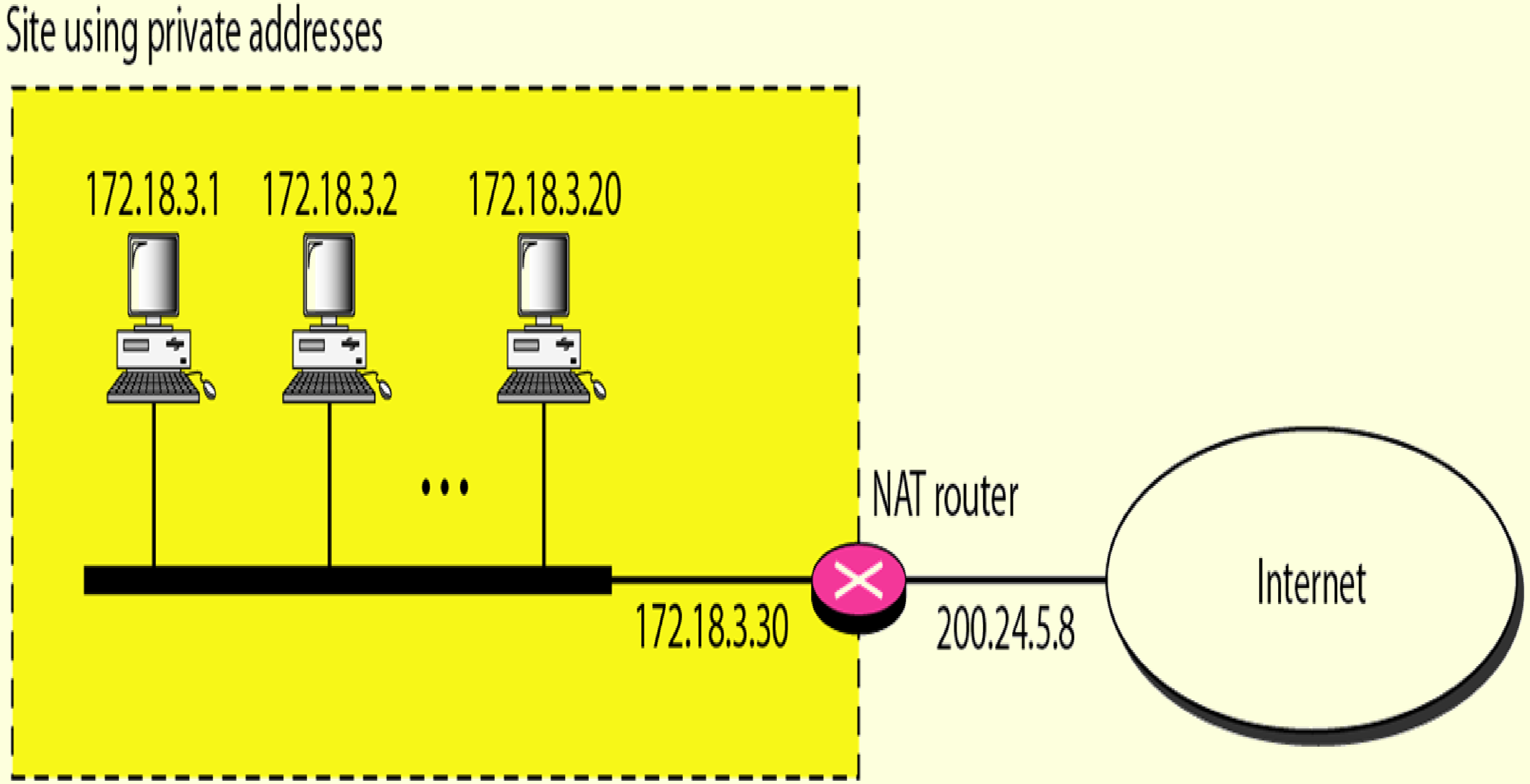
- A user was connected to the Internet with a dial-up line.
- An ISP could dynamically assign an address to this user.
- Now user may have created small networks
- NAT enables a user to have a large set of addresses internally and one address

- Internet authorities have reserved three sets of addresses as private addresses.
  - ✓ Why?
- Organization can use an address of this set without permission
- Unique or not unique ?

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}

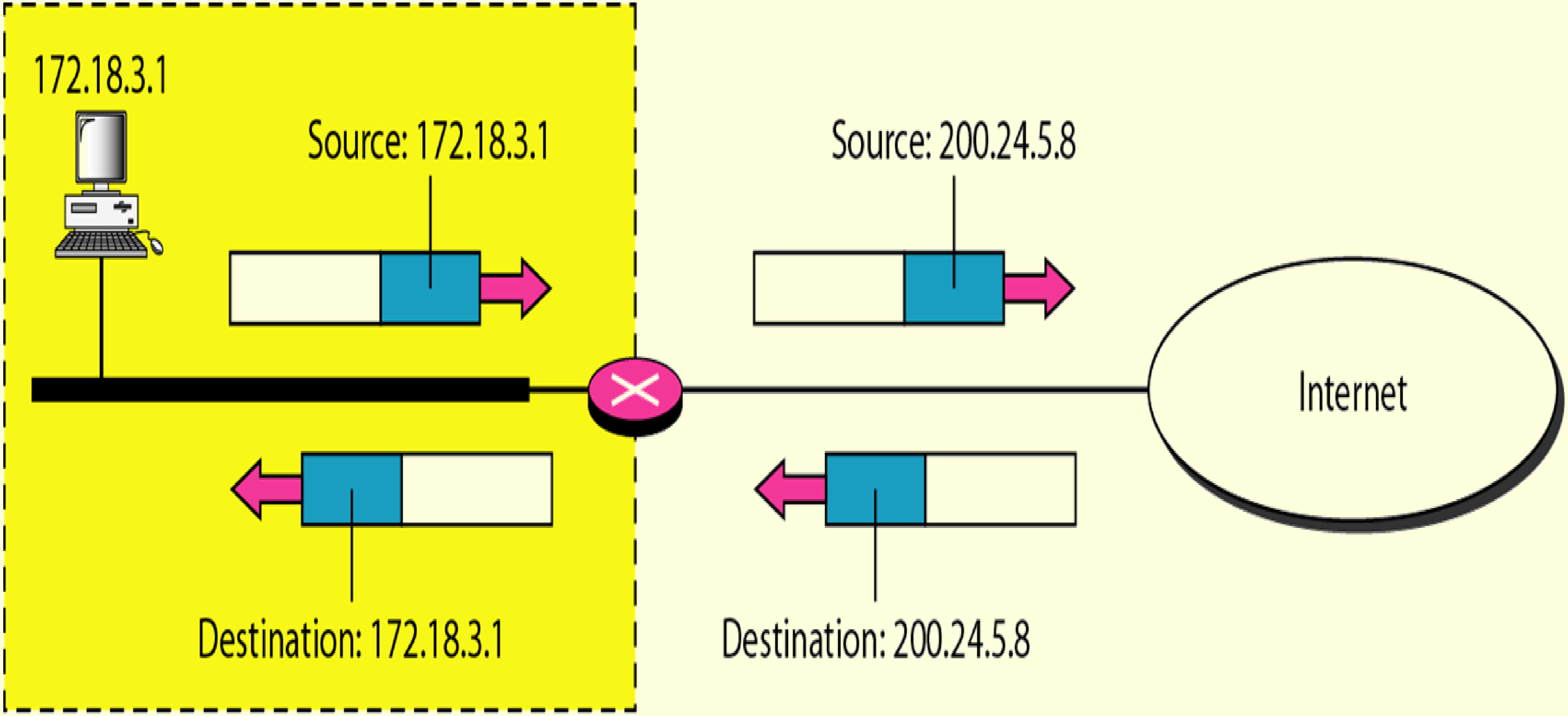
Addresses for private networks

A NAT implementation



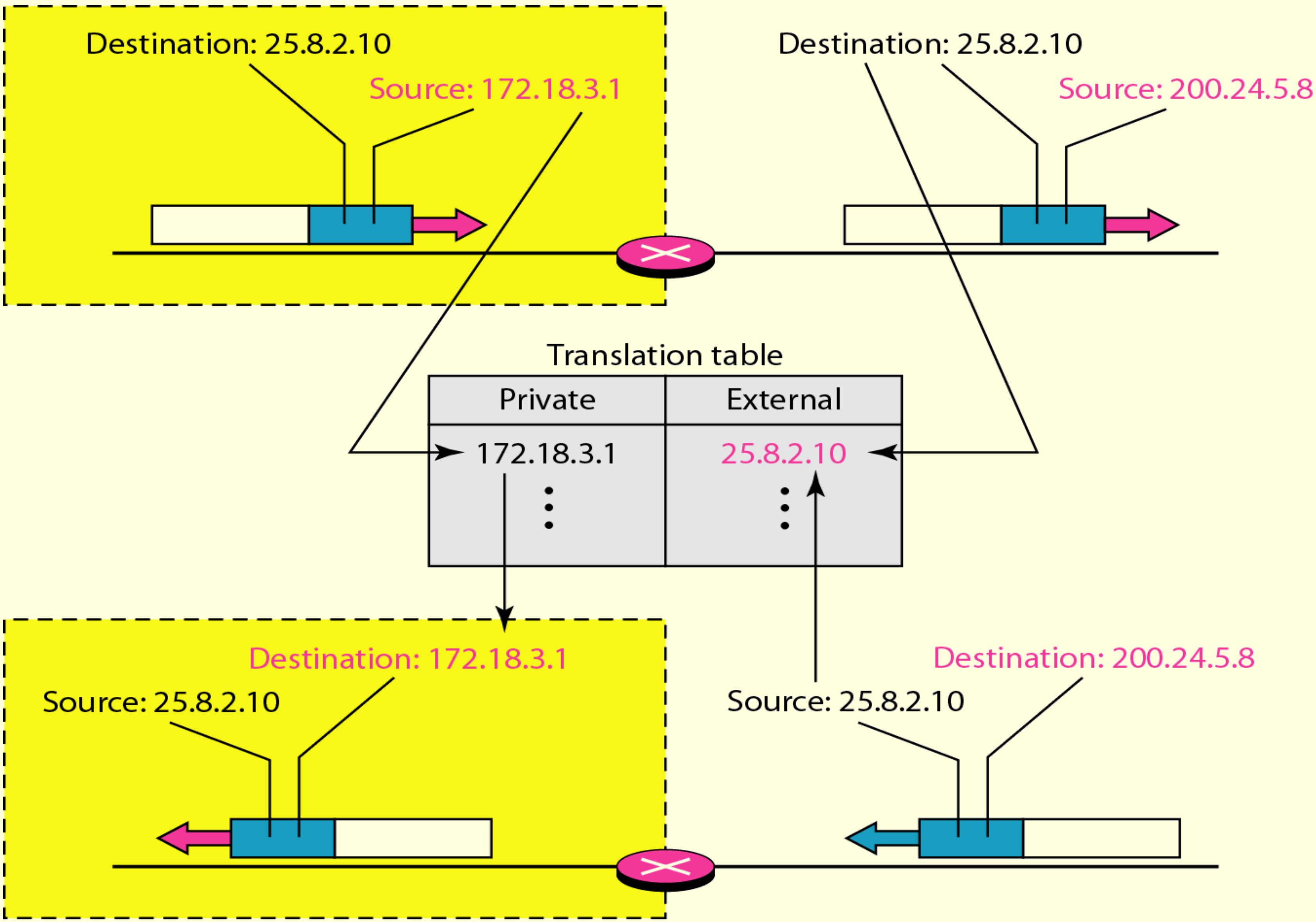
Address Translation

Using One IP Address



Addresses in a NAT

Translation Table



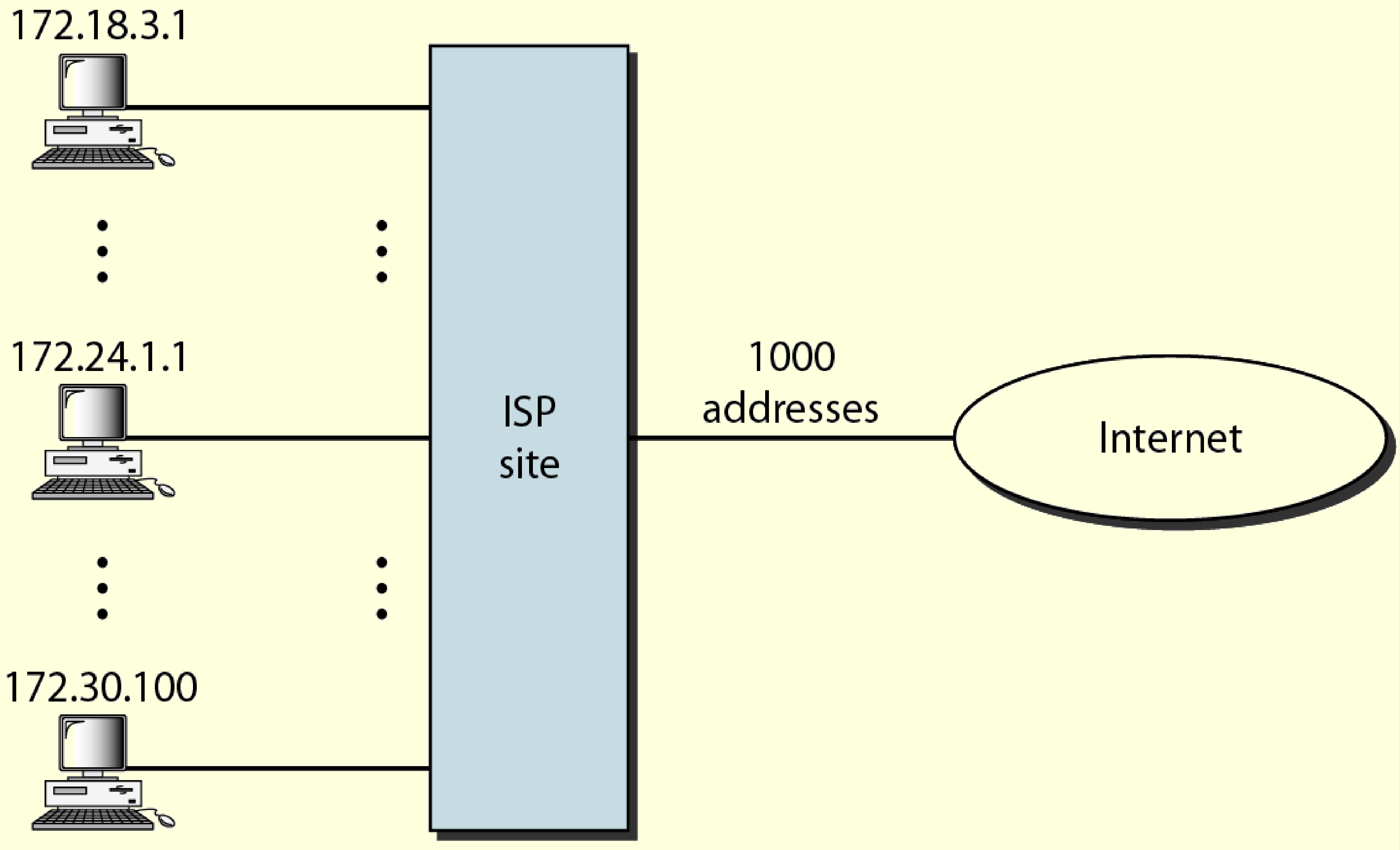
Using a Pool of IP Addresses

Using Both IP Addresses and Port Numbers

Many-to-many relationship

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
...	...	...	...	...

NAT and ISP



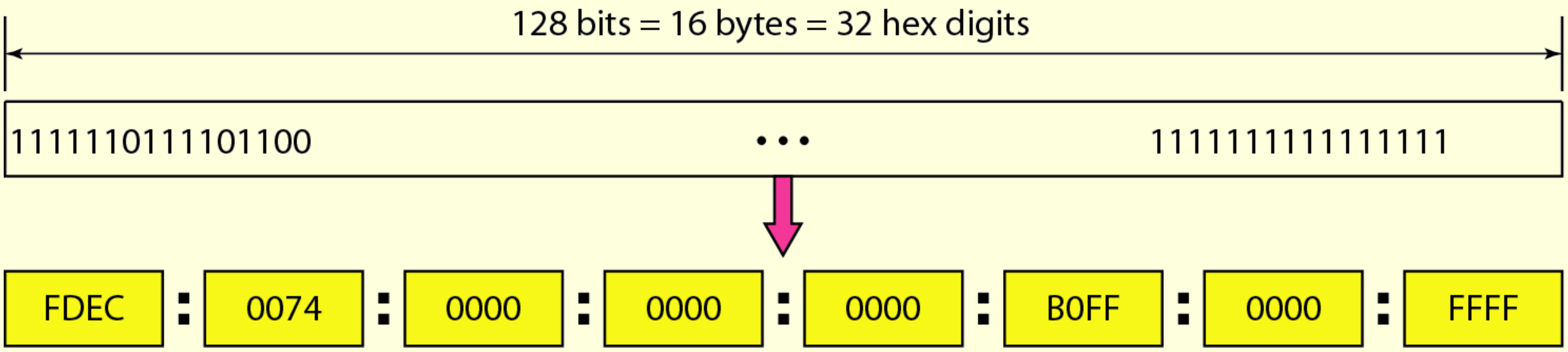
172.18.3.1
172.24.1.1
172.30.100
ISP site
1000 addresses
Internet

IPv6 ADDRESSES

An IPv6 address is 128 bits long.

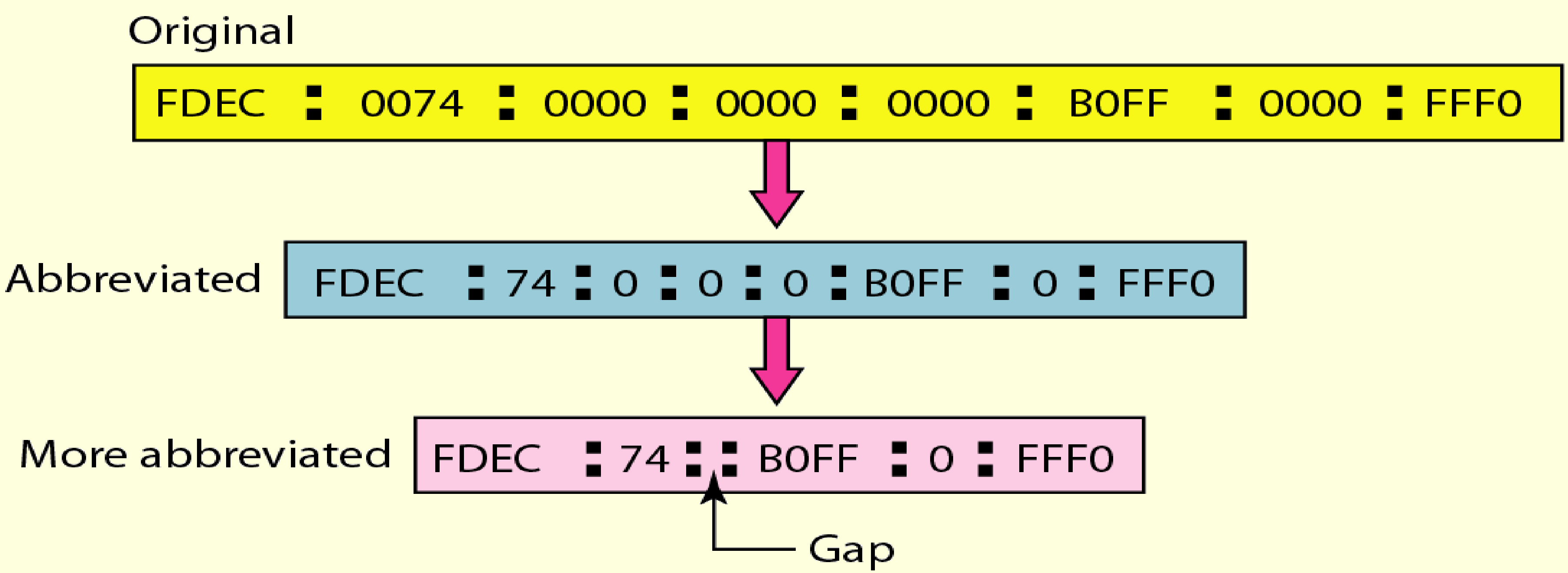
Structure

- Consists of 16 bytes (16*8 ?)
- **128** bits is divided into **eight sections**
- Each 2 bytes in length
- **Two bytes** in hexadecimal notation requires **four hexadecimal** digits



Abbreviated IPv6 addresses

- 0074 can be written as 74
- OOOF as F
- 0000 as O
- 3210 ?



Example: Expand the address 0:15::1:12:1213 to its original.

```
xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
   0:  15:                 :   1:  12:1213
```

0000:0015:0000:0000:0000:0001:0012:1213

Address Space

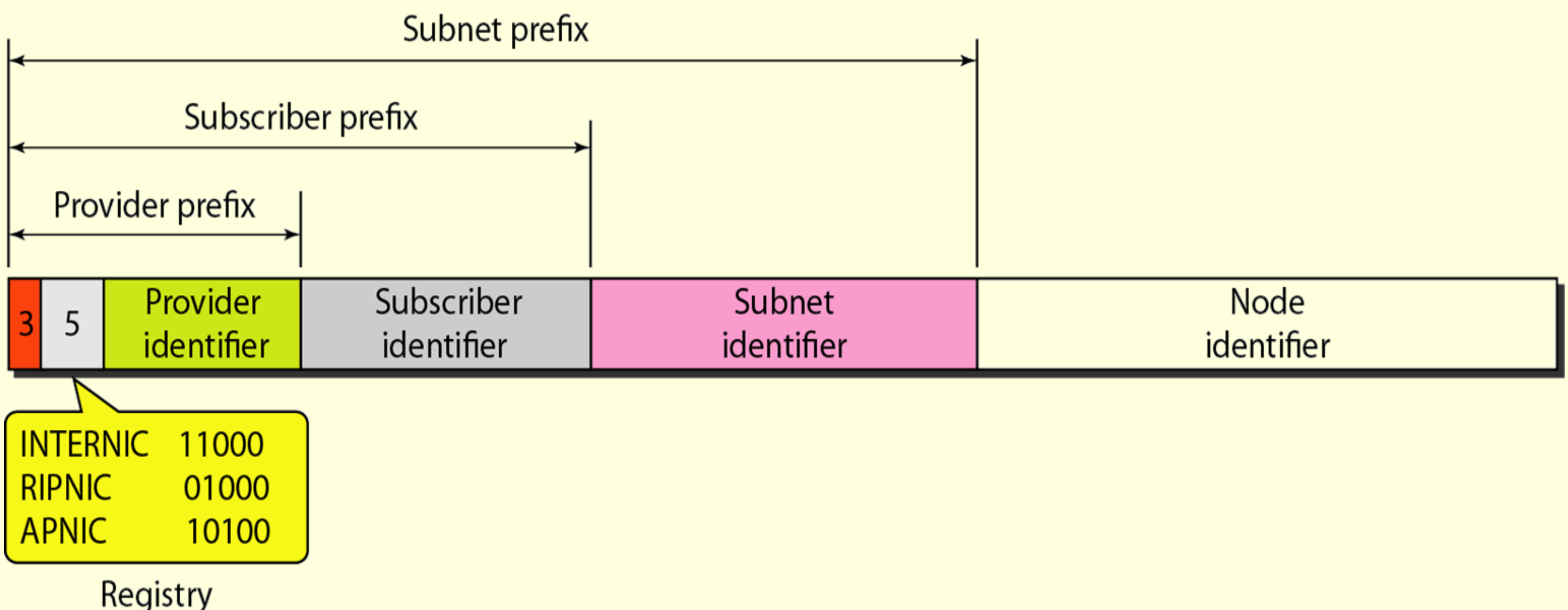
Type Prefix	*Type*	*Fraction*
0000 0000	Reserved	1/256
0000 0001	Unassigned	1/256
0000 001	ISO network addresses	1/128
0000 010	IPX (Novell) network addresses	1/128
0000 011	Unassigned	1/128
0000 1	Unassigned	1/32
0001	Reserved	1/16
001	Reserved	1/8
010	**Provider-based unicast addresses**	**1/8**

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 Addresses

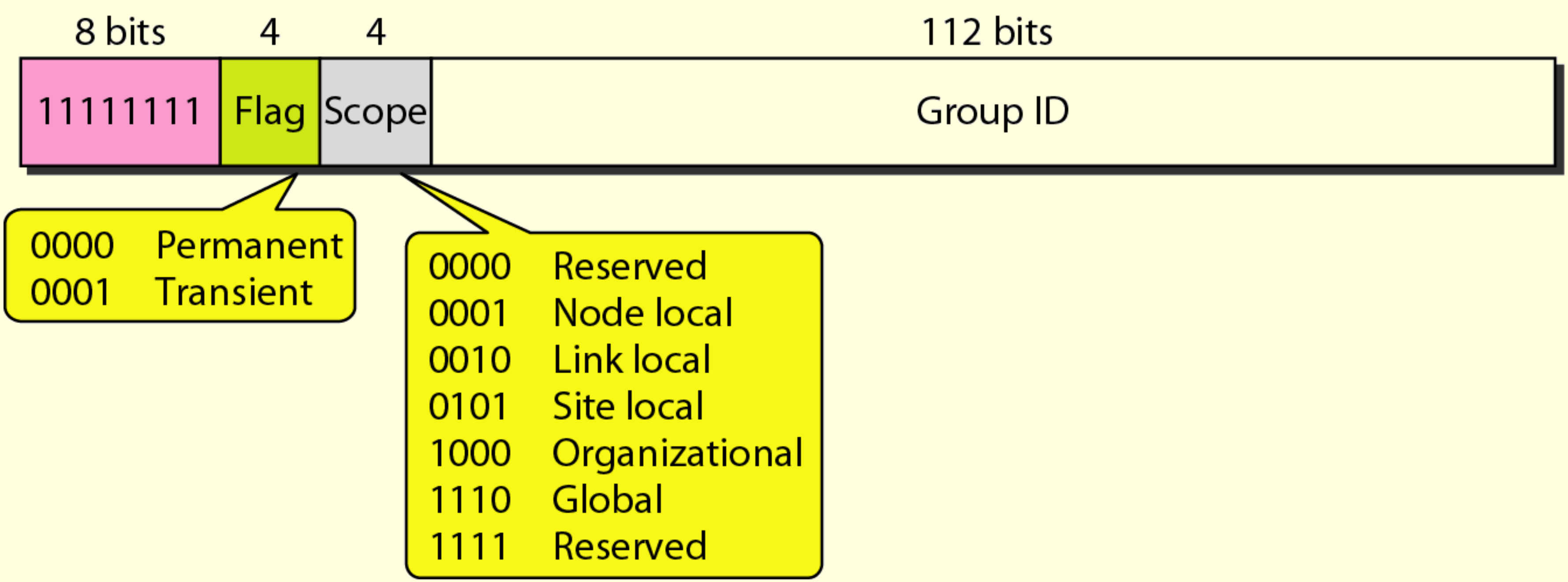
- Single computer .
- Two types of unicast addresses
  - ✓ Geographically based
  - ✓ Provider-based
- Fields for provider :
  - ➢ Type identifier :3-bits
  - ➢ Registry identifier : 5-bit
    - ✓ INTERNIC : North America (11000)
    - ✓ RIPNIC: European registration (01000)
    - ✓ APNIC :Asian (10100)

- Provider identifier : 16-bit
- Subscriber identifier : 24-bit
- Subnet identifier :32-bit
- Node identifier :48 bits



❑ Multicast Addresses

- Group of hosts

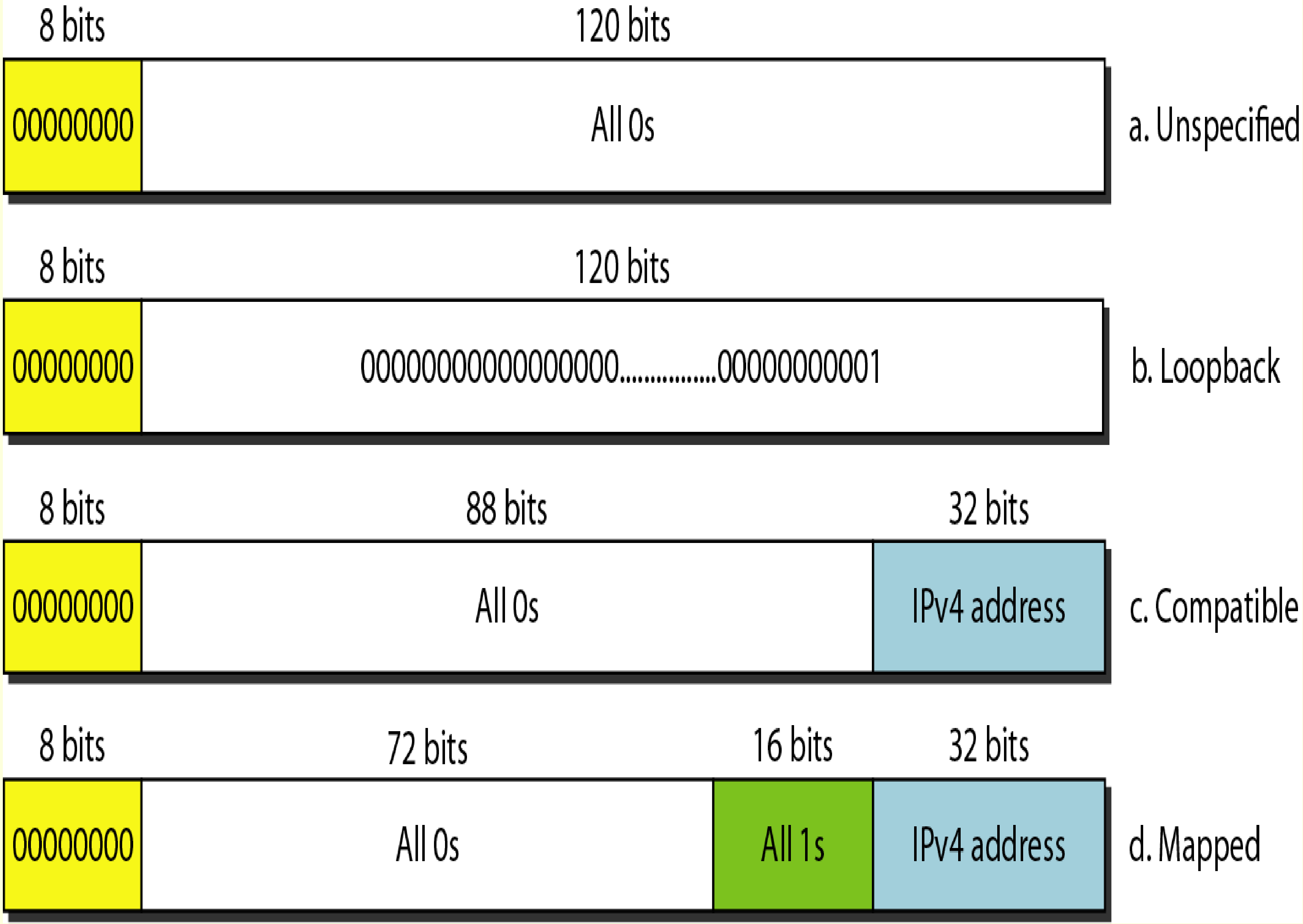


- Any cast address

- A group of nodes & destined to only one of the members
- Usually to the nearest one

❑Reserved Addresses

- Unspecified address :host does not know its own address
- loopback address :host to test itself without going into the network
- A compatible address :transition from IPv4 to IPv6
- A mapped address



8 bits
120 bits
00000000
All 0s
a. Unspecified
8 bits
120 bits
00000000
00000000000000000..............00000000001
b. Loopback
8 bits
88 bits
32 bits
00000000
All 0s
IPv4 address
c. Compatible
8 bits
72 bits
16 bits
32 bits
00000000
All 0s
All 1s
IPv4 address
d. Mapped

❑ Local Addresses

- provide addressing for private networks
- Two type :
  - ✓ A link local address is used in an isolated subnet
  - ✓ Site local address is used in an isolated site with several subnets