Subnetting/Supernetting and Classless Addressing

Address Depletion

- What is Address Deletion Problem in Classful Addressing?

Solutions:

Short term Solution

- Use of Private Addresses
- Subnetting
- Supernetting
- Use of NAT and DHCP
- Classless Addressing

Long term Solution

- IPv6

Prefix Length: Slash Notation

- In classless addressing, Prefix length need to be passed separately.
- Prefix length is added to the address.
- Notation is informally referred as *slash notation* and formally CIDR (*Classless Inter-domain Routing*)
- In classless addressing, we need to know one of the addresses in the block and the prefix length to define the block.

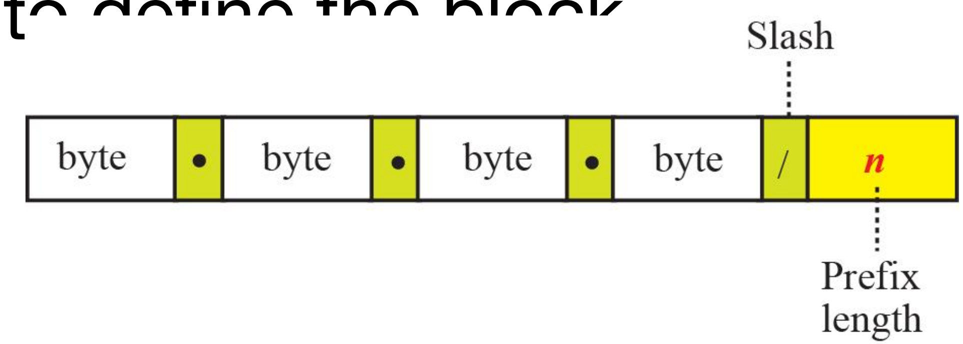
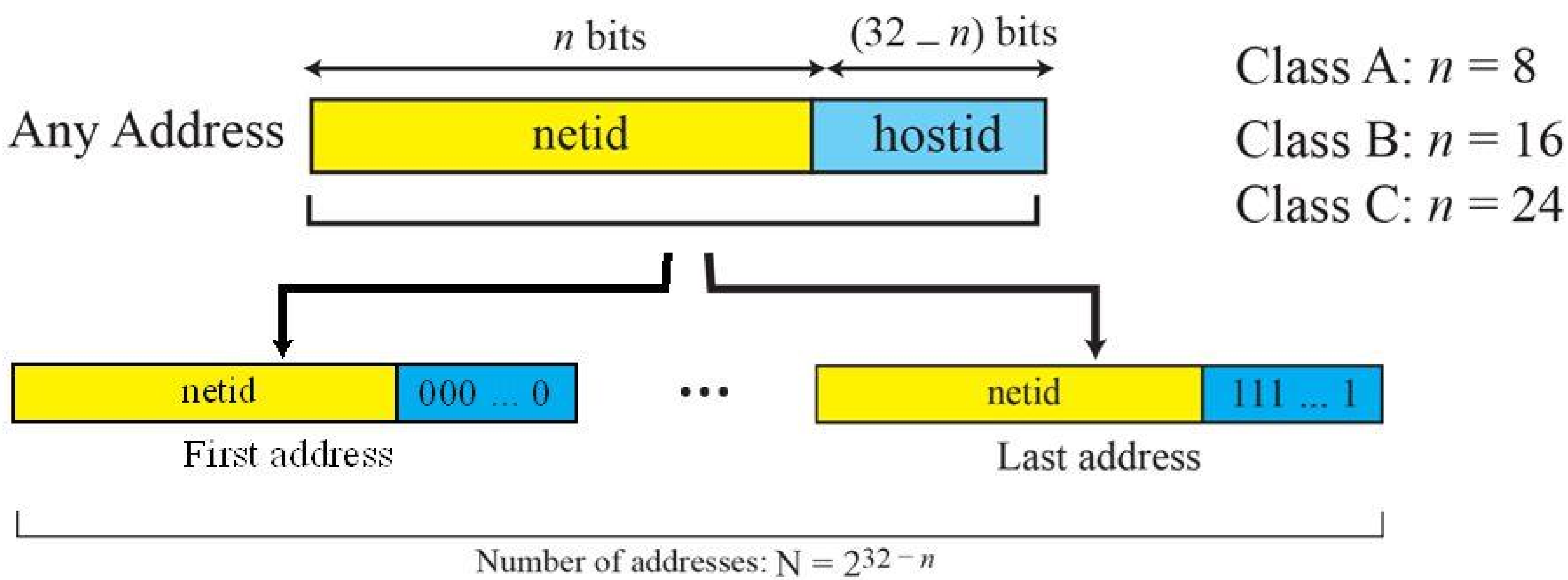


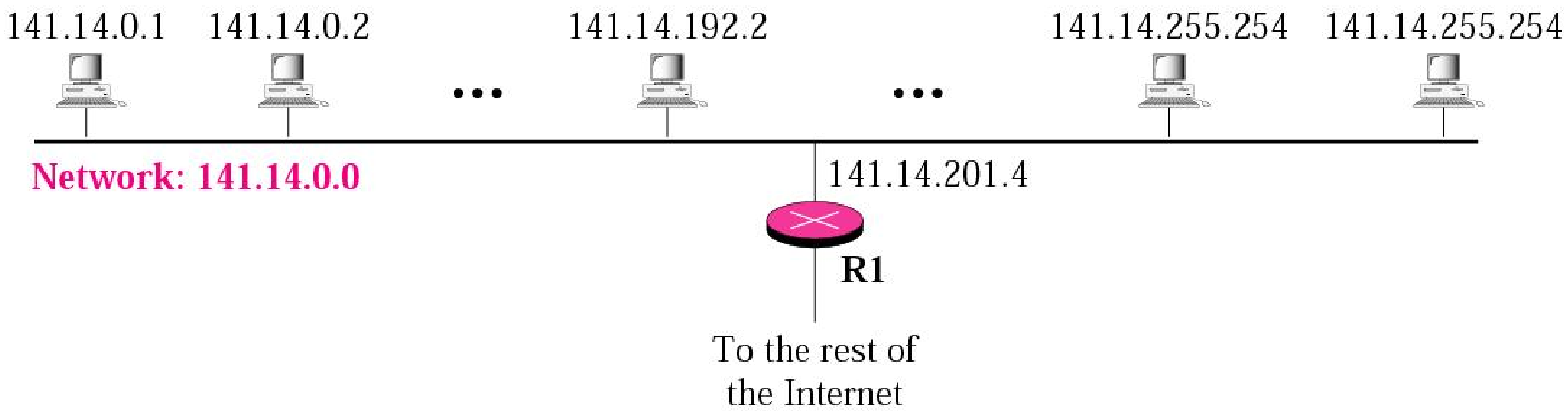
Figure 5.15 *Information extraction in classful addressing*



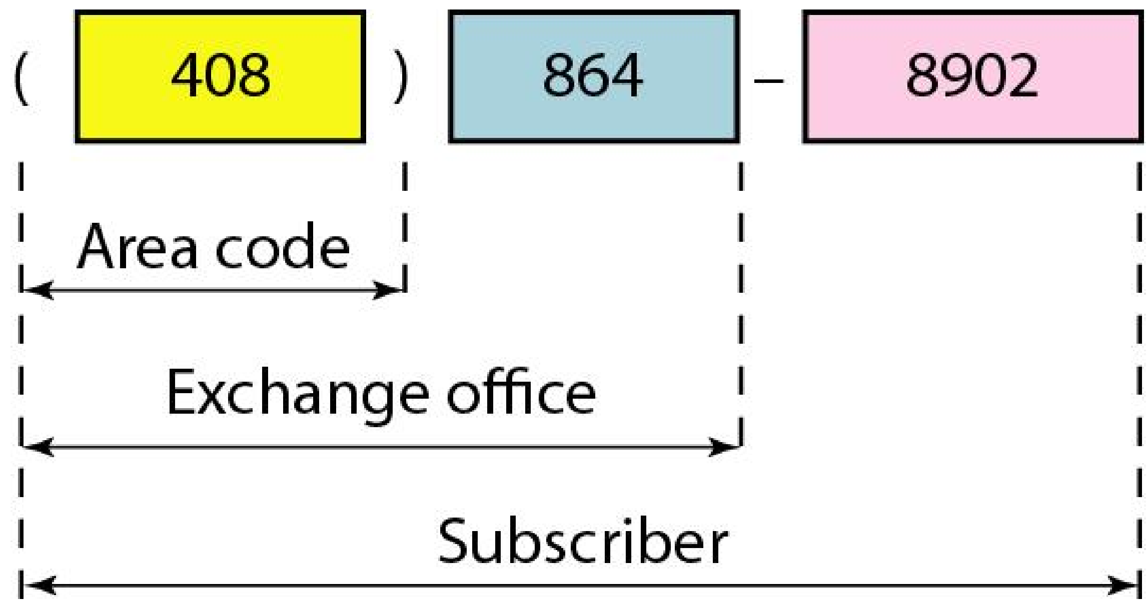
SUBNETTING

IP addresses are designed with two levels of hierarchy.

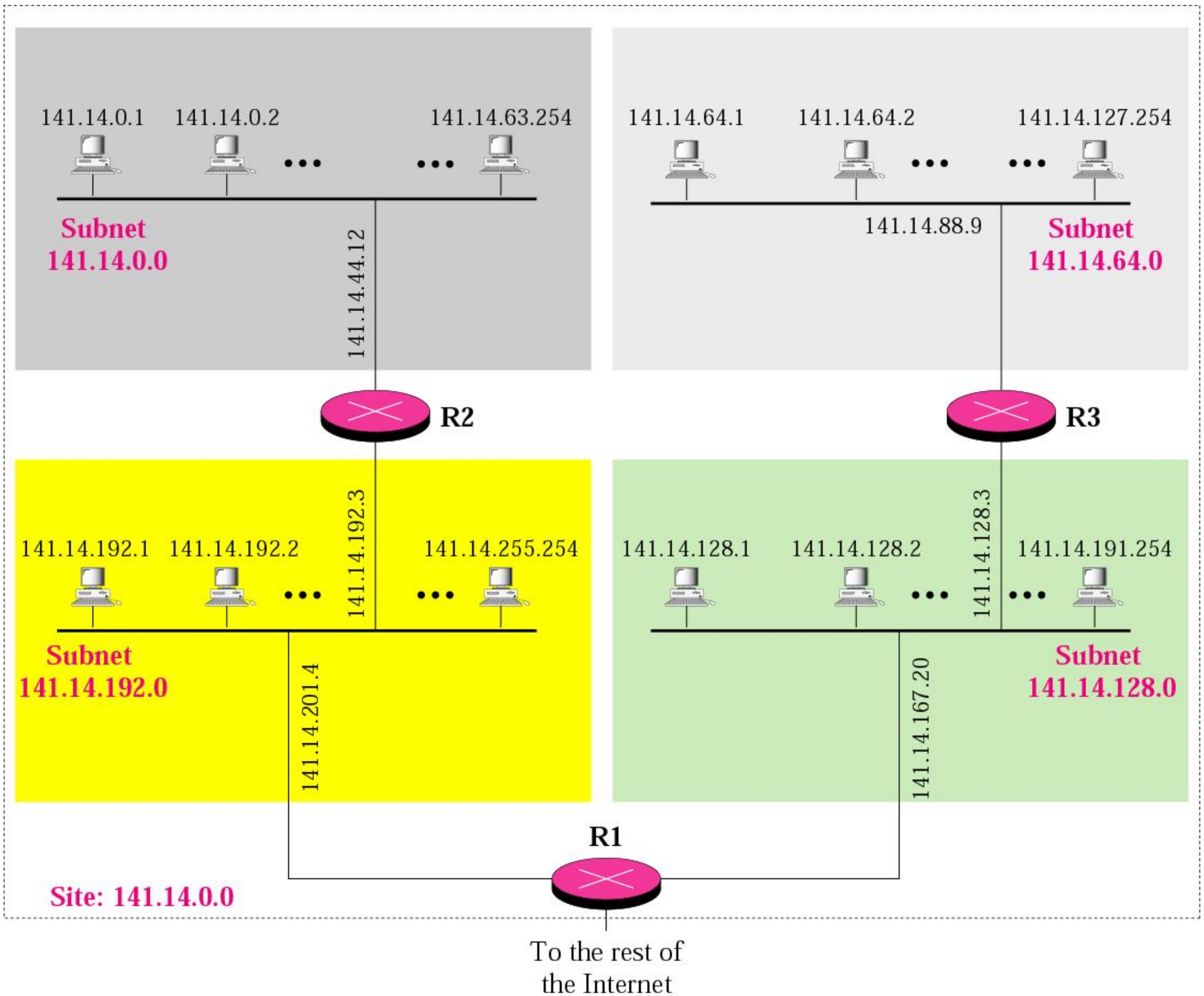
A network with two levels of hierarchy (not subnetted)



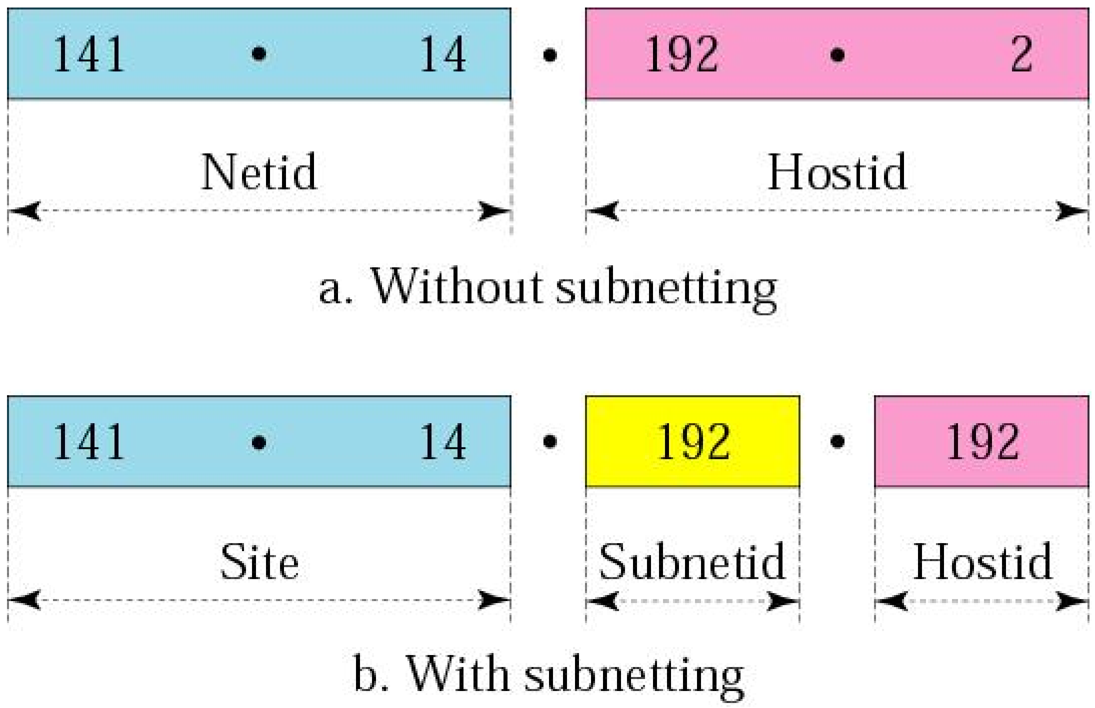
Example of Multi-Level Hierarchy



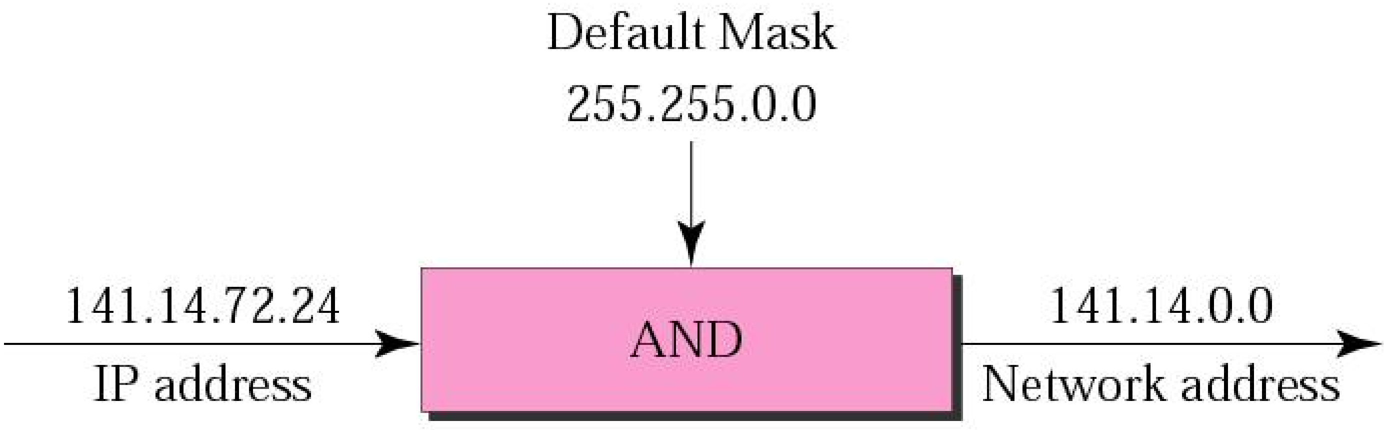
A network with three levels of hierarchy (subnetted)



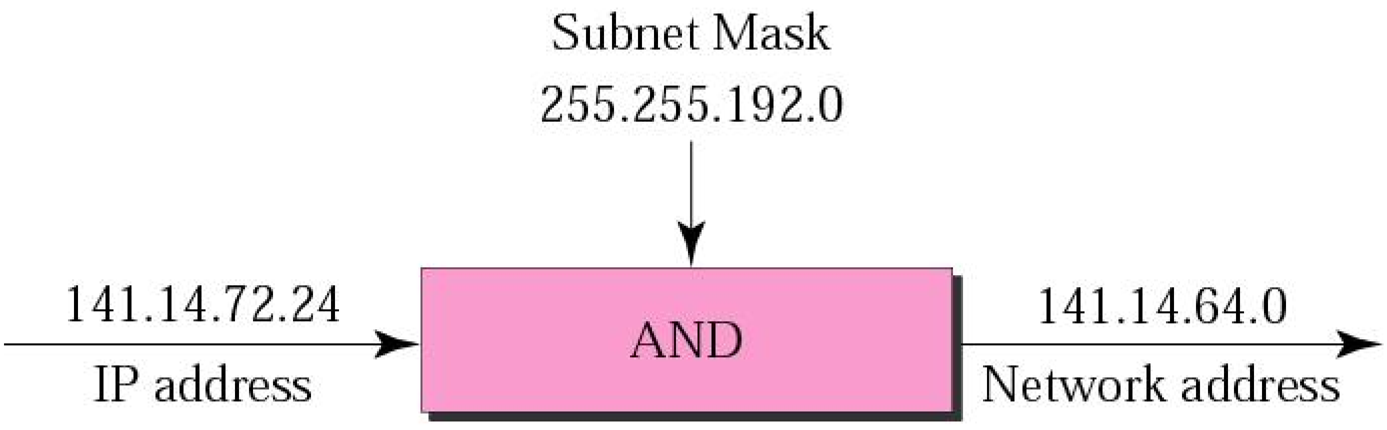
Addresses in a network with and without subnetting



Default mask and subnet mask



a. Without subnetting



b. With subnetting

Finding the Subnet Address

Given an IP address, we can find the subnet address the same way we found the network address in the previous chapter. We apply the mask to the address.

Straight Method

In the straight method, we use binary notation for both the address and the mask and then apply the AND operation to find the subnet address.

Example 1

What is the subnetwork address if the destination address is 200.45.34.56 and the subnet mask is 255.255.240.0?

Solution

11001000 00101101 00100010 00111000

11111111 11111111 1111**0000** **00000000**

11001000 00101101 0010**0000** **00000000**

The subnetwork address is **200.45.32.0**.

Short-Cut Method

** If the byte in the mask is 255, copy the byte in the address.

** If the byte in the mask is 0, replace the byte in the address with 0.

** If the byte in the mask is neither 255 nor 0, we write the mask and the address in binary and apply the AND operation.

Example 2

What is the subnetwork address if the destination address is 19.30.80.5 and the mask is 255.255.192.0?

Solution

Figure 5-6

Example 2

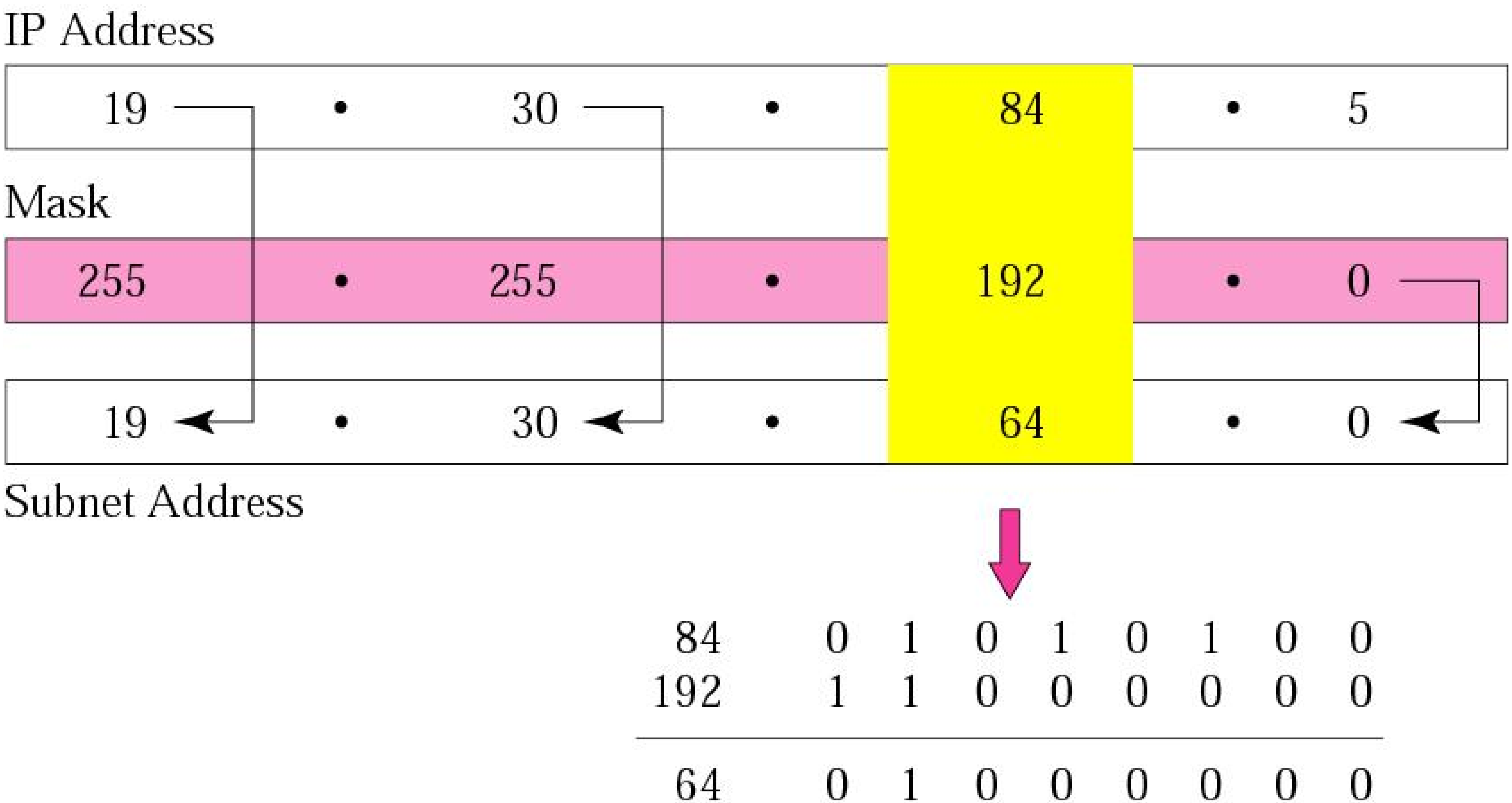
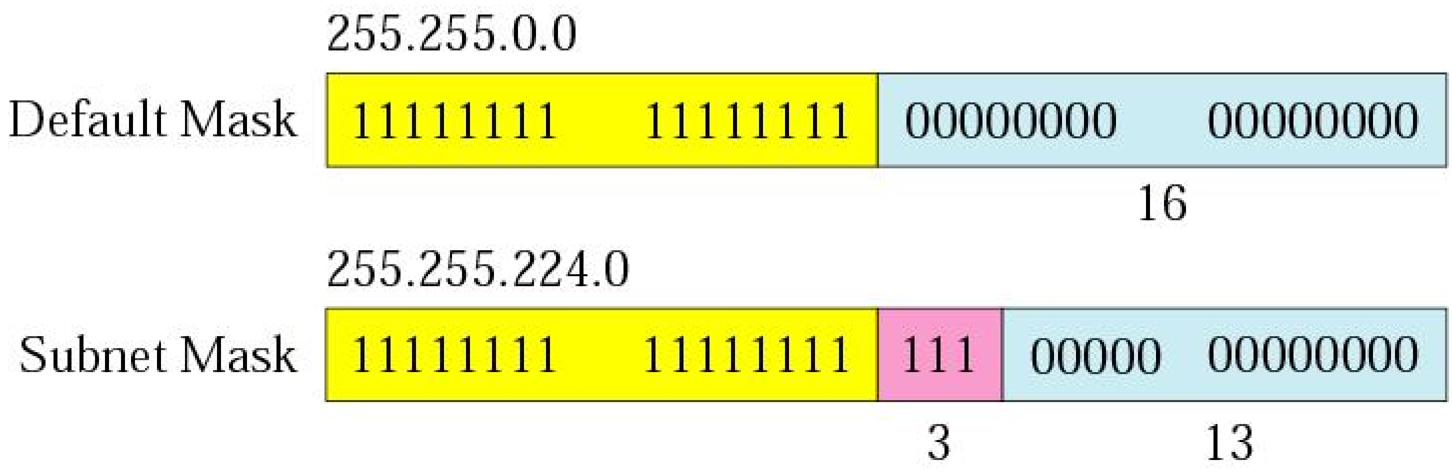


Figure 5-7

Comparison of a default mask and a subnet mask



The number of subnets must be a power of 2.

Example 3

A company is granted the site address 201.70.64.0 .The company needs six subnets. Design the subnets.

Solution

The number of 1s in the default mask is 24 (class C).

Solution (Continued)

The company needs six subnets. This number 6 is not a power of 2. The next number that is a power of 2 is 8 (2^3). We need 3 more 1s in the subnet mask. The total number of 1s in the subnet mask is 27 (24 + 3).

The total number of 0s is 5 (32 – 27). The mask is

Solution (Continued)

<u>11111111 11111111 11111111</u> <u>111</u>00000

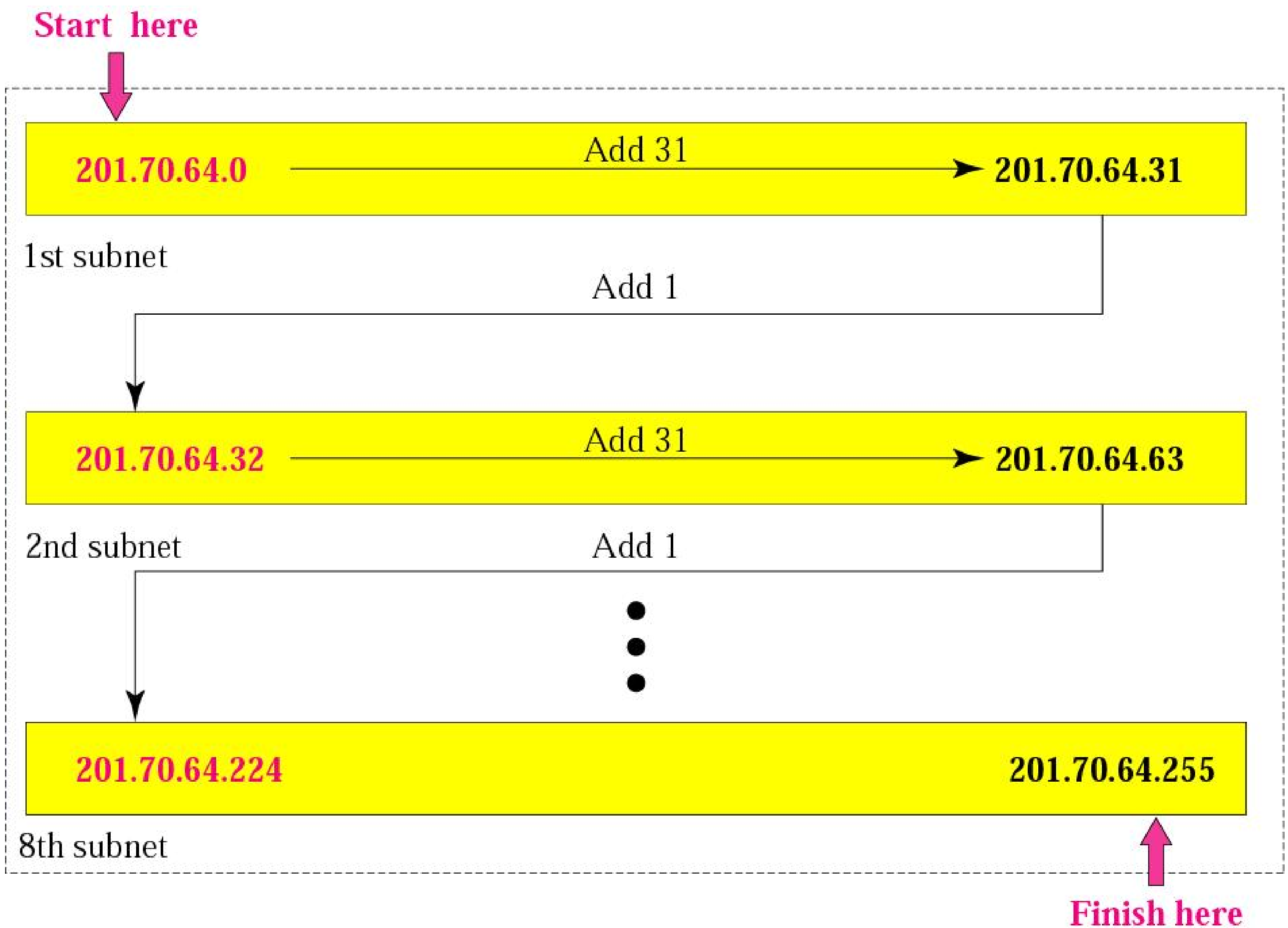
or

255.255.255.224

The number of subnets is 8.

The number of addresses in each subnet is 2^5 (5 is the number of 0s) or 32.

Example 3


Start here
201.70.64.0
Add 31
201.70.64.31
1st subnet
Add 1
201.70.64.32
Add 31
201.70.64.63
2nd subnet
Add 1
201.70.64.224
201.70.64.255
8th subnet
Finish here

Example 4

A company is granted the site address 181.56.0.0. The company needs 1000 subnets. Design the subnets.

Solution

The number of 1s in the default mask is 16 (class B).

Solution (Continued)

The company needs 1000 subnets. This number is not a power of 2. The next number that is a power of 2 is 1024 (2^{10}). We need 10 more 1s in the subnet mask.

The total number of 1s in the subnet mask is 26 (16 + 10).

The total number of 0s is 6 (32 – 26).

Solution (Continued)

The mask is

$$\underline{11111111\ 11111111\ 11111111}\ \underline{11}000000$$

or

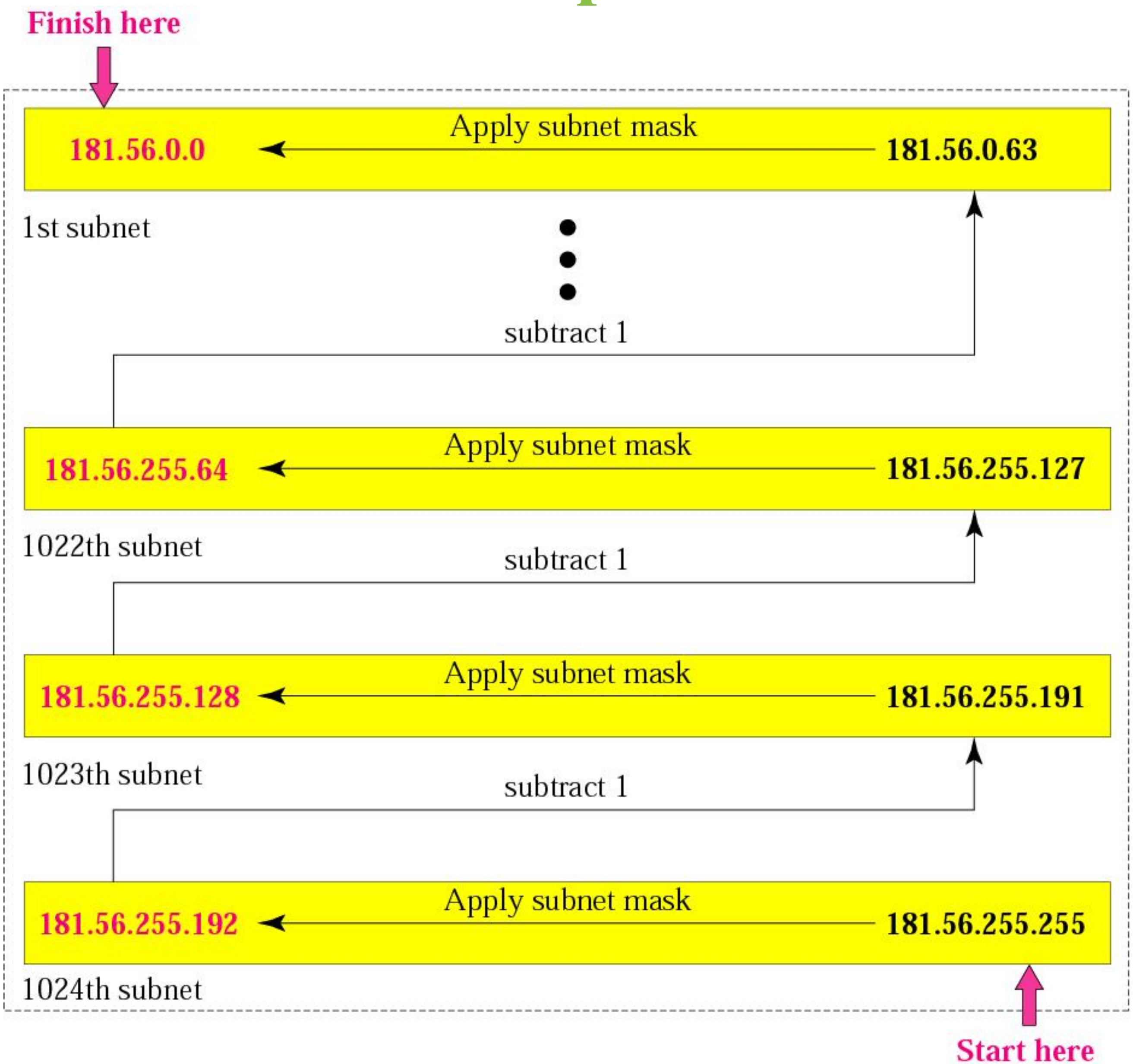
255.255.255.192.

The number of subnets is 1024.

The number of addresses in each subnet is 2^6 (6 is the number of 0s) or 64.

See Figure 5.9

Example 4



Finish here
Apply subnet mask
181.56.0.0
181.56.0.63
1st subnet
subtract 1
Apply subnet mask
181.56.255.64
181.56.255.127
1022th subnet
subtract 1
Apply subnet mask
181.56.255.128
181.56.255.191
1023th subnet
subtract 1
Apply subnet mask
181.56.255.192
181.56.255.255
1024th subnet
Start here

Example 5

Network address given to an organization is 200.50.100.0. After subnetting new Mask is /27.

- Find number of subnets and subnet address of each subnet.
- Find number of IP address in each subnet.

Solution 5

- Initial mask : 24
- New mask is /27
- No of bits used for subnetting = $27-24 = 3$
- Total Subnets created = $2^3 = 8$
- No. of IP Address in each subnet = $2^{32-27} = 2^5 = 32$

Solution 5

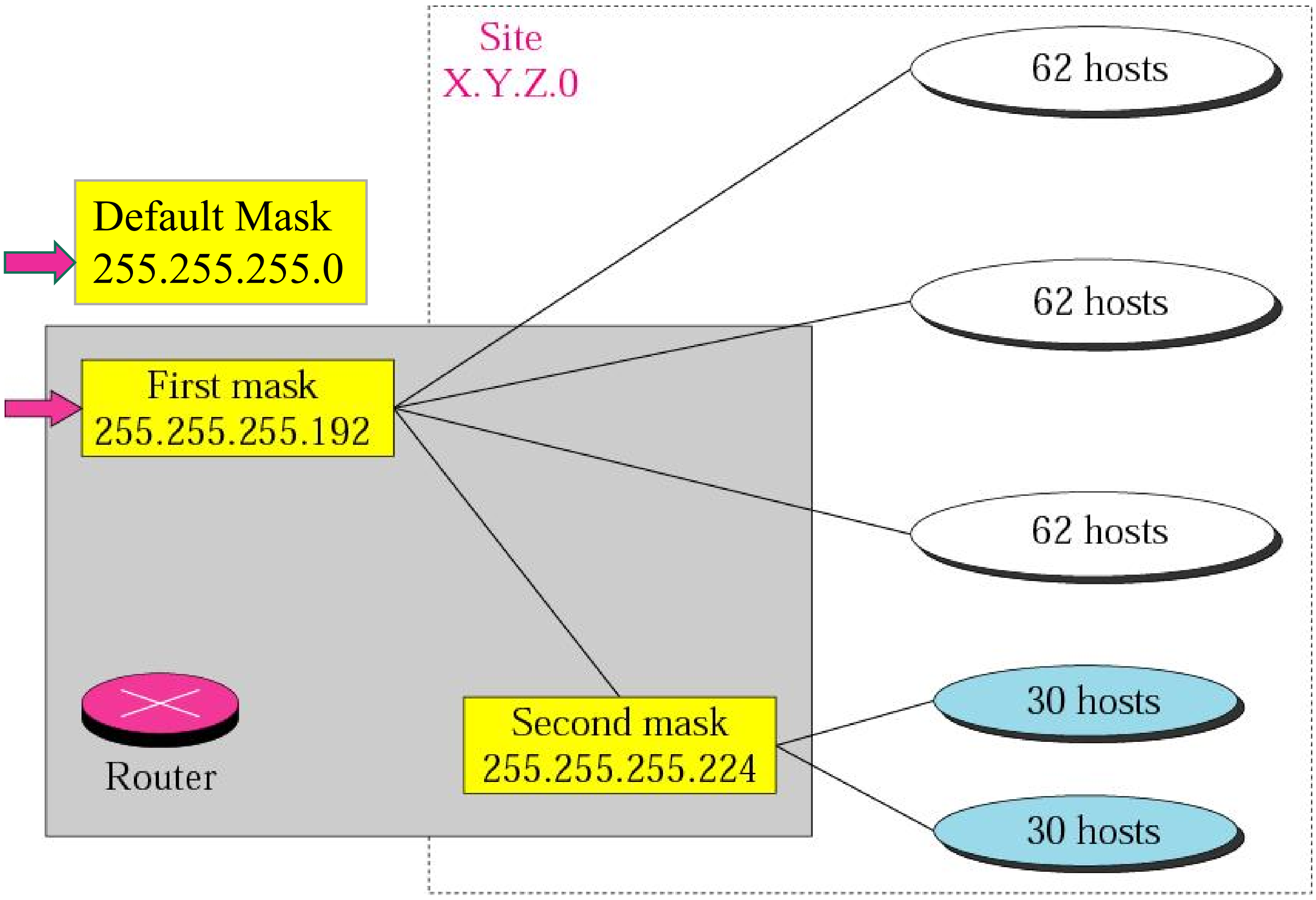
- Starting Address of 1st Subnet =200.50.100.0
- Starting Address of 2nd Subnet =200.50.100.32
- Starting Address of 3rd Subnet =200.50.100.64
- Starting Address of 4th Subnet =200.50.100.96
- Starting Address of 5th Subnet =200.50.100.128
- Starting Address of 6th Subnet =200.50.100.160
- Starting Address of 7th Subnet =200.50.100.192

Example 6

IP address given to an organization is 170.50.100.70. After subnetting Number of valid hosts in each subnet are 4094.

- Find mask of subnets created.
- Find number of subnets and subnet address of each subnet.

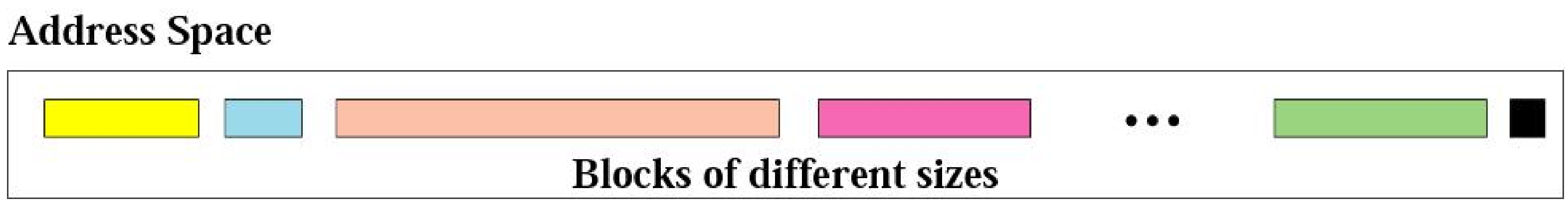
Variable-length subnetting



CLASSLESS ADDRESSING

Figure 5-13

Variable-length blocks



Number of Addresses in a Block

There is only one condition on the number of addresses in a block; it must be a power of 2 (2, 4, 8, . . .).

Beginning Address

The beginning address must be evenly divisible by the number of addresses. For example, if a block contains 4 addresses, the beginning address must be divisible by 4.

If the block has less than 256 addresses, we need to check only the rightmost byte. If it has less than 65,536 addresses, we need to check only the two rightmost bytes, and so on.

Example 9

Which of the following can be the beginning address of a block that contains 16 addresses?

205.16.37.32
190.16.42.44
17.17.33.80
123.45.24.52

Solution

The address 205.16.37.32 is eligible because 32 is divisible by 16. The address 17.17.33.80 is eligible because 80 is divisible by 16.

Example 10

Which of the following can be the beginning address of a block that contains 1024 addresses?

205.16.37.32
190.16.42.0
17.17.32.0
123.45.24.52

Solution

To be divisible by 1024, the rightmost byte of an address should be 0 and the second rightmost byte must be divisible by 4. Only the address 17.17.32.0 meets this condition.

Slash notation or CIDR notation

A.B.C.D/*n*

Slash notation is also called
CIDR
notation.

Example 11

A small organization is given a block with the beginning address and the prefix length **205.16.37.24/29** (in slash notation). What is the range of the block?

Solution

The beginning address is 205.16.37.24. To find the last address we keep the first 29 bits and change the last 3 bits to 1s.

Beginning:**11001111 00010000 00100101 00011**000

Ending : **11001111 00010000 00100101 00011**111

There are only 8 addresses in this block.

Example 12

We can find the range of addresses in Example 11 by another method. We can argue that the length of the suffix is 32 – 29 or 3. So there are $2^3 = 8$ addresses in this block. If the first address is 205.16.37.24, the last address is 205.16.37.31 (24 + 7 = 31).

A block in classes A, B, and C can easily be represented in slash notation as

A.B.C.D/ *n*

where *n* is either 8 (class A), 16 (class B), or 24 (class C).

Example 13

What is the network address if one of the addresses is 167.199.170.82/27?

Solution

The prefix length is 27, which means that we must keep the first 27 bits as is and change the remaining bits (5) to 0s. The 5 bits affect only the last byte. The last byte is 01010010. Changing the last 5 bits to 0s, we get 01000000 or 64. The network address is 167.199.170.64/27.

Example 14

An organization is granted the block 130.34.12.64/26. The organization needs to have four subnets. What are the subnet addresses and the range of addresses for each subnet?

Solution

The suffix length is 6. This means the total number of addresses in the block is 64 (2^6). If we create four subnets, each subnet will have 16 addresses.

Solution (Continued)

Let us first find the subnet prefix (subnet mask). We need four subnets, which means we need to add two more 1s to the site prefix. The subnet prefix is then /28.

Subnet 1: 130.34.12.64/28 to 130.34.12.79/28.

Subnet 2 : 130.34.12.80/28 to 130.34.12.95/28.

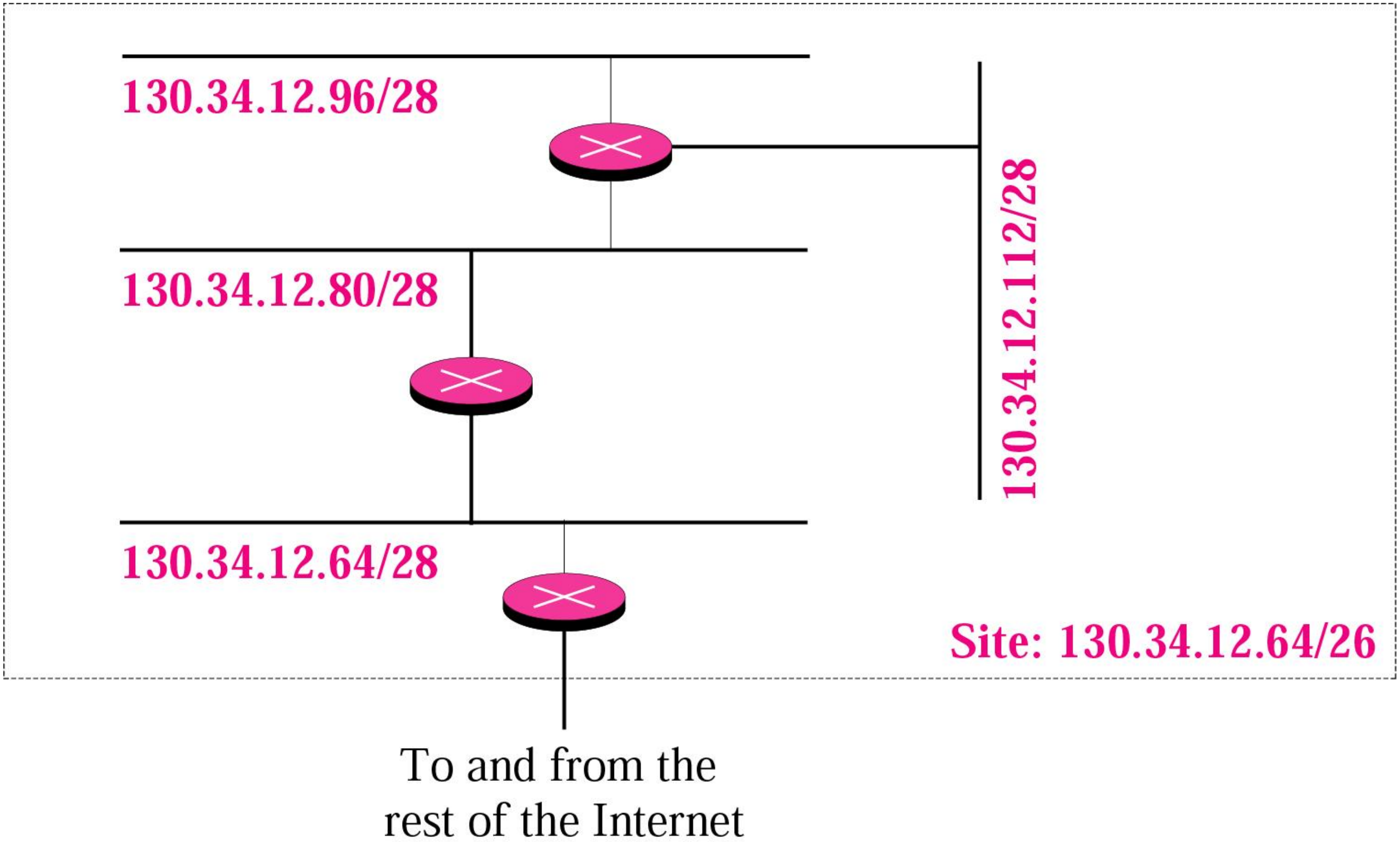
Subnet 3: 130.34.12.96/28 to 130.34.12.111/28.

Subnet 4: 130.34.12.112/28 to 130.34.12.127/28.

See Figure 5.15

Figure 5-15

Example 14



Example 15

- An organization is granted a block of addresses with beginning address 14.24.74.0/24. The organization needs to have 3 blocks of addresses to use in its three subnets as shown below:
  a. One block of 120 addresses.
  b. One block of 60 addresses.
  c. One block of 10 addresses.

Solution

- Total Addresses in block = $2^{32}-2^{24}$ = 256
- first address = 14.24.74.0/24
- Last address = 14.24.74.255/24

a. No. of addresses in first block is not power of 2. We allocate 128 addresses.

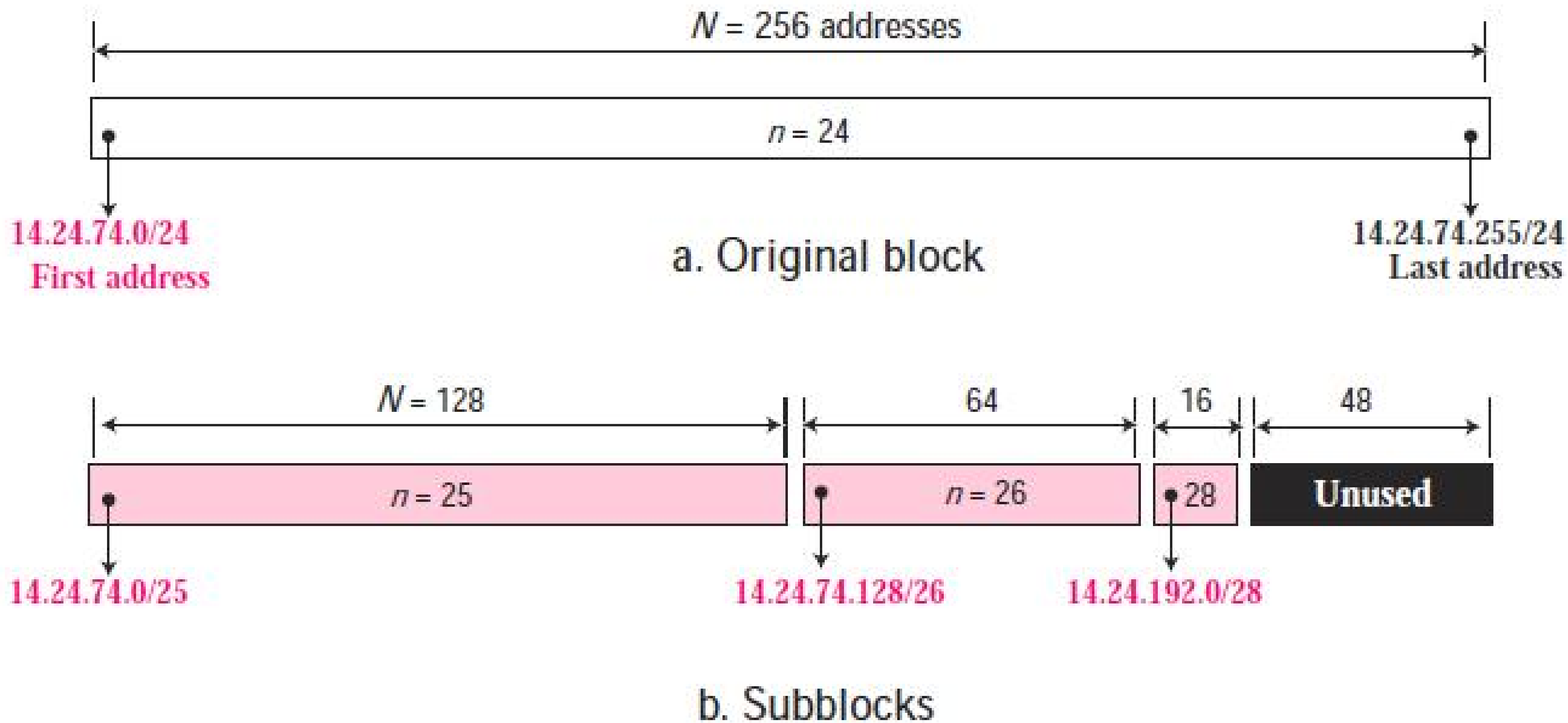
   subnet mask =25

b. No. of addresses in first block is not power of 2. We allocate 64 addresses.

   subnet mask =26

c. No. of addresses in first block is not power of 2. We allocate 16 addresses.

   subnet mask =28



N = 256 addresses
n = 24
14.24.74.0/24
First address
14.24.74.255/24
Last address
a. Original block
N = 128
64
16
48
n = 25
n = 26
28
Unused
14.24.74.0/25
14.24.74.128/26
14.24.192.0/28
b. Subblocks

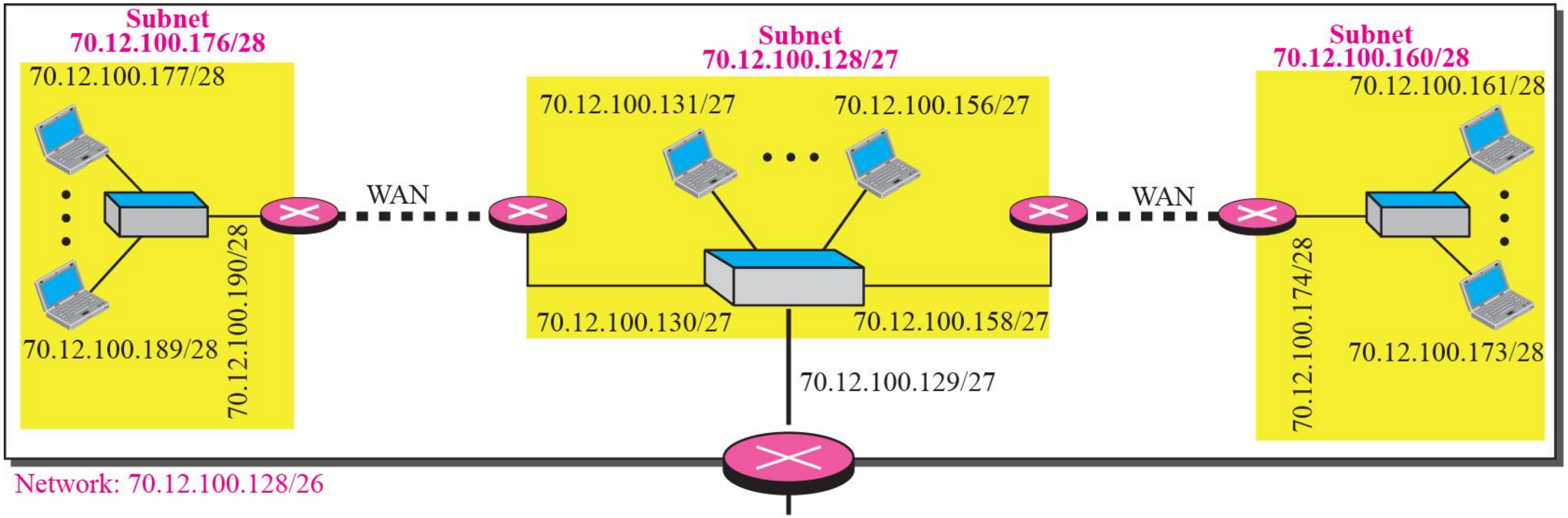
Example 16

Assume a company has three offices: Central, East, and West. The Central office is connected to the East and West offices via private, WAN lines. The company is granted a block of 64 addresses with the beginning address 70.12.100.128/26. The management has decided to allocate 32 addresses for the Central office and divides the rest of addresses between the two other offices.

Central office $N_c = 32$	East office $N_e = 16$	West office $N_w = 16$

follows:

2. We can find the prefix length for each subnetwork:



All addresses from 70.12.100.128 to 70.12.100.191
are delivered to this network

Example 17

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

1. The first group has 64 customers; each needs 256 addresses.
2. The second group has 128 customers; each needs 128 addresses.
3. The third group has 128 customers; each needs 64 addresses.

Design the subblocks and give the slash notation for each subblock. Find out how many addresses are still available after these allocations.

Solution

Group 1

For this group, there are 64 customers and each customer needs 256 addresses.

Total addresses = $64 \times 256 = 16{,}384 = 2^{14}$

new mask = 32-14=/18

First address of Group 1 : 190.100.0.0/18

Last address of Group 1 : 190.100.63.255/18

Solution (Continued)

Group 2

For this group, there are 128 customers and each customer needs 128 addresses.

Total addresses = $128 \times 128 = 16{,}384 = 2^{14}$

new mask = 32-14=/18

First address of Group 1 : 190.100.64.0/18

Last address of Group 1 : 190.100.127.255/18

Solution (Continued)

Group 3

For this group, there are 128 customers and each customer needs 64 addresses.

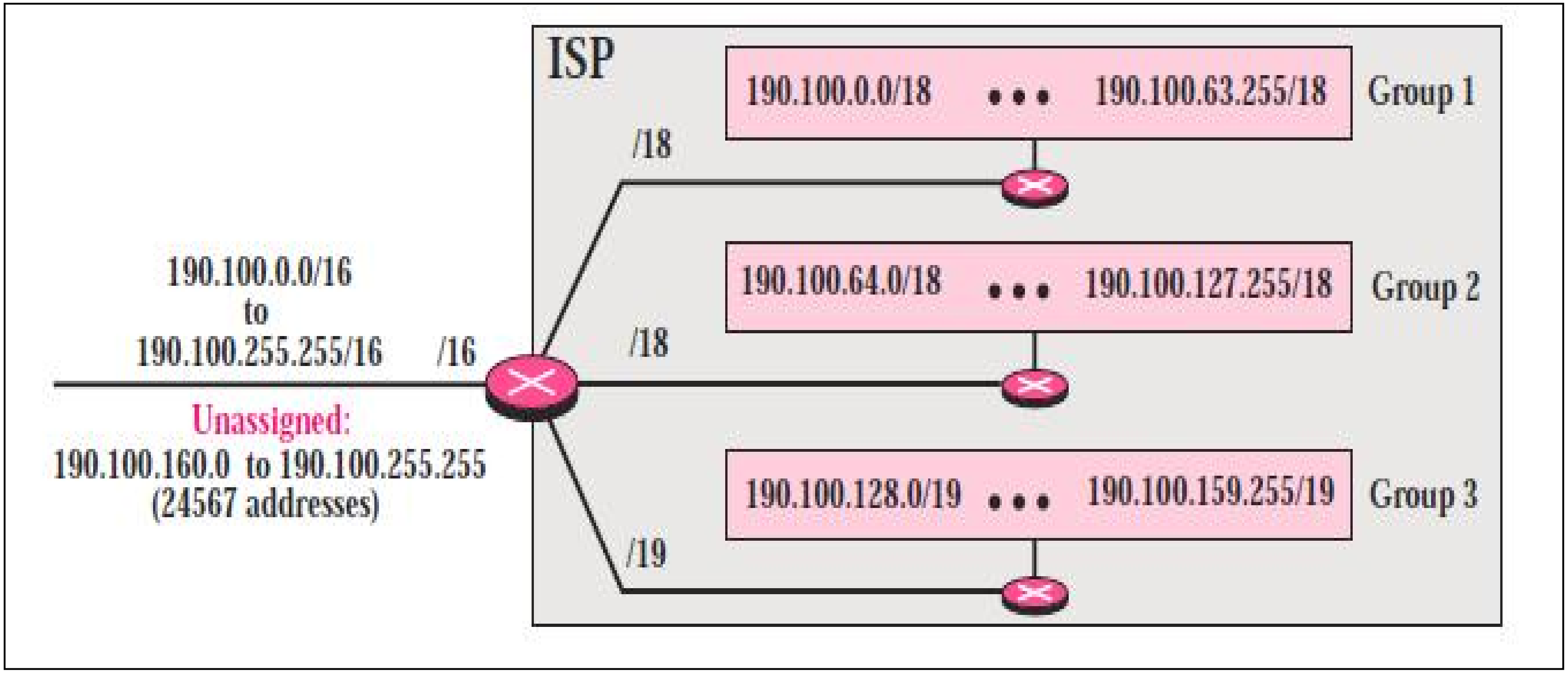
Total addresses = $128 \times 64 = 8192 = 2^{13}$

new mask = 32-13=/19

First address of Group 1 : 190.100.128.0/19

Last address of Group 1 : 190.100.159.255/19

Step 1:


ISP
190.100.0.0/18
190.100.63.255/18
Group 1
/18
190.100.64.0/18
190.100.127.255/18
Group 2
/18
190.100.128.0/19
190.100.159.255/19
Group 3
/19
190.100.0.0/16
to
190.100.255.255/16
/16
Unassigned:
190.100.160.0 to 190.100.255.255
(24567 addresses)

Solution

Group 1

For this group, there are 64 sub blocks .

Old Subnet mask = /18

New subnet mask = $18+\log(2^6)=18+6=24$

01: 190.100.0.0/24 → 190.100.0.255/24

02: 190.100.1.0/24 → 190.100.1.255/24

……………………………………..

64: 190.100.63.0/24 → 190.100.63.255/24

Solution (Continued)

Group 2

For this group, there are 128 sub blocks .

Old Subnet mask = /18

New subnet mask = 18+log(2^7)=18+7=25

001: 190.100.64.0/25 → 190.100.64.127/25

002: 190.100.64.128/25 → 190.100.64.255/25

003: 190.100.127.128/25 → 190.100.127.255/25

Solution (Continued)

Group 3

For this group, there are 128 sub blocks .

Old Subnet mask = /19

New subnet mask = 19+log(2^7)=19+7=26

001:190.100.128.0/26 → 190.100.128.63/26

002:190.100.128.64/26 → 190.100.128.127/26

……………………………

128:190.100.159.192/26 → 190.100.159.255/26

Step 2:

Group: $n = 18$

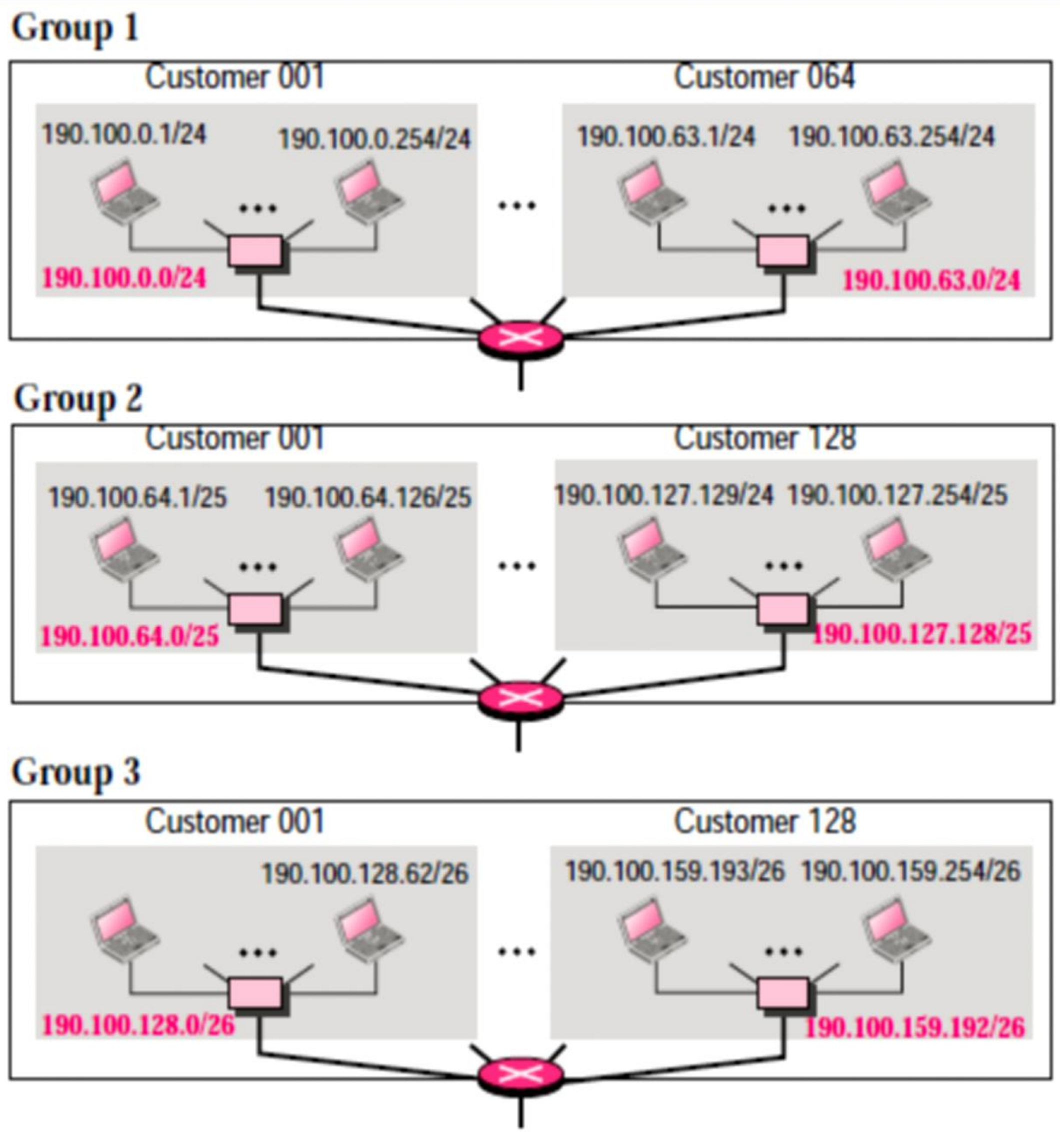
Subnet: $n = 18 + \log_2 (16385/256) = 24$

Group: $n = 18$

Subnet: $n = 18 + \log_2 (16385/128) = 25$

Group: $n = 19$

Subnet: $n = 19 + \log_2 (8192/64) = 26$



Solution (Continued)

Number of granted addresses: 65,536

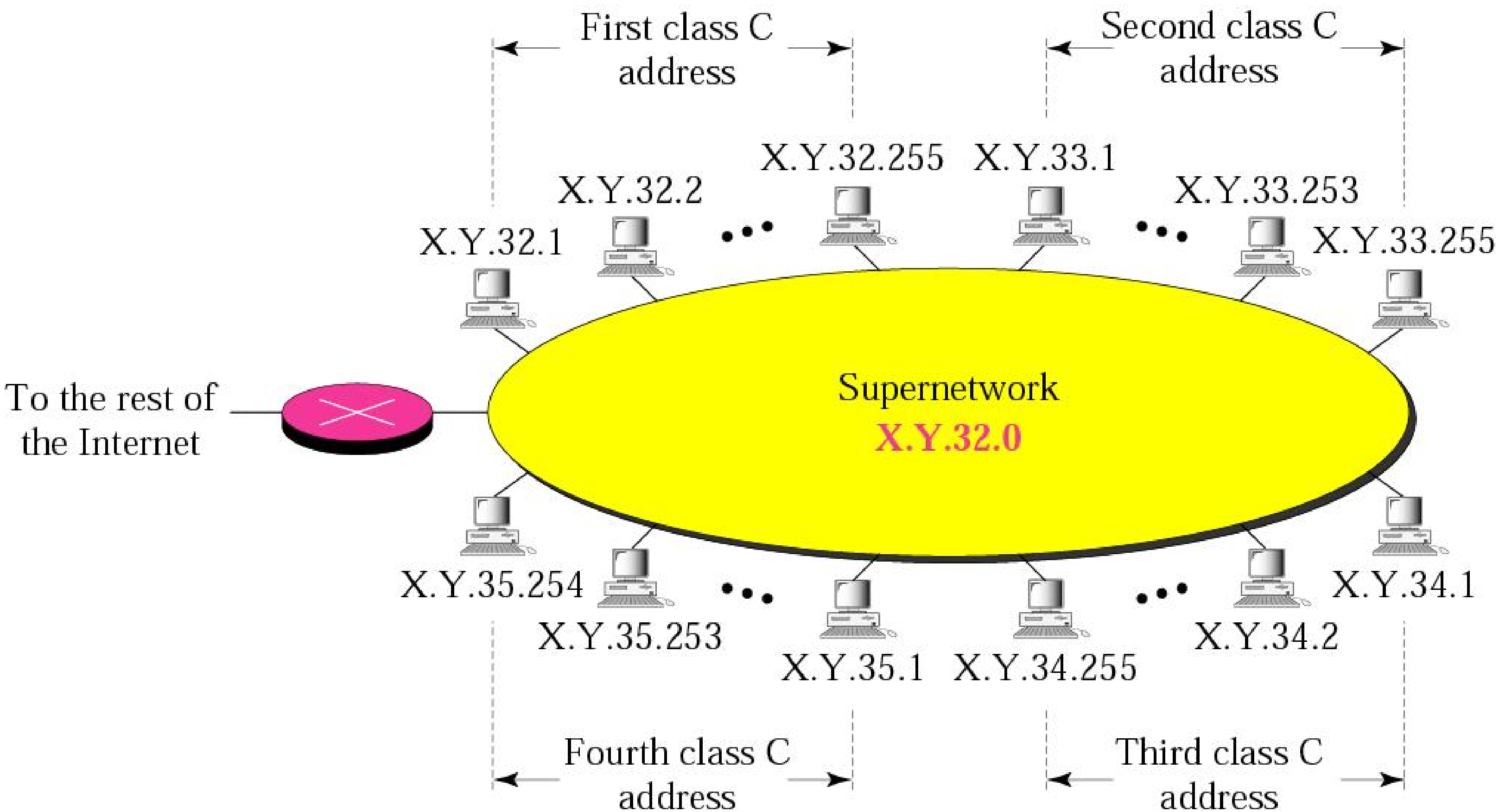
Number of allocated addresses: 40,960

Number of available addresses: 24,576

SUPERNETTING

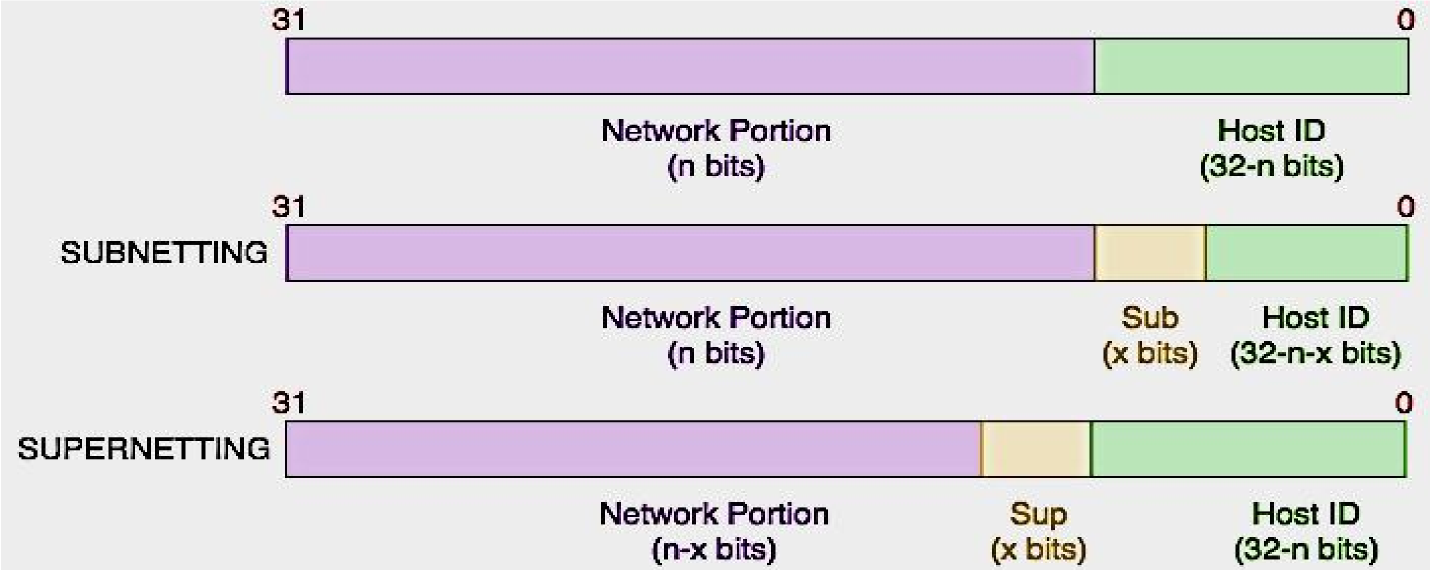
(also referred as Summarization, Aggregation)

A supernetwork



What is Supernetting?

- aggregating networks together to form a larger network



Why Supernetting?

- **The main purpose of supernetting is reducing the size of the routing table on routers**
- It saves memory and processing resources on routing devices.
- also helped slow down the exhaustion of IP addresses through the use of Classless Inter-Domain Routing (CIDR).

Rules: (For Class C Addresses)

** The number of blocks must be a power of 2 (1, 2, 4, 8, 16, . . .).

** The blocks must be contiguous in the address space (no gaps between the blocks).

** The third byte of the first address in the superblock must be evenly divisible by the number of blocks. In other words, if the number of blocks is *N*, the third byte must be divisible by *N*.

Example 5

A company needs 600 addresses. Which of the following set of class C blocks can be used to form a supernet for this company?

- **198.47.32.0 198.47.33.0 198.47.34.0**
- **198.47.32.0 198.47.42.0 198.47.52.0 198.47.62.0**
- **198.47.31.0 198.47.32.0 198.47.33.0 198.47.34.0**
- **198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0**

Solution

1: No, there are only three blocks.

2: No, the blocks are not contiguous.

3: No, 31 in the first block is not divisible by 4.

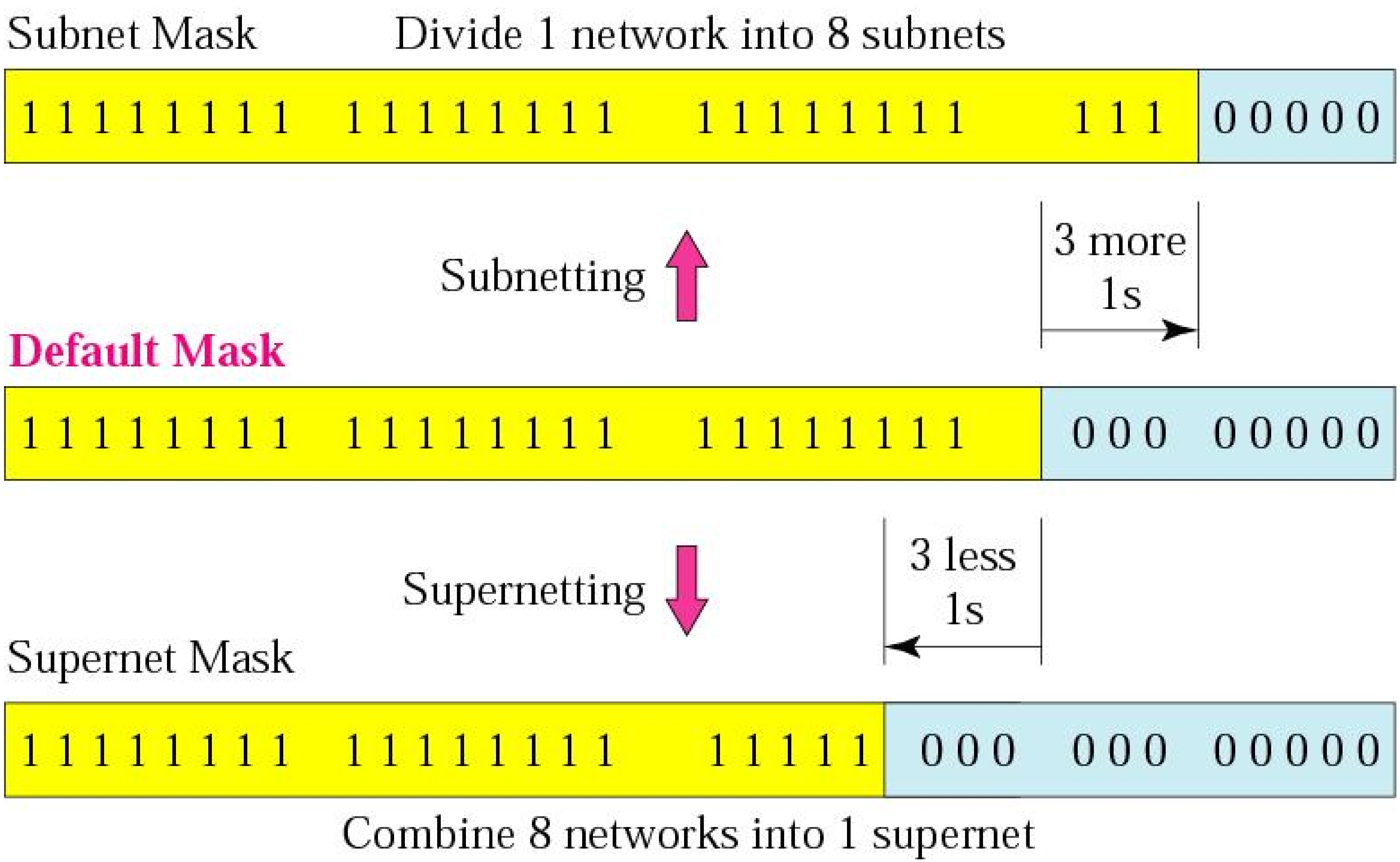
4: Yes, all three requirements are fulfilled.

***In subnetting,
we need the first address of the subnet and the subnet mask to define the range of addresses.***

**In supernetting,
we need the first address of
the supernet
and the supernet mask to
define the range of addresses.**

Figure 5-12

Comparison of subnet, default, and supernet masks



Example 6

We need to make a supernetwork out of 16 class C blocks. What is the supernet mask?

Solution

We need 16 blocks. For 16 blocks we need to change four 1s to 0s in the default mask. So the mask is

11111111 11111111 1111**0000** 00000000

or

255.255.240.0

Example 7

A supernet has a first address of 205.16.32.0 and a supernet mask of 255.255.248.0. A router receives three packets with the following destination addresses:

205.16.37.44

205.16.42.56

205.17.33.76

Which packet belongs to the supernet?

Solution

We apply the supernet mask to see if we can find the beginning address.

205.16.37.44 AND 255.255.248.0 → 205.16.32.0

205.16.42.56 AND 255.255.248.0 → 205.16.40.0

205.17.33.76 AND 255.255.248.0 → 205.17.32.0

Only the first address belongs to this supernet.

Example 8

A supernet has a first address of 205.16.32.0 and a supernet mask of 255.255.248.0. How many blocks are in this supernet and what is the range of addresses?

Solution

The supernet has 21 1s. The default mask has 24 1s. Since the difference is 3, there are 2^3 or 8 blocks in this supernet. The blocks are 205.16.32.0 to 205.16.39.0. The first address is 205.16.32.0. The last address is 205.16.39.255.