Subnetting

IP addresses are designed with 2 levels of hierarchy: network-ID & host-ID

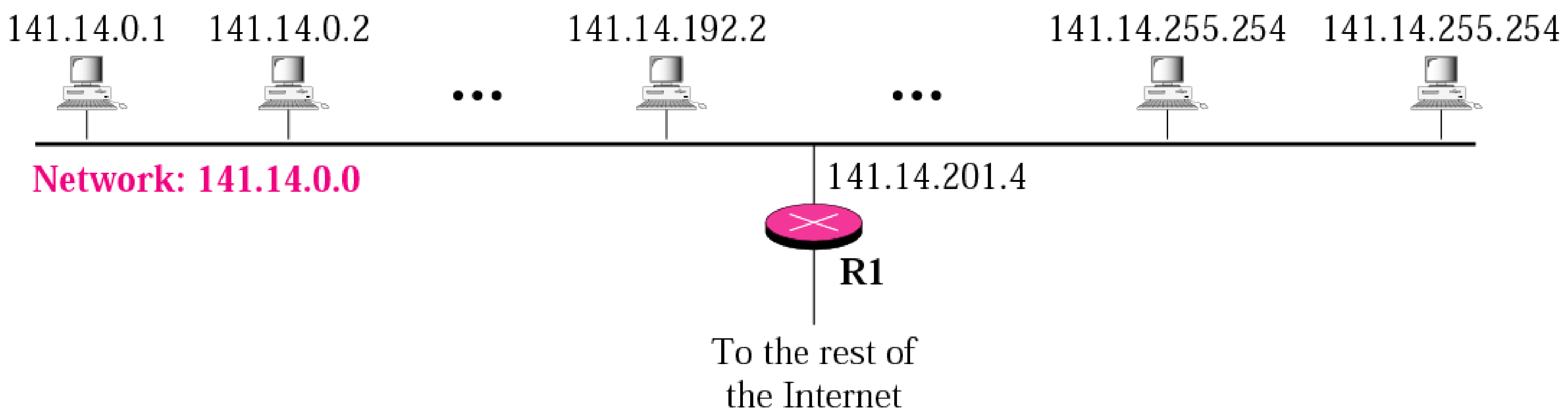
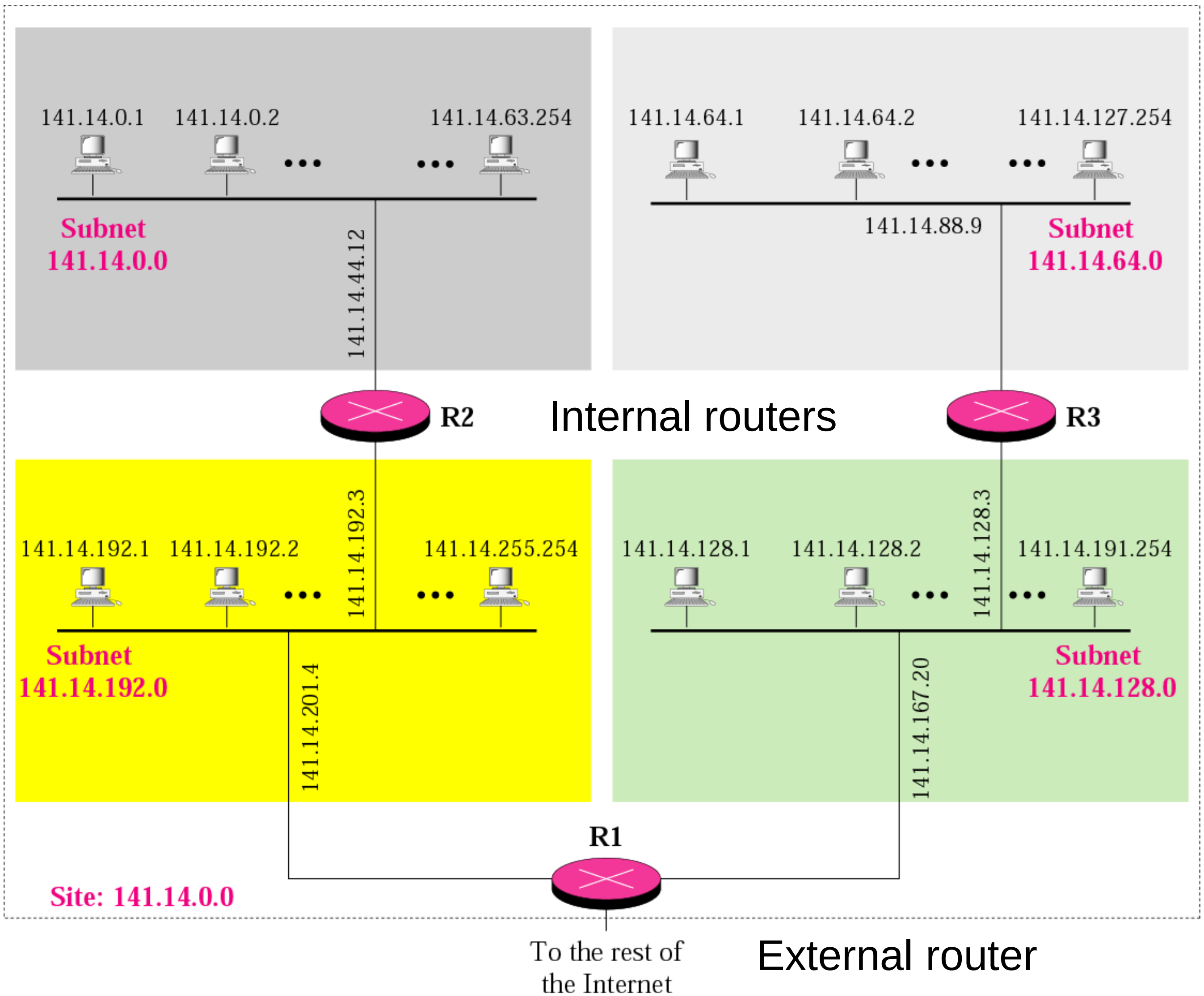


Fig: A network with two levels of hierarchy (not subnetted)

Two levels of hierarchy is not enough

- Solution: ***subnetting***
  - A network is divided into several smaller networks
  - Each smaller network is called a *subnetwork or a subnet*

A network with three levels of hierarchy (subnetted)



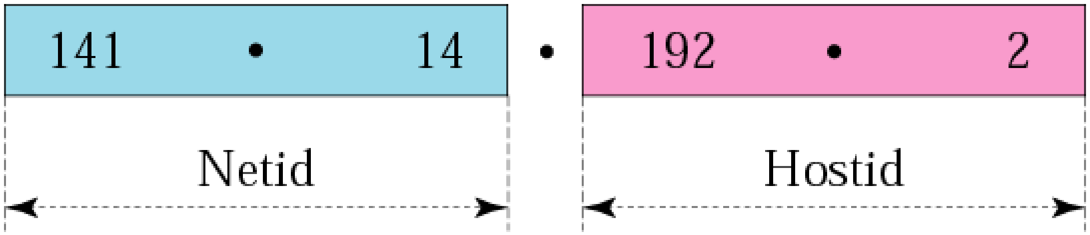
Subnetting (Cont.)

- The subnetworks still appear as a single network to the rest of the Internet
- For example, a packet destined for host 141.14.192.2 still reaches router R1
- However, R1 knows the network 141.14 is physically divided into subnetworks
  - It deliver the packet to subnetwork 141.14.192.0

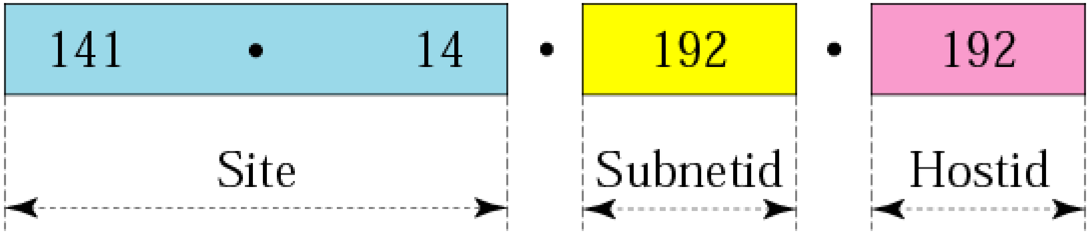
Three Levels of Hierarchy

- Three level
  - Site, subnet, and host
- The routing of an IP datagram now involves three step
  - Delivery to the *site*
  - Delivery to the *subnetwork*
  - Delivery to the *host*

Addresses in a network
With and without subnetting



a. Without subnetting



b. With subnetting

Just like telephone system

Network Addresses/subnetting

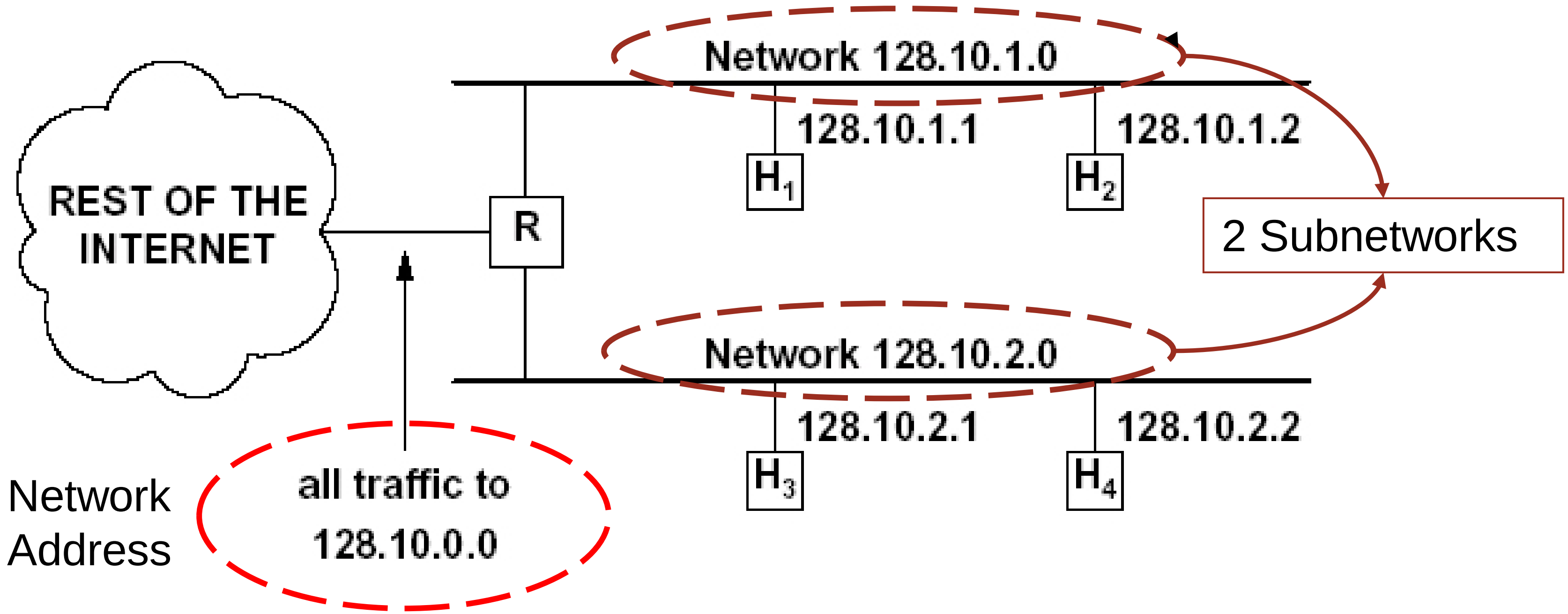


Figure 10.3 A site with two physical networks using subnet addressing to label them with a single class *B* network address. Router *R* accepts all traffic for net 128.10.0.0 and chooses a physical network based on the third octet of the address.

IP-Addressing/**Subnetting**

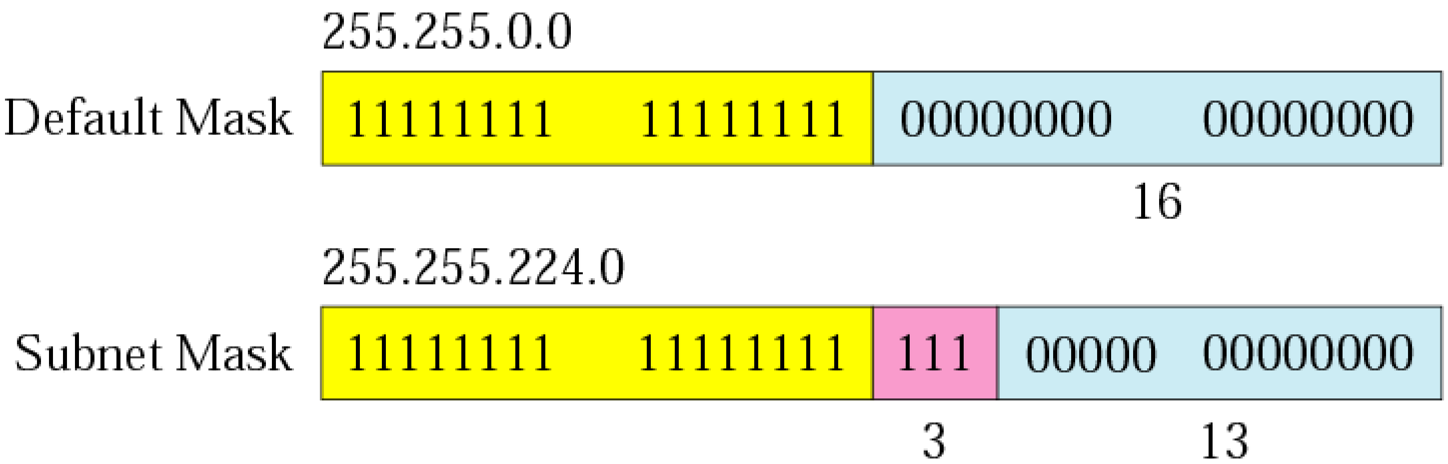
a) IP address designed with 2 levels of hierarchy: network-ID & host-ID.
b) However, often organisation needs to assemble the hosts into groups: the network needs to be divided into several sub-networks (subnets); hence requires 3 levels of hierarchy. (netid: subnetid : hostid)
c) Remember that, the outside world only knows the organisation by its network address. Inside the organisation each sub-network is recognised by its sub-network address.
d) In subnetting, a network is divided into several smaller groups that have its own subnet address depends on the hierarchy of subnetting but still appear as a single network to the rest of the Internet.
e) The question is how a router knows whether it is a network address or a subnet?
    - *The key is using the **subnet mask**. (similar to def. mask).*
f) Only the network administrator knows about the network address and subnet address but router does not. External router has routing table based on network addresses; Internal router has routing table based on sub-network addresses.

Default Mask and Subnet Mask

- The number of *1s* in a default mask is perdetermined
  - 8, 16, or 24

- But, in a subnet mask, the number of 1s is more than the number of 1s in the corresponding default mask

Comparison of a default mask and a subnet mask



Note

The number of subnets must be a power of 2.

Number of Subnetworks

- Found by counting the number of extra bits that are added to the default mask in a subnet mask

- For example, in above figure
  - The number of extra 1s is 3
    - The length of subnetid = 3
  - The number of subnets is 2^3 = 8

Number of Addresses per Subnet

- Found by counting the number of *0s* in the subnet mask

- For example, in above figure
  - The number of 0s is 13
    - The length of hostid = 13
  - The number of addressed in each subnet is 2^13 = 8192

Designing Subnets

- How a network managers design subnets
  - Deciding the number of subnets
  - Finding the subnet mask
  - Find the range of address in each subnet
    - Start with the first subnet and its first address is the first address in the block
    - Add the number of addresses in each subnet minus one to get the last address
    - Add one to the last address in obtain step to obtain the first address in the next subnet

Example-1

A company is granted the site address 201.70.64.0 (class C). The company needs six subnets. Design the subnets.

Solution

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

The company needs six subnets. Since 6 is not a power of 2, the next number that is a power of 2 is 8 (2^3). That means up to 8 subnets.

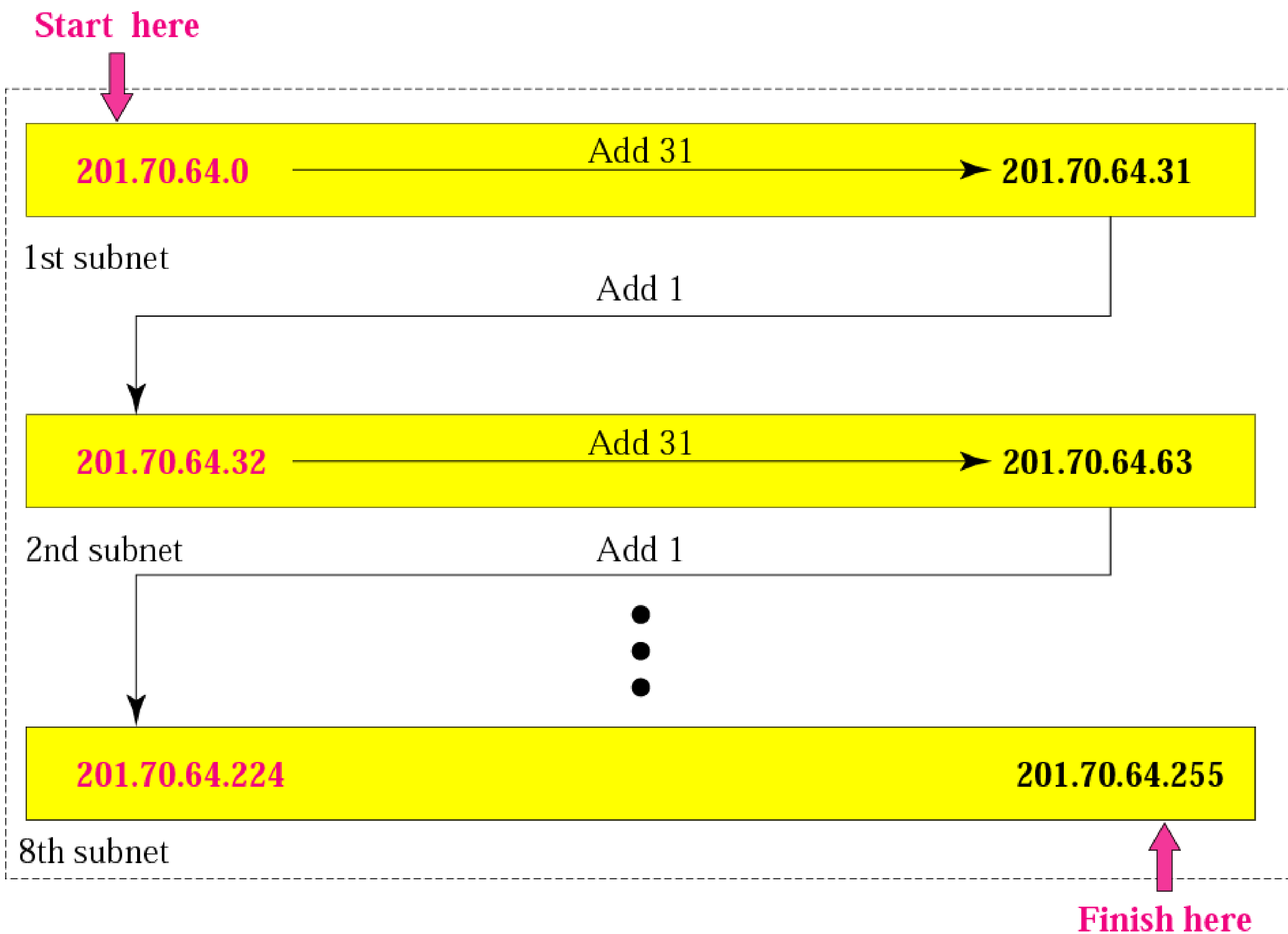
Hence, we need 3 more '1's in the subnet mask = 11111111.11111111.11111111.11100000 or 255.255.255.224

The total number of 1s in the subnet mask is 27 (24 + 3).

Since the total number of 0s is 5 (32 - 27).

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

Solution (Continued)



Example

A company is granted the site address 181.56.0.0 (class B). The company needs 1000 subnets. Design the subnets.

Solution

- The number of 1s in the default mask is 16 (class B).
- The company needs 1000 subnets. Since it is not a power of 2, the next number 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 submask is

11111111 11111111 11111111 11000000

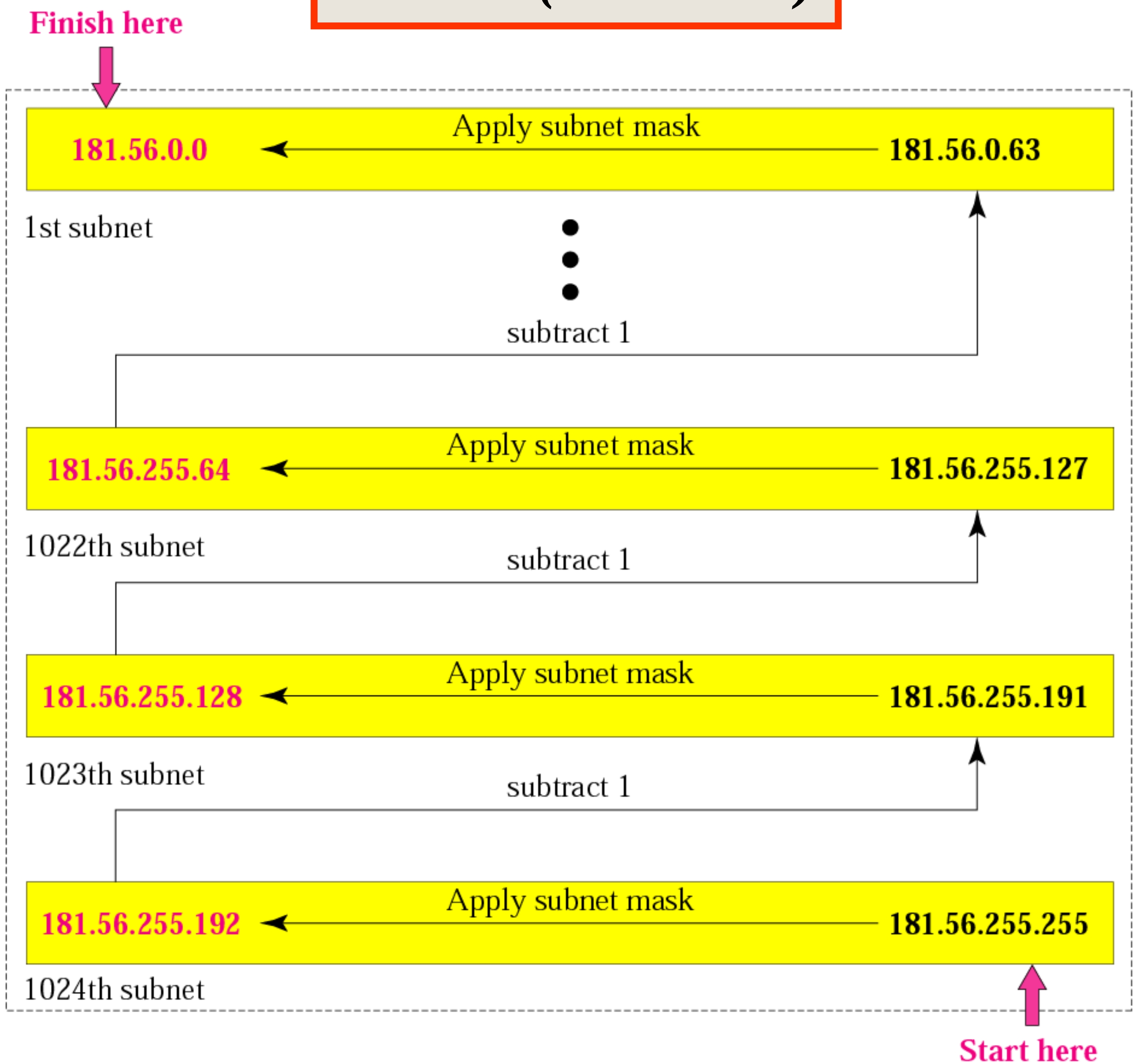
or

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.

Solution (Continued)



Finding the Number Subnet

- ***Subnet prefix***
  - Defined by the number of desired subnets
- If the number of subnets is *s*
  - The number of extra 1s in the prefix length is $\boldsymbol{log_2 s}$
- If we want *fixed-length subnets*
  - Each subnet has the same number of addresses

In fixed-length subnetting, the number of subnets is a power of 2.

Finding the Subnet Address

- Given an IP address, we can find the *subnet address* in the same way as we found the *network address*
  - Apply the mask to the address

- Two ways: *straight* or *short-cut*

Straight Method

- Use binary notation for both the address and the mask

- Then apply the AND operation to find the subnet address

Example-11

What is the subnetwork address if the destination address is 200.45.34.56 given that 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

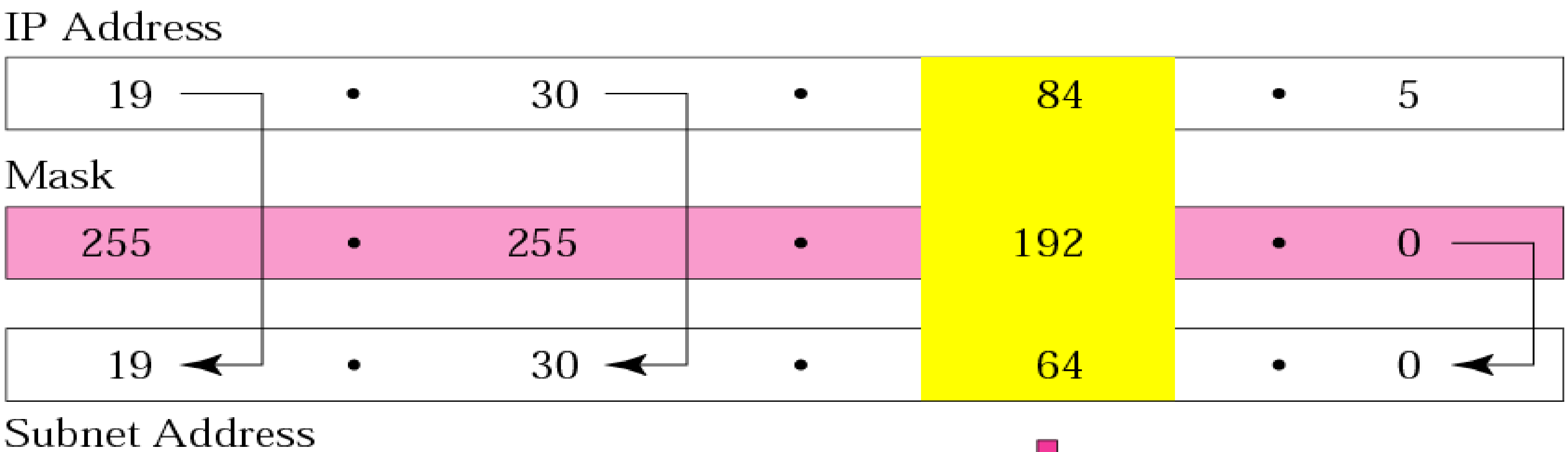
- If the byte in the mask is 255, copy the byte in the address
- If the byte in the mask is 0, replace the byte in the address with 0
- If the byte in the mask is neither 255 nor 0, we write the mask and the address in binary and apply the AND operation

Example-12

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

Solution

Answer: Subnet Address = 19.30.64.0



84	0	1	0	1	0	1	0	0
192	1	1	0	0	0	0	0	0
64	0	1	0	0	0	0	0	0

Example-13

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

Solution

- We need 4 subnets
- We need to add two more 1s ($\log_2 4 = 2$) to the site prefix.
- The subnet prefix is then /28

Solution

- The suffix length is 6 (32-26). 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.

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.

Example-13

- The first address in the first subnet is 130.34.12.64/28
  - Note that the first address of the first subnet is the first address of the block.
  - The last address of the subnet can be found by adding 15 (16 -1) to the first address.
  - The last address is 130.34.12.79/28

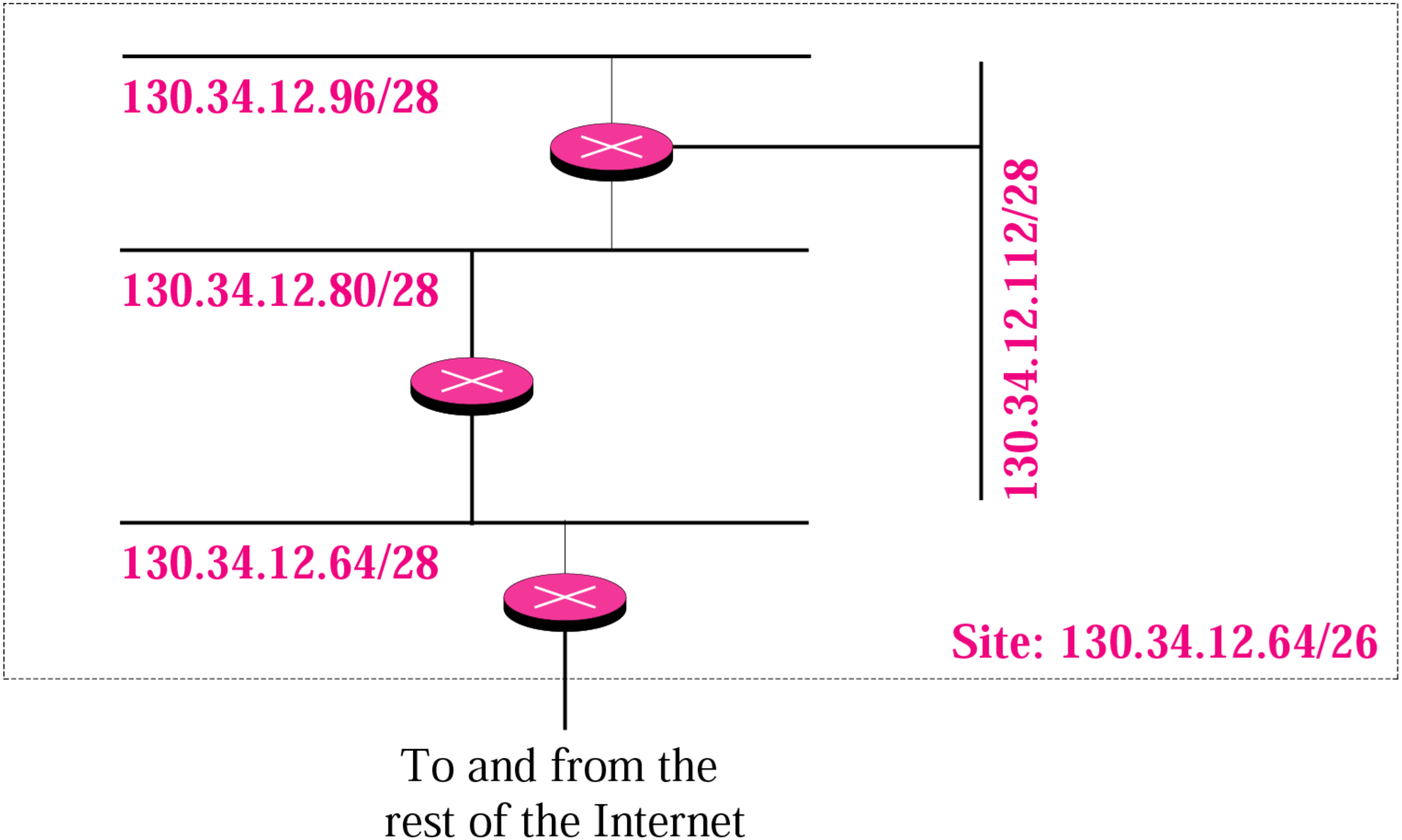
- The first address in the second subnet is 130.34.12.80/28
  - Found by adding 1 to the last address of the previous subnet.
  - Again adding 15 to the first address, we obtain the last address, 130.34.12.95/28.

Example-13

- Similarly, we find the first address of the third subnet to be 130.34.12.96/28 and the last to be 130.34.12.111/28

- Similarly, we find the first address of the fourth subnet to be 130.34.12.112/28 and the last to be 130.34.12.127/28

Example


130.34.12.96/28
130.34.12.80/28
130.34.12.64/28
130.34.12.112/28
Site: 130.34.12.64/26
To and from the
rest of the Internet

Variable-Length Subnets

- In previous examples
  - All of subnets have the same mask
- Variable-length subnet
  - Design subnets of different sizes

Example-14

An organization is granted a block of addresses with the beginning address 14.24.74.0/24. There are $2^{32-24} = 256$ *addresses in this block. The organization needs to have 11 subnets as shown below:*

a. *two subnets, each with 64 addresses.*

b. *two subnets, each with 32 addresses.*

c. *three subnets, each with 16 addresses.*

d. *four subnets, each with 4 addresses.*

Design the subnets.

See Next Slide For One Solution

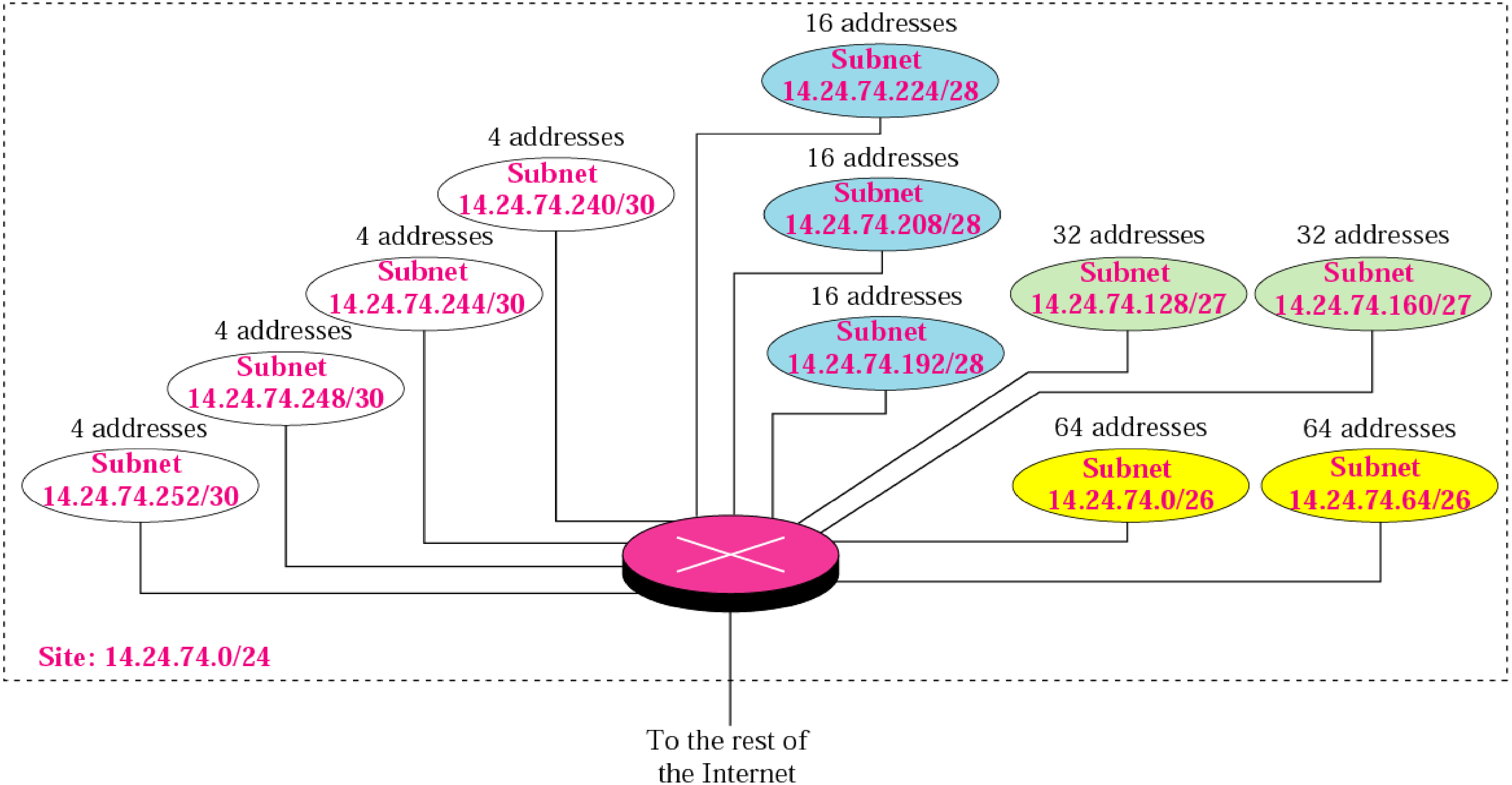
Example-14

- The first 128 addresses are used for the first two subnets, each with 64 addresses.
  - The mask for each network is /26.
  - *(If each subnet needs 64 addresses, that is 2^6. 32-6 = /26)*
  - The subnet address for each subnet is given in the figure

- Use the next 64 addresses for the next two subnets, each with 32 addresses.
  - The mask for each network is /27.
  - *(If each subnet needs 32 addresses, that is 2^5. 32-5=/27)*
  - The subnet address for each subnet is given in the figure.

Example-14

- Use the next 48 addresses for the next three subnets, each with 16 addresses.
  - The mask for each network is /28.
  - The subnet address for each subnet is given in the figure
- Use the last 16 addresses for the last four subnets, each with 4 addresses.
  - The mask for each network is /30.
  - The subnet address for each subnet is given in the figure


16 addresses
Subnet
14.24.74.224/28
4 addresses
Subnet
14.24.74.240/30
16 addresses
Subnet
14.24.74.208/28
4 addresses
Subnet
14.24.74.244/30
32 addresses
Subnet
14.24.74.128/27
32 addresses
Subnet
14.24.74.160/27
16 addresses
Subnet
14.24.74.192/28
4 addresses
Subnet
14.24.74.248/30
4 addresses
Subnet
14.24.74.252/30
64 addresses
Subnet
14.24.74.0/26
64 addresses
Subnet
14.24.74.64/26
Site: 14.24.74.0/24
To the rest of
the Internet

Example-15

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 sub-blocks and give the slash notation for each sub-block. Find out how many addresses are still available after these allocations.

Solution

Group 1

For this group of 64 customers, each customer needs 256 addresses. This means the suffix length is 8 ($2^8 = 256$). The prefix length is then 32 - 8 = 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

Total = 64 × 256 = 16,384

Solution (Continued)

Group 2

For this group of 128 customers, each customer needs 128 addresses. This means the suffix length is 7 ($2^7 = 128$). The prefix length is then 32 - 7 = 25. The addresses are:

001: 190.100.64.0/25 □ 190.100.64.127/25

002: 190.100.64.128/25 □ 190.100.64.255/25

……………………………………..

127: 190.100.127.0/25 □ 190.100.127.127/25

128: 190.100.127.128/25 □ 190.100.127.255/25

Total = 128 × 128 = 16,384

Solution (Continued)

Group 3

For this group of 128 customers, each customer needs 64 addresses. This means the suffix length is 6 ($2^6 = 64$). The prefix length is then 32 - 6 = 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

Total = 128 × 64 = 8,192

Solution (Continued)

Number of granted addresses: 65,536

Number of allocated addresses: 40,960

Number of available addresses: 24,576

The available addresses range from:

190.100.160.0 □ 190.100.255.255

Total = 96 × 256 = 24,576

Another Example:

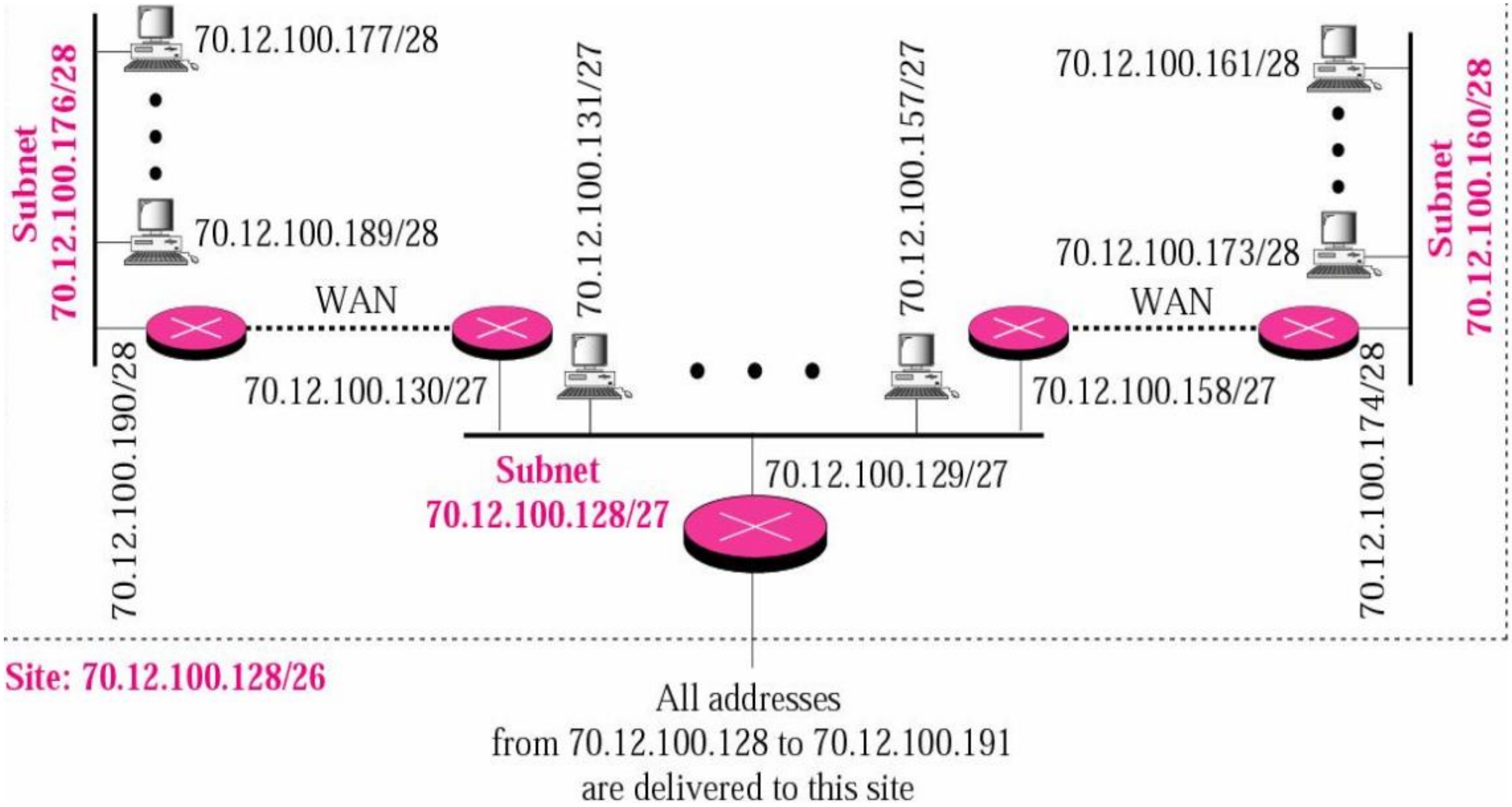
Given, 192.168.0.0/16 (host=1000->1024-> /22)

192.168.0.0/22 - 192.168.3.255/22

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, point-to-point 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 offices.
  - Figure 5.8 shows the configuration designed by the management.

Example-16



70.12.100.177/28
70.12.100.189/28
Subnet
70.12.100.176/28
WAN
70.12.100.190/28
70.12.100.130/27
70.12.100.131/27
70.12.100.157/27
70.12.100.161/28
70.12.100.173/28
Subnet
70.12.100.160/28
WAN
70.12.100.158/27
70.12.100.174/28
Subnet
70.12.100.128/27
70.12.100.129/27
Site: 70.12.100.128/26
All addresses
from 70.12.100.128 to 70.12.100.191
are delivered to this site

Solution

- The company will have three subnets, one at Central, one at East, and one at West.
- The Central office uses the network address 70.12.100.128/27.
- This is the first address, and the mask /27 shows that there are 32 addresses in this network.
- The addresses in this subnet are 70.12.100.128/27 to 70.12.100.159/27
- Note that three of these addresses are used for the routers and the company has reserved the last address in the sub-block.
- Note that the interface of the router that connects the Central subnet to the WAN needs no address
  - It is a point-to-point connection

Solution (Continued)

- The West office uses the network address 70.12.100.160/28.
- The mask /28 shows that there are only 16 addresses in this network.
- The addresses in this subnet are 70.12.100.160/28 to 70.12.100.175/28.
- Note that one of these addresses is used for the router and the company has reserved the last address in the sub-block.
- Note also that the interface of the router that connects the West subnet to the WAN needs no address
  - It is a point-to- point connection

Solution (Continued)

- The East office uses the network address 70.12.100.176/28.
  n The mask /28 shows that there are only 16 addresses in this network.
- The addresses in this subnet are 70.12.100.176/28 to 70.12.100.191/28.
- Note that one of these addresses is used for the router and the company has reserved the last address in the sub-block.
- Note also that the interface of the router that connects the East subnet to the WAN needs no address
  - It is a point-to-point connection