IP addressing and Subnetting

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Learning outcome

- فهم ضرورة استخدام العناوين المنطقية
- التعرف على العنونة IPv4
- التمييز بين العناوين الخاصة والعناوية العامة وضرورة استخدام كل منها
- التعرف على بنية العناوين المستخدمة في النسخة الرابعة والنسخة السادسة ومعرفة آليات العنونة في كل منها
- المقارنة بين العنونة IPv4 و IPv6.
- معرفة ضرورات تجزئة الشبكات وآليات التجزئة
- التعرف على آلية عمل بروتوكول ترجمة العناوين الشبكية NAT.
- التعرف على كيفية إدارة فضاء العناوين عالمياً.

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How many addresses in IPv6?

- IPv6 Addresses:
  - 2128=340,282,366,920,938,463,463,374,607,431,768,211,456 ≈ 3.4 x 1038

- Surface area of Earth: 510,072,000 km2
- Size of Atom: 10-10 m = 0.1 nm = 1 Angstrom (Å)
- “Area of Atom”: 1 square angstrom ($Å^2$)= 10-20 m2
- Number of atoms on Earth’s surface: 510,072,000 km^2 / 10^{-20} m^2 = 5.1 x 10^{31}
- **Number of IPv6 addresses for each atom on the surface of the Earth: ~ 6.7 million.**

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IPv6 – Internet for everything!

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الشكل العام للعناوين IPv6

Global Routing Prefix (n bits)	Subnet ID (m bits)	Interface ID (128-n-m bits)

- بادئة توجيه عام Global routing prefix: تحدد طبيعة العنوان (متعدد بث، مخصص لكتلة ما،.....)
- محدد الشبكة الجزئية Subnet ID: ويحدد الشبكة الجزئية التي ينتمي إليها العنوان ضمن الكتلة الأساسية.
- محدد واجهة التوصيل Interface ID: ويحدد واجهة التوصيل الوحيدة المرتبطة بهذا العنوان.

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طرق التعبير عن العنوان IPv6

❖ يتم بشكل أساسي التعبير عن العنوان من هذا النوع باستخدام ثمانية حقول يفصل بين كل منها وجاره بنقطتين، وكل منها يتم تمثيله بأربع خانات سداسي عشرية.

xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx

2001:0250:02FF:0210:0250:8BFF:FEDE:67C8

❖ يمكن الاستغناء عن كتابة الأصفار السابقة في كل حقل

2001:250:2FF:210:250:8BFF: FEDE:67C8

Types of Address Inscription

❖ يمكن التعبير عن حقل صفري أو مجموعة حقول صفرية متجاورة بنقتين مضاعفتين

FEDC: 0000:0000:0000:00DC:0000:7076:0010

FEDC:: DC:0:7076:10

❖ يسمح باستخدام التوجيه المجالي اللاصفي Classless Interdomain Routing

FDEC::BBFF:0:FFFF/60

Types of Address Inscription

❖ يسمح بلصق العنوان IPv4 في نهائته من أجل دمج الشبكات التي تستخدم هذه العناوين في الشبكات التي تستخدم العنونة IPv6.

FEDC:BA98:7654:3210:FEDC:BA98:7654:3210

FEDC:BA98:7654:3210:FEDC:BA98:118.84.50.16

❖ يسمح بالعناوين التي تتشكل من أصفار أو من واحدات بكليتها

EXAMPLE 2

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

a. 205.16.37.32 *b.190.16.42.44*

c. 17.17.33.80 *d.123.45.24.52*

Solution

Only two are eligible (a and c). 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.

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EXAMPLE 3

Which of the following can be the beginning address of a block that contains 256 addresses?

a.205.16.37.32 b.190.16.42.0

c.17.17.32.0 d.123.45.24.52

Solution

In this case, the right-most byte must be 0. the IP addresses use base 256 arithmetic. When the right-most byte is 0, the total address is divisible by 256. Only two addresses are eligible (b and c).

EXAMPLE 4

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

a. 205.16.37.32 b.190.16.42.0

c. 17.17.32.0 d.123.45.24.52

Solution

In this case, we need to check two bytes because 1024 = 4 × 256. The right-most byte must be divisible by 256. The second byte (from the right) must be divisible by 4. Only one address is eligible (c).

EXAMPLE 5 - FIND FIRST ADDRESS

What is the first address in the block if one of the addresses is 167.199.170.82/27?

Solution

Address in binary:

10100111 11000111 10101010 01010010

Keep the left 27 bits:

10100111 11000111 10101010 01000000

Result in CIDR notation: 167.199.170.64/27

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EXAMPLE 6– 1ST ADDRESS USING BINARY

What is the first address in the block if one of the addresses is 140.120.84.24/20?

Solution

The first, second, and fourth bytes are easy; for the third byte we keep the bits corresponding to the number of 1s in that group. The first address is 140.120.80.0/20.

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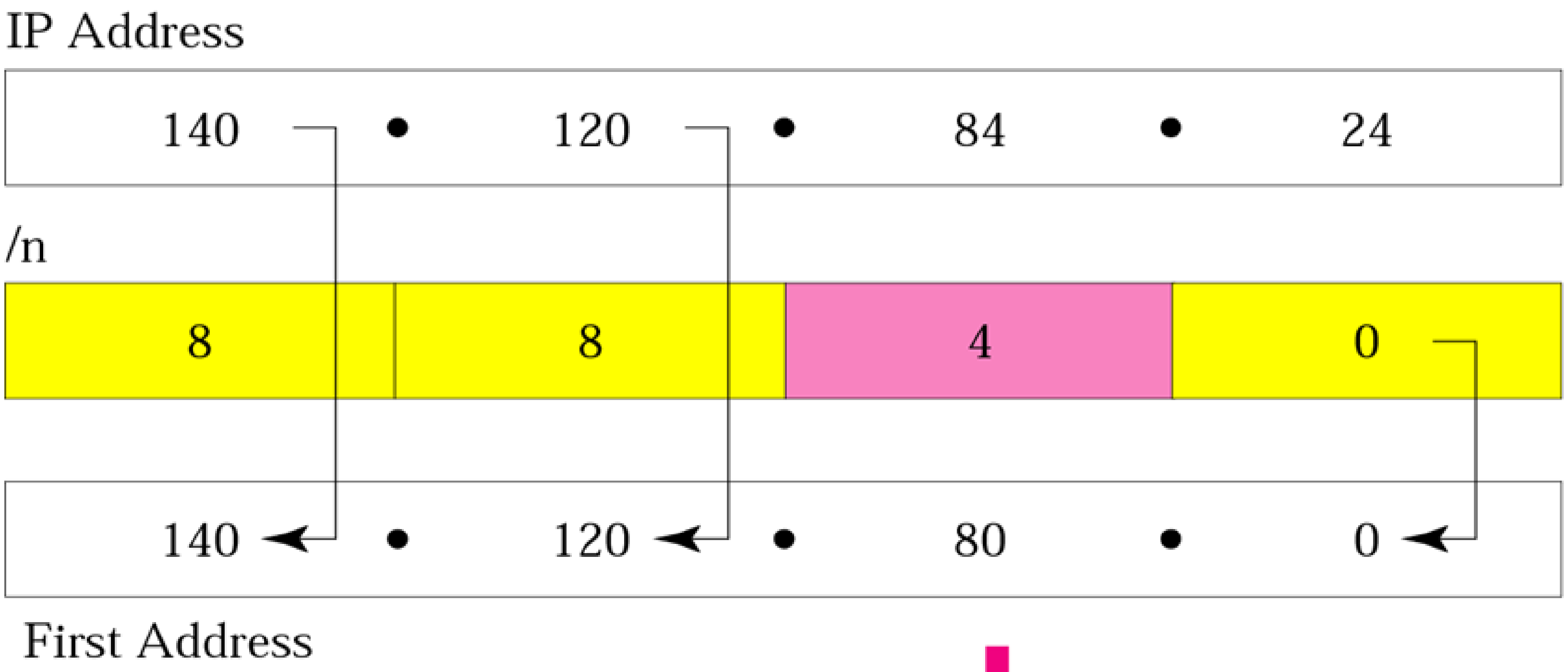
EXAMPLE 6– Solution



84	0	1	0	1	0	1	0	0
Keep left 4 bits	**0**	**1**	**0**	**1**	0	0	0	0

Result in decimal: 80

مدخل إلى الشبكات

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Example 7 - Number of Addresses

Find the number of addresses in the block if one of the addresses is 140.120.84.24/20.

Solution

The prefix length is 20. The number of addresses in the block is 2^{32-20} or 2^{12} or 4096. Note that this is a large block with 4096 addresses.

EXAMPLE 8 - FIND LAST ADDRESS

Find the last address in the block if one of the addresses is 140.120.84.24/20.

Solution

We found in the previous examples that the first address is 140.120.80.0/20 and the number of addresses is 4096. To find the last address, we need to add 4095 (4096 − 1) to the first address.

EXAMPLE 8 (Continued)

To keep the format in dotted-decimal notation, we need to represent 4095 in base 256 and do the calculation in base 256. We then add the first address to this number (in base 255) to obtain the last address as shown below:

```
140 . 120 .  80 .   0
              15  .  255
--------------------------
140 . 120 .  95 .  255
```

The last address is 140.120.95.255/20.

Alternate Method

- Not crazy about base 256 arithmetic? Do it in binary.
- .80.0 in binary is 01010000.00000000
- 4095 in binary is 1111 11111111
- Add the two values:

01010000.00000000
1111.11111111
01011111.11111111

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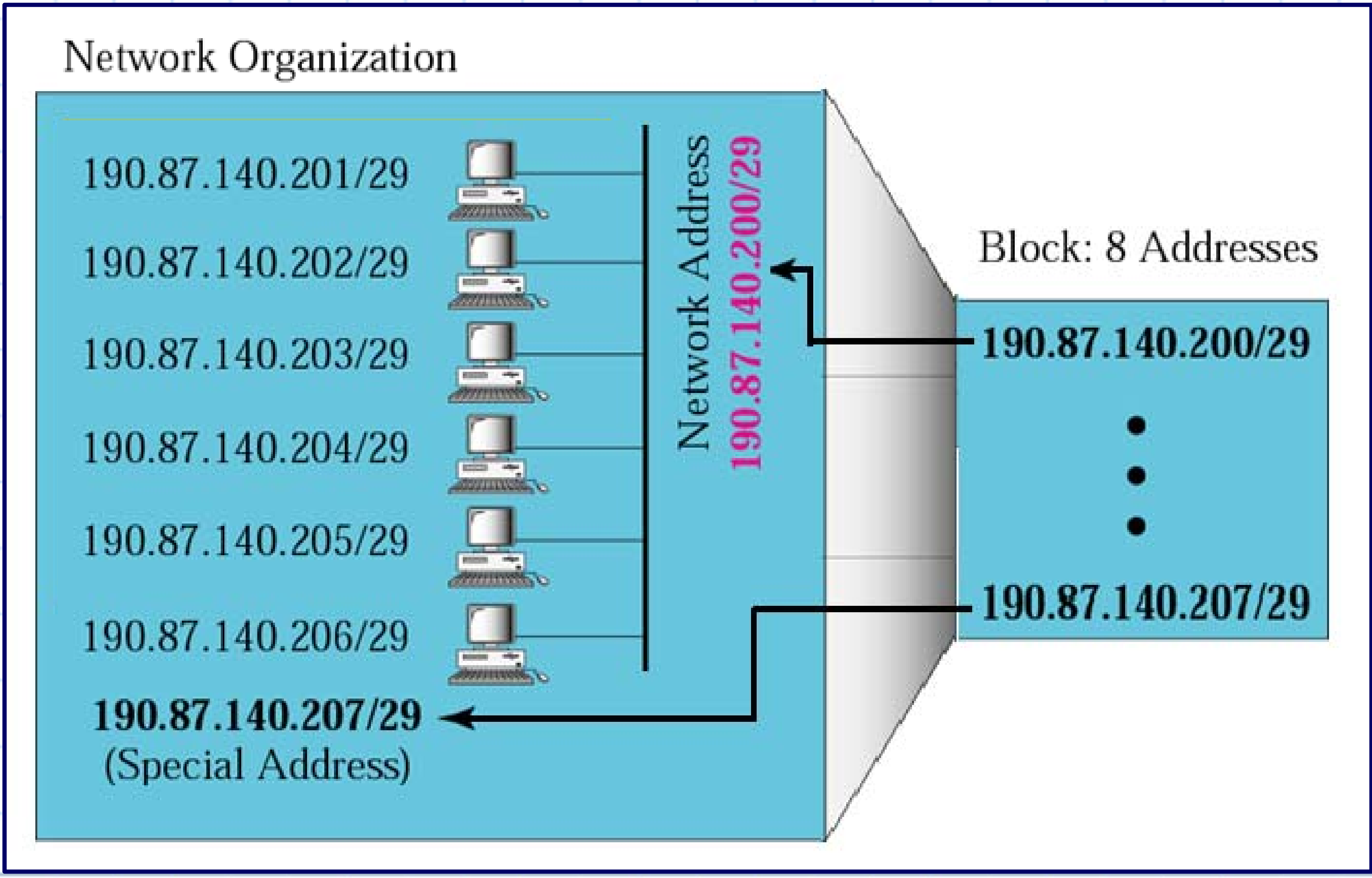
Example 10 - Find the Block

Find the block if one of the addresses is

190.87.140.202/29.

Solution

We follow the procedure in the previous examples to find the first address, the number of addresses, and the last address. To find the first address, we notice that the mask (/29) has five 1s in the last byte. So we write the last byte as powers of 2 and retain only the leftmost five as shown below:


Network Organization
190.87.140.201/29
190.87.140.202/29
190.87.140.203/29
190.87.140.204/29
190.87.140.205/29
190.87.140.206/29
190.87.140.207/29
(Special Address)
Network Address
190.87.140.200/29
Block: 8 Addresses
190.87.140.200/29
190.87.140.207/29

EXAMPLE 11

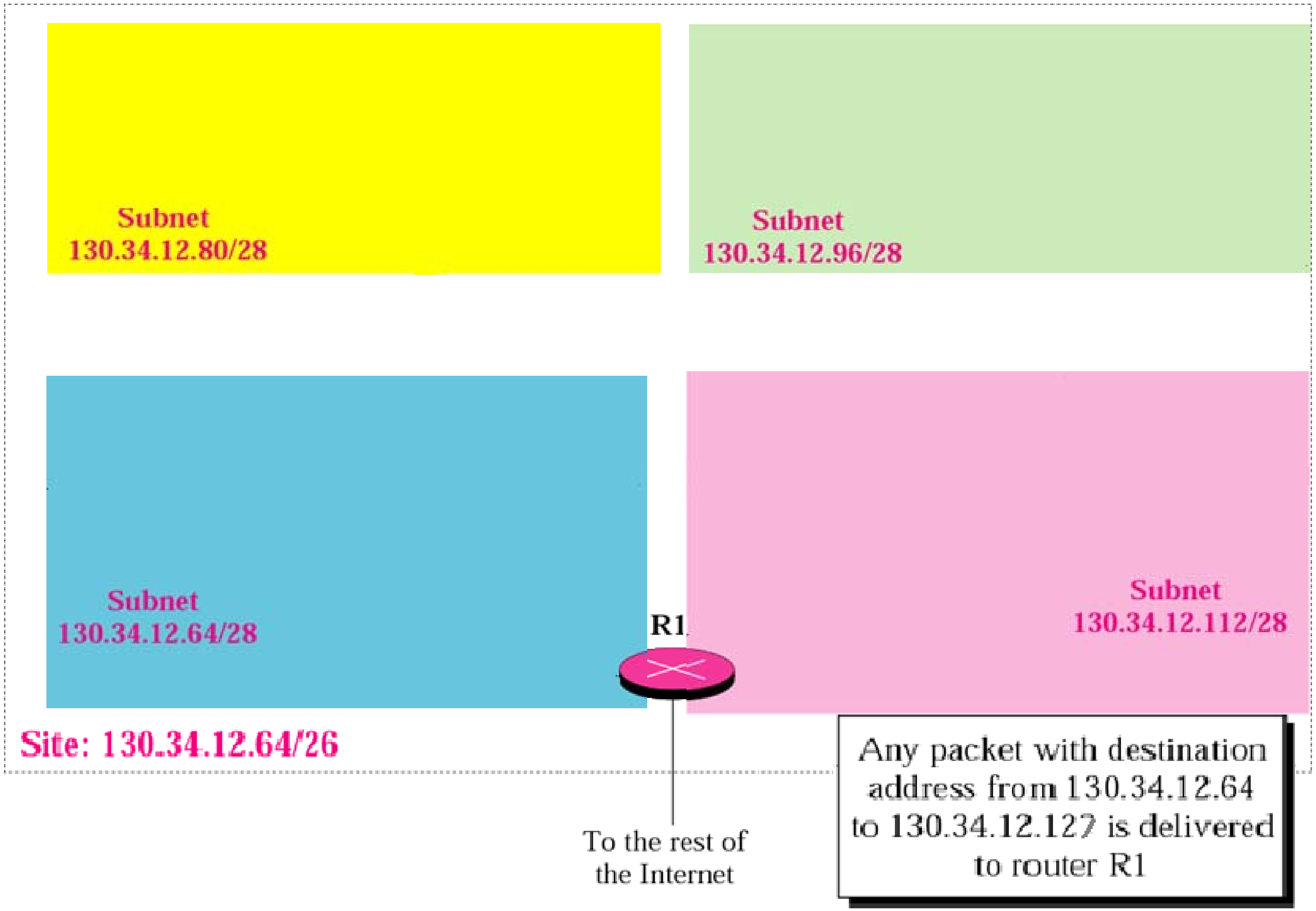
An organization is granted the block 130.34.12.64/26. The organization needs 4 subnets. What is the subnet prefix length?

Solution

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

Example 12

What are the subnet addresses and the range of addresses for each subnet in the previous example?



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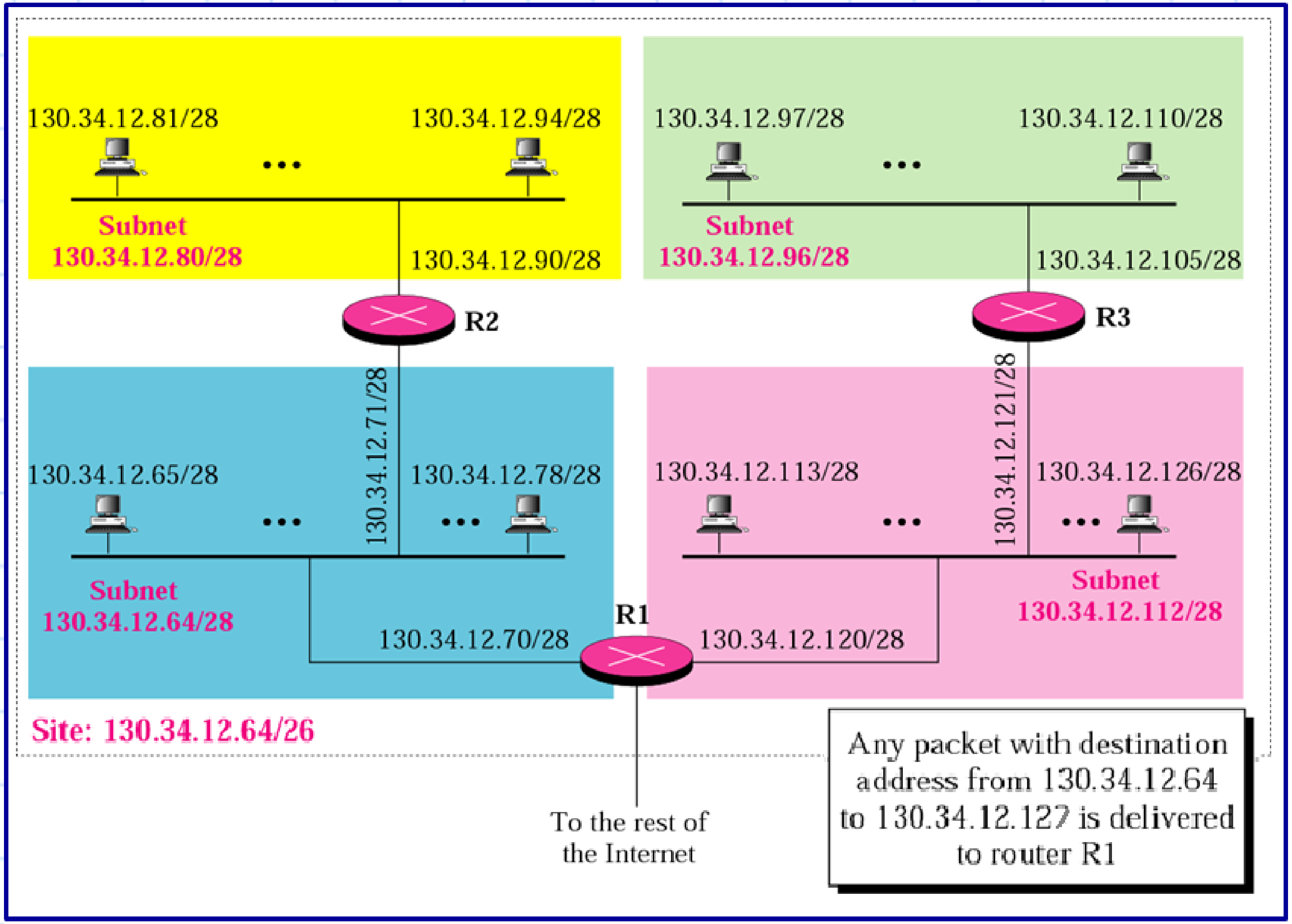
Example 12

What are the subnet addresses and the range of addresses for each subnet in the previous example?



EXAMPLE 12 (CONTINUED)

The site has $2^{32-26} = 64$ addresses. Each subnet has $2^{32-28} = 16$ addresses. Now let us find the first and last address in each subnet.

1. The first address in the first subnet is 130.34.12.64/28, using the procedure we showed in the previous examples. 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.

EXAMPLE 12 (CONTINUED)

2.The first address in the second subnet is 130.34.12.80/28; it is 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.

3. 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.

4. 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 13

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.

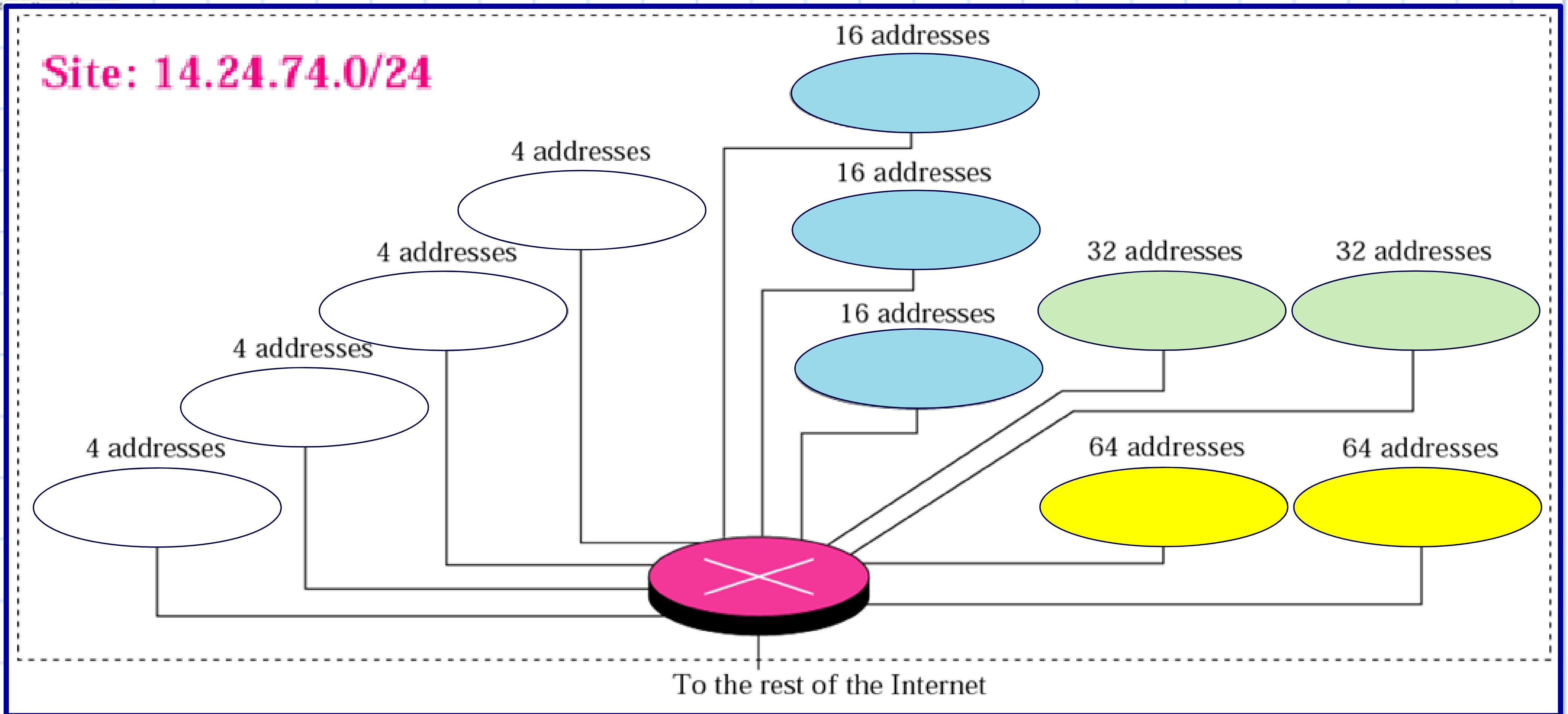
b. two subnets, each with 32 addresses.

c. three subnets, each with 16 addresses.

d. four subnets, each with 4 addresses.

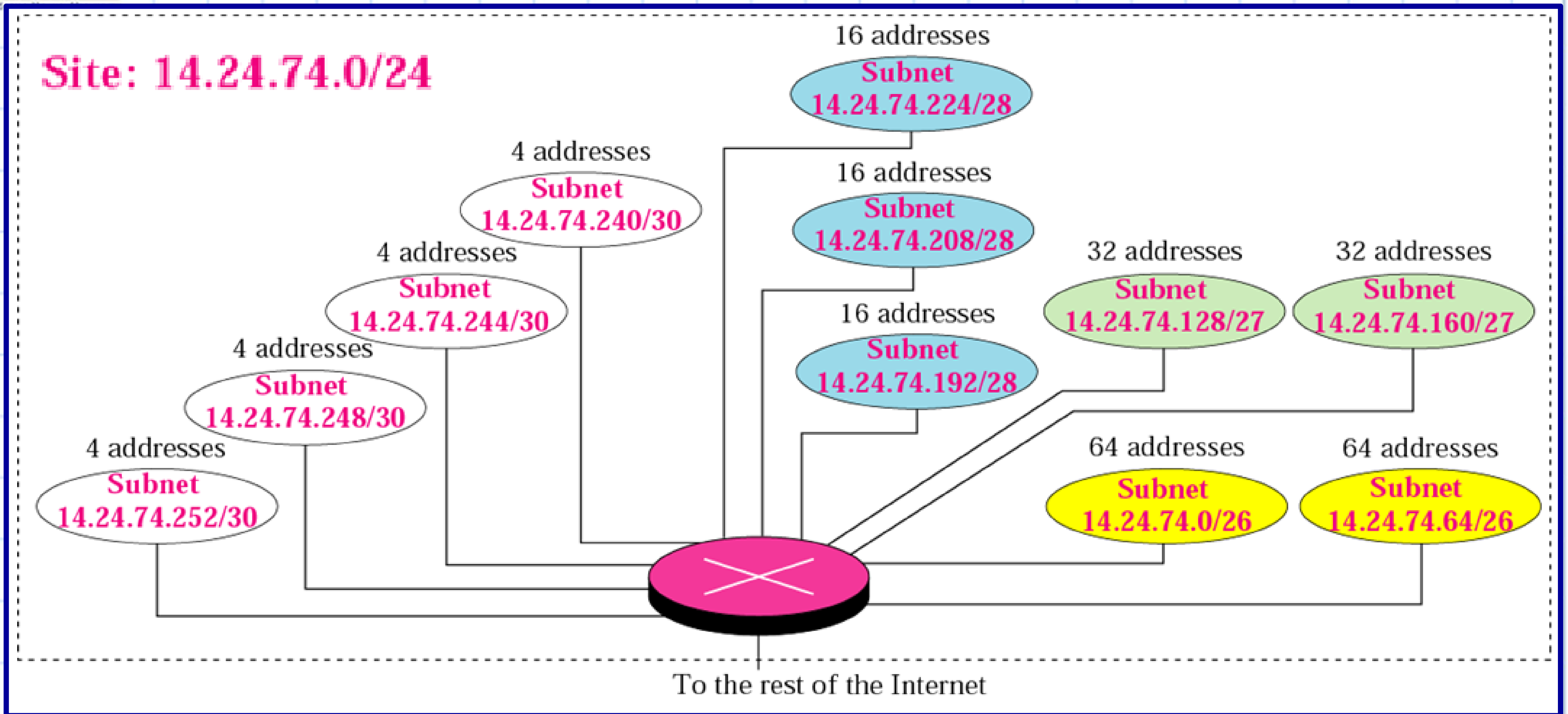
Design the subnets.

EXAMPLE 13



Site: 14.24.74.0/24
16 addresses
4 addresses
16 addresses
4 addresses
32 addresses
32 addresses
16 addresses
4 addresses
4 addresses
64 addresses
64 addresses
To the rest of the Internet

EXAMPLE 13



Site: 14.24.74.0/24
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
To the rest of the Internet

EXAMPLE 13

1. *We use the first 128 addresses for the first two subnets, each with 64 addresses. Note that the mask for each network is /26.*
2. *We use the next 64 addresses for the next two subnets, each with 32 addresses. Note that the mask for each network is /27.*
3. *We use the next 48 addresses for the next three subnets, each with 16 addresses.*
4. *We use the last 16 addresses for the last four subnets, each with 4 addresses.*

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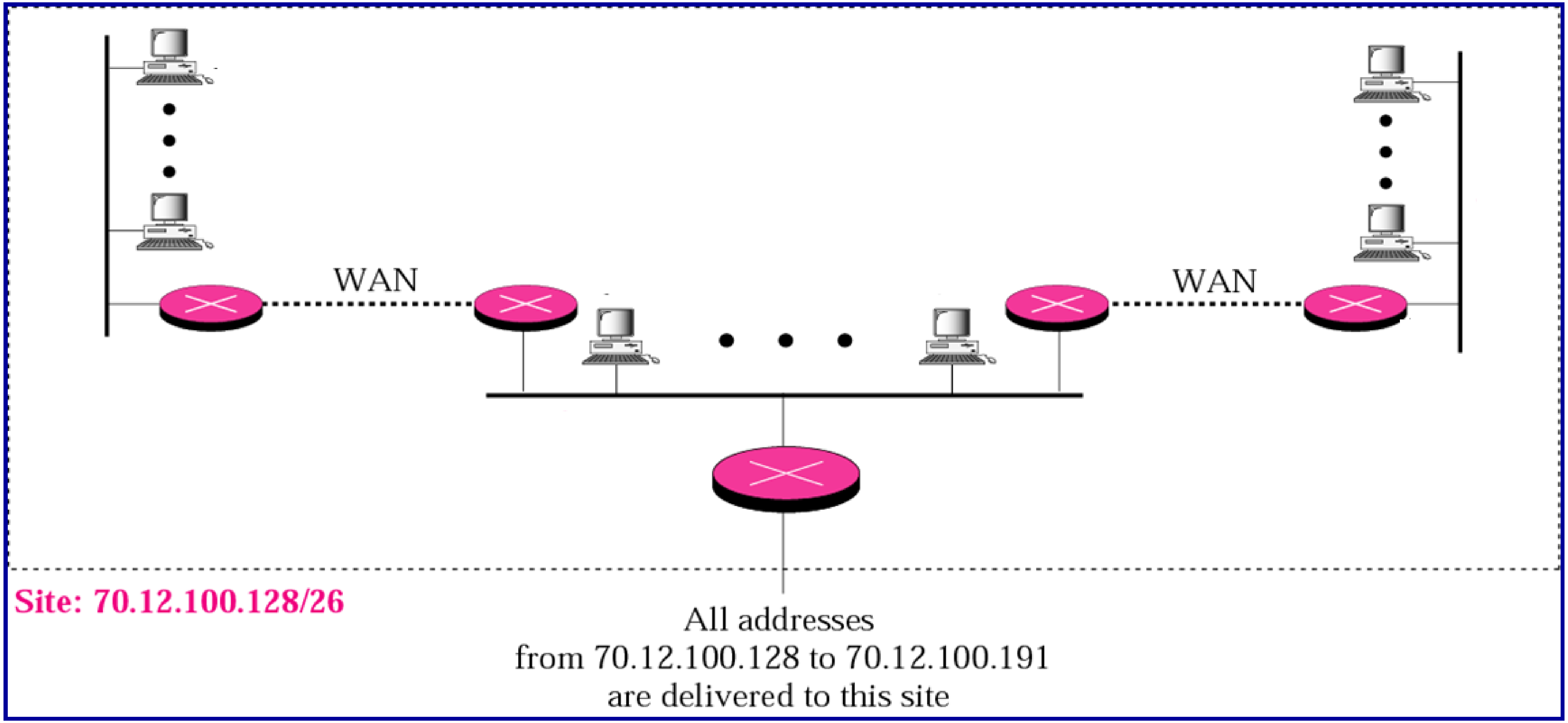
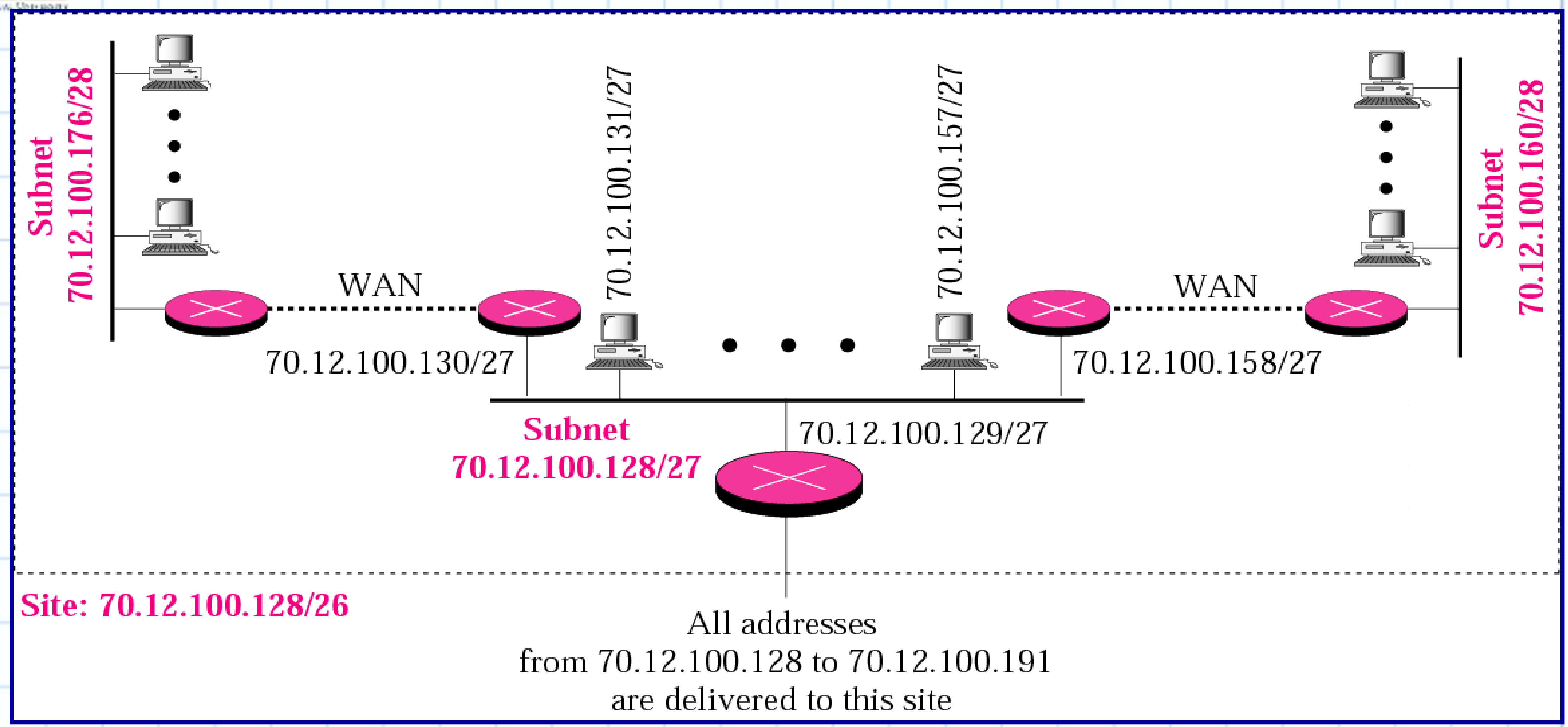
EXAMPLE 14

As another example, 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.


WAN
WAN
Site: 70.12.100.128/26
All addresses
from 70.12.100.128 to 70.12.100.191
are delivered to this site



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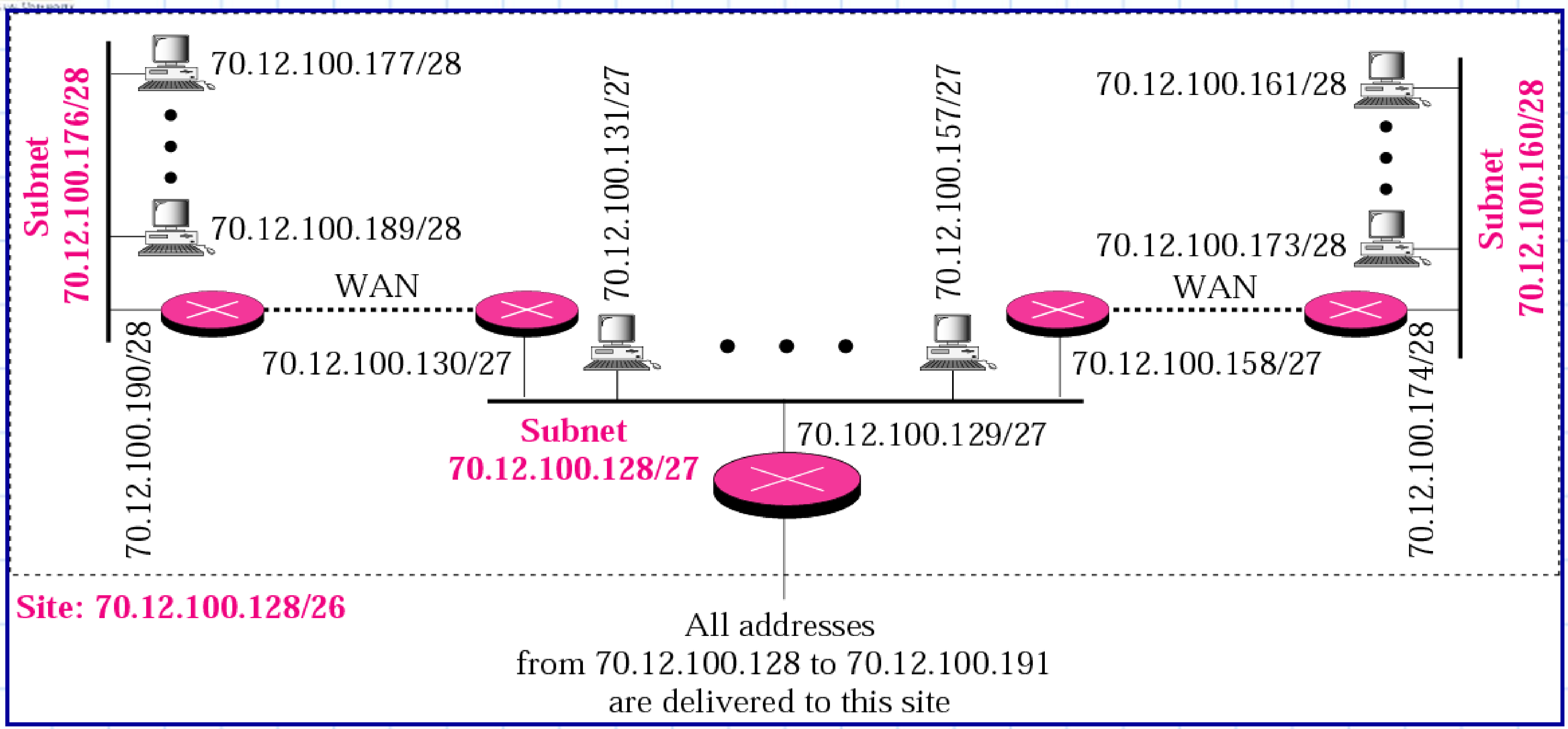
Subnet
70.12.100.176/28
70.12.100.177/28
70.12.100.189/28
70.12.100.190/28
WAN
70.12.100.130/27
70.12.100.131/27
70.12.100.157/27
Subnet
70.12.100.128/27
70.12.100.129/27
70.12.100.161/28
70.12.100.173/28
WAN
70.12.100.158/27
70.12.100.174/28
Subnet
70.12.100.160/28
Site: 70.12.100.128/26
All addresses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

EXAMPLE 14 (CONTINUED)

The company will have three subnets, one at Central, one at East, and one at West. The following lists the subblocks allocated for each network:

a. 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. Note that three of these addresses are used for the routers and the company has reserved the last address in the sub-block. The addresses in this subnet are 70.12.100.128/27 to 70.12.100.159/27. Note that the interface of the router that connects the Central subnet to the WAN needs no address because it is a point-to-point connection.

EXAMPLE 14(CONTINUED)

b. 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. Note that one of these addresses is used for the router and the company has reserved the last address in the sub-block. The addresses in this subnet are 70.12.100.160/28 to 70.12.100.175/28. Note also that the interface of the router that connects the West subnet to the WAN needs no address because it is a point-to- point connection.

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

Practice Problem

- An organization is granted the block 16.0.0.0/8. The administrator wants to create 500 fixed-length subnets.
  - Find the subnet mask
  - Find the number of addresses in each subnet
  - Find the first and last address in the first subnet

ADDRESS ALLOCATION

- Address allocation is the responsibility of a global authority called the Internet Corporation for Assigned Names and Addresses (ICANN). It usually assigns a large block of addresses to an ISP to be distributed to its Internet users.

EXAMPLE 15

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.

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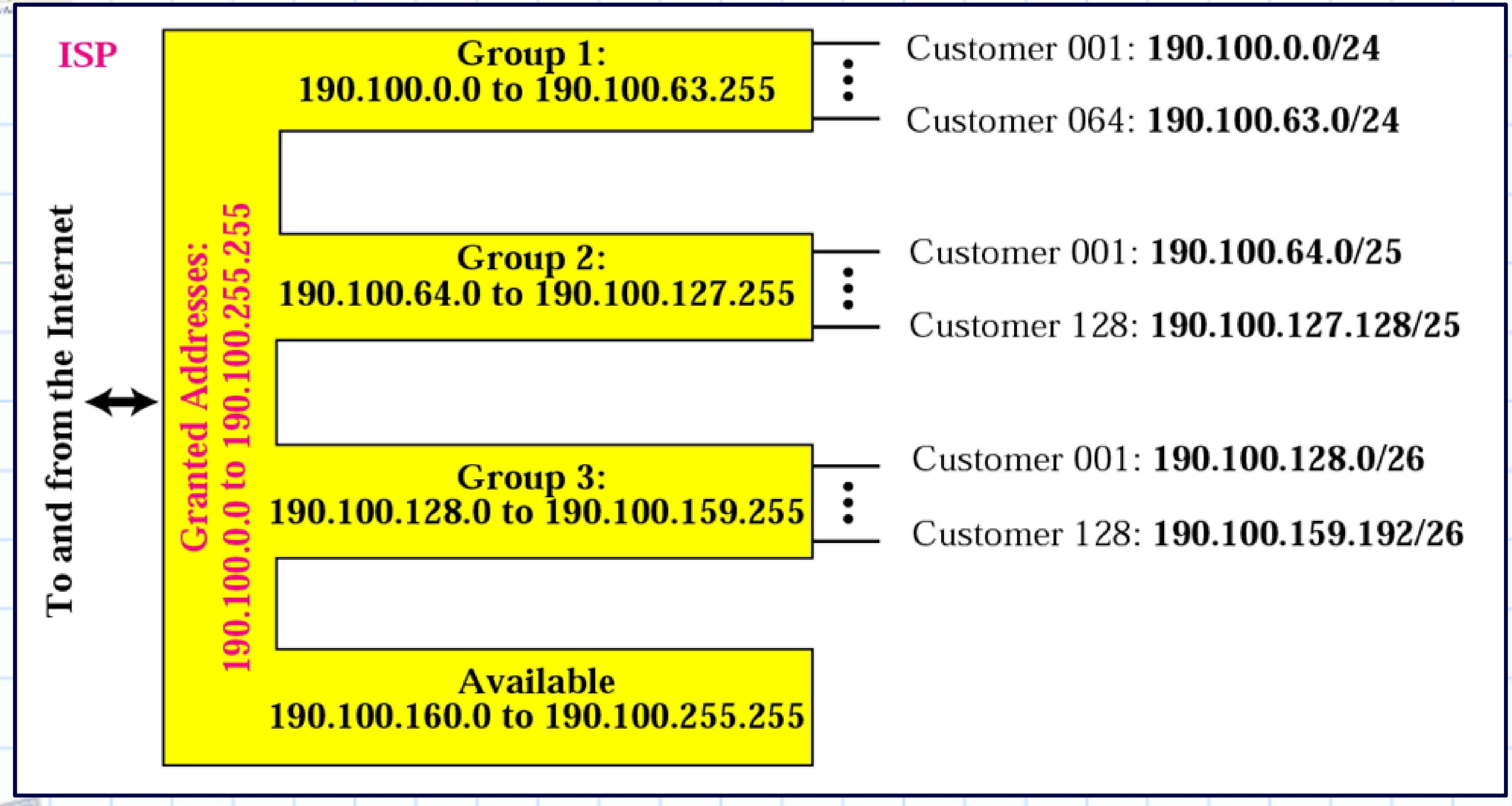
Example 15


ISP
To and from the Internet
Granted Addresses:
190.100.0.0 to 190.100.255.255
Group 1:
190.100.0.0 to 190.100.63.255
Customer 001: 190.100.0.0/24
Customer 064: 190.100.63.0/24
Group 2:
190.100.64.0 to 190.100.127.255
Customer 001: 190.100.64.0/25
Customer 128: 190.100.127.128/25
Group 3:
190.100.128.0 to 190.100.159.255
Customer 001: 190.100.128.0/26
Customer 128: 190.100.159.192/26
Available
190.100.160.0 to 190.100.255.255

EXAMPLE 15 (CONTINUED)

Group 1

For this group, each customer needs 256 addresses. This means the suffix length is 8 (2^8 =256). 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

EXAMPLE 15 (CONTINUED)

Group 2

For this group, 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:

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 × 128 = 16,384

EXAMPLE 15 (CONTINUED)

Group 3

For this group, each customer needs 64 addresses. This means the suffix length is 6 (26 = 64). 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 = 8,192

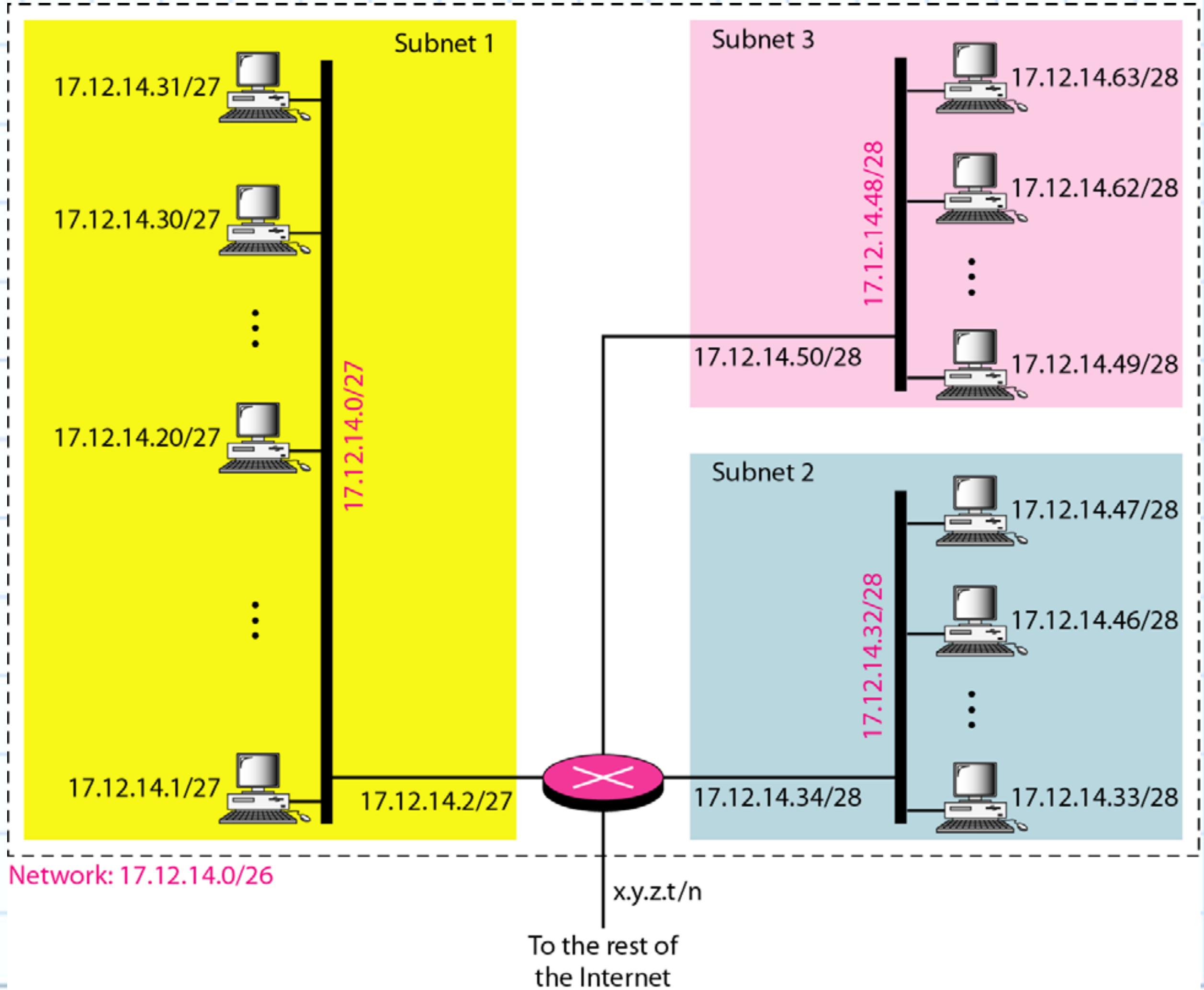
EXAMPLE 15 (CONTINUED)

Number of granted addresses to the ISP: 65,536

Number of allocated addresses by the ISP: 40,960

Number of available addresses: 24,576

Configuration and addresses in a subnetted network



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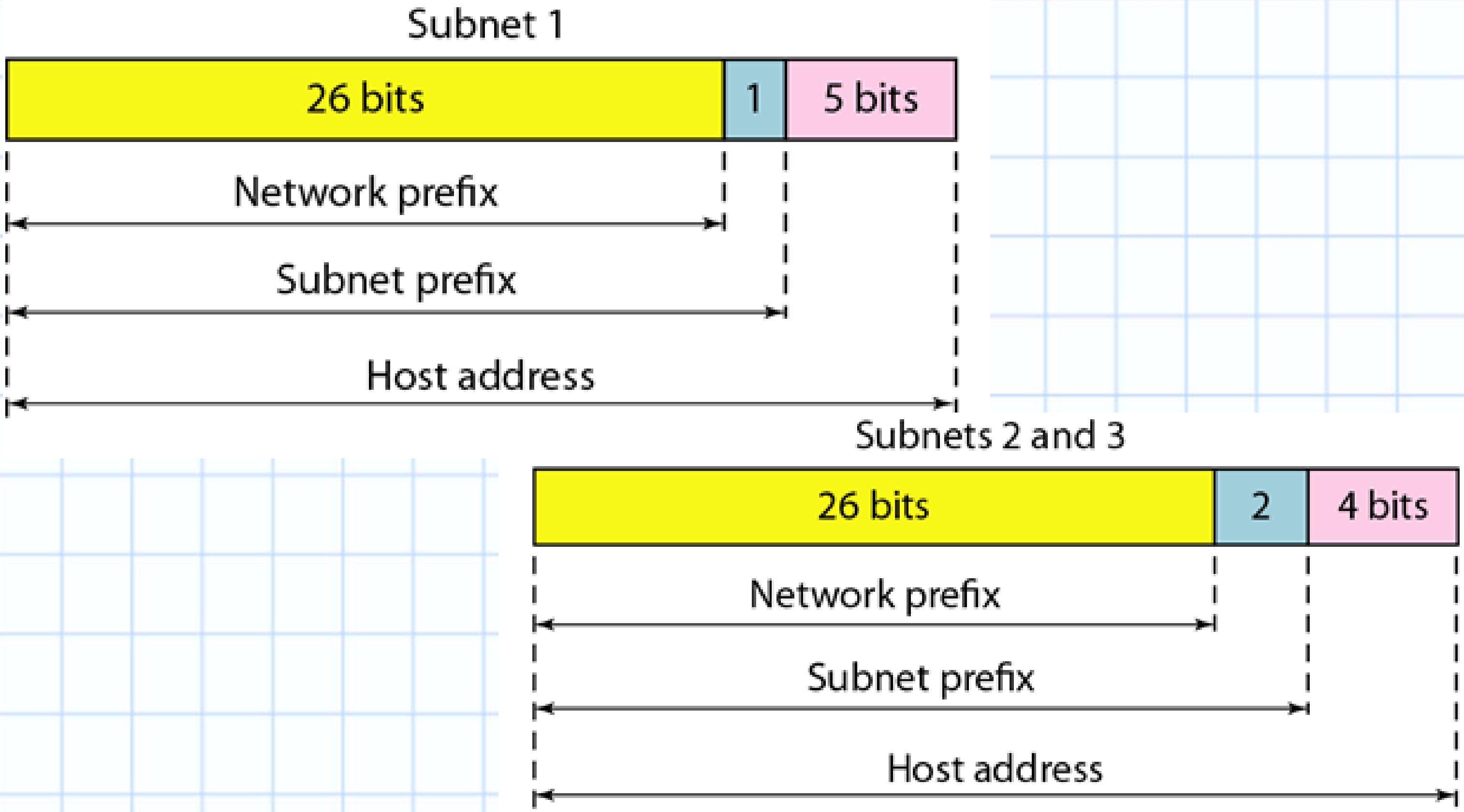
Three-level hierarchy in an IPv4 address



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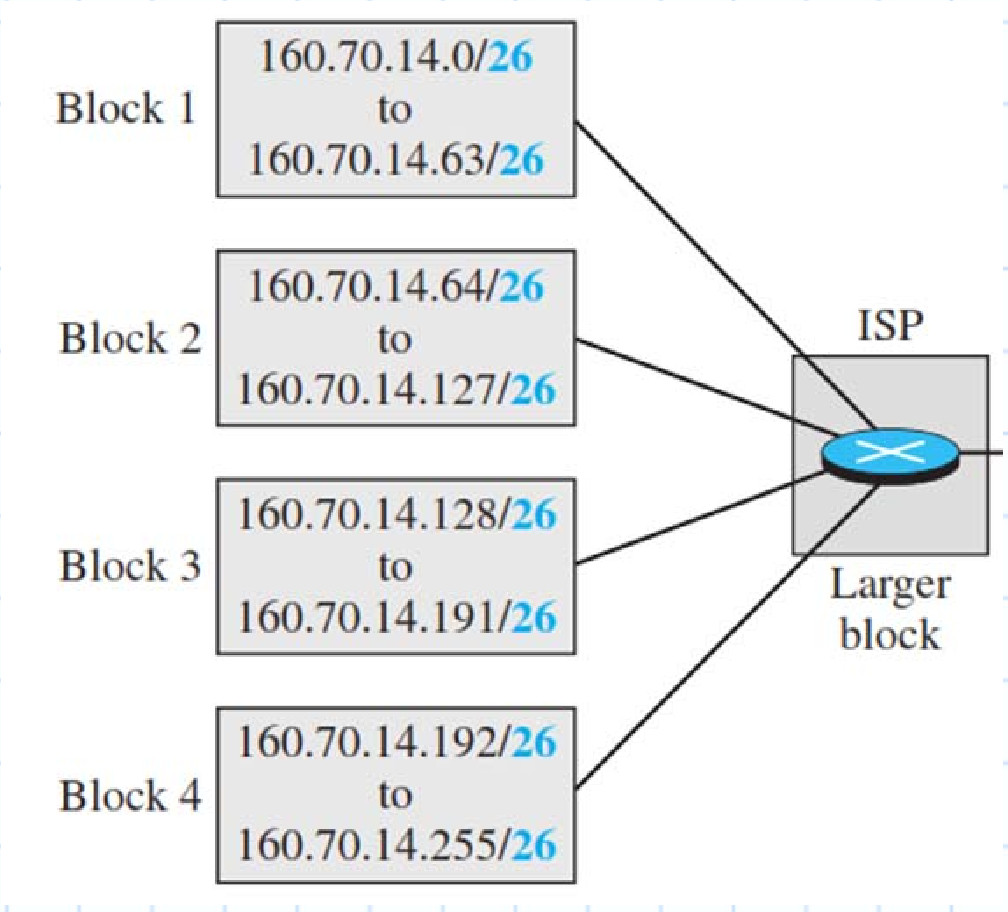
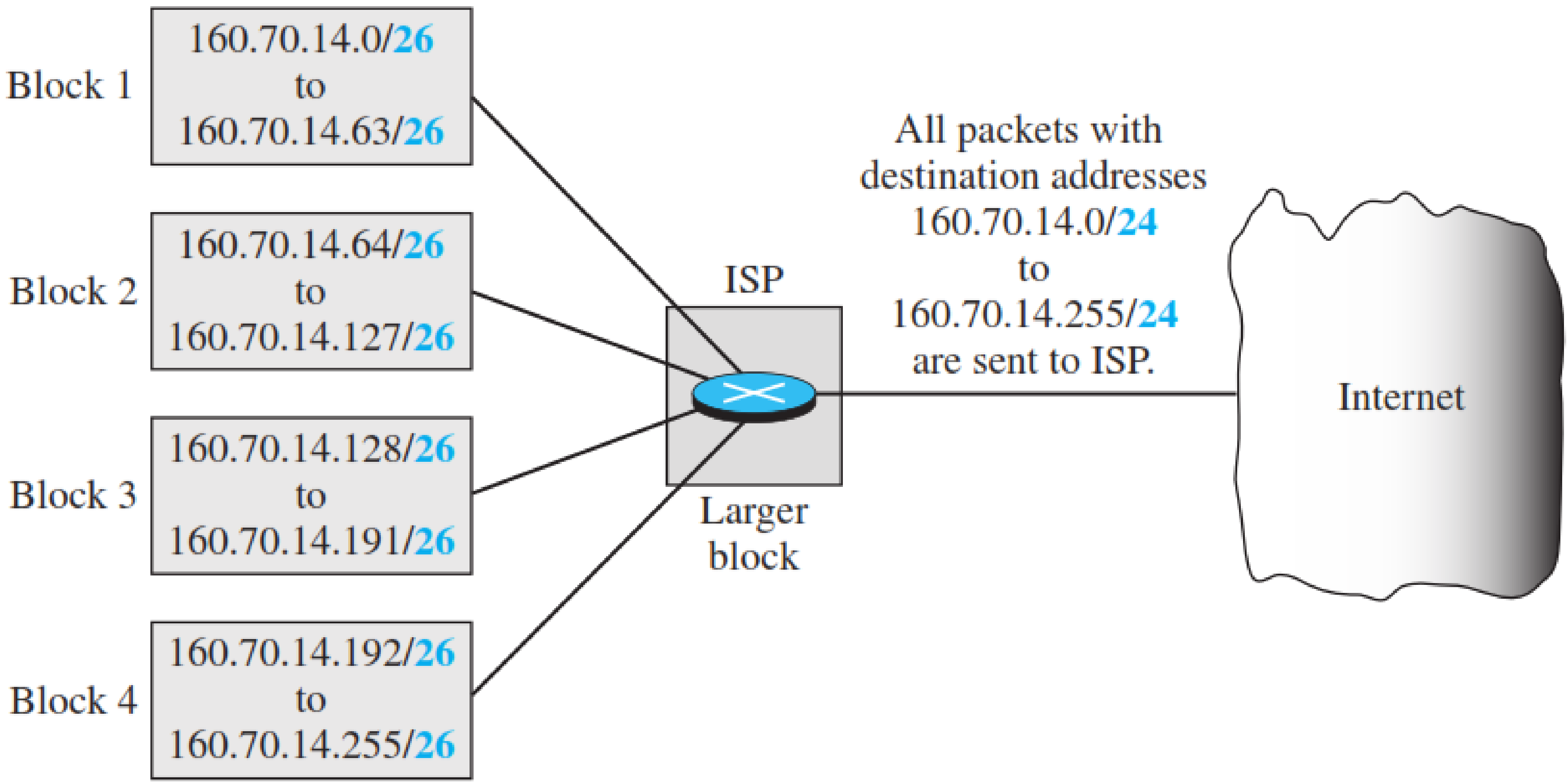
Example of address aggregation

Block 1	160.70.14.0/26 to 160.70.14.63/26
Block 2	160.70.14.64/26 to 160.70.14.127/26
Block 3	160.70.14.128/26 to 160.70.14.191/26
Block 4	160.70.14.192/26 to 160.70.14.255/26

Example of address aggregation



Example of address aggregation



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