Chapter 5

IP Addresses: Classless Addressing

Objectives

Upon completion you will be able to:

- *Understand the concept of classless addressing*
- *Be able to find the first and last address given an IP address*
- *Be able to find the network address given a classless IP address*
- *Be able to create subnets from a block of classless IP addresses*
- *Understand address allocation and address aggregation*

5.1 VARIABLE-LENGTH BLOCKS

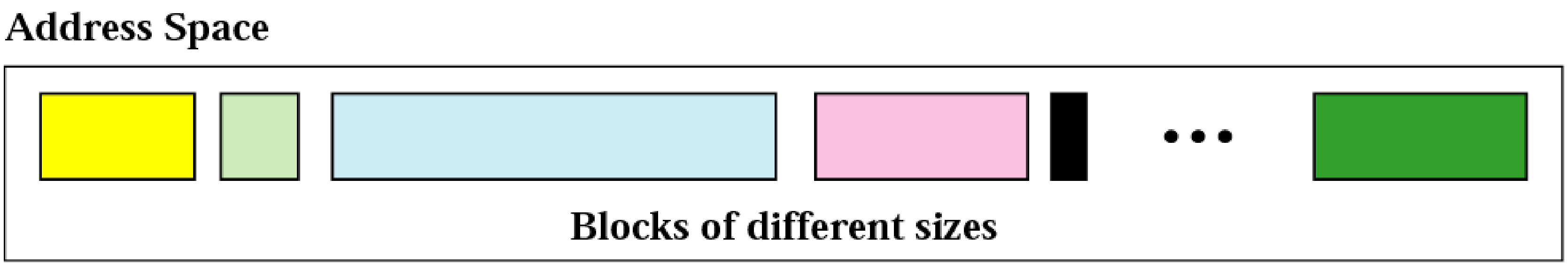
ISPs came into existence in 1990s. Provides IP addresses to individuals. Prior to this ICANN was able to assign a Class address which resulted in wastage of chunk of addresses.

In classless addressing variable-length blocks are assigned that belong to no class. In this architecture, the entire address space (232 addresses) is divided into blocks of different sizes.

Restrictions
Finding the Block
Granted Block

- In classless addressing variable length blocks are assigned that belongs to no class.
- A block can range from very small to very large.
- Entire address space is divided into blocks of different sizes.
- See fig.

Figure 5.1 ***Variable-length blocks***



Restrictions

- Number of addresses in a Block
  - It must be a power of two

- First Address
  - Must be exactly divisible by number of addresses.
  - If block contains 16 address, first address must be divisible by 16, etc.
  - If a block has only 256 or less addresses, only need to check last bye.

Example 1

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***

Example 1

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.

Example 2

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***

Example 2

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. As we mentioned in Chapter 4, 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 3

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***

Example 3

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).

Mask

- Masks in Classful addressing are implicit.
  - Class A has 255.0.0.0 (/8)
  - Class B has 255.255.0.0 (/16)

- Classless Addressing
  - When an address is given, the block the address belongs to cannot be found unless we have the mask.
  - i.e The address must be accompanied by mask.
  - Given in CIDR notation. (in terms of number of 1's)
  - CIDR: Classless Interdomain Routing.
  - An address in classless addressing is shown in fig.

Figure 5.2 *Format of classless addressing address*

x.y.z.t/n

The *n* after slash defines the number of bits that are same in every address in the block.

We can easily find the number of addresses in the block and the last address from this information.

Table 5.1 *Prefix lengths*

/n	Mask	/n	Mask	/n	Mask	/n	Mask
/1	128.0.0.0	/9	255.128.0.0	/17	255.255.128.0	/25	255.255.255.128
/2	192.0.0.0	/10	255.192.0.0	/18	255.255.192.0	/26	255.255.255.192
/3	224.0.0.0	/11	255.224.0.0	/19	255.255.224.0	/27	255.255.255.224
/4	240.0.0.0	/12	255.240.0.0	/20	255.255.240.0	/28	255.255.255.240
/5	248.0.0.0	/13	255.248.0.0	/21	255.255.248.0	/29	255.255.255.248
/6	252.0.0.0	/14	255.252.0.0	/22	255.255.252.0	/30	255.255.255.252
/7	254.0.0.0	/15	255.254.0.0	/23	255.255.254.0	/31	255.255.255.254
/8	255.0.0.0	/16	255.255.0.0	/24	255.255.255.0	/32	255.255.255.255

Note:

Classful addressing is a special case of classless addressing.

Finding the block

- When a classless address is given, we can find the block We can find the first address, number of addresses, and the last address.

- Finding the first address.
  – AND the mask and address to find the first address.
  – Just keep the first n bits, and change the rest of bits to 0.

Example 4

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

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What is the first address in the block 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 following shows the process:

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*

Example 5

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

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Solution

Figure 5.3 shows the 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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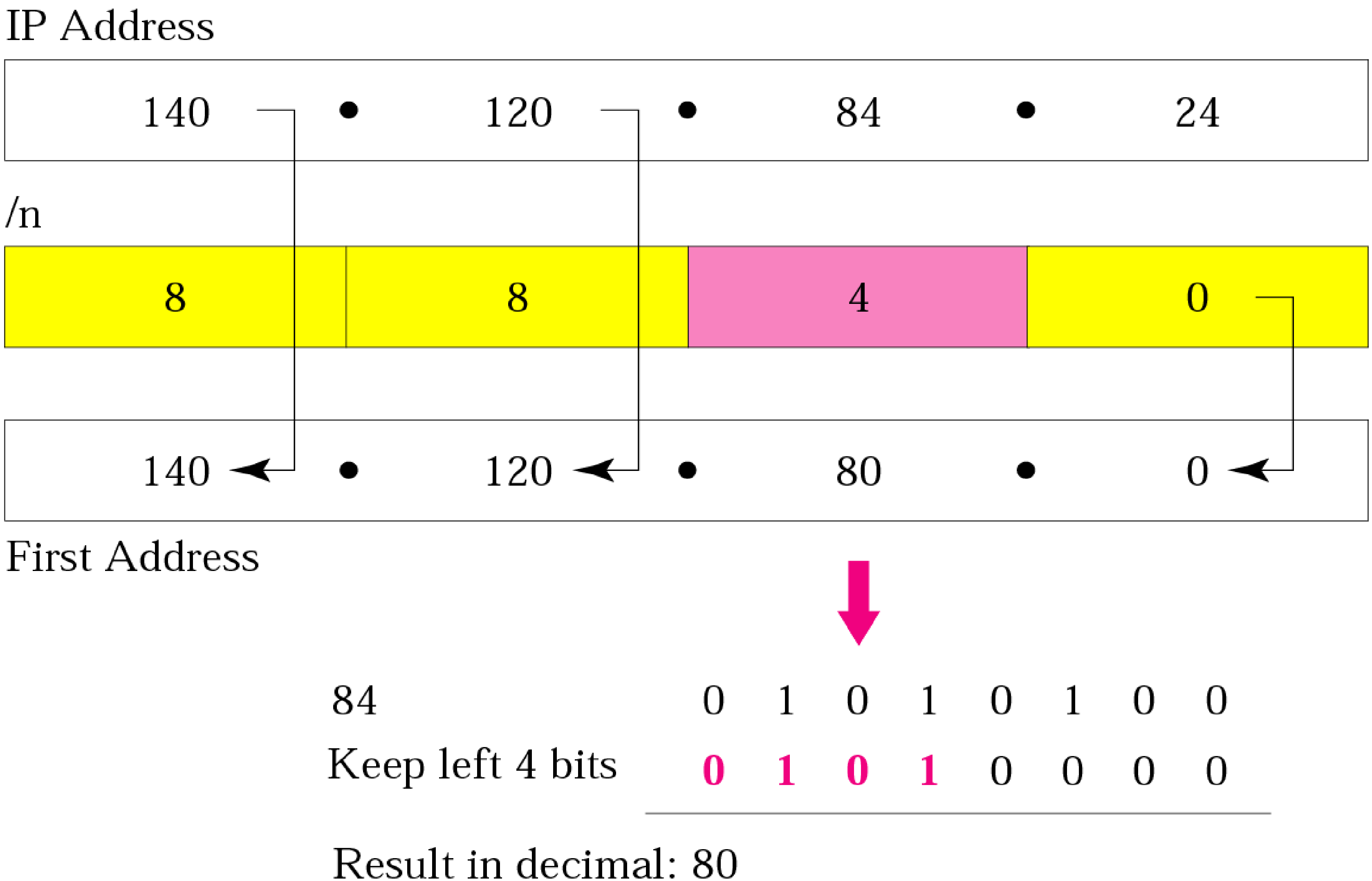
Figure 5.3 *Example 5*



Example 6

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

Example 6

Find 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 as defined in the previous example. To find the third byte, we write 84 as the sum of powers of 2 and select only the leftmost 4 (m is 4) as shown in Figure 5.4. The first address is 140.120.80.0/20.

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Figure 5.4 ***Example 6***

	128	64	32	16	8	4	2	1
Write 84 as sum of:	0	64	0	16	0	4	0	0
Select only leftmost 4:	0	64	0	16				
Add to find the result:	80							

Example 7

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

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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.

Finding the last address in the block

- Method 1: Add the number of addresses in the block minus 1 to the first address to find the last address.

- Method 2: Add the first address to the complement of the mask.

Example 8

Using the first method, find the last address in the block if one of the addresses is 140.120.84.24/20.

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Using the first method, 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.

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Example 8 *(Continued)*

To keep the format in dotted-decimal notation, we need to represent 4095 in base 256 (see Appendix B) and do the calculation in base 256. We write 4095 as 15.255. 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.

Example 9

Using the second method, find the last address in the block if one of the addresses is 140.120.84.24/20.

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Using the second method, find the last address in the block if one of the addresses is 140.120.84.24/20.

Solution

The mask has twenty 1s and twelve 0s. The complement of the mask has twenty 0s and twelve 1s. In other words, the mask complement is

00000000 00000000 00001111 11111111

or 0.0.15.255. We add the mask complement to the beginning address to find the last address.

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Example 9 *(Continued)*

We add the mask complement to the beginning address to find the last address.

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

The last address is 140.120.95.255/20.

Example 10

Find the block if one of the addresses is 190.87.140.202/29.

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Example 10

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:

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Example 10 *(Continued)*

202	➡ **128 + 64 + 0 + 0 + 8 + 0 + 2 + 0**
The leftmost 5 numbers are	➡ **128 + 64 + 0 + 0 + 8**
The first address is 190.87.140.200/29	

The number of addresses is 2^{32-29} or 8. To find the last address, we use the complement of the mask. The mask has twenty-nine 1s; the complement has three 1s. The complement is 0.0.0.7. If we add this to the first address, we get 190.87.140.207/29. In other words, the first address is 190.87.140.200/29, the last address is 190.87.140.207/29. There are only 8 addresses in this block.

Example 11

Show a network configuration for the block in the previous example.

Solution

The organization that is granted the block in the previous example can assign the addresses in the block to the hosts in its network. However, the first address needs to be used as the network address and the last address is kept as a special address (limited broadcast address). Figure 5.5 shows how the block can be used by an organization. Note that the last address ends with 207, which is different from the 255 seen in classful addressing.

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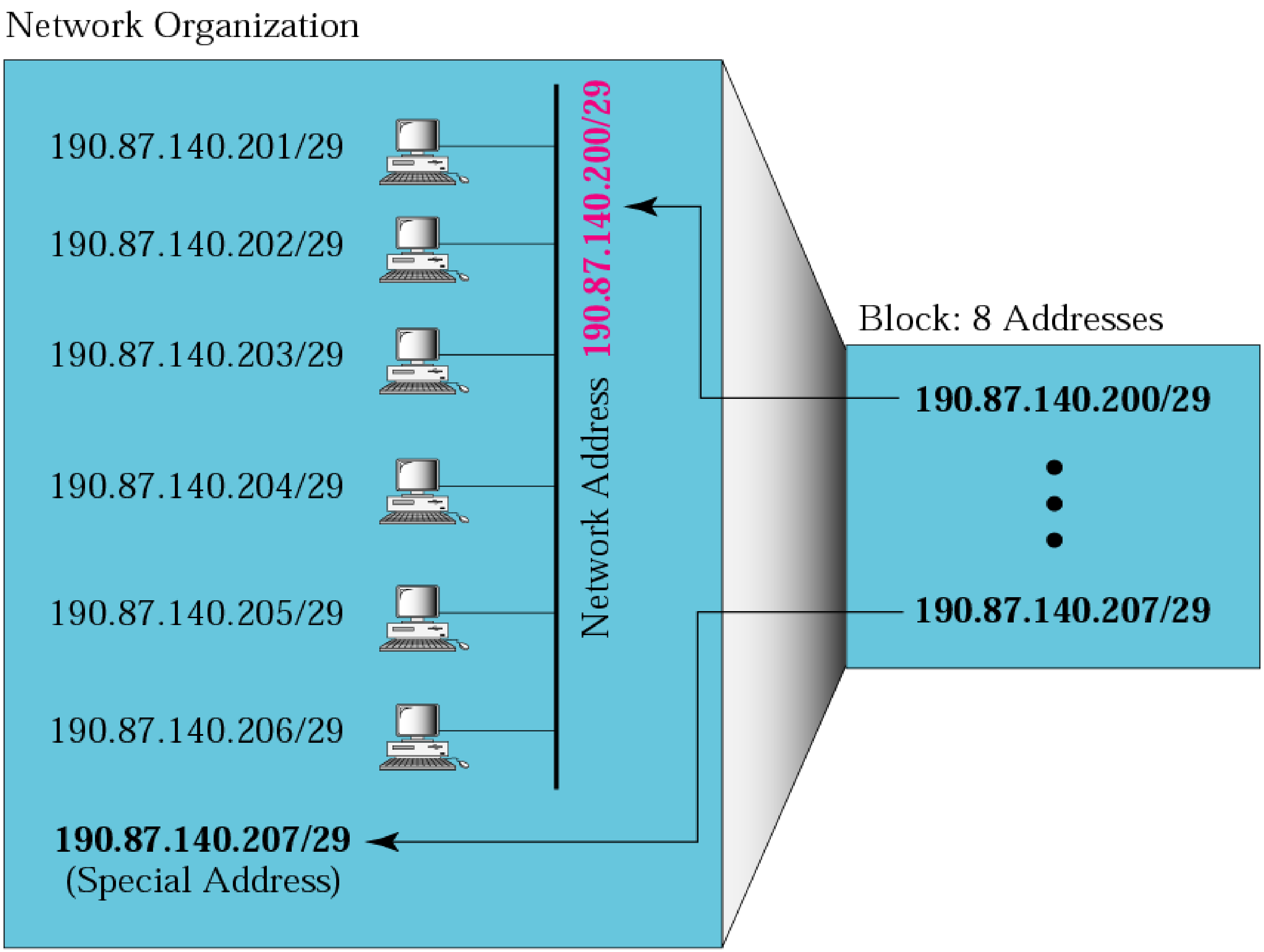
Figure 5.5 *Example 11*



Note:

In classless addressing, the last address in the block does not necessarily end in 255.

Note:

In CIDR notation, the block granted is defined by the first address and the prefix length.

5.2 SUBNETTING

When an organization is granted a block of addresses, it can create subnets to meet its needs. The prefix length increases to define the subnet prefix length.

Finding the Subnet Mask
Finding the Subnet Addresses
Variable-Length Subnets

Note:

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

Finding the subnet mask

- The number of desired subnets defines subnet prefix.
- If number of subnets is s, the number of extra 1's in prefix length is log2s, where s= 2^number of extra 1s.
- For fixed length subnets, the number of subnets needs to be power of 2.

Example 12

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

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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 13

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

Solution

Figure 5.6 shows one configuration.

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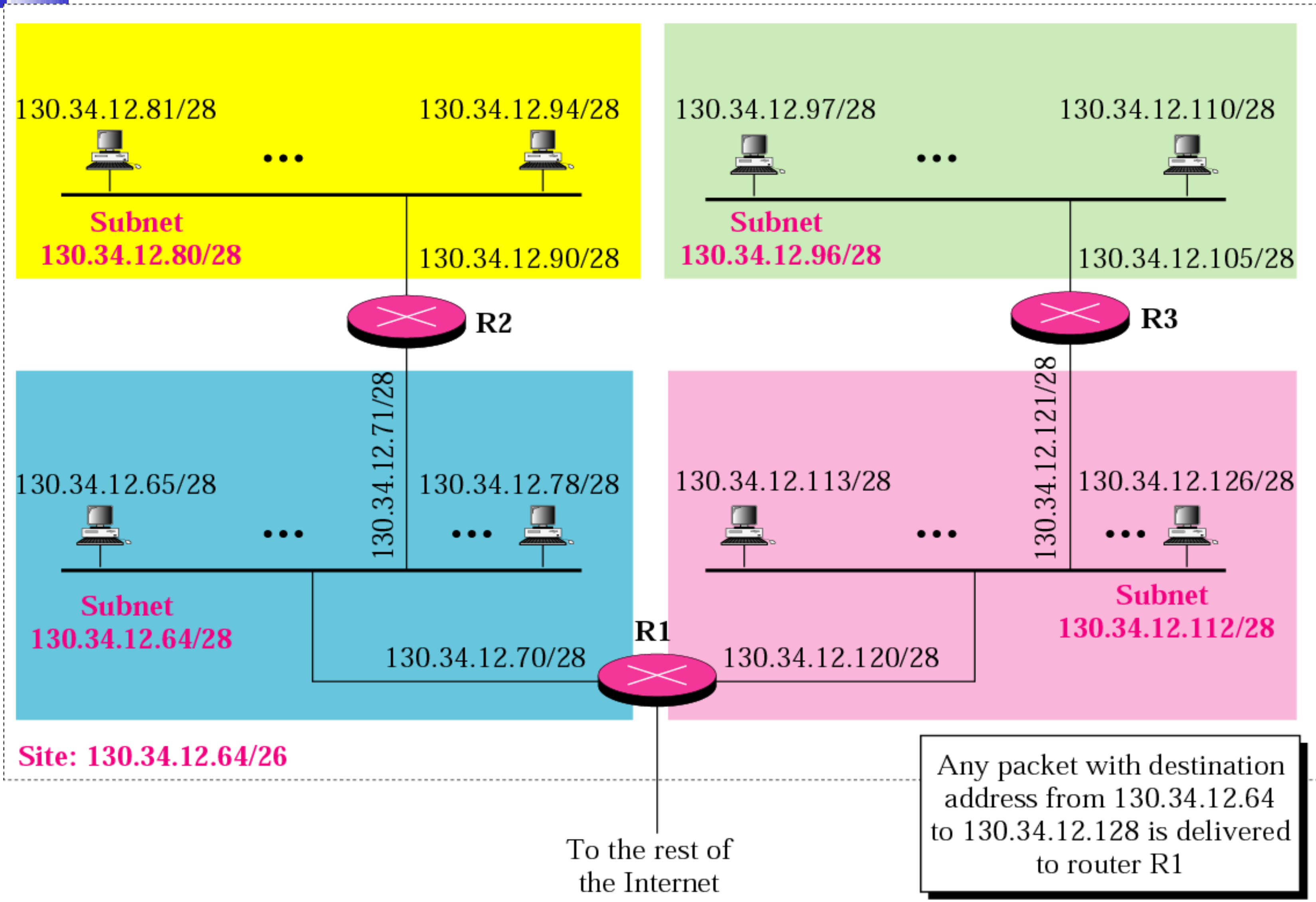
Figure 5.6 *Example 13*



Example 13 *(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.

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Example 13 *(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 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.*

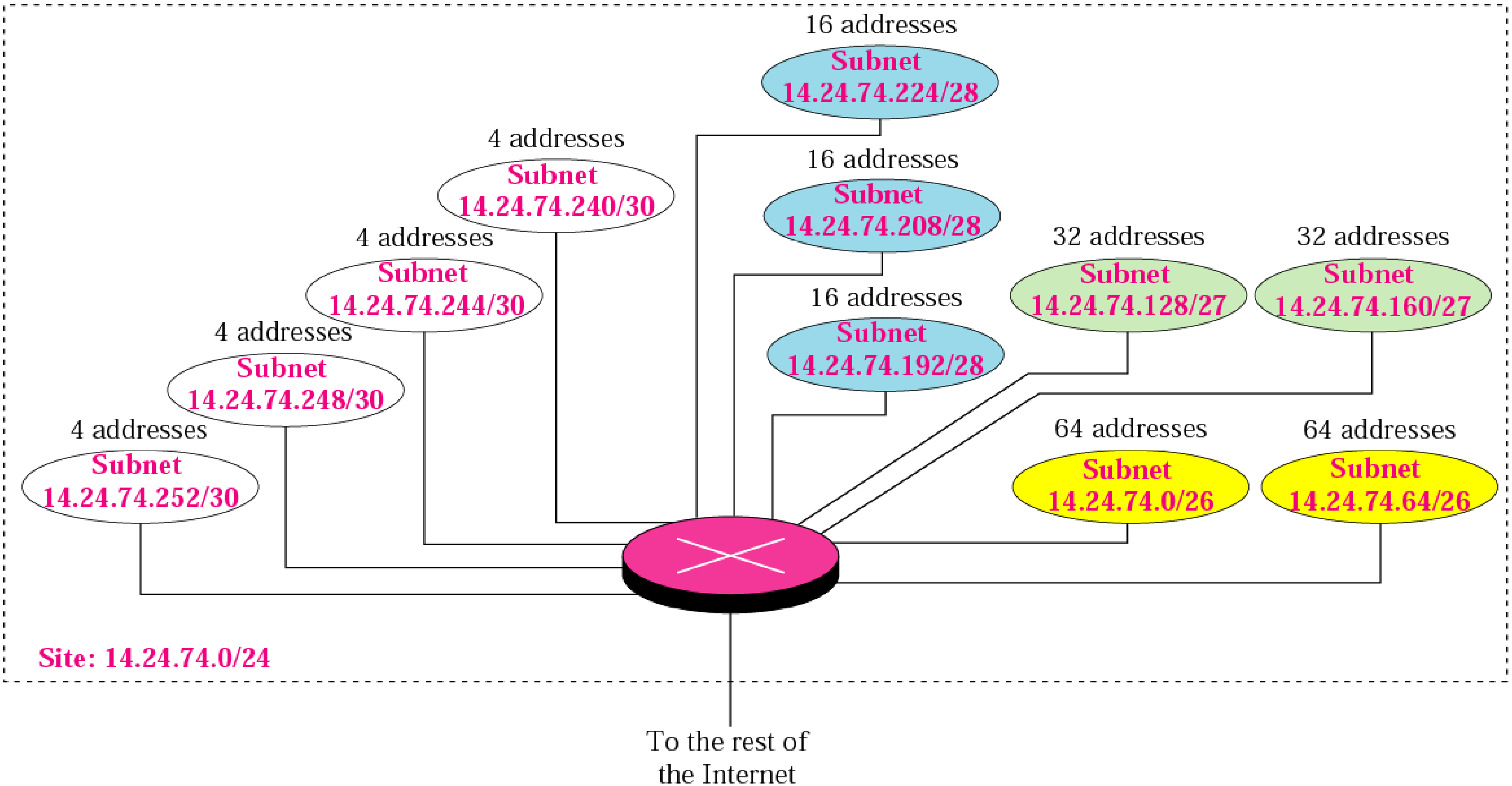
***c.** three subnets, each with 16 addresses.*

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

Design the subnets.

See Next Slide For One Solution

Figure 5.7 *Example 14*



Example 14 (Continted)

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. The subnet address for each subnet is given in the figure.

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. The subnet address for each subnet is given in the figure.

See Next Slide

Example 14 *(Continuted)*

3. ***We use the next 48 addresses for the next three subnets, each with 16 addresses. Note that the mask for each network is /28. The subnet address for each subnet is given in the figure.***

4. ***We use the last 16 addresses for the last four subnets, each with 4 addresses. Note that the mask for each network is /30. The subnet address for each subnet is given in the figure.***

Example 15

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. Figure 5.8 shows the configuration designed by the management.

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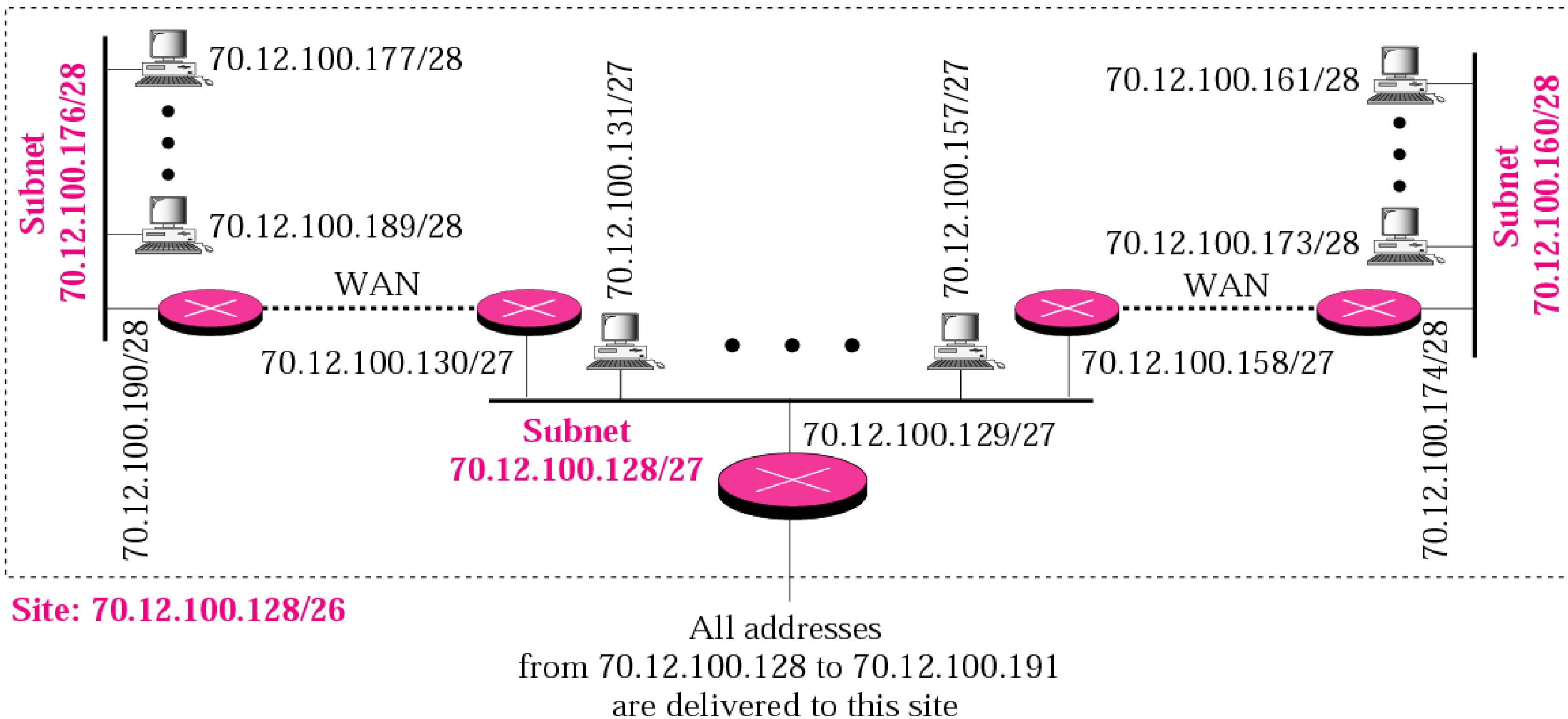
Figure 5.8 *Example 15*



Example 15 *(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.

See Next Slide

Example 15 *(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.***

See Next Slide

Example 15 (Continued)

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.***

5.3 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 16

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.***

See Next Slide

Example 16 (Continued)

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

Solution

Figure 5.9 shows the situation.

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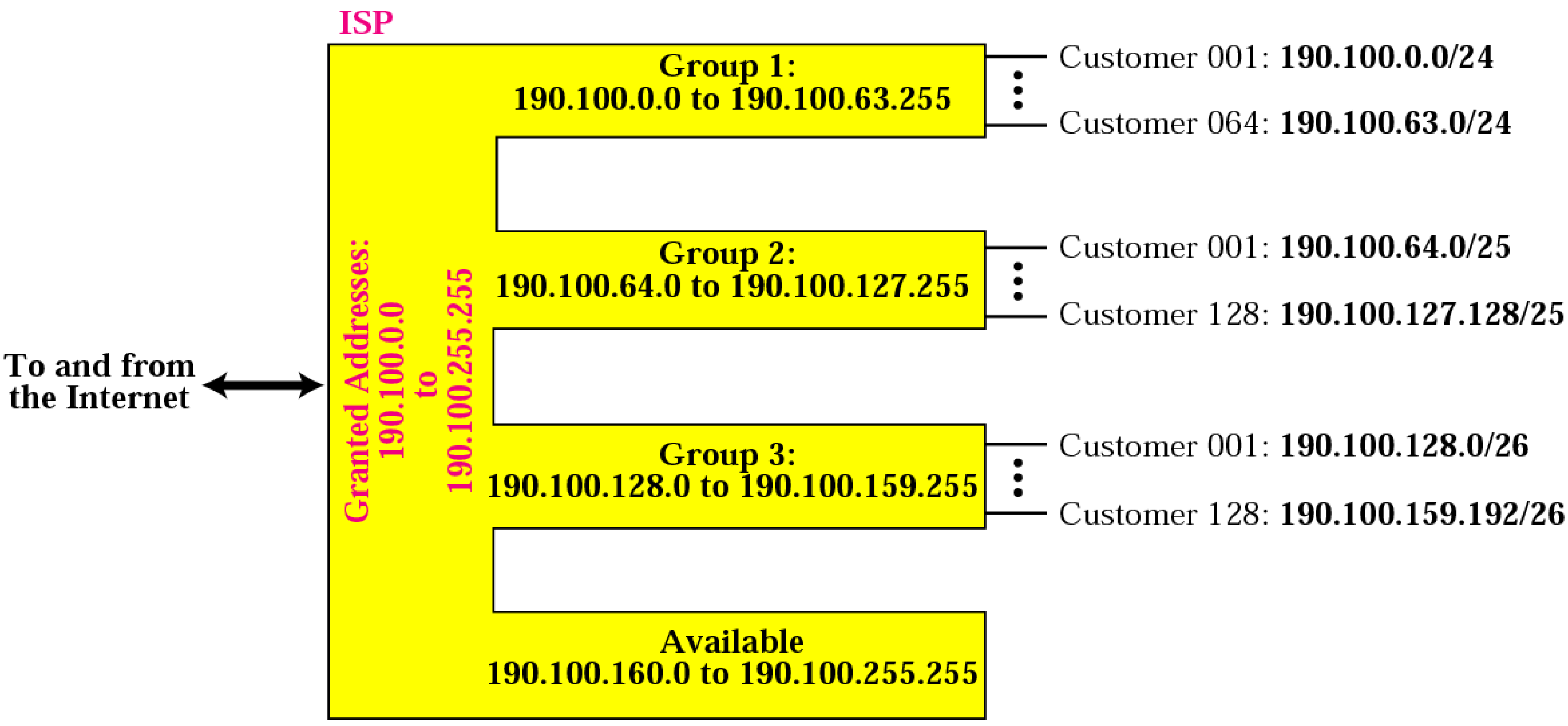
Figure 5.9 *Example 16*



Example 16 *(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		

See Next Slide

Example 16 (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

See Next Slide

Example 16 (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		

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Example 16 (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