Classless Addressing

Classful IP addressing Concept

IP address of Class C: ***192.168.10.0***

Two Parts:

1. Length of Net ID: **24 bits**
2. Length Host ID: **8 bits**

So, number of IP address of this block: $\mathbf{2^{8} = 256}$

Address Range:

- first address: ***192.168.10.0***
- last address: ***192.168.10.255***

Mask: 11111111 11111111 11111111 00000000

=> 255.255.255.0

Classless IP addressing Concept

IP address: ***192.168.10.0/27***

Two Parts:

1. Length of Net ID: **27 bits**
2. Length Host ID: 32-27 = **5 bits**

So, number of IP address of this block: $\mathbf{2^5 = 32}$

Address Range:

- first address: ***192.168.10.0***
- last address: ***192.168.10.31***

Mask: 11111111 11111111 11111111 11100000

=> 255.255.255.224

Classful IP Address

IP address of Class C:

192.168.10.0

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2. Length Host ID: **8 bits**

So, number of IP address of this block: 2^8 **= 256**

Address Range:

- first address: ***192.168.10.0***
- last address: ***192.168.10.255***

Mask: 11111111 11111111 11111111 00000000

=> 255.255.255.0

Classless IP Address

IP address:

192.168.10.0/27

Two Parts:

1. Length of Net ID: **27 bits**
2. Length Host ID: 32-27 = **5 bits**

So, number of IP address of this block: 2^5 **= 32**

Address Range:

- first address: ***192.168.10.0/27***
- last address: ***192.168.10.31/27***

Mask: 11111111 11111111 11111111 11100000

=> 255.255.255.224

Slash notation

To enable the variable-length blocks, the slash notation is introduced

A.B.C.D/*n*

Slash notation is also called CIDR notation

/prefix length represented using ‘1’, as masking.

The remaining unmasked ‘0’ is referred to the **suffix length**

CIDR = Classless InterDomain Routing

The n after the slash defines the number of bits that are the same in every address in the block. So if n is 20, it means the twenty leftmost bits are identical in each address.

Prefix Length

/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

Classful addressing is a special case of classless addressing.

Classless Addressing Rules

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, . . .).

For example, a household may be given a block of 2 addresses. A small business may be given 16 addresses. A large organization may be given 1024 addresses.

Subnetting (Fixed Length)

Given, Network address: ***192.168.10.0/27***

Two Parts: Net ID: **27 bits** & Host ID: 32-27 = **5 bits**

So, number of IP address of this block: $\mathbf{2^5 = 32}$

Address Range:***192.168.10.0/27 ~ 192.168.10.31/27***

Mask: 11111111 11111111 11111111 11100000

=> 255.255.255.224

Q. Now create 4 subnets of fixed length of IP addresses.

Subnetting (Fixed Length)

Given, Network address: ***192.168.10.0/27***

Two Parts: Net ID: **27 bits** & Host ID: 32-27 = **5 bits**

So, number of IP address of this block: **2^5 = 32**

Address Range:*192.168.10.0/27* ~ *192.168.10.31/27*

Mask: 11111111 11111111 11111111 11100000 => 255.255.255.224

Q. Now create 4 subnets of fixed length of IP addresses.

Ans: Each Subnet size: 32/4 = 8 (2^3) (# of IPs in each Subnet). So, Net ID of each subnet is 32-3 = 29 bits.

Therefore, IP address of each subnet is like: X.Y.Z.A/29

Subnet Mask:

11111111 11111111 11111111 11111000 => 255.255.255.248

Subnetting (Fixed Length)

Given, Network address: ***192.168.10.0/27***

Two Parts: Net ID: **27 bits** & Host ID: 32-27 = **5 bits**

So, number of IP address of this block: $\mathbf{2^5 = 32}$; Range: *192.168.10.0/27* ~ *192.168.10.31/27*

Q. Now create 4 subnets of fixed length of IP addresses.

Ans: Each Subnet size: 32/4 = 8 (2^3) (# of IPs in each Subnet). So, Net ID of each subnet is 32-3 = 29 bits.

Therefore, IP address of each subnet is like: X.Y.Z.A/29

Subnet Mask: 11111111 11111111 11111111 11111000 => 255.255.255.248

```
Now each subnet range of the 4 subnets is as follows:
                                            binary form of the last byte
1) 192.168.10.0/29 - 192.168.10.7/29                   000 - 111
2) 192.168.10.8/29 - 192.168.10.15/29               1  000 - 1 111
3) 192.168.10.16/29 - 192.168.10.23/29              10 000 - 10 111
4) 192.168.10.24/29 - 192.168.10.31/29              11 000 - 11 111
```

Subnetting (Variable Length)

Given, Network address: ***192.168.10.0/27***

Q. Now create 4 subnets of variable length of IP addresses as follows.

```
i) First subnet will be given 16 (2^4) IP addresses
ii) Second subnet will be given 8 (2^3) IP addresses
iii) Third subnet will be given 4 (2^2) IP addresses
iv) Fourth subnet will be given 4 (2^2) IP addresses

Net id has has 27 bits here and host id has 32-27 =5 bits
So total number of ip addresses is = 2^5 = 32
So the range of the block is : 192.168.10.0/27 ~ 192.168.10.31/27

Now lets doing the subnetting:
 Last IP address = 1st IP address + number of IP address in the subnet -1
 Net ID (/28) = 32 (total IP address bits)- 4 (host id bits)
i) 1st subnet: 192.168.10.0/28 ~ 192.168.10.15/28
ii) 2nd subnet: 192.168.10.16/29 ~ 192.168.10.23/29
iii) 3rd subnet: 192.168.10.24/30 ~ 192.168.10.27/30
iv) 4th subnet: 192.168.10.28/30 ~ 192.168.10.31/30
```

More Examples about Subnetting

- Fixed Length Subnetting:

  https://youtu.be/y3MZtoe38_c

- Variable Length Subnetting:

  https://youtu.be/4fJVBaZM21E

Classless Addressing Rules:

- ***Number of Addresses in a Block***
  - The number of addresses in a block must be a power of 2 (2, 4, 8, . . .)
- ***Beginning Addresses***
  - The beginning address must *be evenly divisible by the number of addresses.*
    - Ex: if a block contains 4 addresses, the beginning address must be divisible by 4.
    - *Make the rightmost number of bits in the beginning address are zero*
  - 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 right most bytes, and so on.

Example-1

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-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. 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?

205.16.37.32
190.16.42.0
17.17.32.0
123.45.24.52

Solution

In this case, we need to check two bytes because $1024 = 4 \times 256$. The right-most byte must be divisible by 256 (should be 0). The second byte (from the right) must be divisible by 4. Only one address is eligible (c).

Subnetting

- Allows larger network break into a bunch of smaller networks.
- For example—from one network creating six networks called subnetting.
- Reasons of subneting:
  - Reduced network traffic
  - Optimizing network performance
  - Simplified management
  - Facilitated spanning large geographical distances

Finding The Blocks

- When a classless address is given, we can find the block
  - The first address in the block
  - The number of addressed in the block
  - n The last address in the block

Finding The First Address

- We can derive the first address if we know
  - One of the address in the block
  - The *prefix length(n)*, or a *mask*, or the *suffix length*
- Solution 1
  - AND the mask and the address to find the first address, i.e., network address
- Solution 2
  - Just keep the first *n* bits and change the rest to 0s

Example-4

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
- We must keep the first 27 bits as it 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.

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

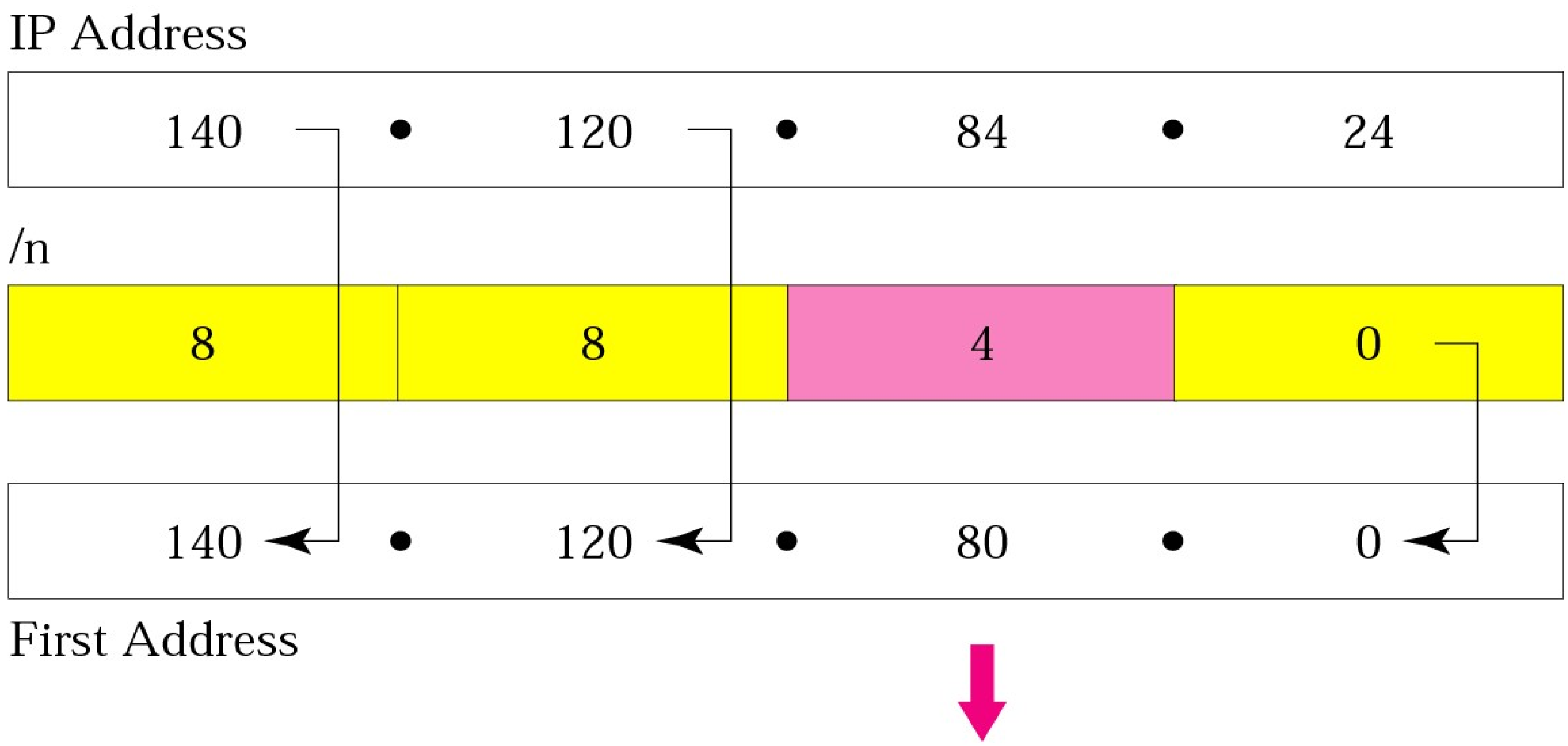
Find the first address in the block if one of the addresses is 140.120.84.24/20.

Solution

- The first, second, and fourth bytes are 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

See Next Slide

Example 5



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

Example-6

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.

Find the last address in the block

- Two methods

- First method
  - **Add the number of addresses in the block minus 1 to the first address**
- Second method
  - **Add the first address to the *complement of the mask***

Example-7

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

Solution

- Using the first method found in the example 7
  - The first address is 140.120.80.0/20
  - The number of addresses is 4096.
- To find the last address
  - Add 4095 (4096 - 1) to the first address

Example-7

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

Solution

Using second method:
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.

See Next Slide

Example-7

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-8

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

Solution

•Follow the procedure in the previous examples to find:

• The first address

- ***The first address is 190.87.140.200/29***

•The number of addresses

- ***The number of addresses is 2^(32-29) or 8***

•The last address

- ***The last address is 190.87.140.207/20***

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
  - The number of subnets needs to be a power of 2

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

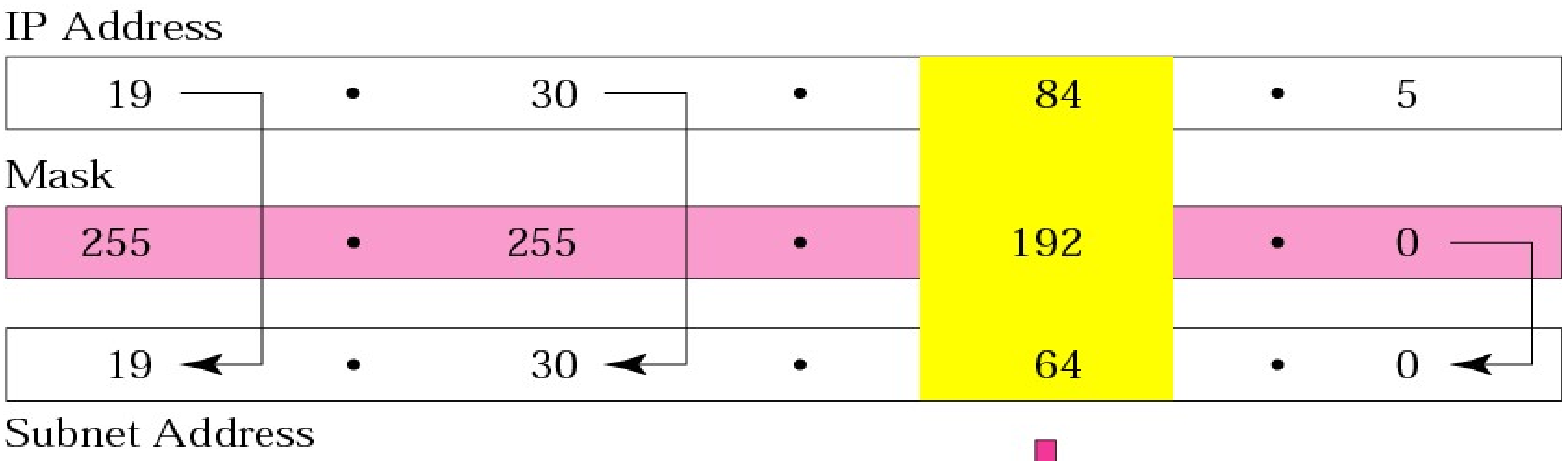
- If the byte in the mask is 255, copy the byte in the address
- If the byte in the mask is 0, replace the byte in the address with 0
- If the byte in the mask is neither 255 nor 0, we write the mask and the address in binary and apply the AND operation

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

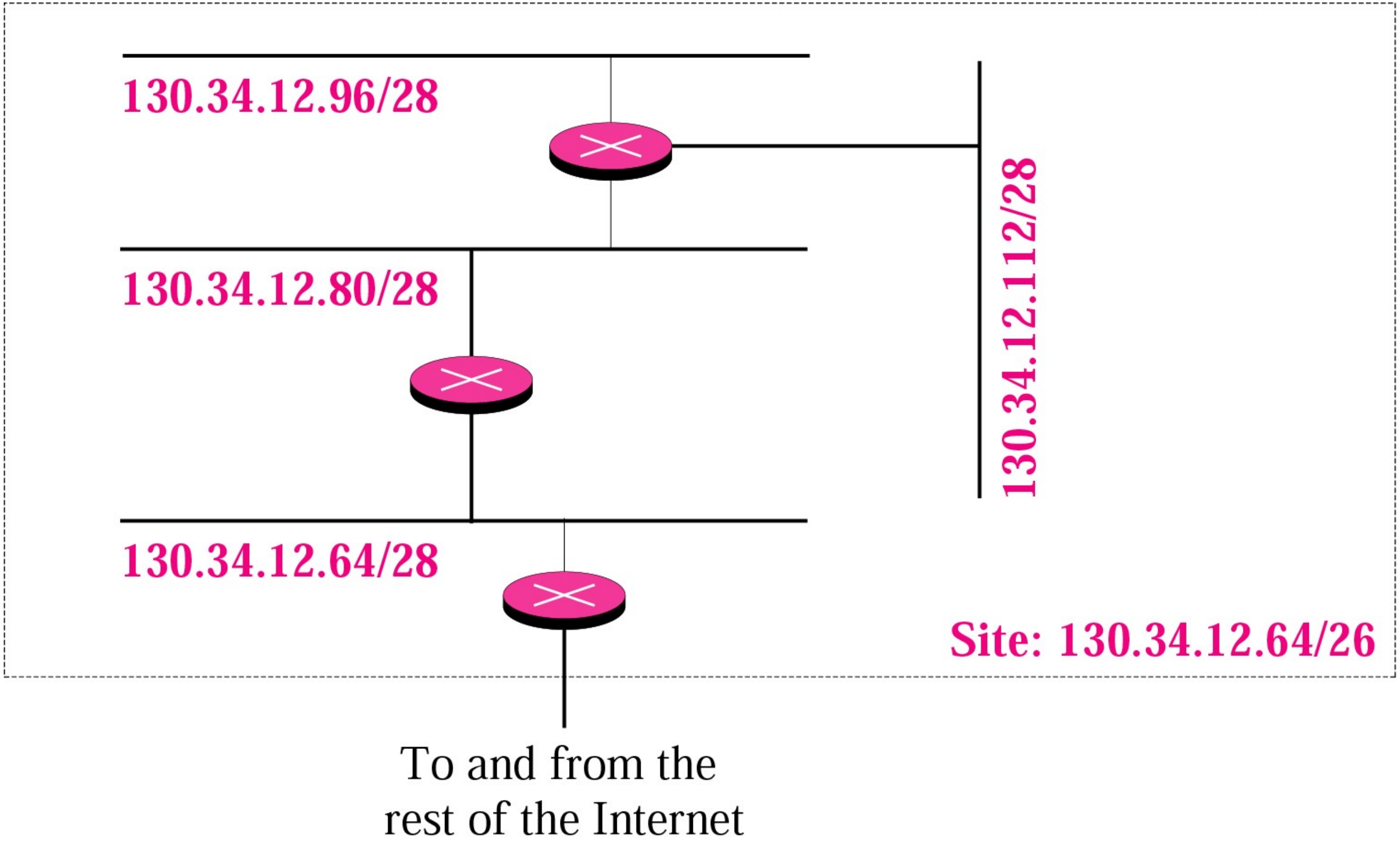
- The first address in the second subnet is 130.34.12.80/28
  - Found by adding 1 to the last address of the previous subnet.
  - Again adding 15 to the first address, we obtain the last address, 130.34.12.95/28.

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.

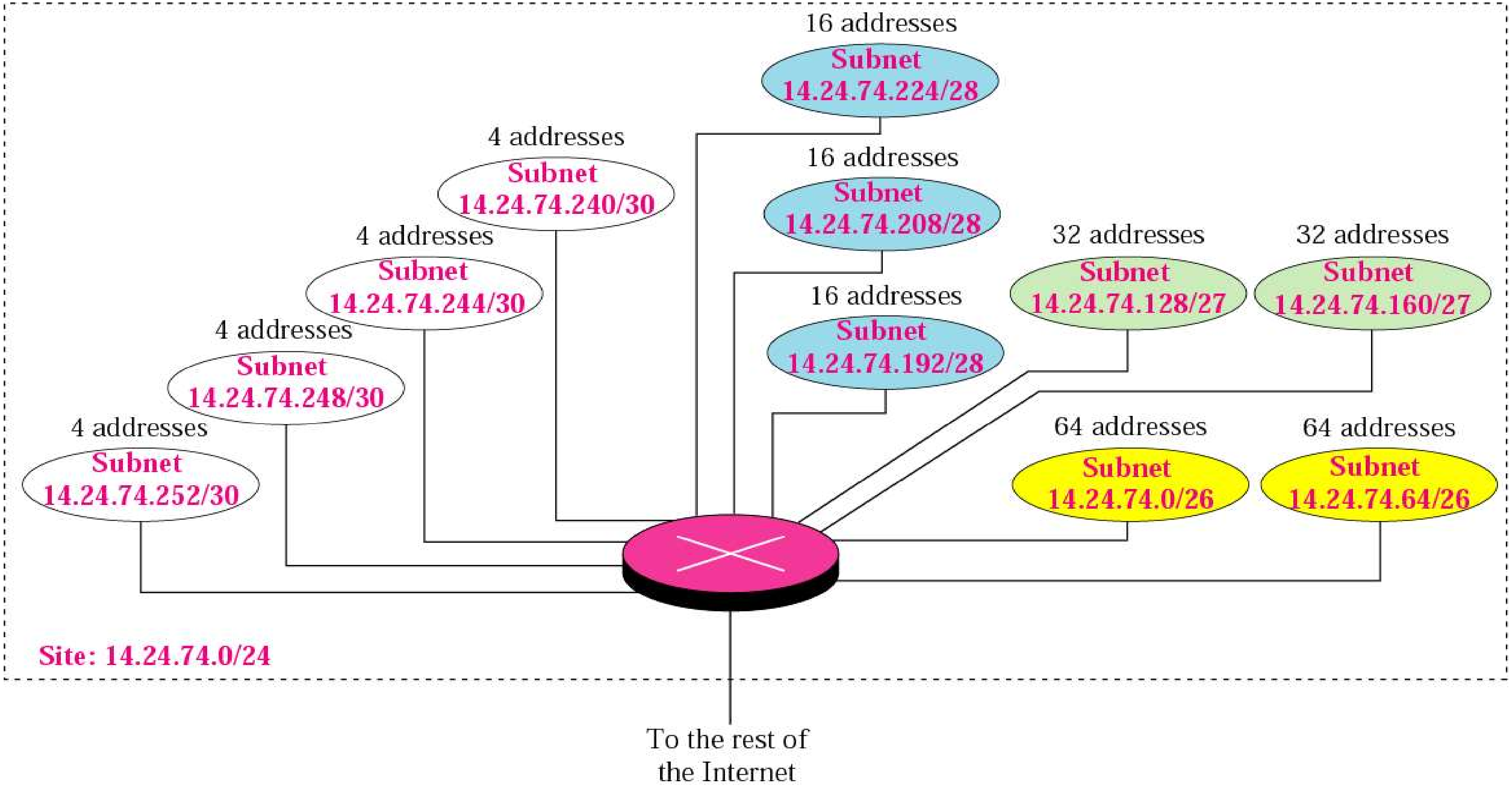
See Next Slide For One Solution

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 = $128 \times 128 = 16{,}384$

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:

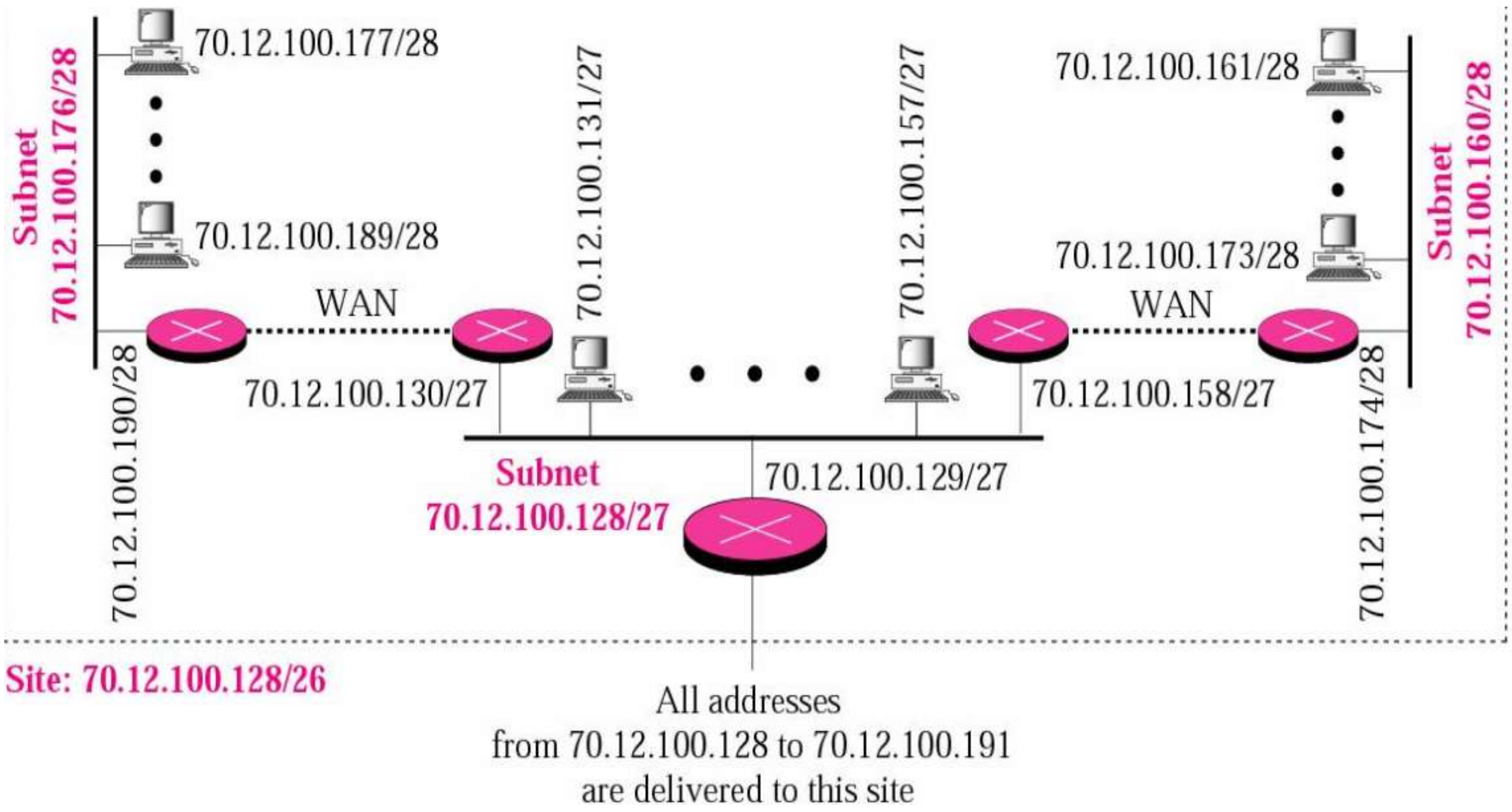
Given, 192.168.0.0/16 (host=1000->1024-> /22)

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
70.12.100.190/28
WAN
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