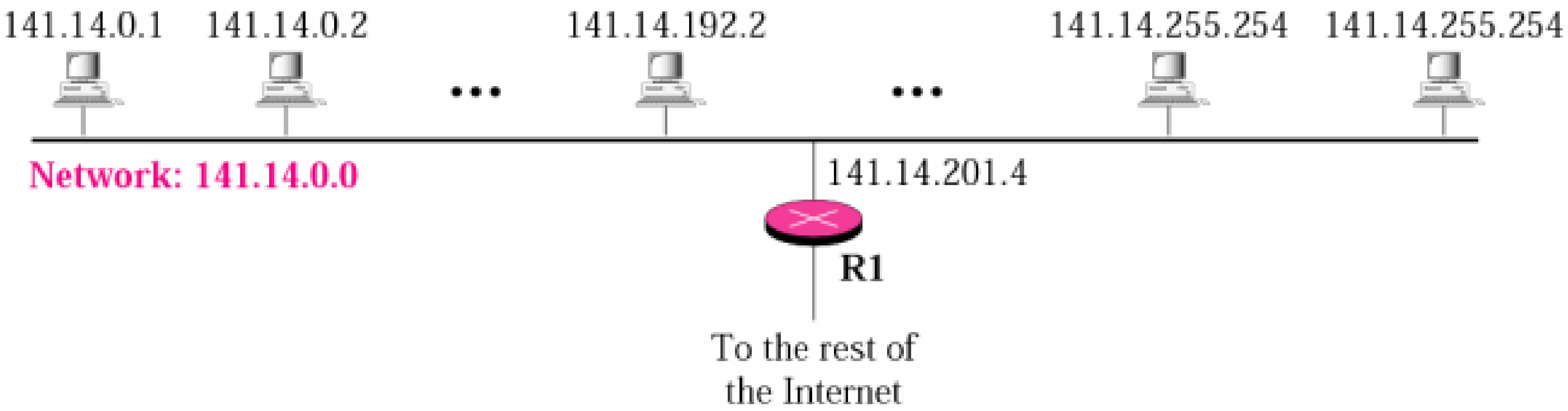
Chapter 5

Subnetting/Supernetting and Classless Addressing

A network with two levels of hierarchy (not subnetted)

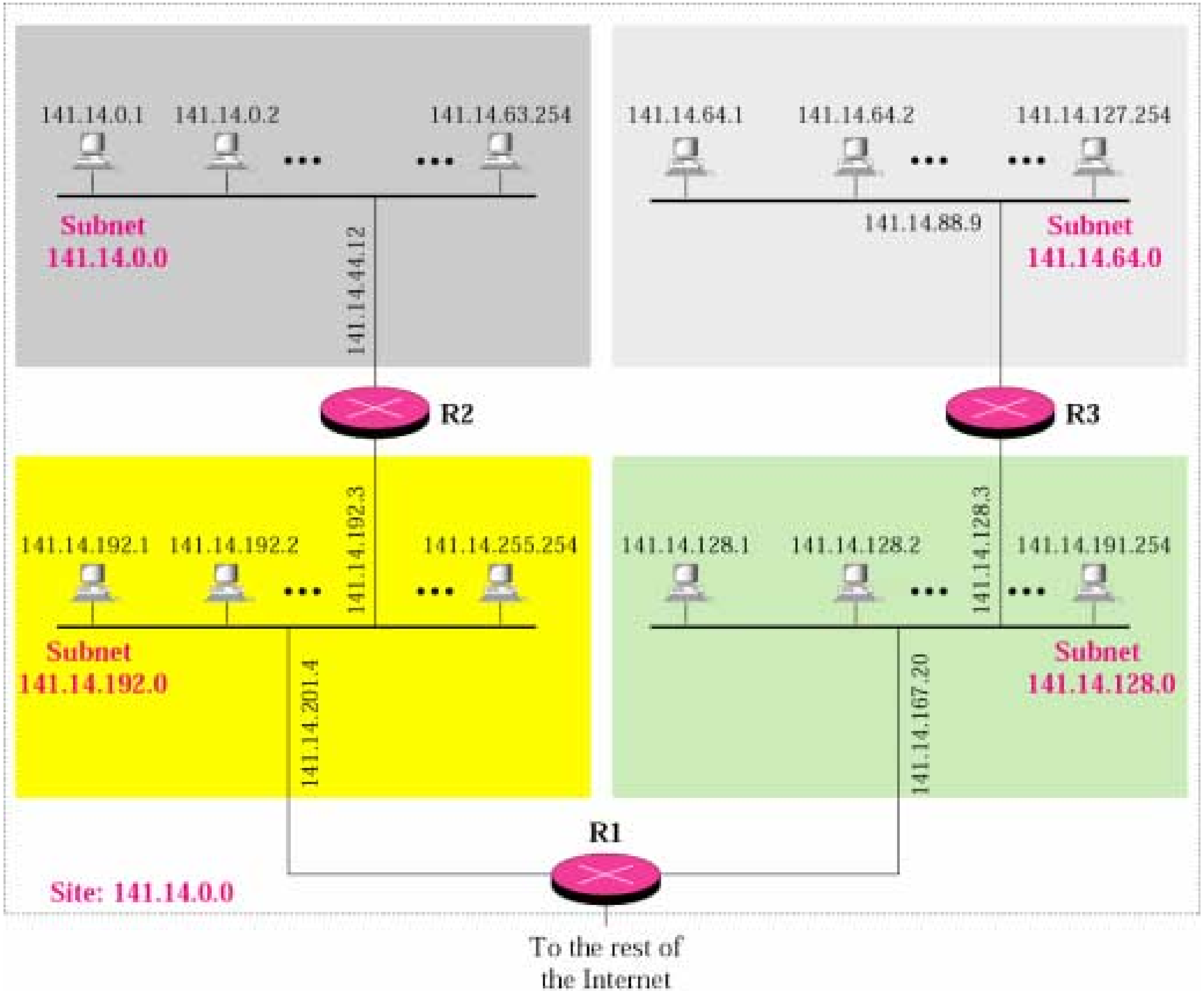


The network above (network 141.14.0.0) uses class B addressing, it has therefore 254x254 = 64516 hosts.

A LAN with 64516 hosts is too big. An additional level of hierarchy is required in order to brake the large number of hosts into several smaller groups. For example, we can brake the hosts into four groups (subnets):

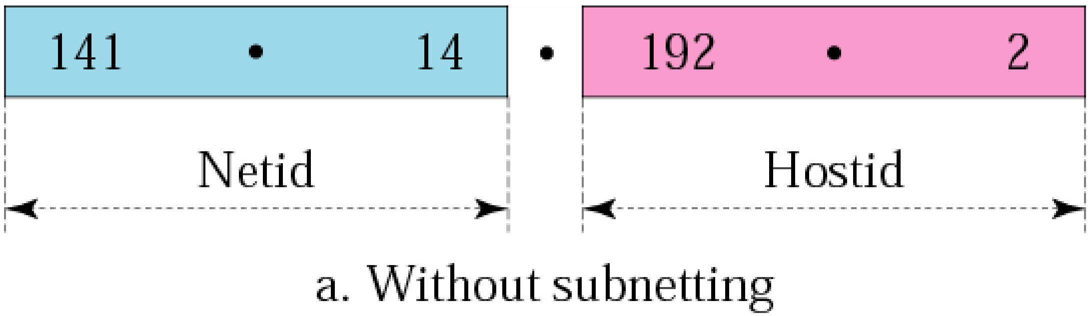
Subnet 141.14.0.0	**has hosts 141.14.0.1**	**… 141.14.63.254**
Subnet 141.14.64.0	**has hosts 141.14.64.1**	**… 141.14.127.254**
Subnet 141.14.128.0	**has hosts 141.14.128.1**	**… 141.14.191.254**
Subnet 141.14.192.0	**has hosts 141.14.192.1**	**… 141.14.255.254**

A network with three levels of hierarchy (subnetted)

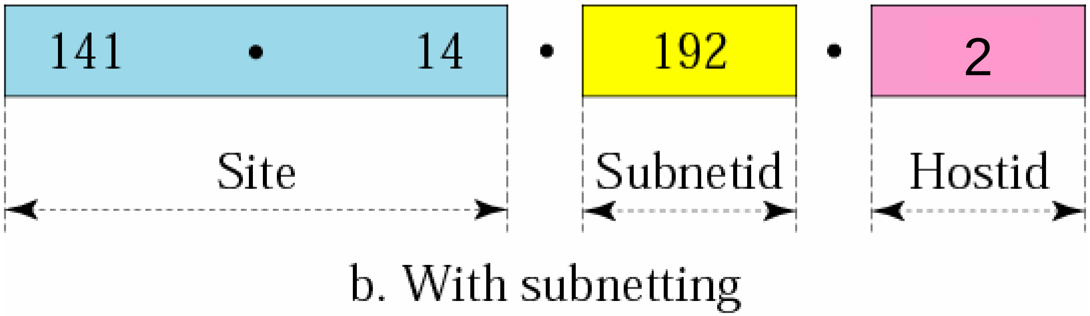


Addresses in a network with and without subnetting

Two-level hierarchy



Three-level hierarchy



Net address: 141.14.0.0

Subnet address: 141.14.192.0

Host address: 141.14.192.2

Hierarchy concept in a telephone number

Equivalent to a
Net ID

Equivalent to a
Subnet ID

Equivalent to a
Host ID

Example 1

IP address: 130.45.34.56
Mask: 255.255.240.0 What is the subnet address?

IP = 10000010 00101101 00100010 00111000

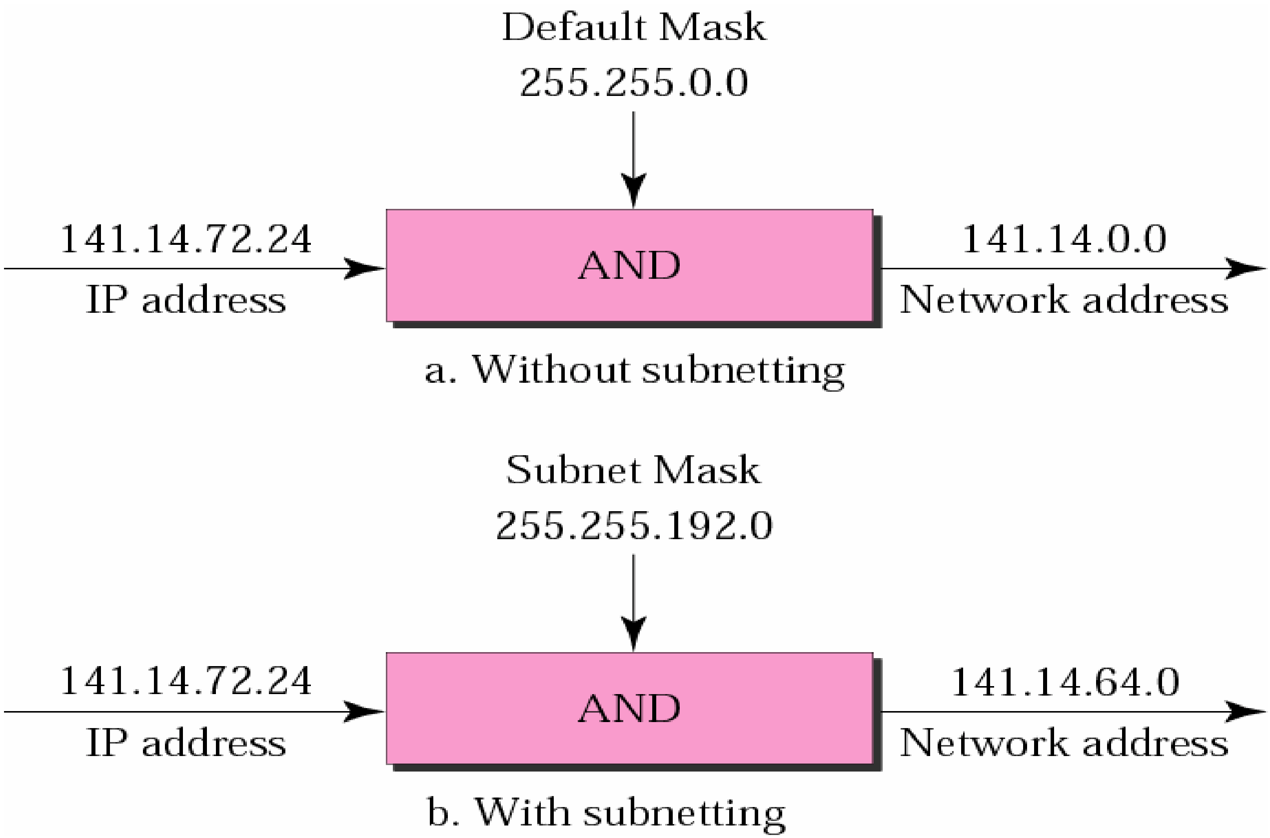
M = 11111111 11111111 11110000 00000000

&& = 10000010 00101101 00100000 00000000

130 45 32 0

The subnetwork address is **130.45.32.0**.

Default mask and subnet mask



IP address: **nnnnnnnn.nnnnnnnn.sshhhhhh.hhhhhhhh**

Mask (binary): **11111111.11111111.11000000.00000000**

Mask (dec): **255.255.192.0**

Finding the subnetwork address

Straight Method

Convert IP address into binary form,

AND with the mask,

convert to dot-decimal form

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.

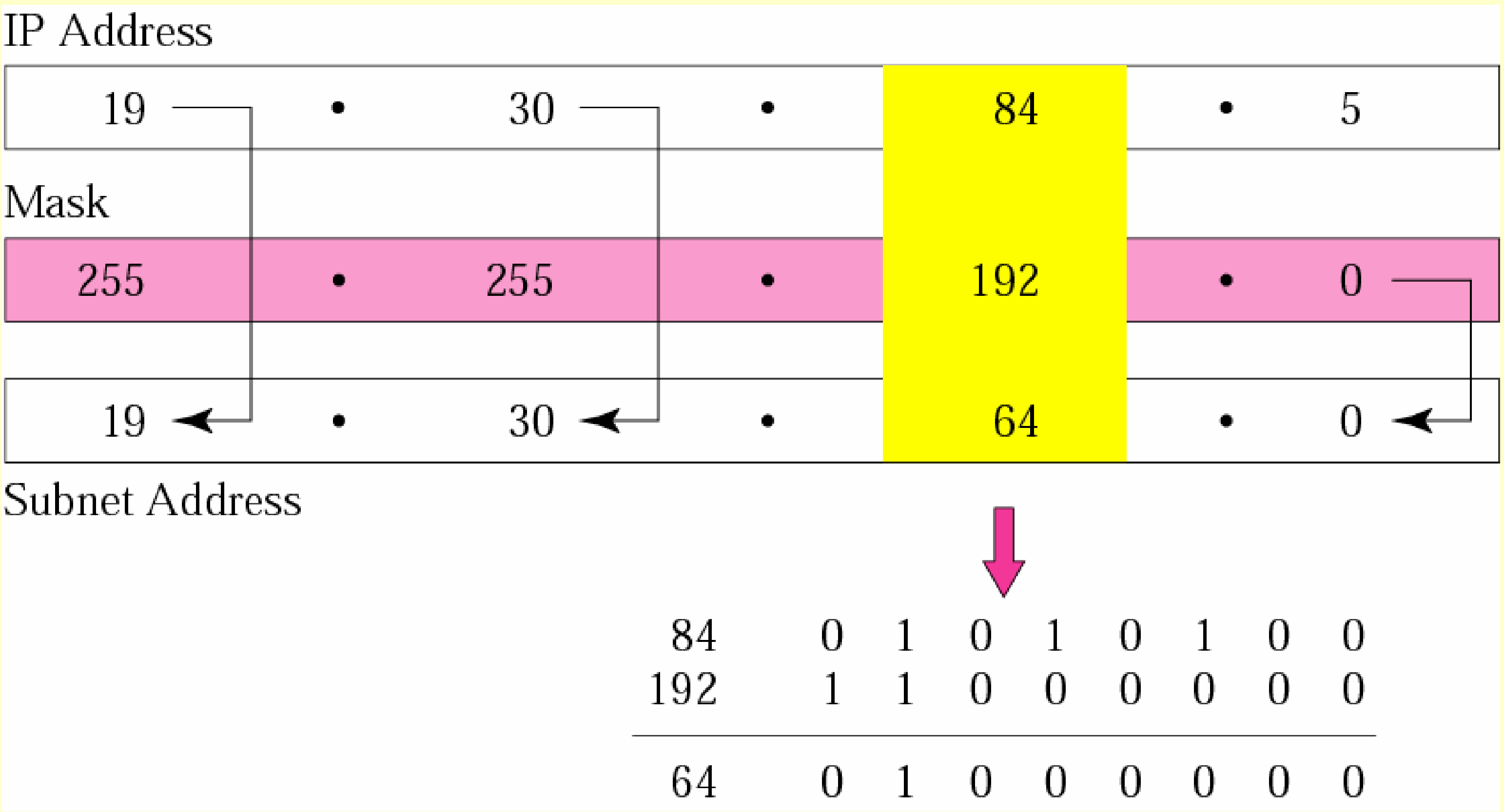
If the byte in the mask is neither 255 nor 0, write the mask and the address in binary and apply the AND operation (as above).

Example 2

IP = 19.30.80.5

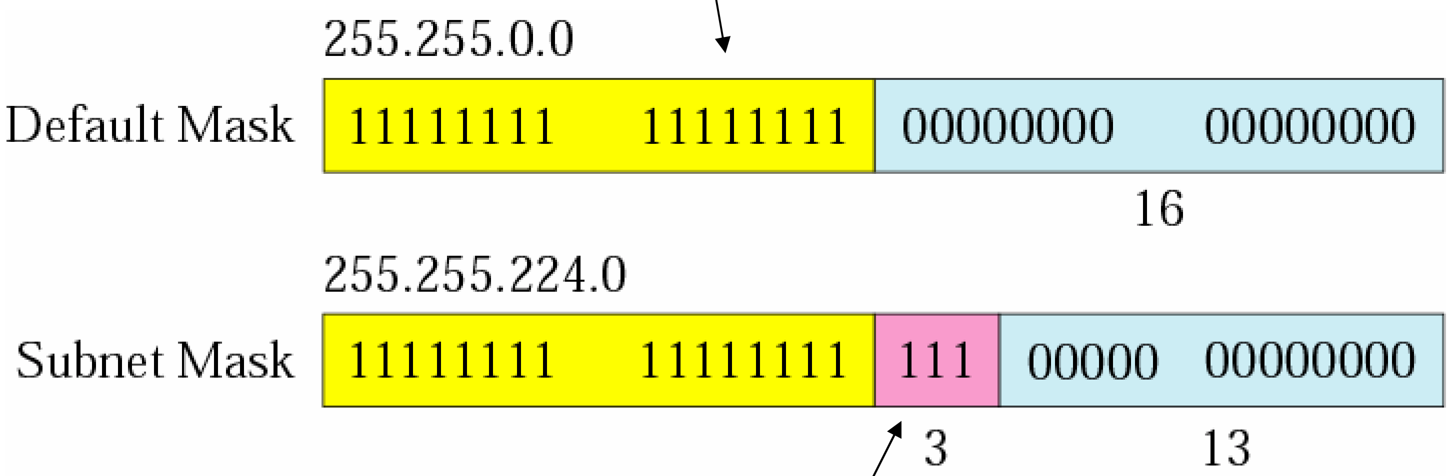
M = 255.255.192.0

What is the subnet address?



Comparison of a default mask and a subnet mask

8, 16 or 24 bits (class A, B or C)



Number of subnets = $2^3 = 8$

Number of subnets must be power of 2

Example 3

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

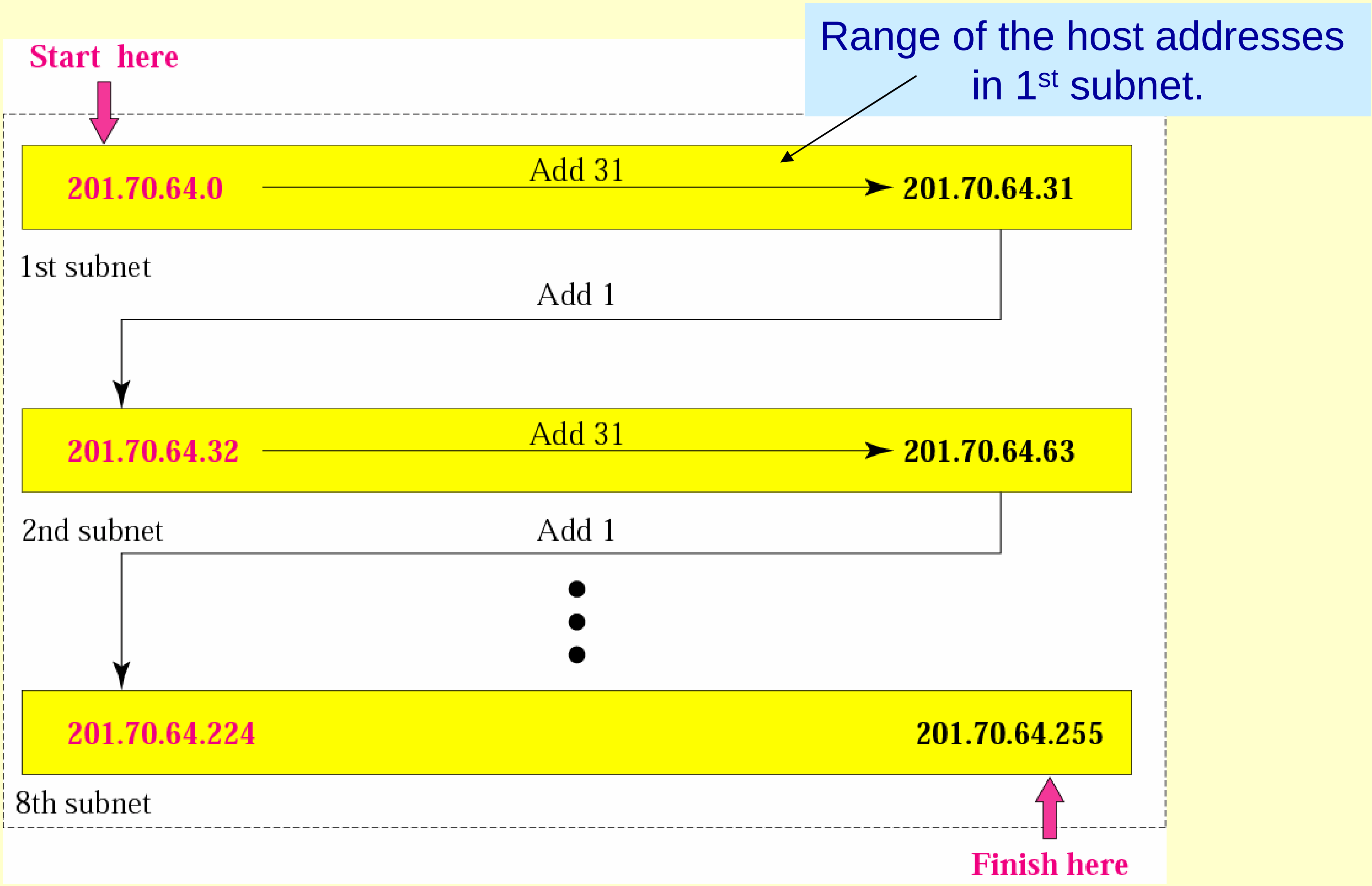
Solution:

Company can have 8 subnets (not six)
The given IP is class C, therefore we consider only the last byte. Subnets:

```
.00000000    → 201.70.64.0
.00100000    → 201.70.64.32
.01000000    → 201.70.64.64
.01100000    → 201.70.64.96
.  .  .  .  .  .  .  .  .  .  .  .  .  .  .
.11000000    → 201.70.64.192
.11100000    → 201.70.64.224
```

Subnet mask = 255.255.255.224

Example 3 (cont.)



Example 4

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

Solution:

Company can have 1024 = 2^{10} subnets (not 1000)
The given IP is class B, therefore we consider only the last two bytes. The company will have the subnets:

```
.00000000.00000000  →  181.56.0.0
.00000000.01000000  →  181.56.0.64
.00000000.10000000  →  181.56.0.128
.  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
.11111111.11000000  →  181.56.255.192
```

Subnet mask = 255.255.255.192

Supernetting

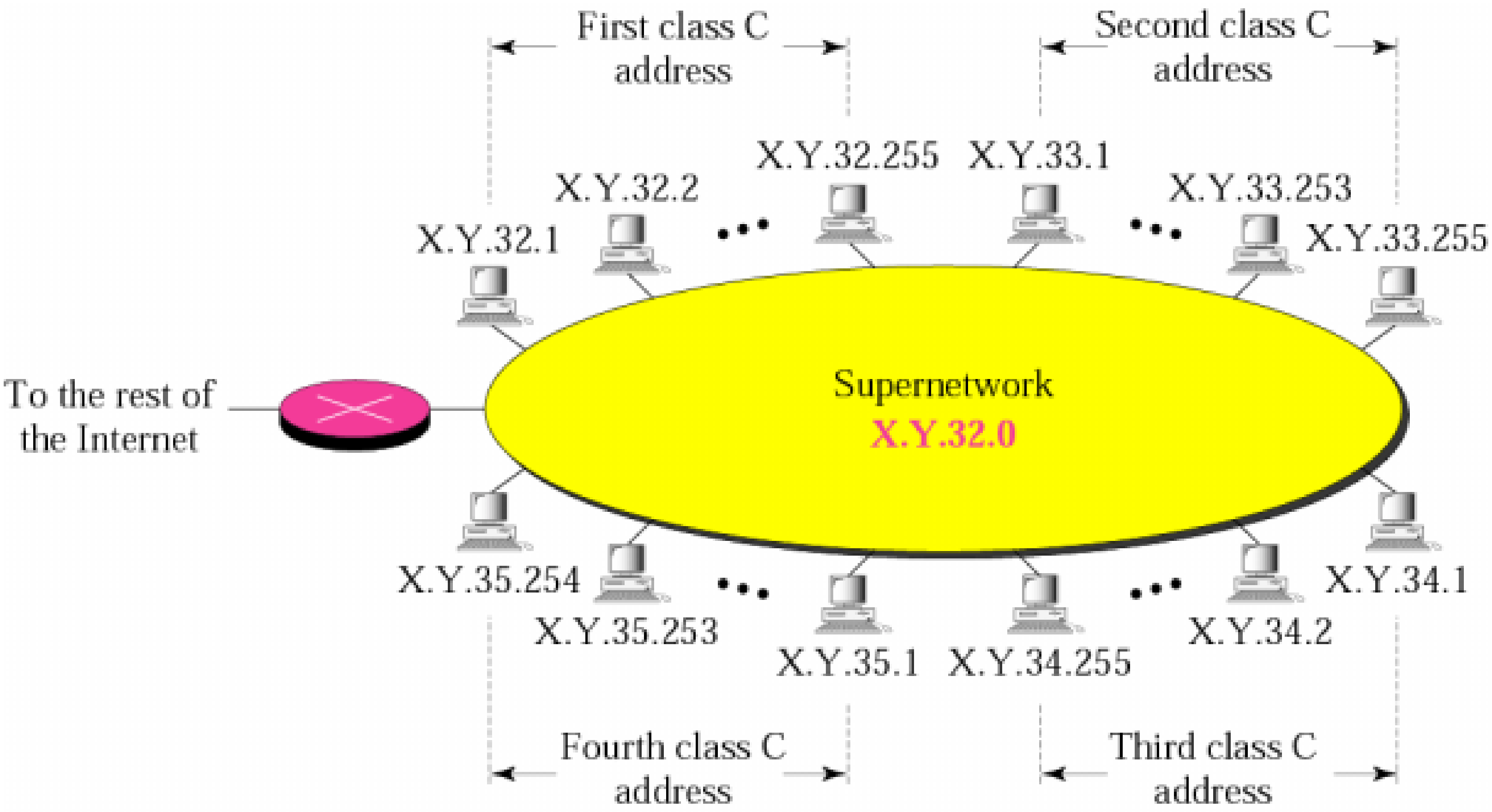
Classes A and B are almost depleted.
Class C addresses are still available.

What if a company needs a network larger than 254 hosts?

→ Give the company several consecutive blocks of C addresses and treat these as a single supernetwork

(Supernetting applies only to the class C addresses)

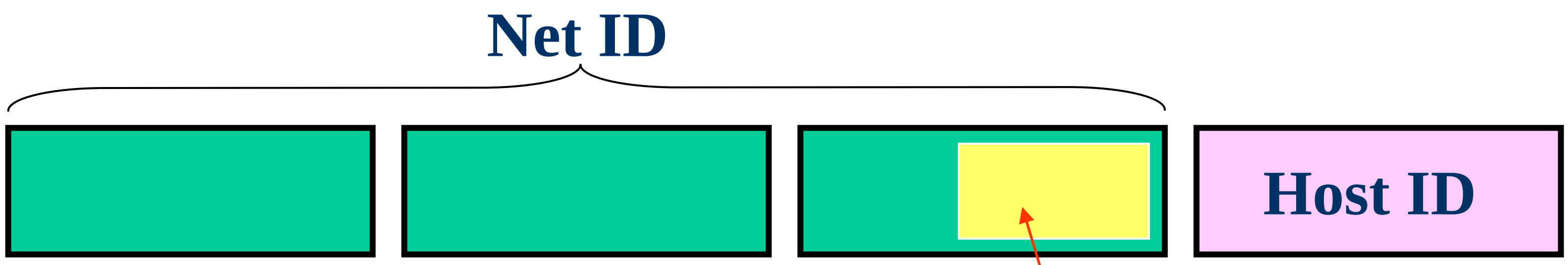
A supernetwork



Supernetting (cont.)

Suppose we use 2^m consecutive blocks

Class C address:



m zero bits

Supernet address:

xxxxxxxx.xxxxxxxx.xxx00000.00000000

This byte is divisible by 2^m

Default mask: **255.255.255.0**

Supernet mask: **$255.255.(2^{8-m}-1)*2^m.0 = 255.255.252.0$**

Supernetting (cont.)

Rules:

- The number of blocks must be a power of 2
- 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, the 3rd byte must have m zeroes to the left (2^m is number of blocks)

Example 5

A company needs 1000 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	198.47.52.0
198.47.32.0	198.47.33.0	198.47.34.0	198.47.35.0

Example 5

Need 4 blocks

198.47.32.0 198.47.33.0 198.47.34.0

Must be consecutive

198.47.32.0 198.47.42.0 198.47.52.0 198.47.62.0

3rd byte of the first block must be divisible by 4

198.47.31.0 198.47.32.0 198.47.33.0 198.47.52.0

OK

198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0

Note

In order to define the range of IP addresses we need the following:

In subnetting:

The first address of the subnet + subnet mask

In supernetting:

The first address of the supernet + supernet mask

Subnet/supernet address from IP address:

$SA = IP$ **AND** SM — *SM – supernet/subnet mask*

Number of hosts in the range:

$h = 2^z$ — *z = zeroes(SM)*

Range of IP addresses:

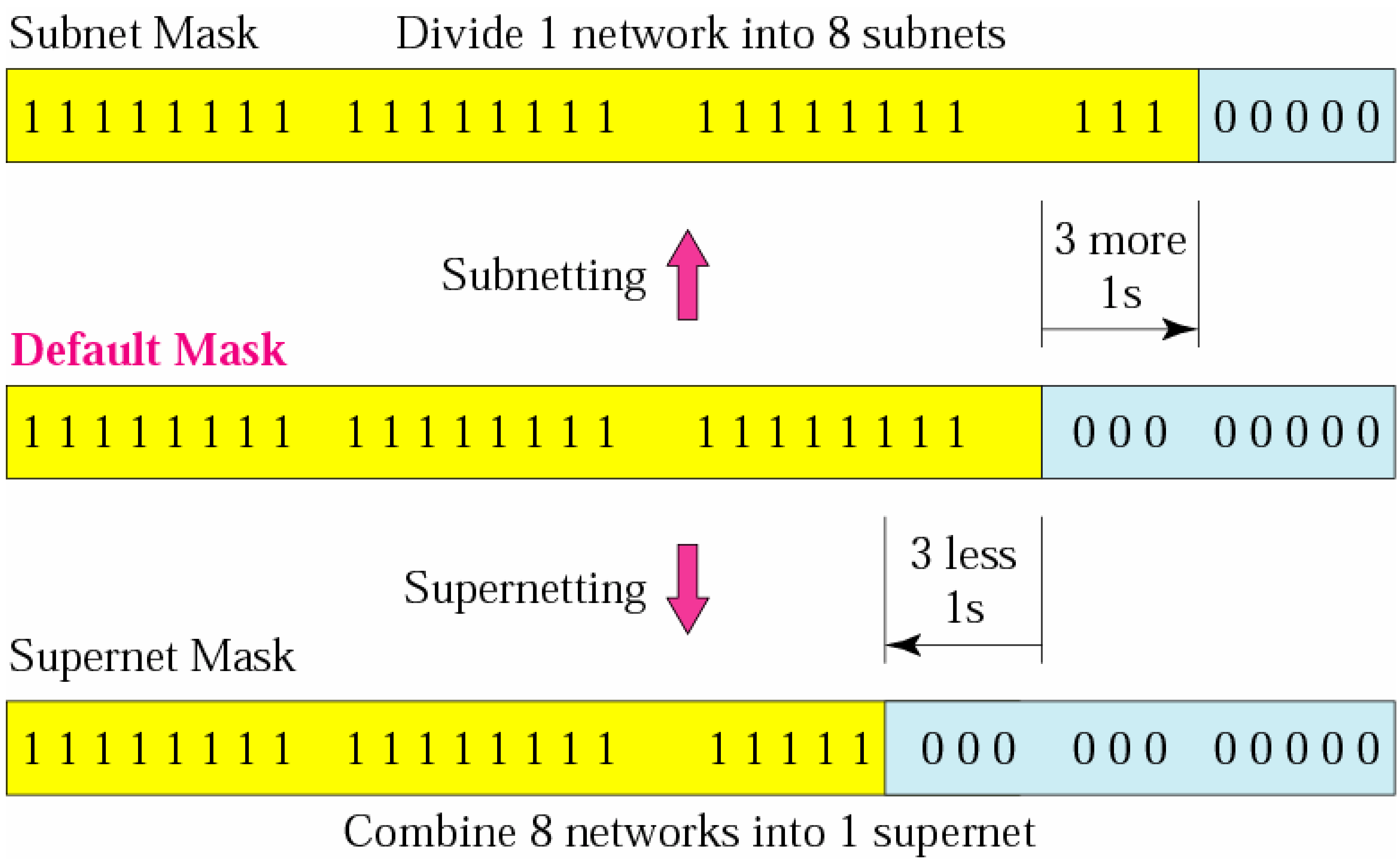
$IP_1, \ldots, IP_2 = SA+1, \ldots, SA+h-1$

Number of blocks:

$b = 2^m$, $m = ones(DM$ **XOR** $SM)$ — *DM – Default mask*

$m = |ones(DM) - ones(SM)|$

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

SA =205.16.32.0

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.

```
00100101 (37)
11111000 (248)
00100000 (32)
```

```
00101010 (42)
11111000 (248)
00101000 (40)
```

```
00100001 (33)
11111000 (248)
00100000 (32)
```

The third byte of the third IP address even doesn't have to be AND-ed since the second byte is not 16.

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?

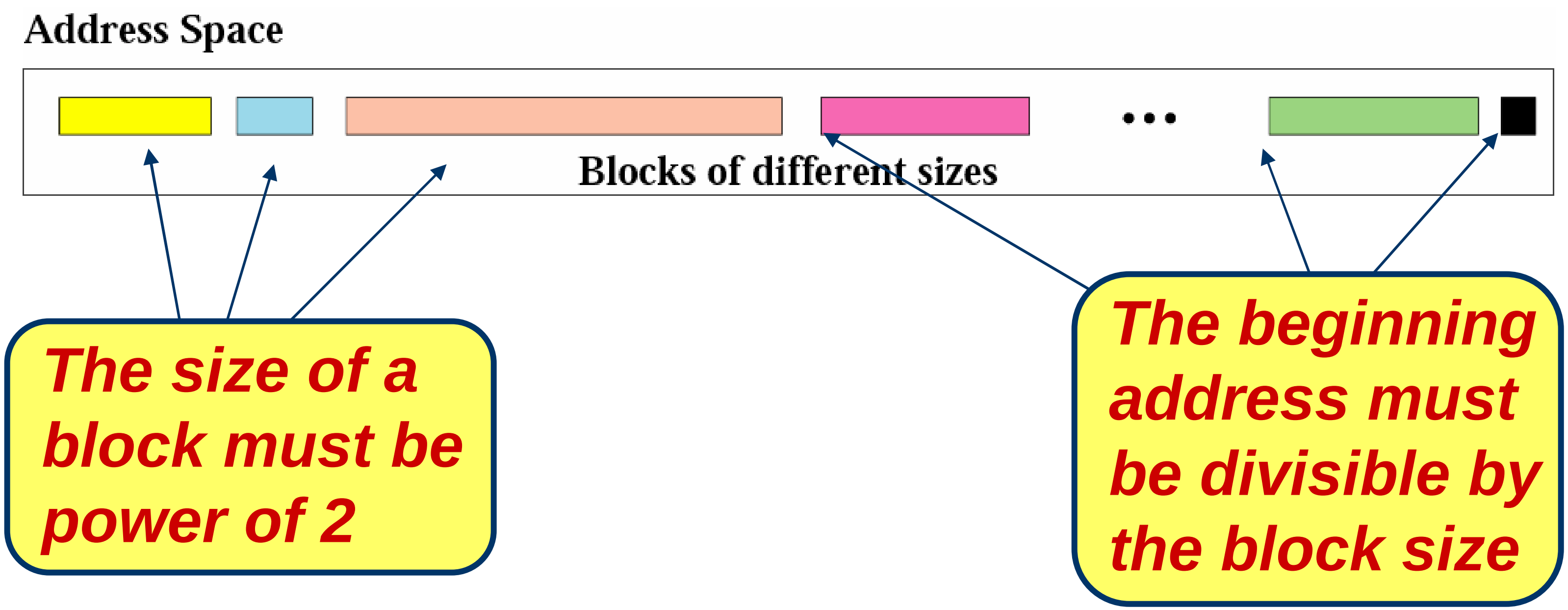
Solution

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.

Classless Addressing

In classfull addressing only blocks of sizes nx256 (class C), 256x256 (Class B) or 256x256x256 (class A) can be given to an organization or service provider. What if some organizations/households need networks of size 2, 4, 16, 32, 64 or 128?

This brings us to variable-length blocks in IP address space:



Suppose an IP space of only 16 addresses and six organizations with blocks of sizes 2 or 4.

Address	Block	Org
0000	IP=0	Org 1
0001	M =1110	
0010	IP=2	Org 5
0011	M =1110	
0100	IP=4	Org 4
0101	M =1100	
0110		
0111		
1000	IP=8	Org 2
1001	M =1110	
1010	IP=10	Org 6
1011	M =1110	
1100	IP=12	Org 3
1101	M =1100	
1110		
1111		

Good

Address	Block	Org
0000	IP=0	Org 1
0001	M =1110	
0010	IP=2	Org 5
0011	M =1000	
0100		
0101		
0110	IP=6	Org 4
0111	M =1110	
1000	IP=8	Org 2
1001	M =1110	
1010	IP=10	Org 6
1011	M =1000	
1100		
1101		
1110	IP=12	Org 3
1111	M =1110	

Wrong

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

A mask consists of *z* consecutive zeroes at the right and *32-z* ones at the left. Instead of using long masks (like 255.255.224.0) it is more convenient to use the number of ones in the mask (like 19). If this number is attached to the end of a (classless) IP address, we get the “slash” notation, or CIDR (Classless Interdomain Routing)

A.B.C.D/*n*

The first *n* bits of the classless address is called prefix, while the last *32-n* bits is called suffix.

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:**<u>11001111 00010000 00100101 00011</u>**000

Ending : **<u>11001111 00010000 00100101 00011</u>**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).

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.

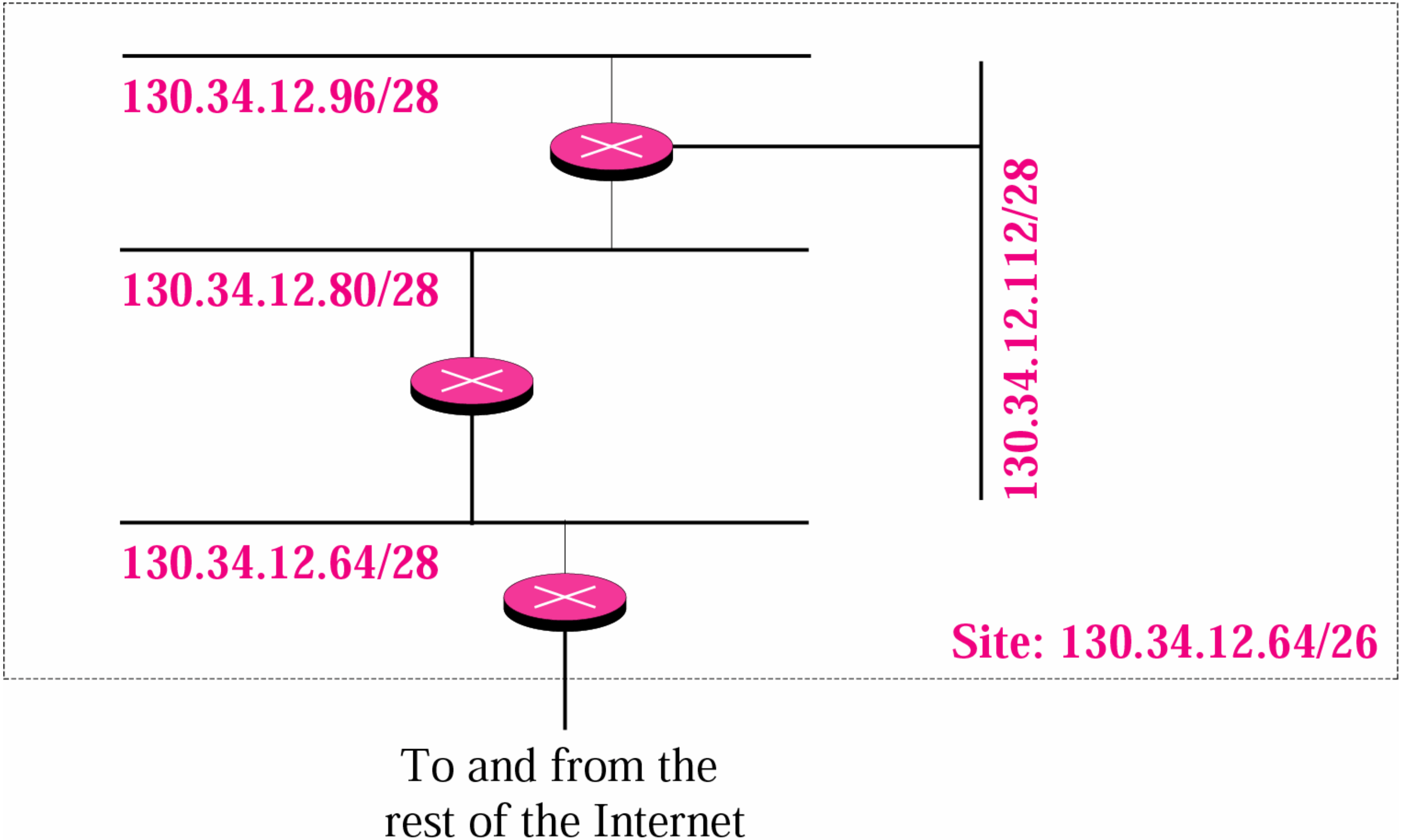
Subnet 2 : 130.34.12.80/28 to 130.34.12.95/28.

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

Example 14


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

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 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, 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 x 256 = 16,384

Solution (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:

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

Total = 128 x 128 = 16,384

Solution (Continued)

Group 3

For this group, 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 x 64 = 8,192

Solution (Continued)

Number of granted addresses: 65,536

Number of allocated addresses: 40,960

Number of available addresses: 24,576