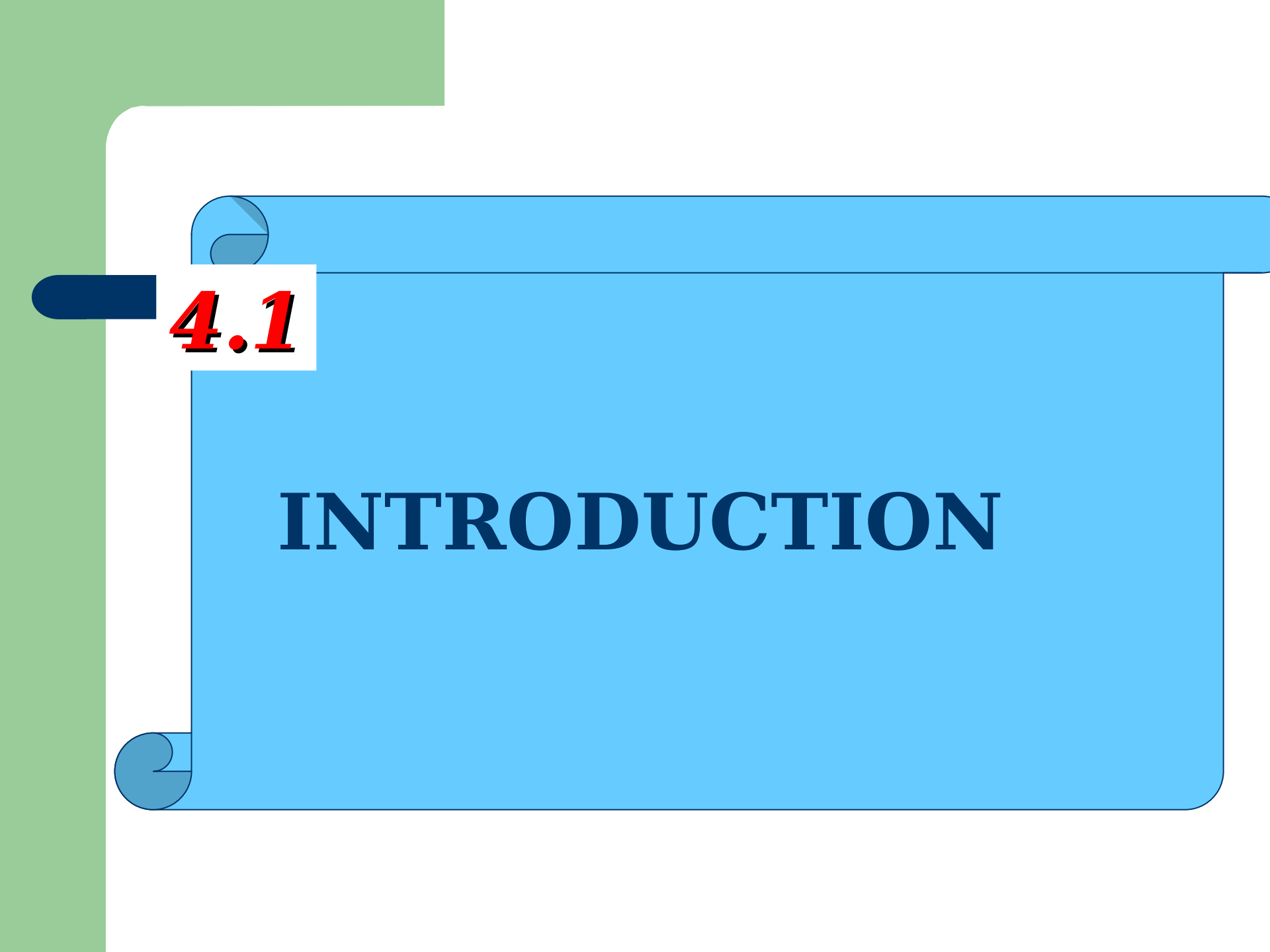


IP Addresses

IP Addresses: Classful Addressing

CONTENTS

- **INTRODUCTION**
- **CLASSFUL ADDRESSING**
 - **Different Network Classes**
 - **Subnetting**
- **Classless Addressing**
 - **Supernetting**
 - **CIDR (classless Interdomain Routing)**



4.1

INTRODUCTION

What is an IP Address?

An IP address is a 32-bit address.

Note

The IP addresses are unique.

Address Space

addr1

addr2

addr15

addr31

addr41 addr226

Address space rule

**The address space in a protocol
That uses N-bits to define an
Address is:**

$$2^N$$

IPv4 address space

The address space of IPv4 is

2^{32}

or

4,294,967,296.

Binary Notation

110101 10010101 00011101 111010

Dotted-decimal notation

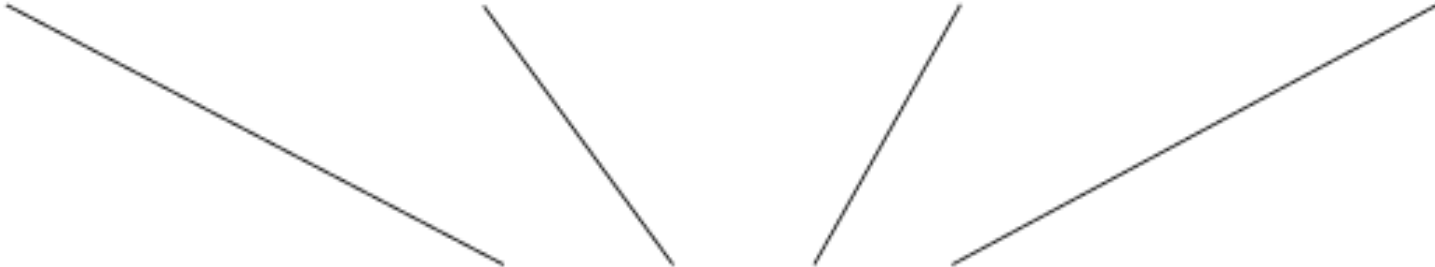
10000000

00001011

00000011

00011111

128.11.3.31



Hexadecimal Notation

11 0101 1001 0101 0001 1101 1110

75

95

1D

EA

0x75951DEA

Example 1

Change the following IP address from binary notation to dotted-decimal notation.

10000001 00001011 00001011

Solution. 1

129.11.11.239

Example 2

Change the following IP address from dotted-decimal notation to binary notation:

111.56.45.78

Solution

1101111 00111000 00101101 0100

Example 3

Find the error in the following IP Address
111.56.045.78

Solution

There are no leading zeroes in
Dotted-decimal notation (045)

Example 3 (continued)

Find the error in the following IP Address
75.45.301.14

Solution

In decimal notation each number ≤ 255
301 is out of the range

Example 4

Change the following binary IP address
Hexadecimal notation

10000001 00001011 00001011 11101111

Solution

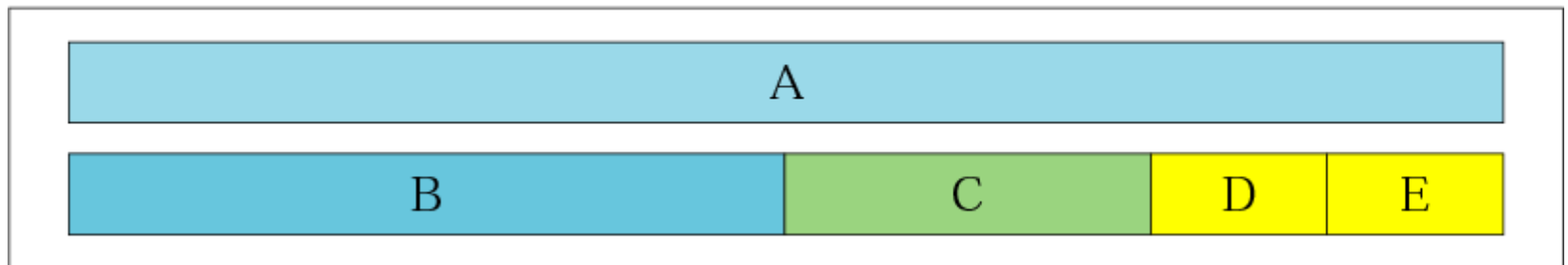
0X810B0BEF or 810B0BEF16



CLASSFUL ADDRESSING

Occupation of the address space

Address space



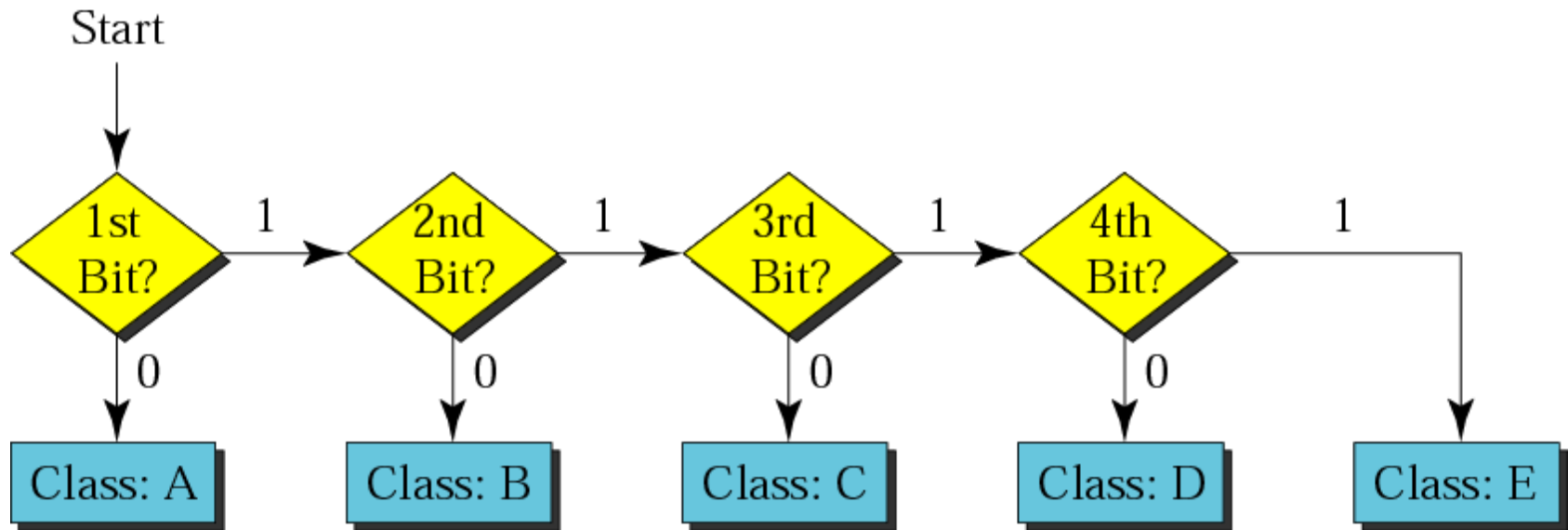
In classful addressing the address space is divided into 5 classes:

A, B, C, D, and E.

Finding the class in binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

Finding the address class



Example 5

Show that Class **A** has
 $2^{31} = 2,147,483,648$ addresses

Example 6

Find the class of the following IP addresses

00000001 00001011 00001011 11101111
11000001 00001011 00001011 11101111

Solution

- 00000001 00001011 00001011 11101111
1st is 0, hence it is Class A
- 11000001 00001011 00001011 11101111
1st and 2nd bits are 1, and 3rd bit is 0 hence, Class C

Finding the class in decimal notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0 to 127			
Class B	128 to 191			
Class C	192 to 223			
Class D	224 to 239			
Class E	240 to 255			

Example 7

Find the class of the following addresses
158.223.1.108
227.13.14.88

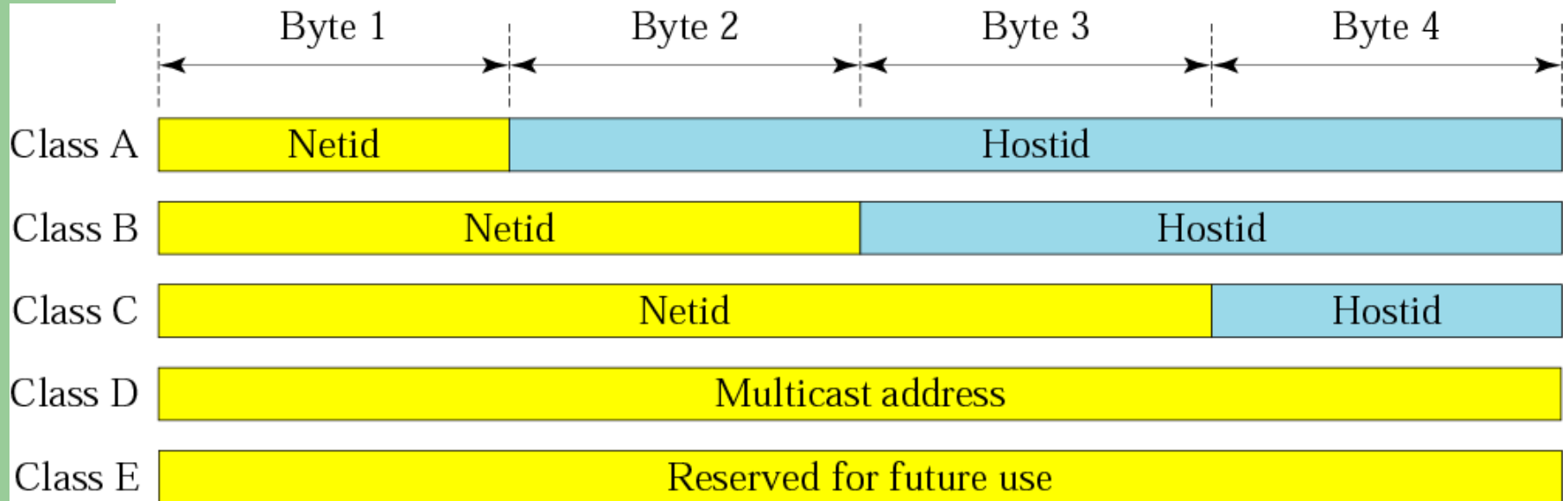
Solution

- 158.223.1.108
1st byte = 158 ($128 < 158 < 191$) class B
- 227.13.14.88
1st byte = 227 ($224 < 227 < 239$) class D

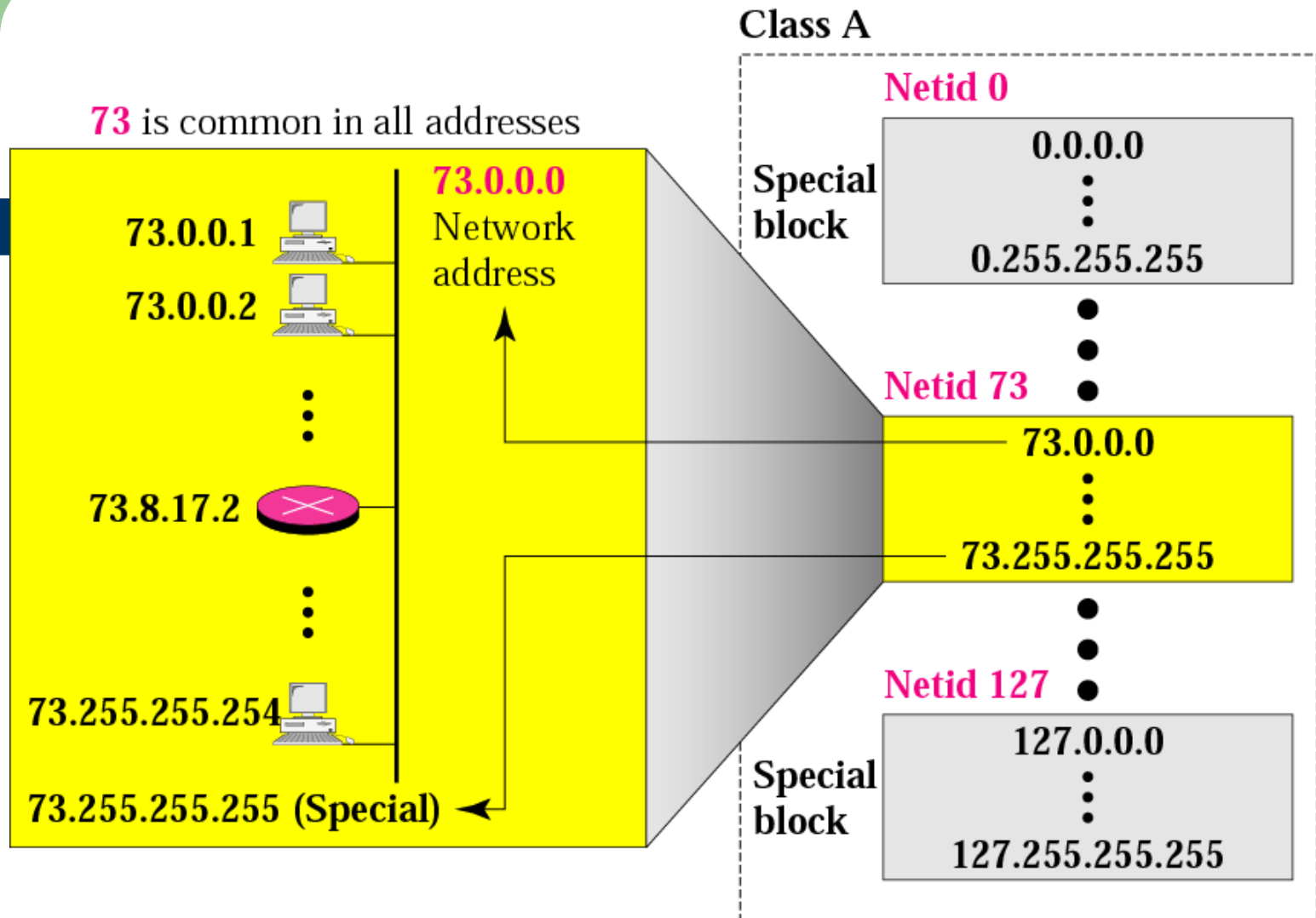
IP address with appending port number

- 158.128.1.108:25
- the four octets before colon is the IP address
- The number after colon (25) is the port number

Netid and hostid



Blocks in class A



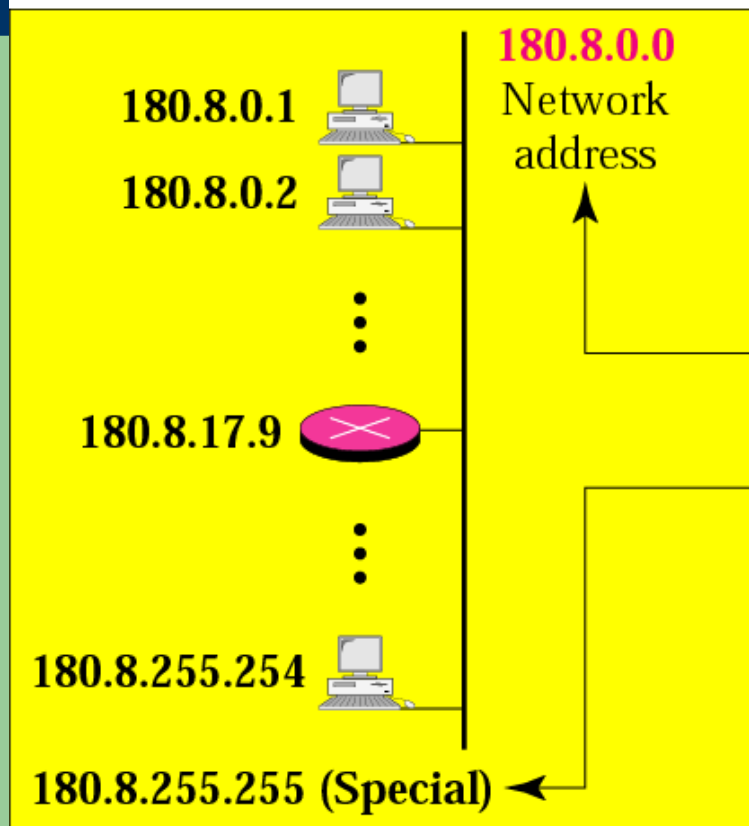
128 blocks: 16,777,216 addresses in each block

Note

***Millions of class A addresses
are wasted.***

Blocks in class B

180.8 is common in all addresses



Class B

Netid 128.0

128.0.0.0

⋮

128.0.255.255

⋮

Netid 180.8

180.8.0.0

⋮

180.8.255.255

⋮

Netid 191.255

191.255.0.0

⋮

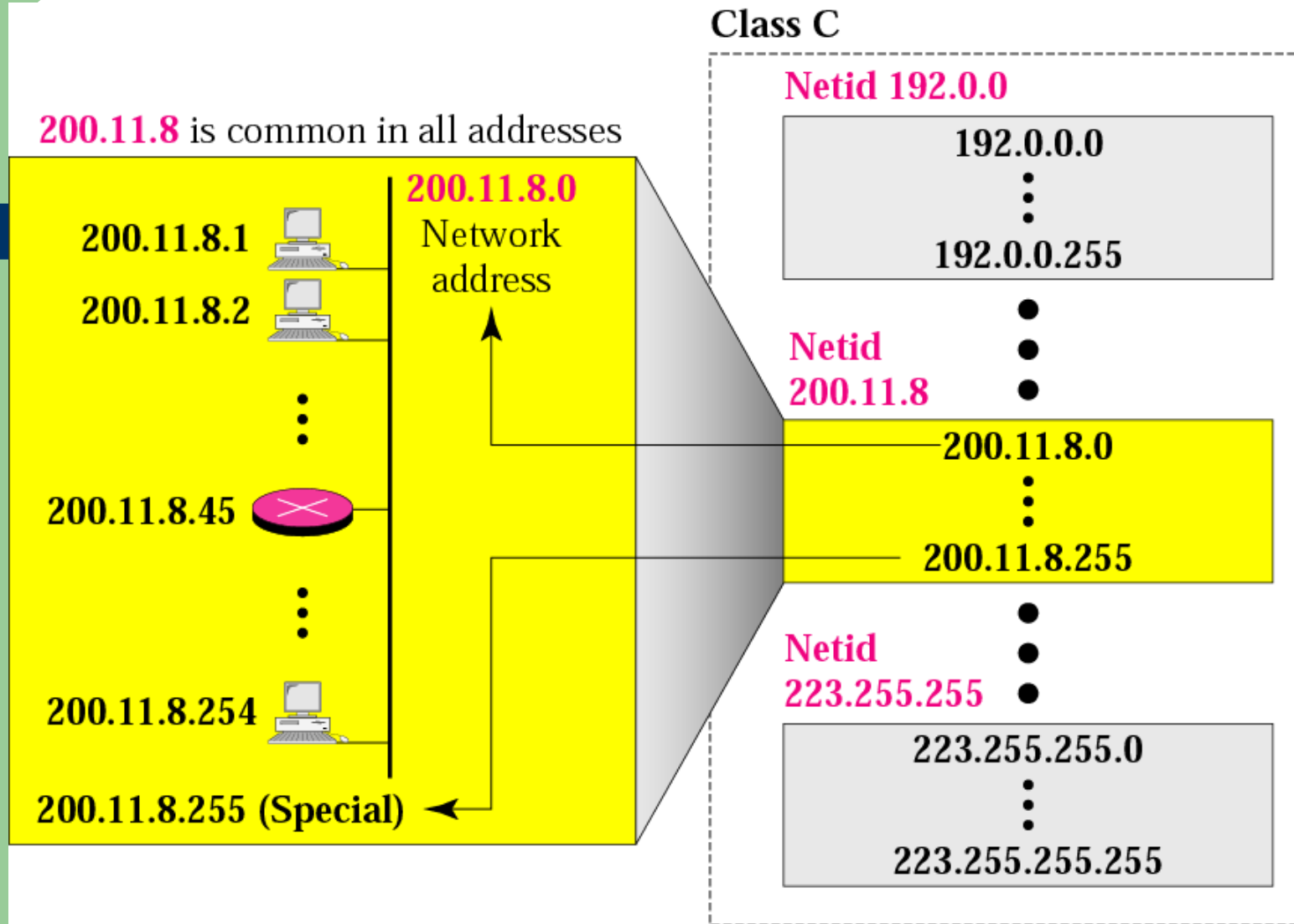
191.255.255.255

16,384 blocks: 65,536 addresses in each block

Note

***Many class B addresses
are wasted.***

Blocks in class C



2,097,152 blocks: 256 addresses in each block

Note

The number of addresses in a class C block is smaller than the needs of most organizations.

Note

***Class D addresses
are used for multicasting;
there is only
one block in this class.***

Note

Class E addresses are reserved for special purposes; most of the block is wasted.

Network Addresses

The network address is the first address.

The network address defines the network to the rest of the Internet.

Given the network address, we can find the class of the address, the block, and the range of the addresses in the block

Note

***In classful addressing,
the network address
(the first address in the block)
is the one that is assigned
to the organization.***

Example 8

Given the network address 132.21.0.0, find the class, the block, and the range of the addresses

Solution

The 1st byte is between 128 and 191.

Hence, Class B

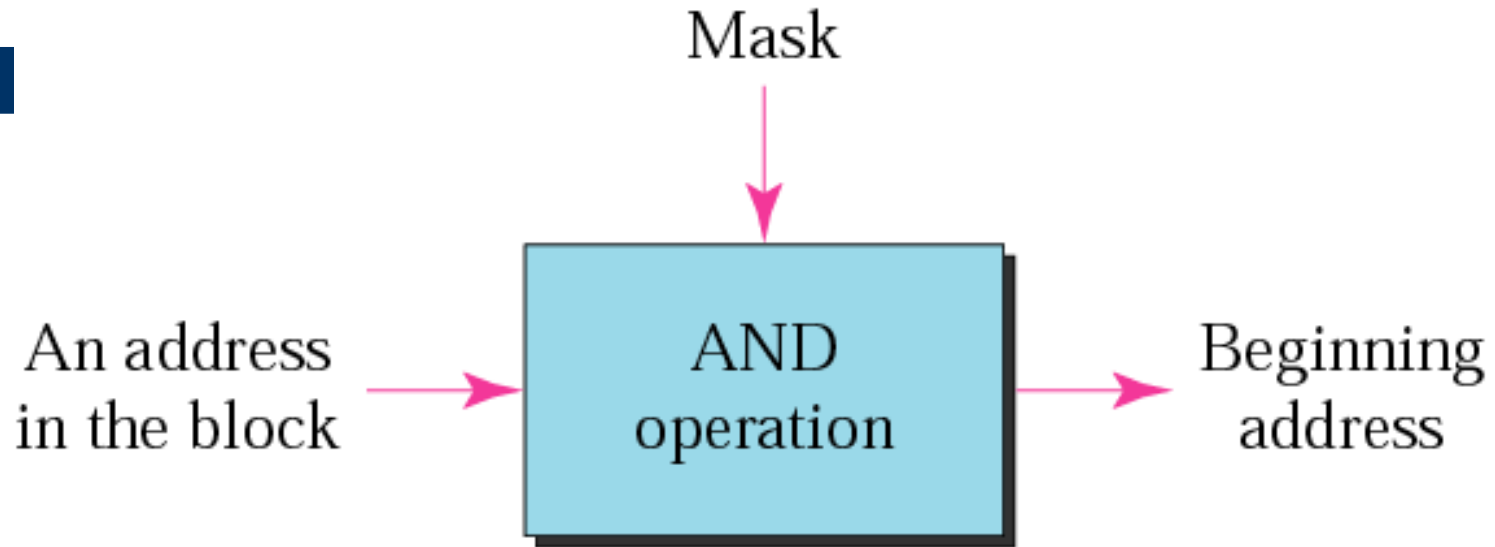
The block has a netid of 132.21.

The addresses range from
132.21.0.0 to 132.21.255.255.

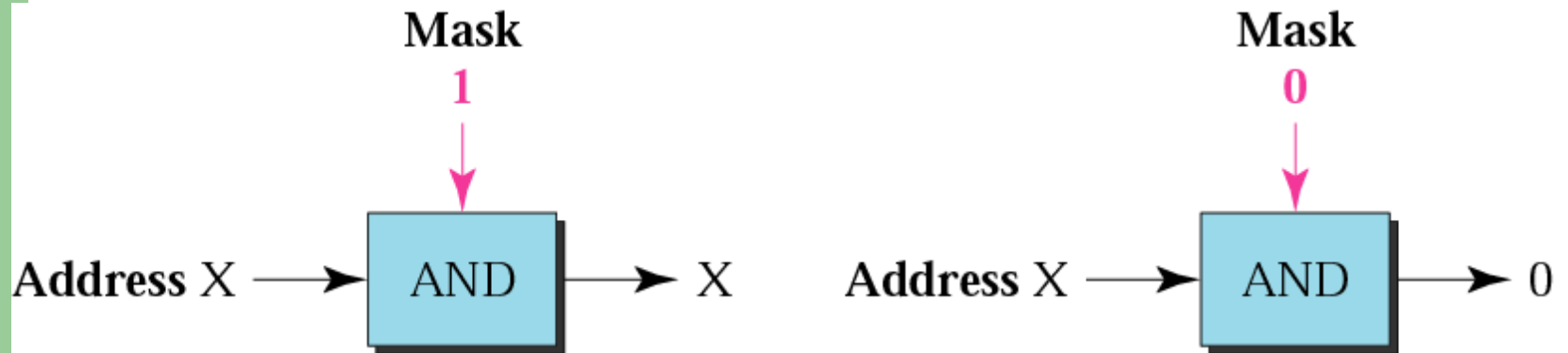
Mask

- A mask is a 32-bit binary number.
- The mask is **ANDed** with IP address to get
 - The block address (Network address)
 - **Mask And IP address = Block Address**

Masking concept



AND operation



Note

The network address is the beginning address of each block.

It can be found by applying the default mask to any of the addresses in the block (including itself).

It retains the **netid** of the

Default Mak

- Class A default mask is 255.0.0.0
- Class B default mask is 255.255.0.0
- Class C Default mask 255.255.255.0

Chapter 5

Subnetting/Supernetting and Classless Addressing

CONTENTS

- **SUBNETTING**
- **SUPERNETTING**
- **CLASSLESS ADDRESSING**

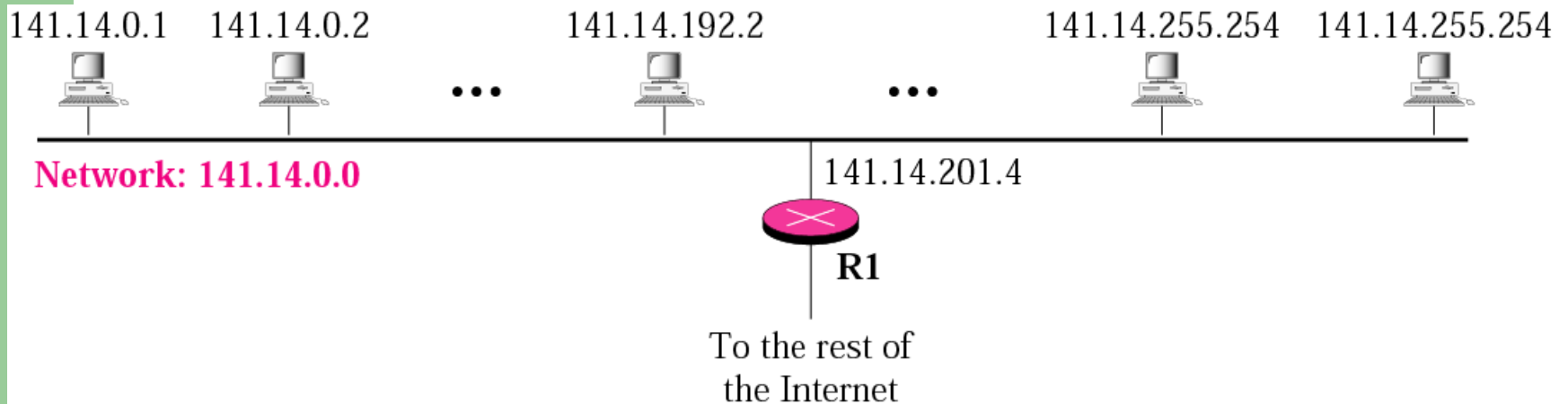
5.1

SUBNETTING

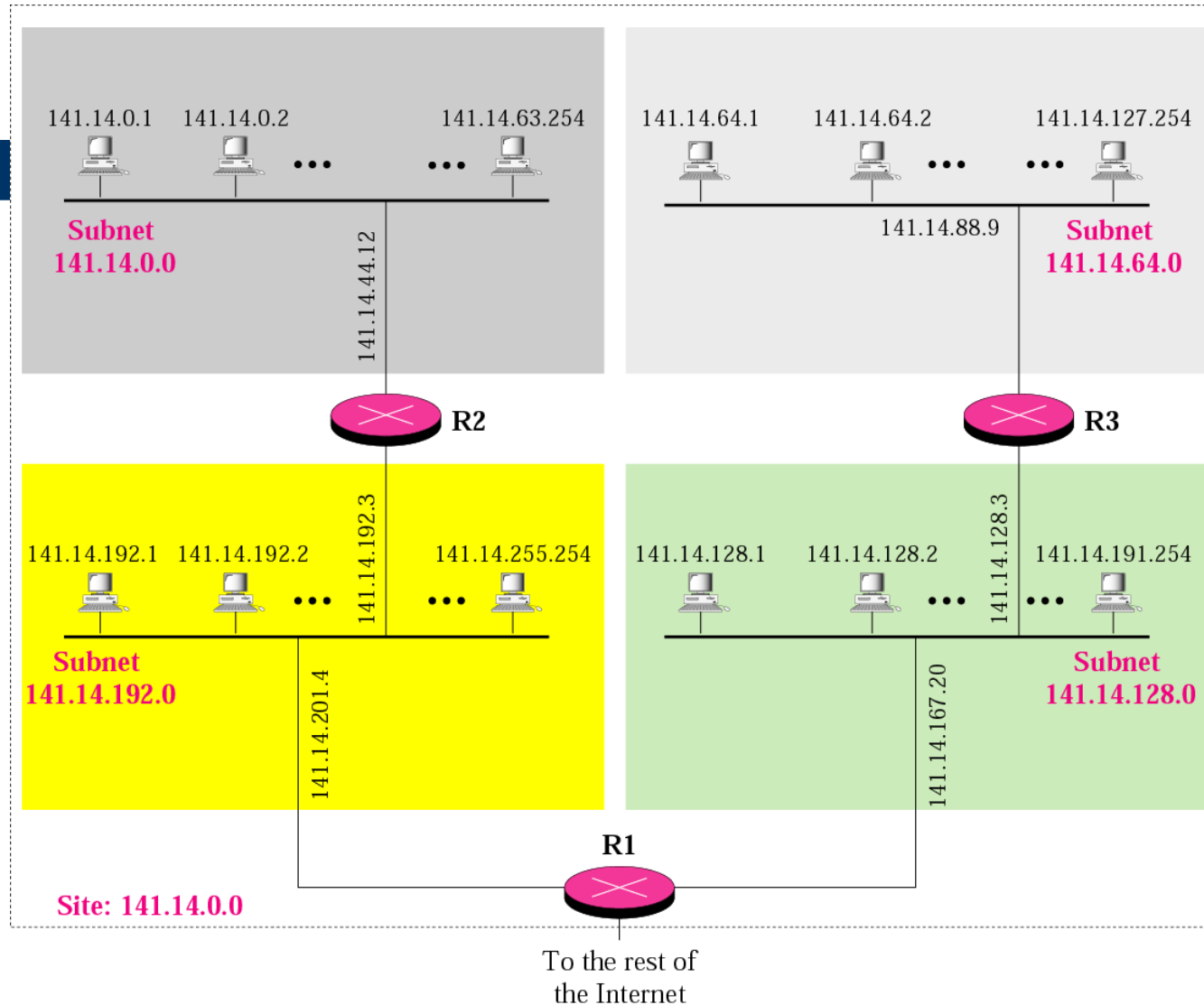
Note

***IP addresses are designed
with
two levels of hierarchy.***

A network with two levels of hierarchy (not subnetted)



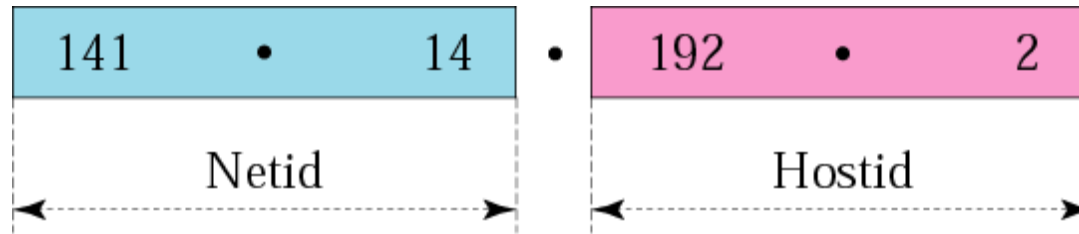
A network with three levels of hierarchy (subnetted)



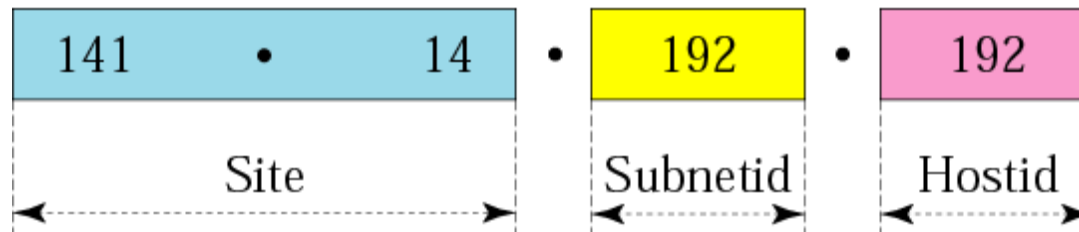
Note

- Subnetting is done by borrowing bits from the host part and add them the network part

Addresses in a network with and without subnetting

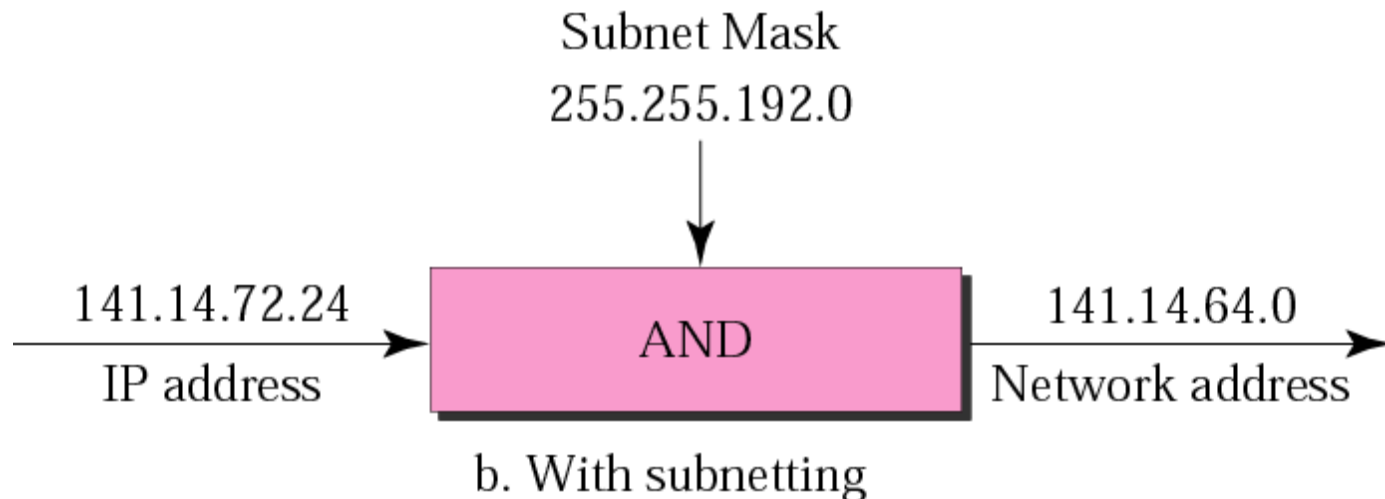
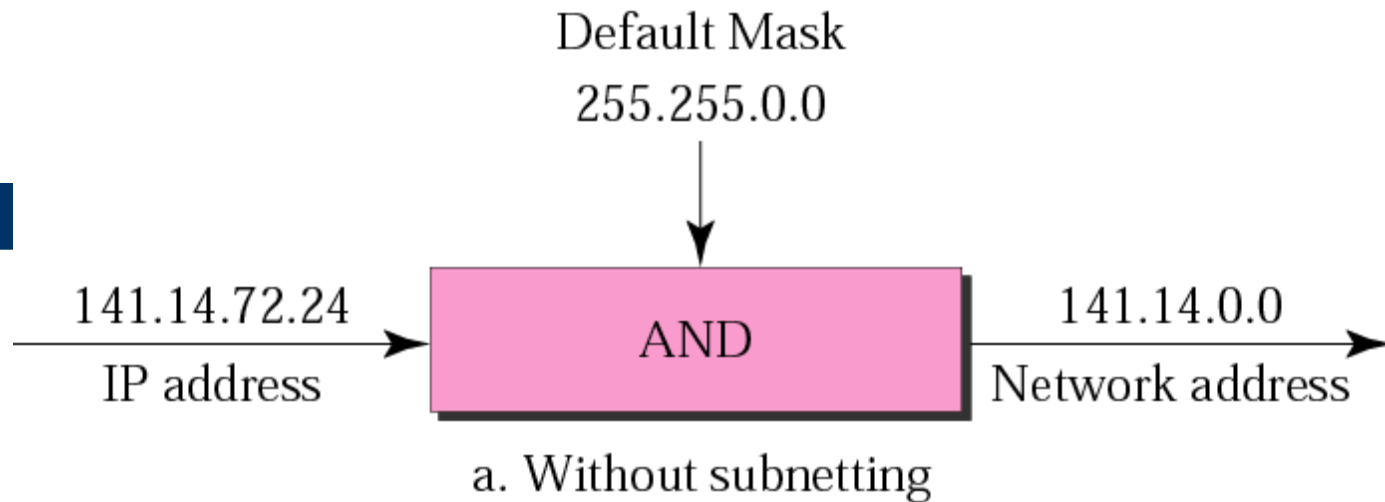


a. Without subnetting



b. With subnetting

Mask and subnet mask



Finding the Subnet Address

Given an IP address, we can find the subnet address the same way we found the network address. We apply the mask to the address. We can do this in two ways: straight or short-cut.

Straight Method

In the straight method, we use binary notation for both the address and the mask and then apply the AND operation to find the subnet address.

Example 9

What is the subnetwork address if the destination address is 200.45.34.56 and the subnet mask is 255.255.240.0?

Solution

11001000 00101101 00100010
00111000

11111111 11111111 11110000
00000000

11001000 00101101 0010**0000**
00000000

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

Example 10

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

Solution

See next slide

Solution

IP Address

19	•	30	•	84	•	5
----	---	----	---	----	---	---

Mask

255	•	255	•	192	•	0
-----	---	-----	---	-----	---	---

19	•	30	•	64	•	0
----	---	----	---	----	---	---

Subnet Address

↓

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

Comparison of a default mask and a subnet mask

	255.255.0.0			
Default Mask	11111111 11111111		00000000 00000000	
			16	
	255.255.224.0			
Subnet Mask	11111111 11111111		111	00000 00000000
			3	13

Note

***The number of subnets must
be
a power of 2.***

Example 11

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).

Solution (Continued)

The company needs six subnets. This number 6 is not a power of 2. The next number that is a power of 2 is 8 (2^3). We need 3 more 1s in the subnet mask. The total number of 1s in the subnet mask is 27 ($24 + 3$).

Solution (Continued)

11111111 11111111
11111111 11100000

or

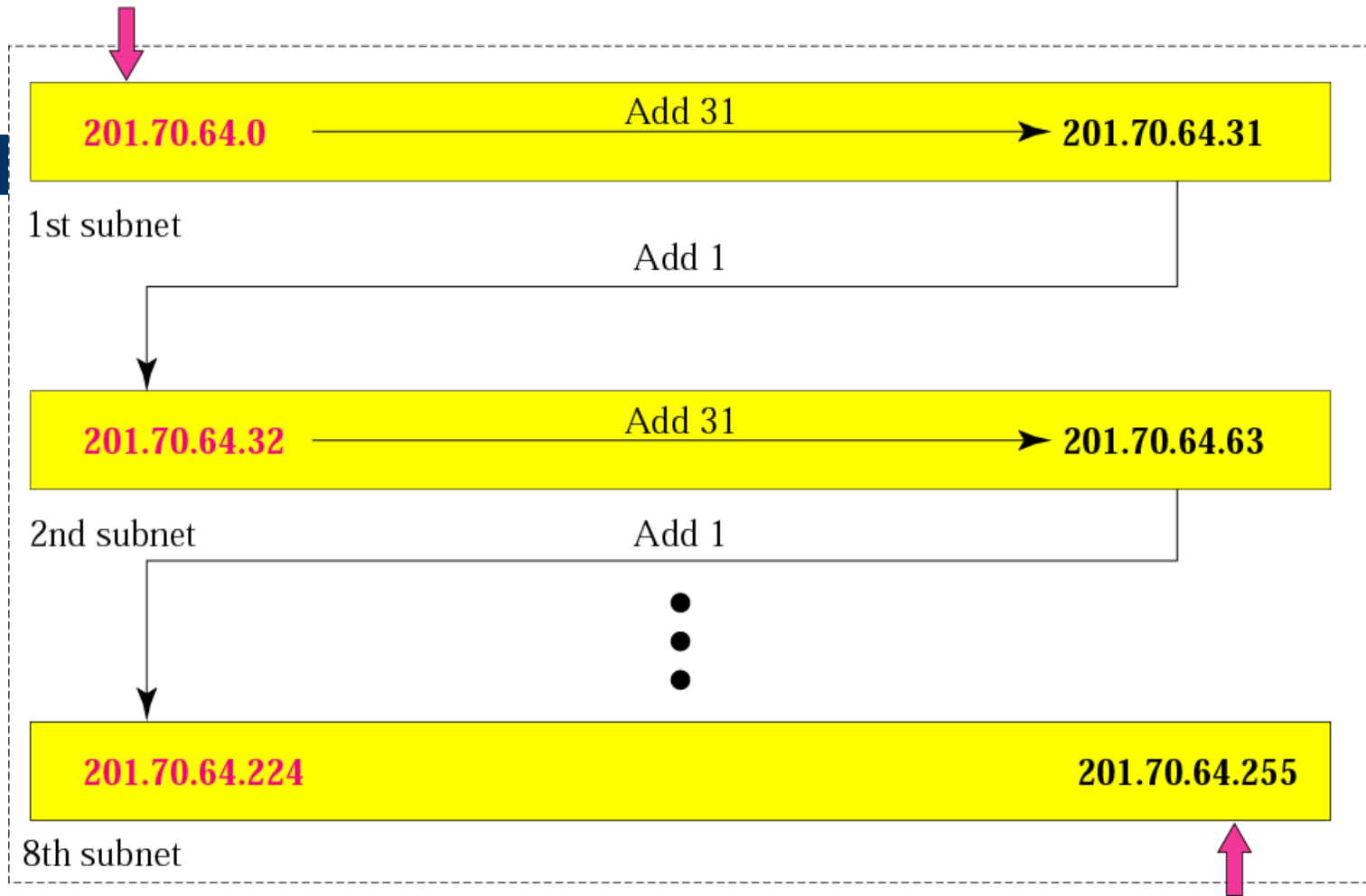
255.255.255.224

The number of subnets is 8.

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

Example 3

Start here



Finish here

Example 12

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).

Solution (Continued)

The company needs 1000 subnets.
This number is not a power of 2.
The next number that is a power of 2 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

Solution (Continued)

The mask is



<u>11111111</u>	<u>11111111</u>	<u>11111111</u>
<u>11</u> 000000		

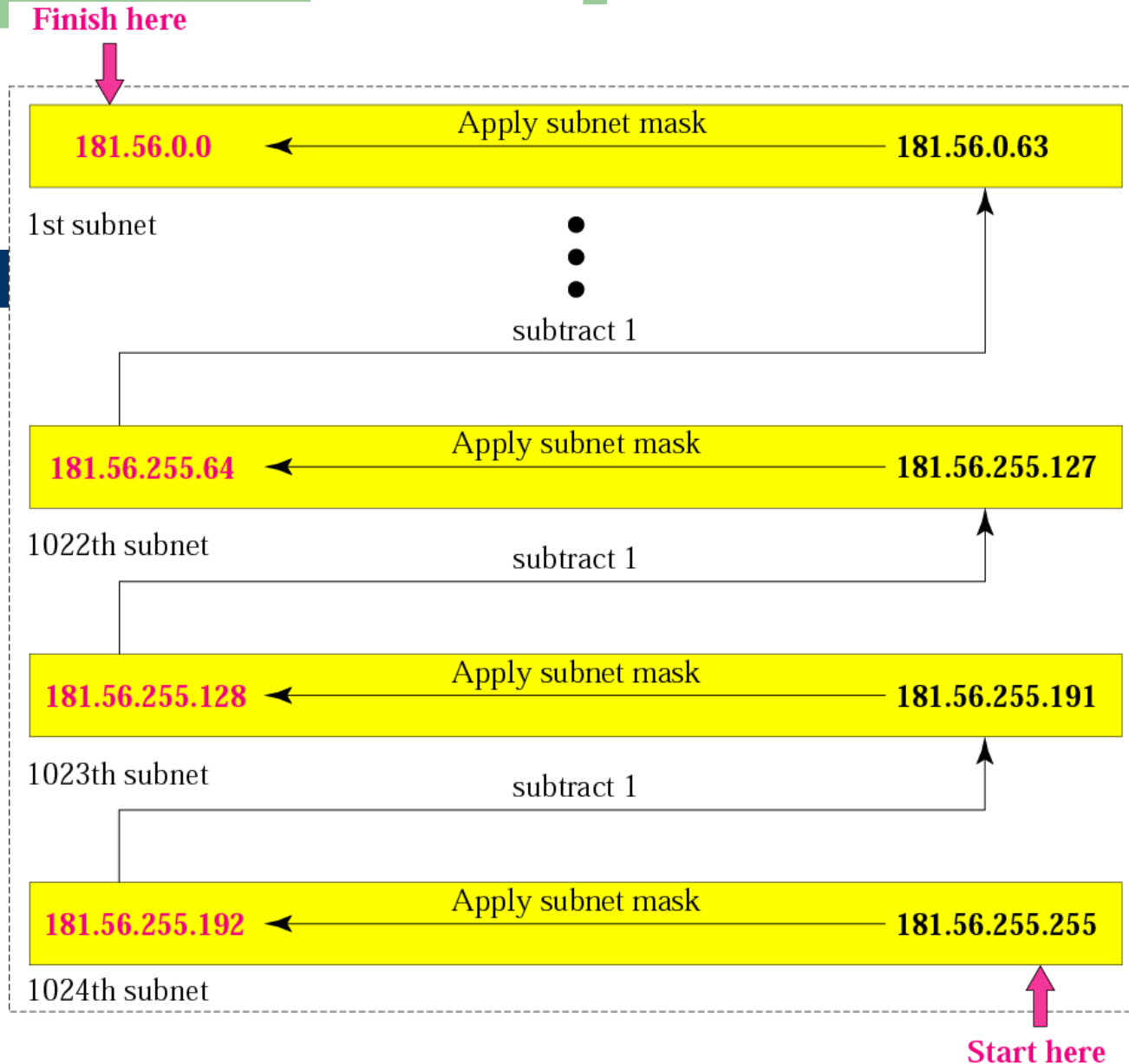
or

255.255.255.192.

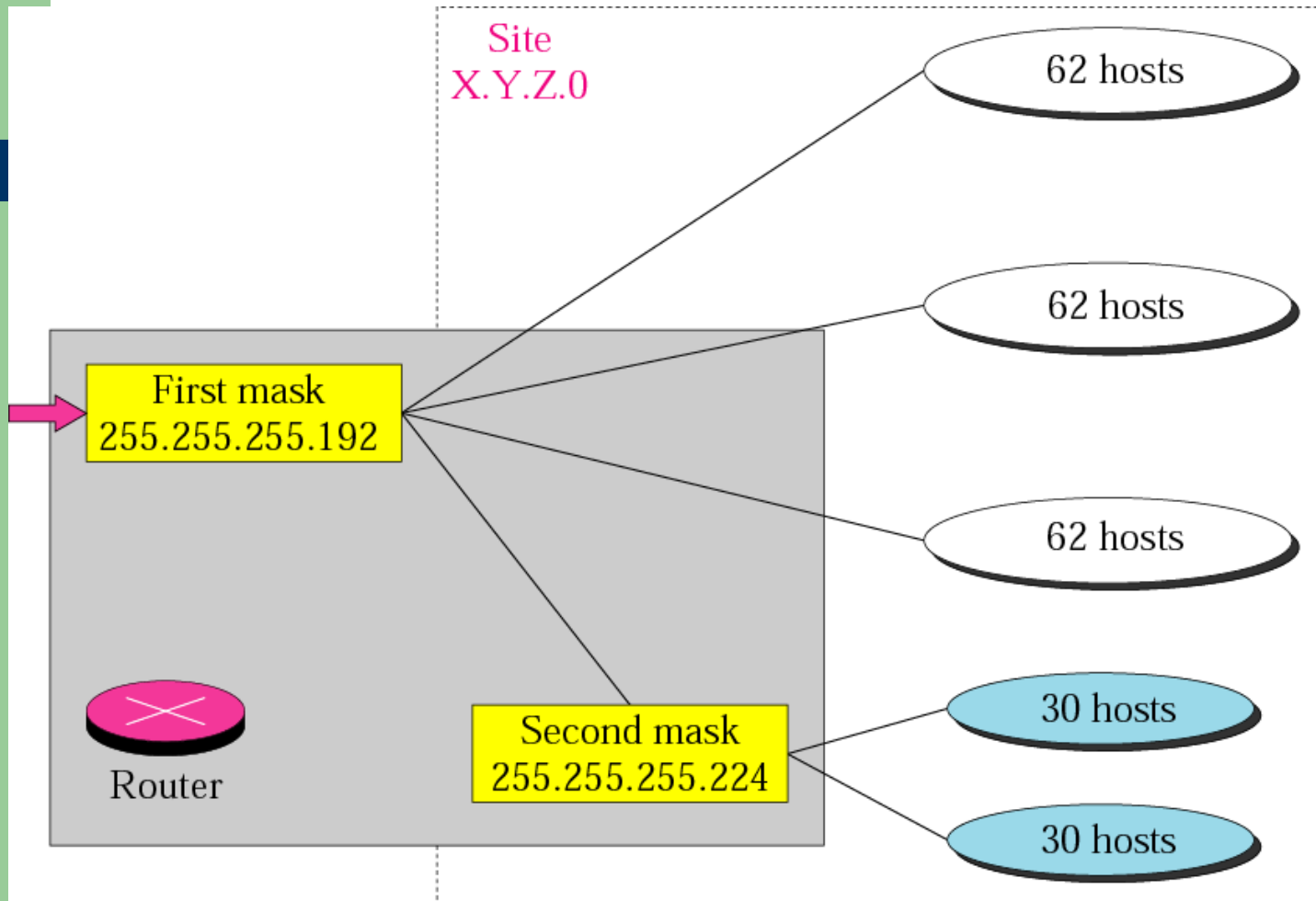
The number of subnets is 1024.

The number of addresses in each subnet is 2^6 (6 is the number of 0s)

Example 4



Variable-length subnetting



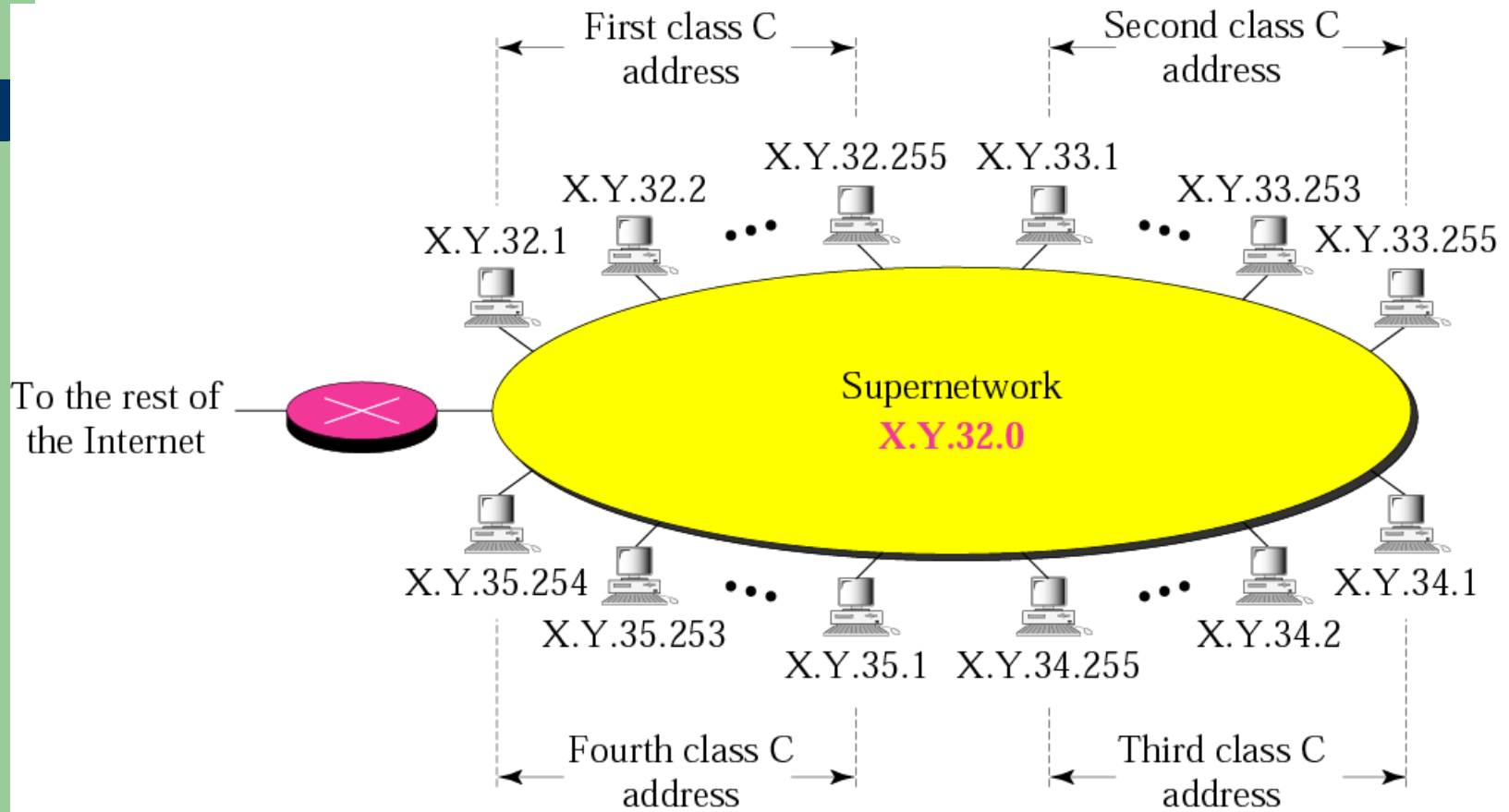


SUPERNETTING

What is supernetting?

- Supernetting is the opposite of subnetting
- In subnetting you borrow bits from the host part
- Supernetting is done by borrowing bits from the network side.
- And combine a group of networks into one large supernetwork.

A supernetwork



Rules:

- ❑ The number of blocks must be a power of 2 (1, 2, 4, 8, 16, . . .).
- ❑ 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, if the number of blocks is N , the third byte must be divisible by N .

Example 5

A company needs 600 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

198.47.34.0 198.47.33.0 198.47.32.0

Solution

1: No, there are only three blocks.

2: No, the blocks are not contiguous.

3: No, 31 in the first block is not divisible by 4.

4: Yes, all three requirements are fulfilled.

Note

***In subnetting,
we need the first address of
the
subnet and the subnet
mask to
define the range of
addresses.***

Note

**In supernetting,
we need the first address of
the supernet
and the supernet mask to
define the range of
addresses.**

Comparison of subnet, default, and supernet masks

Subnet Mask

Divide 1 network into 8 subnets

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

Subnetting



3 more
1s



Default Mask

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Supernetting



3 less
1s



Supernet Mask

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Combine 8 networks into 1 supernet

Example 13

We need to make a supernet out of 16 class C blocks. What is the supernet?

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 14

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

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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

Example 15

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

5.3

CLASSLESS ADDRESSING

Variable-length blocks

Address Space



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, . . .). A household may be given a block of 2 addresses. A small business may be given 16 addresses. A

Beginning Address

The beginning address must be evenly divisible by the number of addresses. For example, if a block contains 4 addresses, the beginning address must be divisible by 4. 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

Example 16

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.B.C.D/*n*

Note

***Slash notation is also called
CIDR
notation.***

Example 17

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: 11001111 00010000 00100101
00011000
- Ending : 11001111 00010000 00100101
00011111
- There are only 8 addresses in this block.

Example 17 cont'd

We can find the range of addresses in Example 17 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 ($24 + 7 = 31$).

Note

**A block in classes A, B, and C
can easily be represented in
slash
notation as
A.B.C.D/ n
where *n* is
either 8 (class A), 16 (class**

Example 18

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 19

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

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 19 cont'd

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 20

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

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 = $64 \times 256 = 16,384$

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

.....

128: 190.100.127.128/25 → 190.100.127.255/25

Total = $128 \times 128 = 16,384$

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 = $128 \times 64 = 8192$

Solution (Continued)

Number of granted addresses:
65,536

Number of allocated addresses:
40,960

Number of available addresses:
24,576