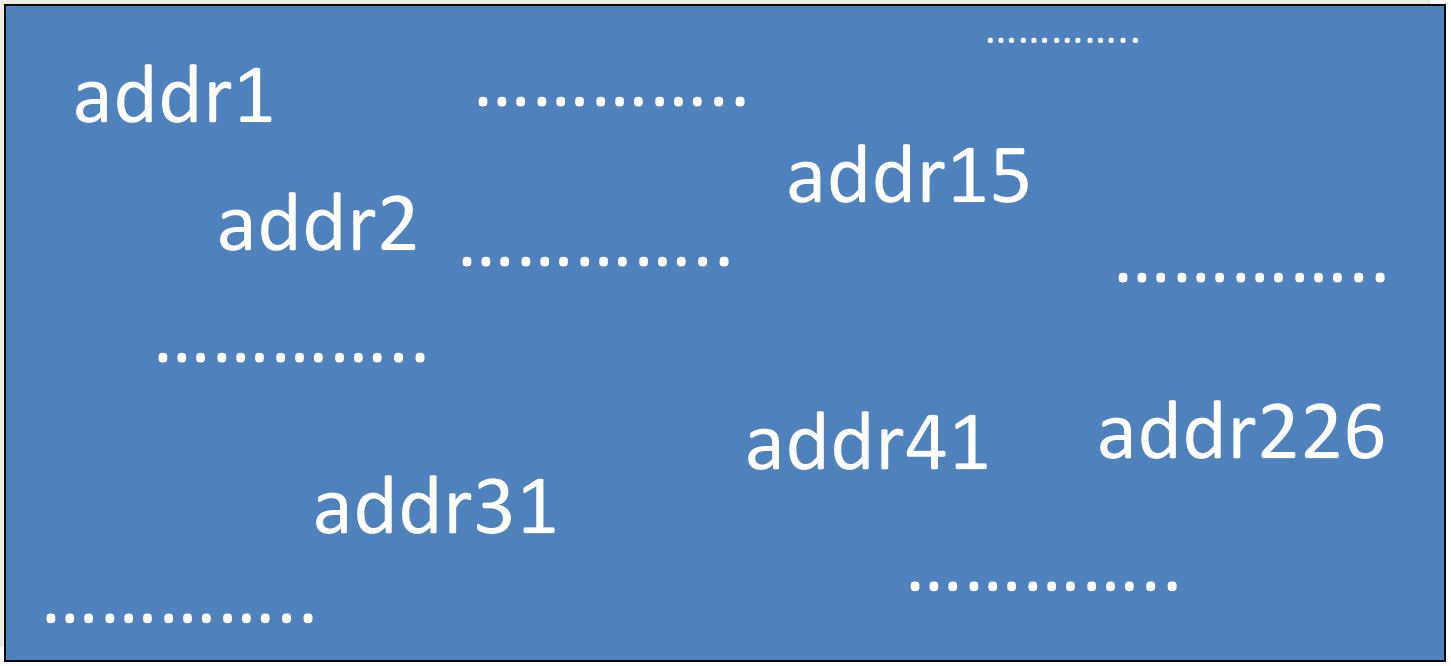
IP Addresses
Classful Addressing

INTRODUCTION

An IP address is a 32-bit address.

The IP addresses are unique.

Address Space



RULE:

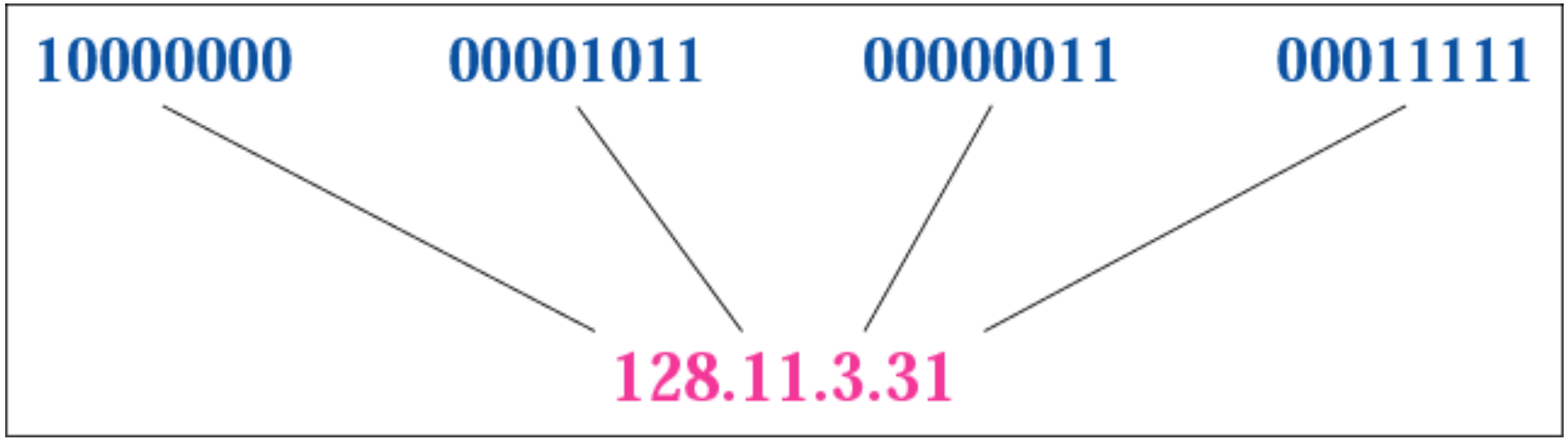
If a protocol uses *N* bits to define an address, the address space is 2^N because each bit can have two different values (0 and 1) and *N* bits can have 2^N values.

The address space of IPv4 is 2^{32} or 4,294,967,296

Binary Notation

01110101 10010101 00011101 11101010

Dotted-decimal notation



Hexadecimal Notation

0111 0101 1001 0101 0001 1101 1110 1010

75 95 1D EA

0x75951DEA

Example 1

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

10000001 00001011 00001011 11101111

Solution

129.11.11.239

Example 2

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

111.56.45.78

Solution

01101111 00111000 00101101 01001110

Example 3

Find the error, if any, 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, if any, in the following IP address:

75.45.301.14

Solution

In dotted-decimal notation, each number is less than or equal to 255; 301 is outside this range.

Example 4

Change the following IP addresses from binary notation to hexadecimal notation.

10000001 00001011 00001011 11101111

Solution

0X810B0BEF or $810B0BEF_{16}$

CLASSFUL ADDRESSING

IP Addressess

• IP is a network layer - it must be capable of providing communication between hosts on different kinds of networks (different data-link implementations).

• The address must include information about what *network* the receiving host is on. This is what makes routing feasible.

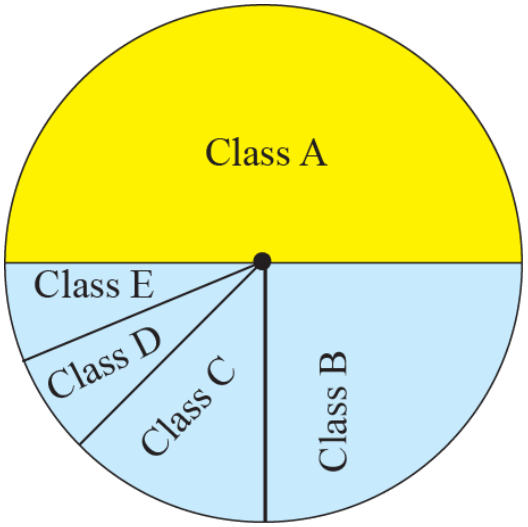
• IP addresses are *logical* addresses (not physical)32 bits.[IPv4]

• Includes a network ID and a host ID.

• Every host must have a unique IP address.

• IP addresses are assigned by a central authority (*American Registry for Internet Numbers* for North America).

Occupation of the address space



Class A: 2^{31} = 2,147,483,648 addresses, 50%

Class B: 2^{30} = 1,073,741,824 addresses, 25%

Class C: 2^{29} = 536,870,912 addresses, 12.5%

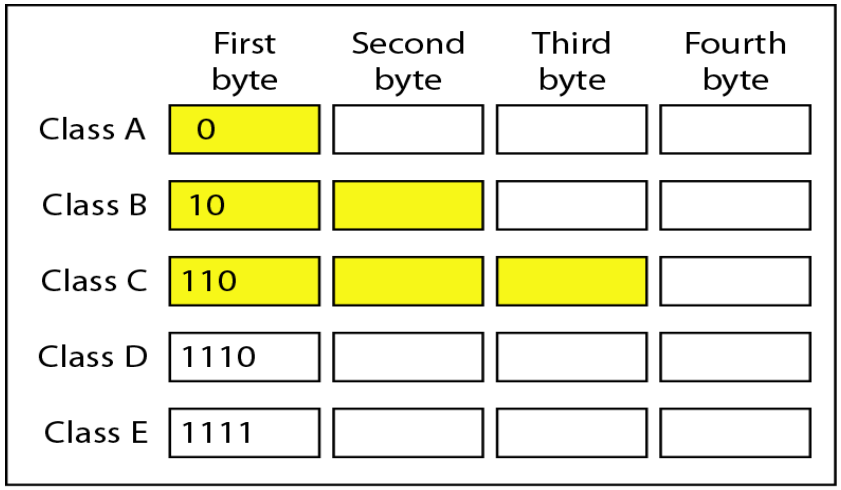
Class D: 2^{28} = 268,435,456 addresses, 6.25%

Class E: 2^{28} = 268,435,456 addresses, 6.25%

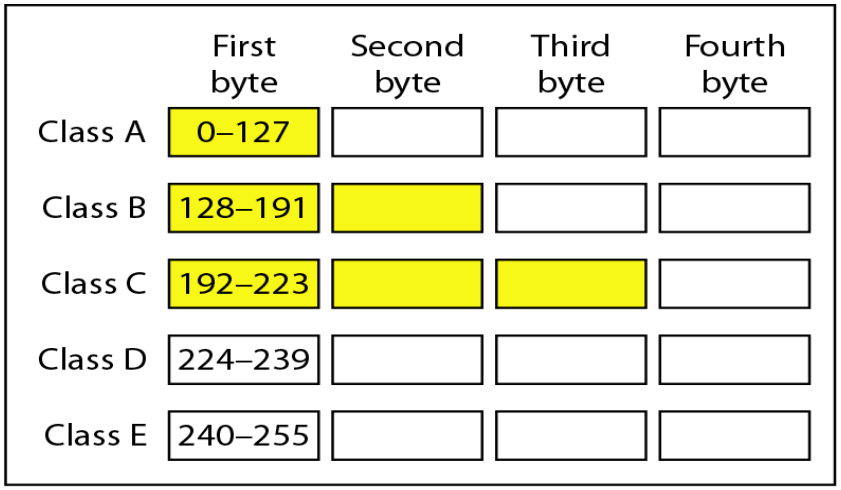
Note

In classful addressing, the address space is divided into five classes: A, B, C, D, and E.

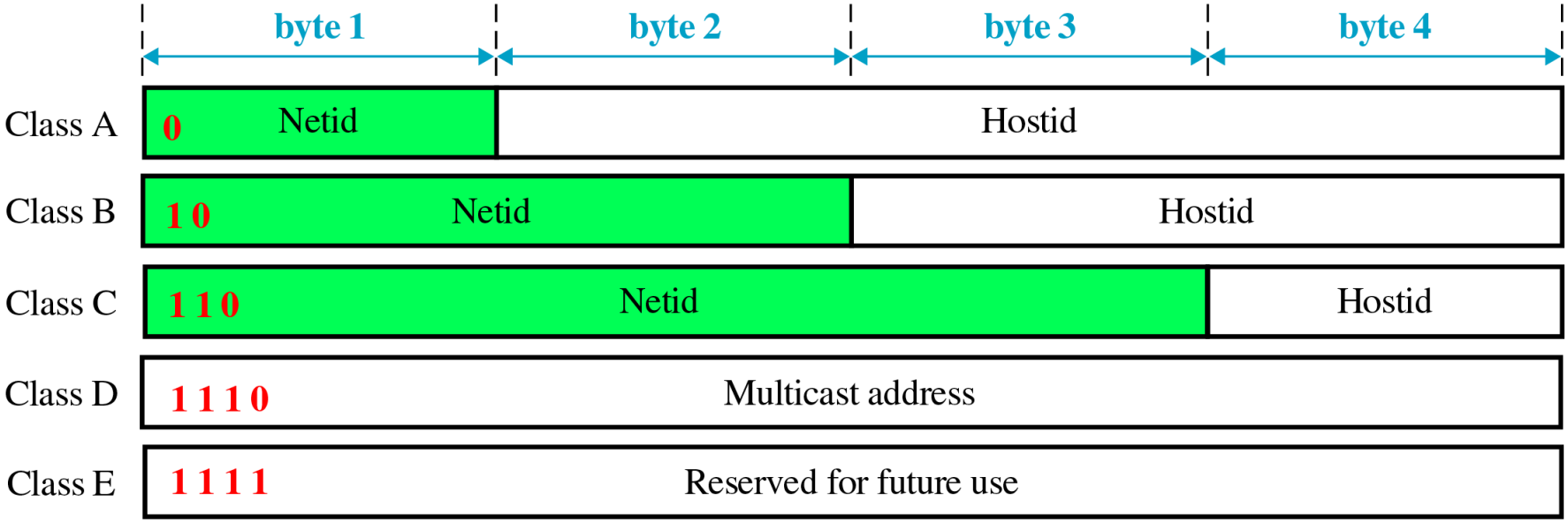
Classful IP Address



a. Binary notation

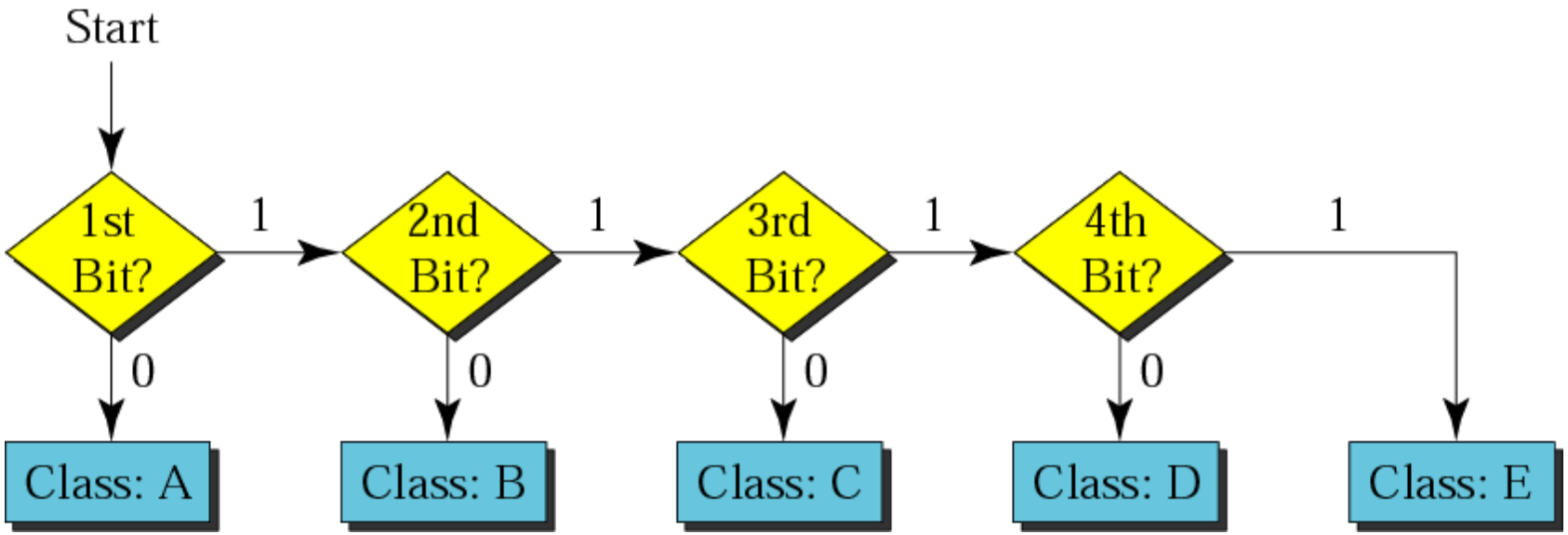


b. Dotted-decimal notation

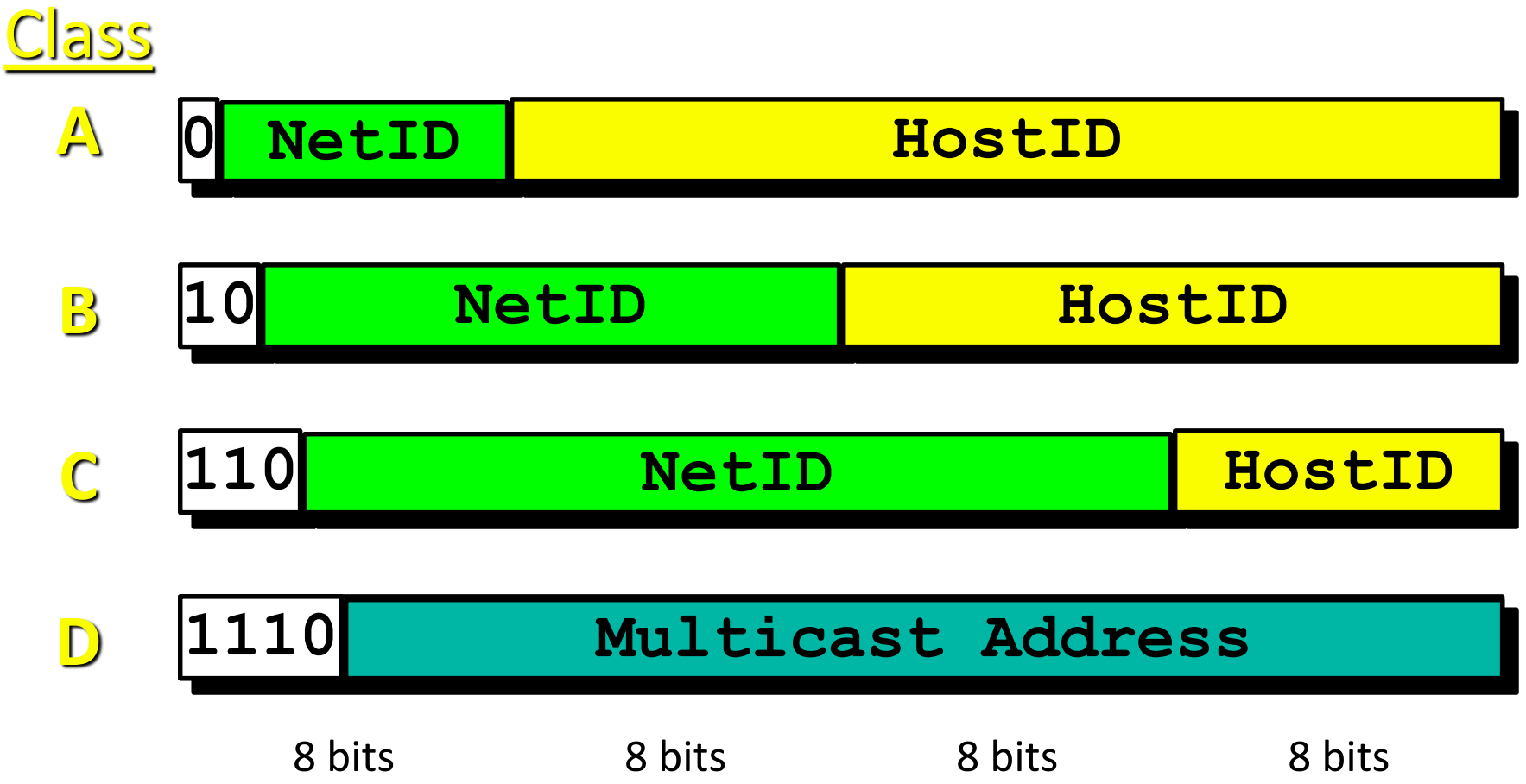


Class	Leading bits	Size of *network number* bit field	Size of *rest* bit field	Number of networks	Addresses per network	Start address	End address
Class A	0	8	24	128 (2^7)	16,777,216 (2^{24})	0.0.0.0	127.255.255.255
Class B	10	16	16	16,384 (2^{14})	65,536 (2^{16})	128.0.0.0	191.255.255.255
Class C	110	24	8	2,097,152 (2^{21})	256 (2^8)	192.0.0.0	223.255.255.255
Class D (multicast)	1110	not defined	not defined	not defined	not defined	224.0.0.0	239.255.255.255
Class E (reserved)	1111	not defined	not defined	not defined	not defined	240.0.0.0	255.255.255.255

Finding the address class



The *four for*mats of IP Addresses



Example 1

Find the class of each address.

a. **0**0000001 00001011 00001011 11101111

b. **110**00001 10000011 00011011 11111111

c. **14**.23.120.8

d. **252**.5.15.111

Solution

a. The first bit is 0. This is a class A address.

b. The first 2 bits are 1; the third bit is 0. This is a class C address.

c. The first byte is 14; the class is A.

d. The first byte is 252; the class is E.

Network and Host IDs

- A Network ID is assigned to an organization by a global authority.
- Host IDs are assigned locally by a system administrator.
- Both the Network ID and the Host ID are used for routing.

IP Addresses

- IP Addresses are usually shown in *dotted decimal* notation:

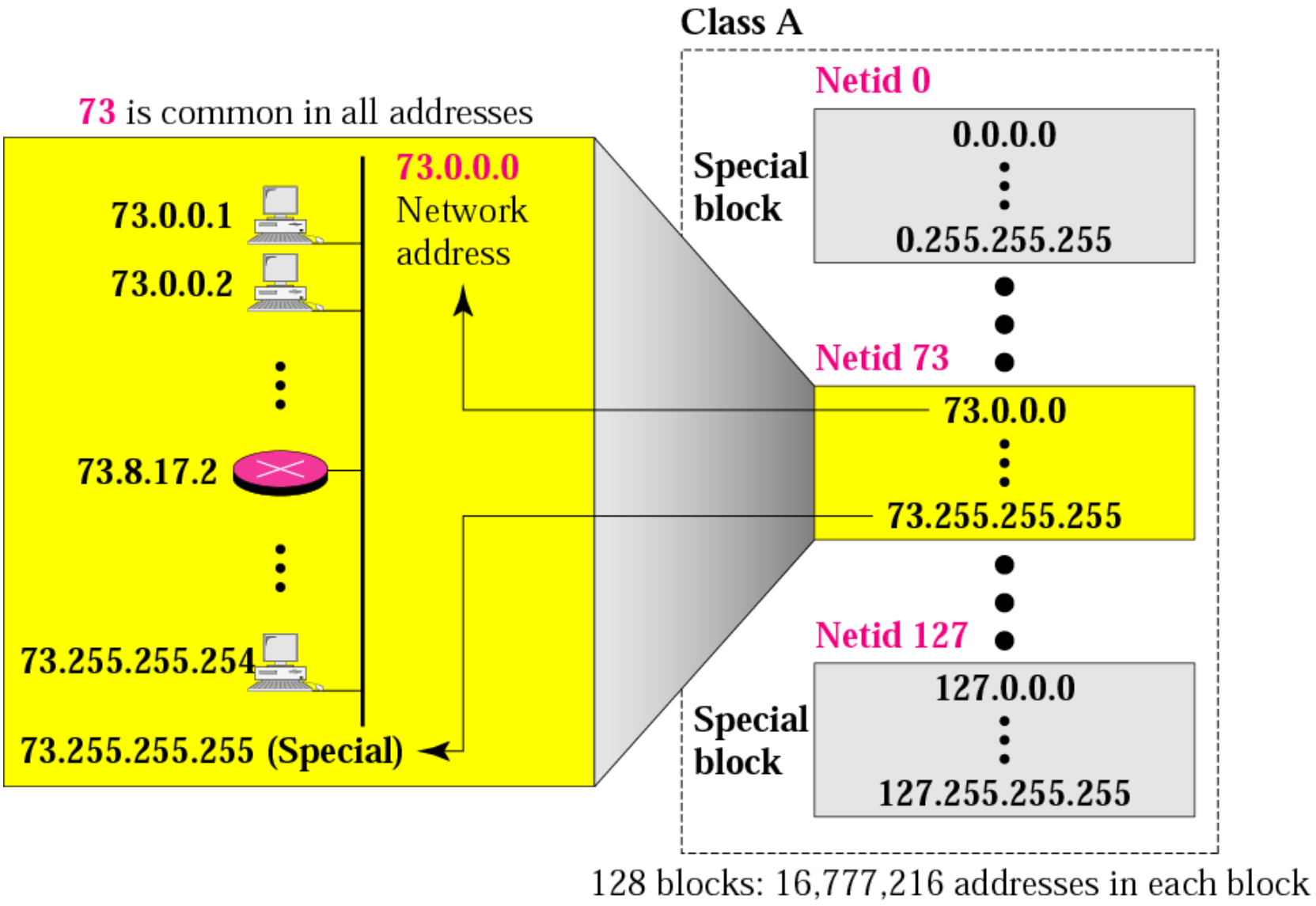
1.2.3.4 `00000001 00000010 00000011 00000100`

- cs.rpi.edu is 128.213.1.1

`10000000 11010101 00000001 00000001`

CS has a class B network

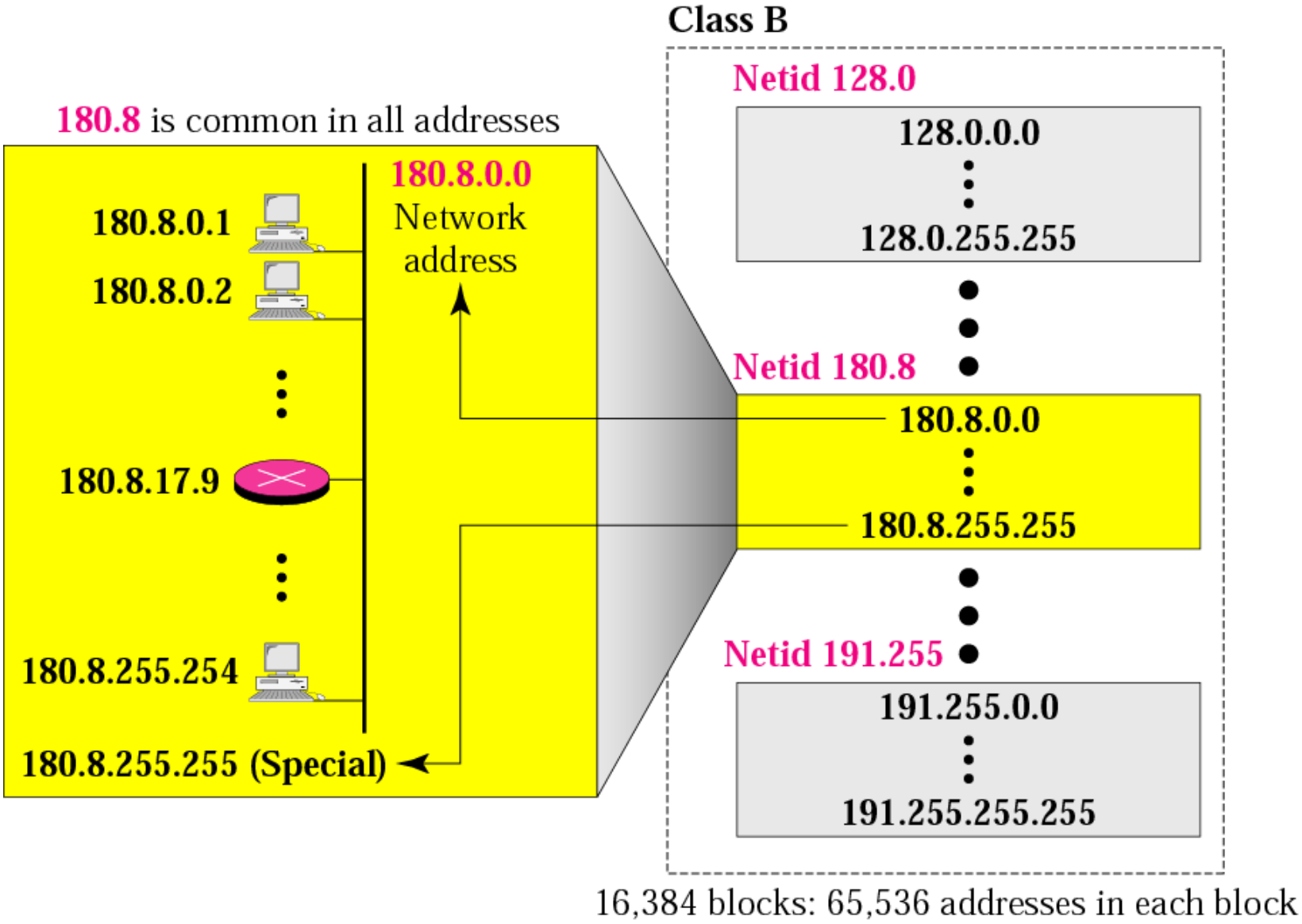
Blocks in class A



Note

Millions of class A addresses are wasted.

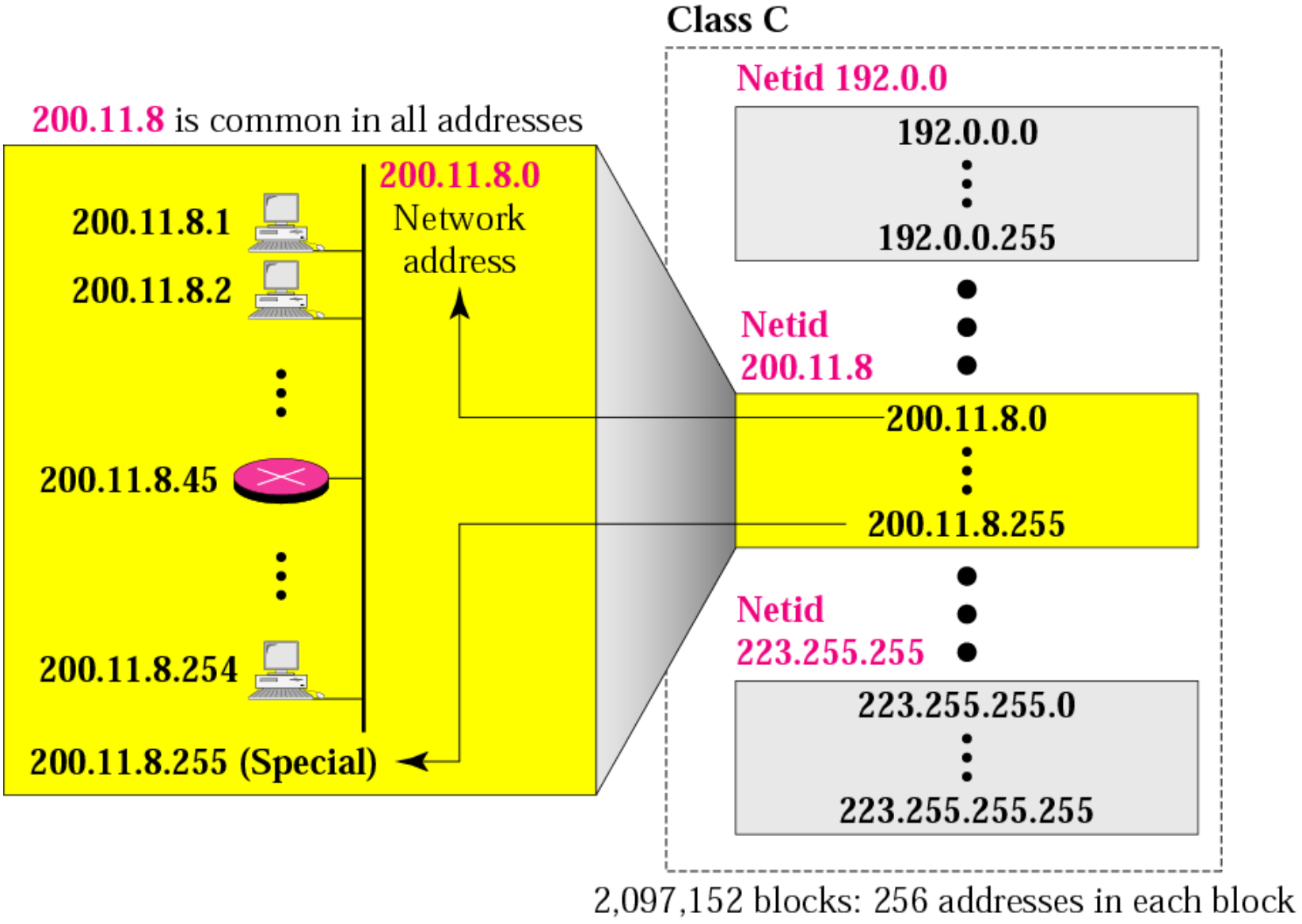
Blocks in class B



Note

Many class B addresses are wasted.

Blocks in class C



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 9

Given the network address 17.0.0.0, find the class, the block, and the range of the addresses.

Solution

The class is A because the first byte is between 0 and 127. The block has a netid of 17. The addresses range from 17.0.0.0 to 17.255.255.255.

Example 10

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

Solution

The class is B because the first byte is between 128 and 191. The block has a netid of 132.21. The addresses range from 132.21.0.0 to 132.21.255.255.

Example 11

Given the network address 220.34.76.0, find the class, the block, and the range of the addresses.

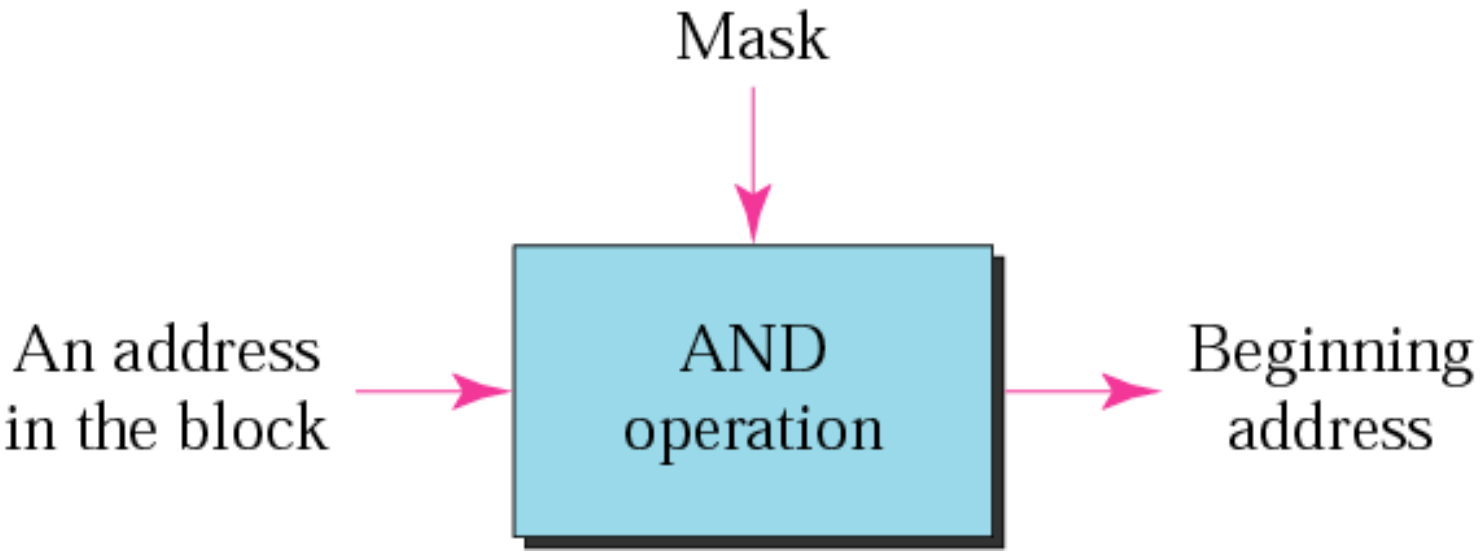
Solution

The class is C because the first byte is between 192 and 223. The block has a netid of 220.34.76.The addresses range from 220.34.76.0 to 220.34.76.255.

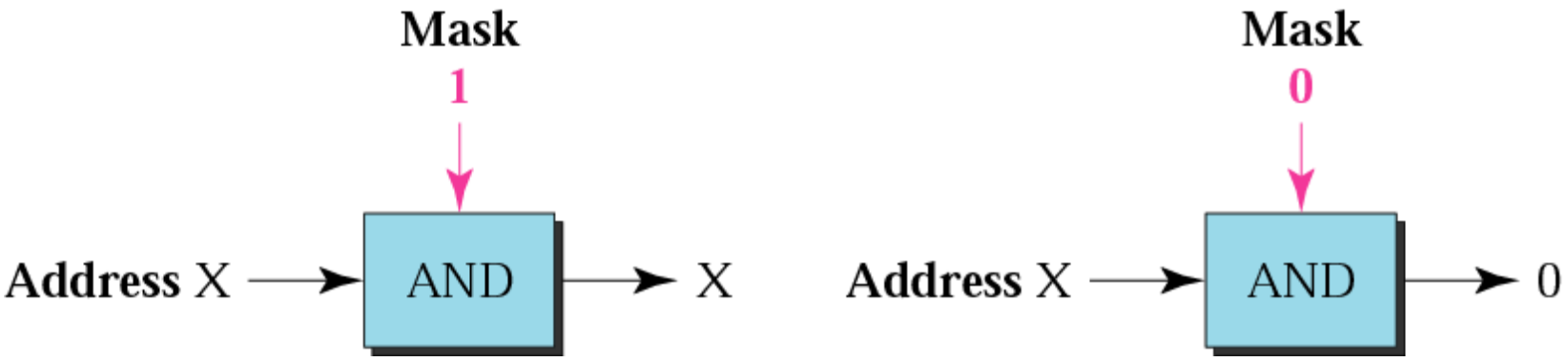
Mask

- A mask is a 32-bit number in which the *n leftmost bits* are Is and the 32 - *n rightmost bits are Os.*
- *However, in classless addressing the mask* for a block can take any value from 0 to 32. It is very convenient to give just the value of *n preceded by a slash (CIDR notation).*
- In 1Pv4 addressing, a block of addresses can be defined as **x.y.z.t/n** in which x.y.z.t defines one of the addresses and the *In defines the mask.*

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 block and sets the hostid to zero.

Number of blocks and block size in classful IPv4 addressing

Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

Default masks for classful addressing

Class	*Binary*	*Dotted-Decimal*	*CIDR*
A	11111111 00000000 00000000 00000000	255.0.0.0	/8
B	11111111 11111111 00000000 00000000	255.255.0.0	/16
C	11111111 11111111 11111111 00000000	255.255.255.0	/24

Example 12

Given the address 23.56.7.91, find the beginning address (network address).

Solution

The default mask is 255.0.0.0, which means that only the first byte is preserved and the other 3 bytes are set to 0s. The network address is 23.0.0.0.

Example 13

Given the address 132.6.17.85 and, find the beginning address (network address).

Solution

The default mask is 255.255.0.0, which Means that the first 2 bytes are preserved and the other 2 bytes are set to 0s. The network address is 132.6.0.0.

Example 14

Given the address 201.180.56.5, find the beginning address (network address).

Solution

The default mask is 255.255.255.0, which means that the first 3 bytes are preserved and the last byte is set to 0. The network address is 201.180.56.0.

Note

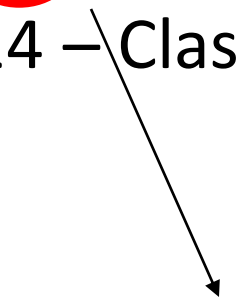
We must not apply the default mask of one class to an address belonging to another class.

CIDR (Classless Inter-Domain Routing) Notation

18.46.74.10/8 – Class A

141.24.74.69/16 - Class B

200.14.70.22/24 – Class C



Number of 1’s in the mask

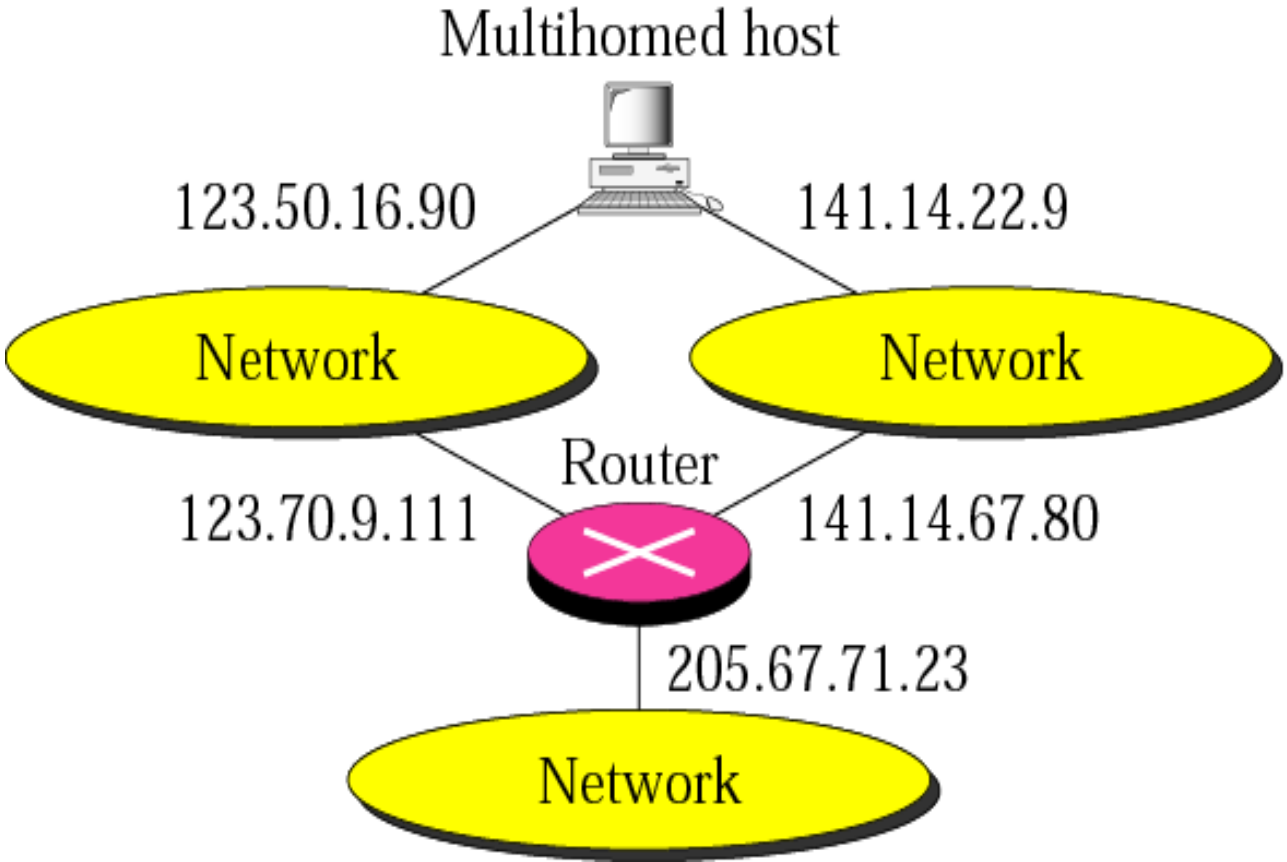
Location, Not Names

- An internet address defines the **network location of a device,** not its identity.

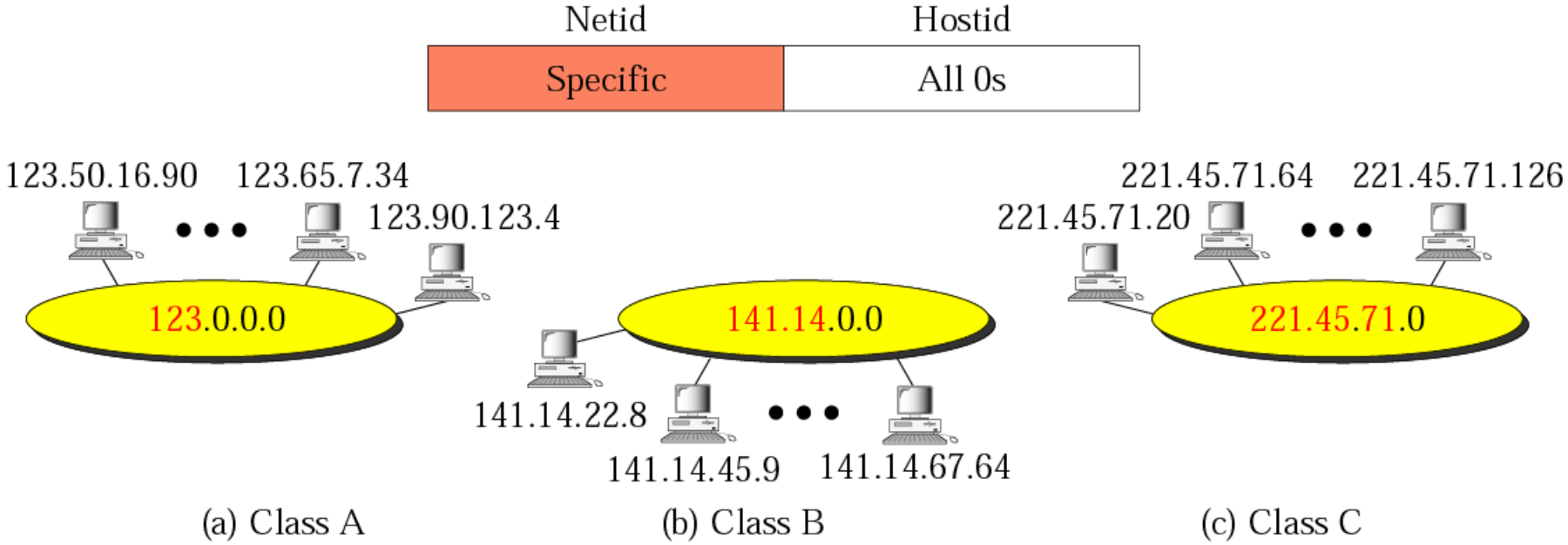
- Movement of **Computer/ Node** from one network to another means that its IP address must be changed.

Multihomed devices

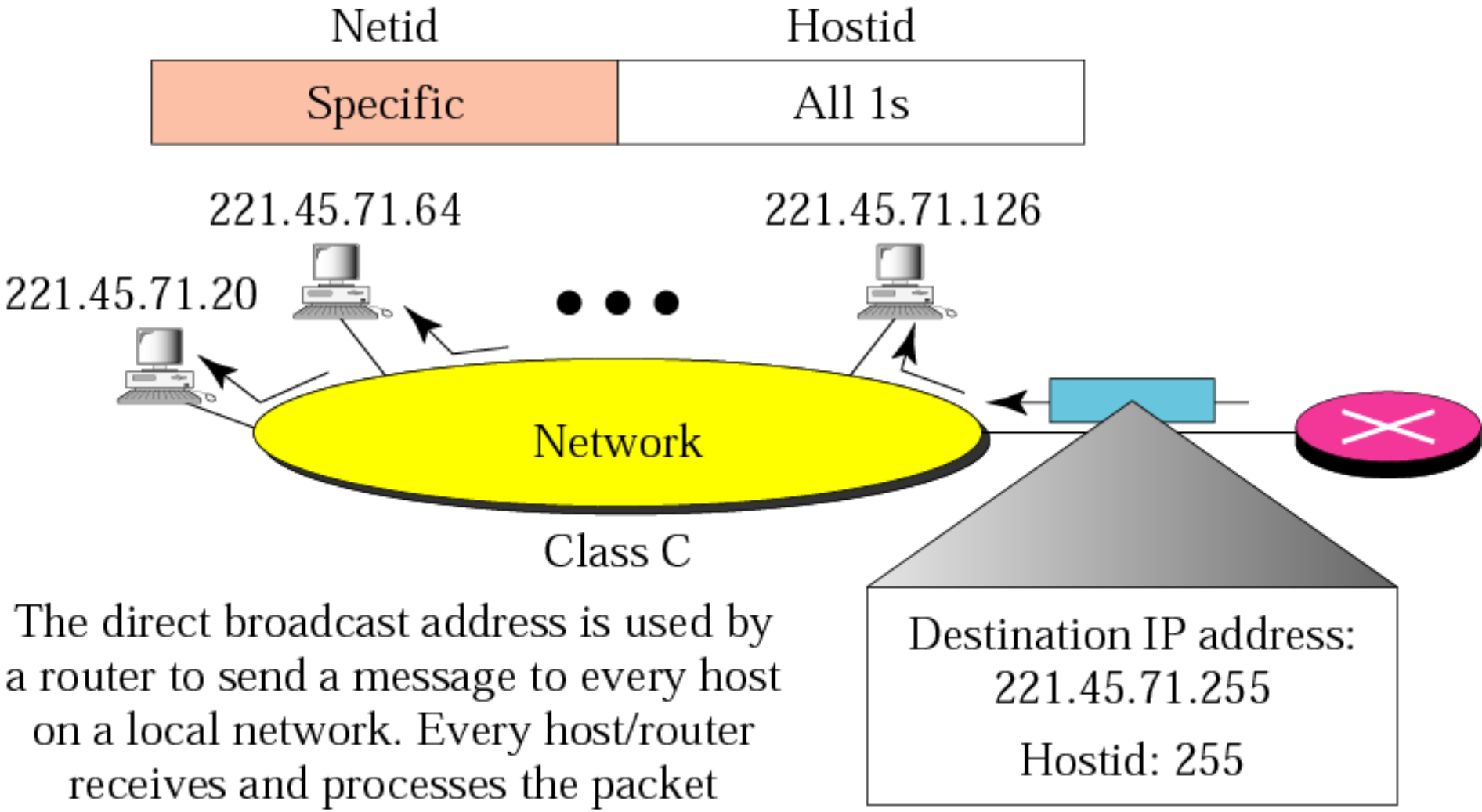
- A Device has different address for each network connected to it. Such computers are called as Multihomed Computers.
- Each of these addresses can belong to a different class.
- The router has more than one IP address, one for each interface.



Network addresses

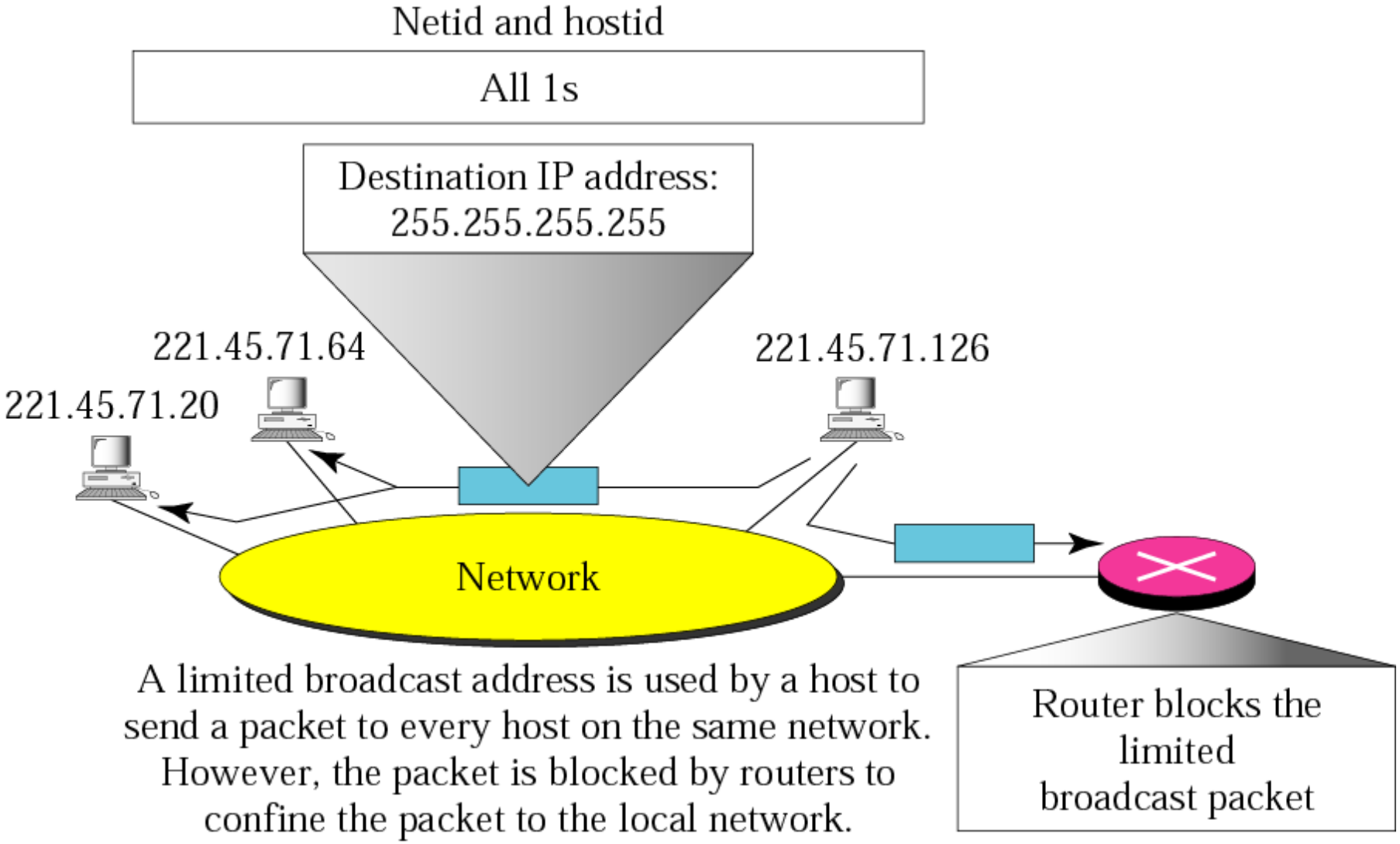


Example of direct broadcast address - Host IDs are all 1's.

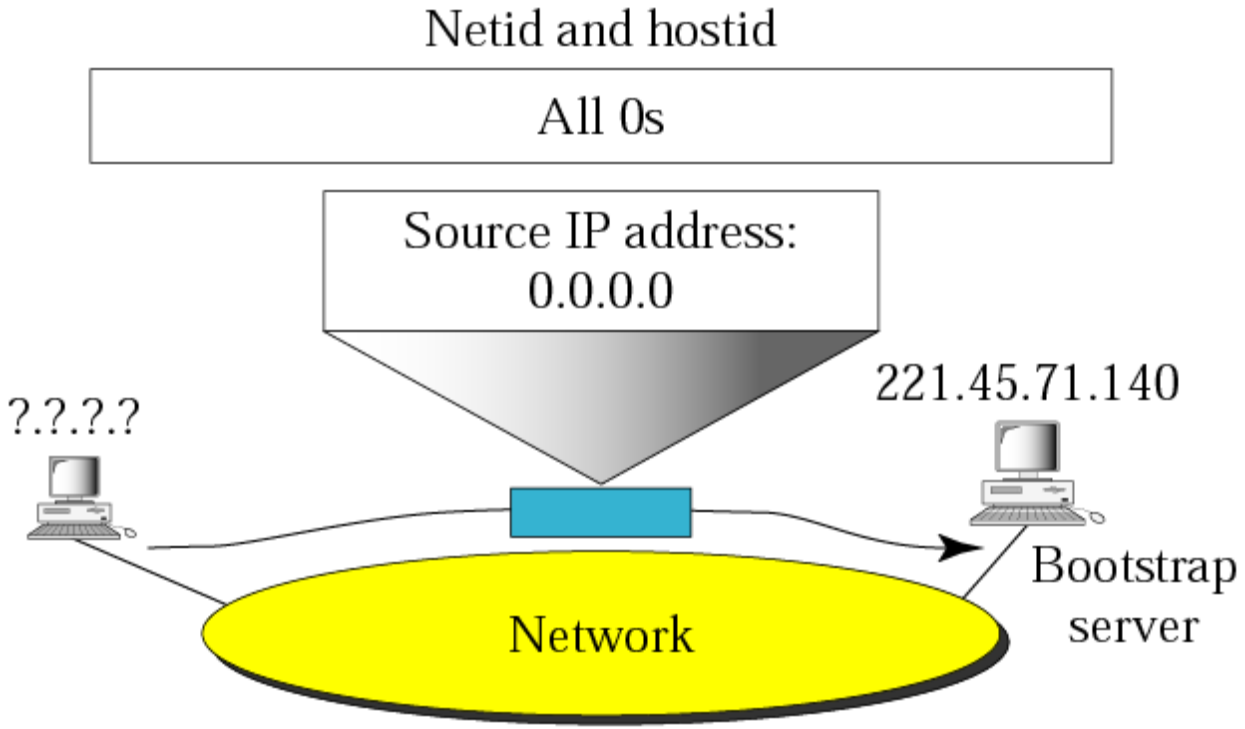


The direct broadcast address is used by a router to send a message to every host on a local network. Every host/router receives and processes the packet with a direct broadcast address.

Example of limited broadcast address

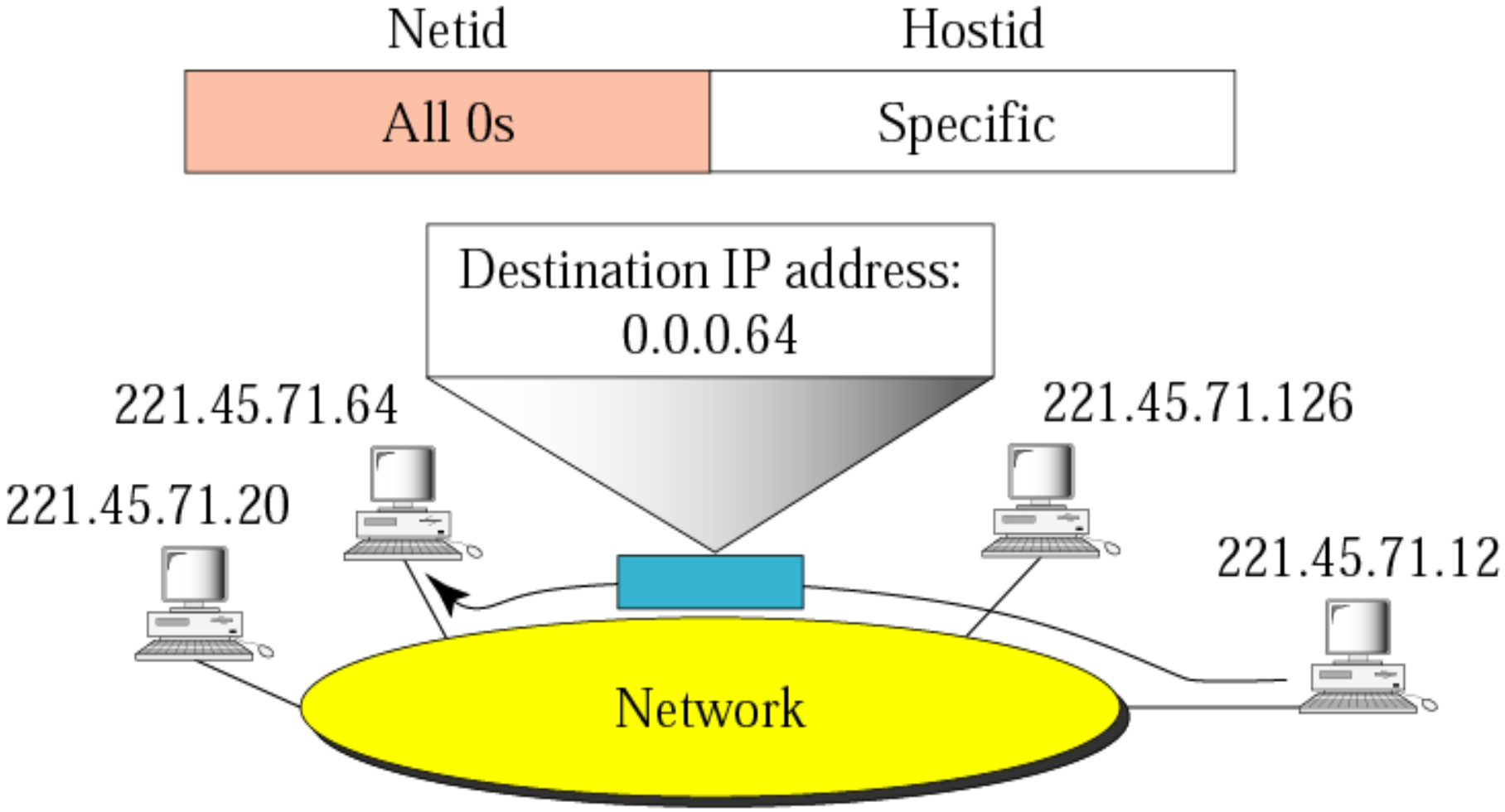


Example of *this* host on *this* address



A host that does not know its IP address uses the IP address 0.0.0.0 as the source address and 255.255.255.255 as the destination address to send a message to a bootstrap server.

Example of specific host on *this* network



This address is used by a router or host
to send a message to a specific host on the same network.

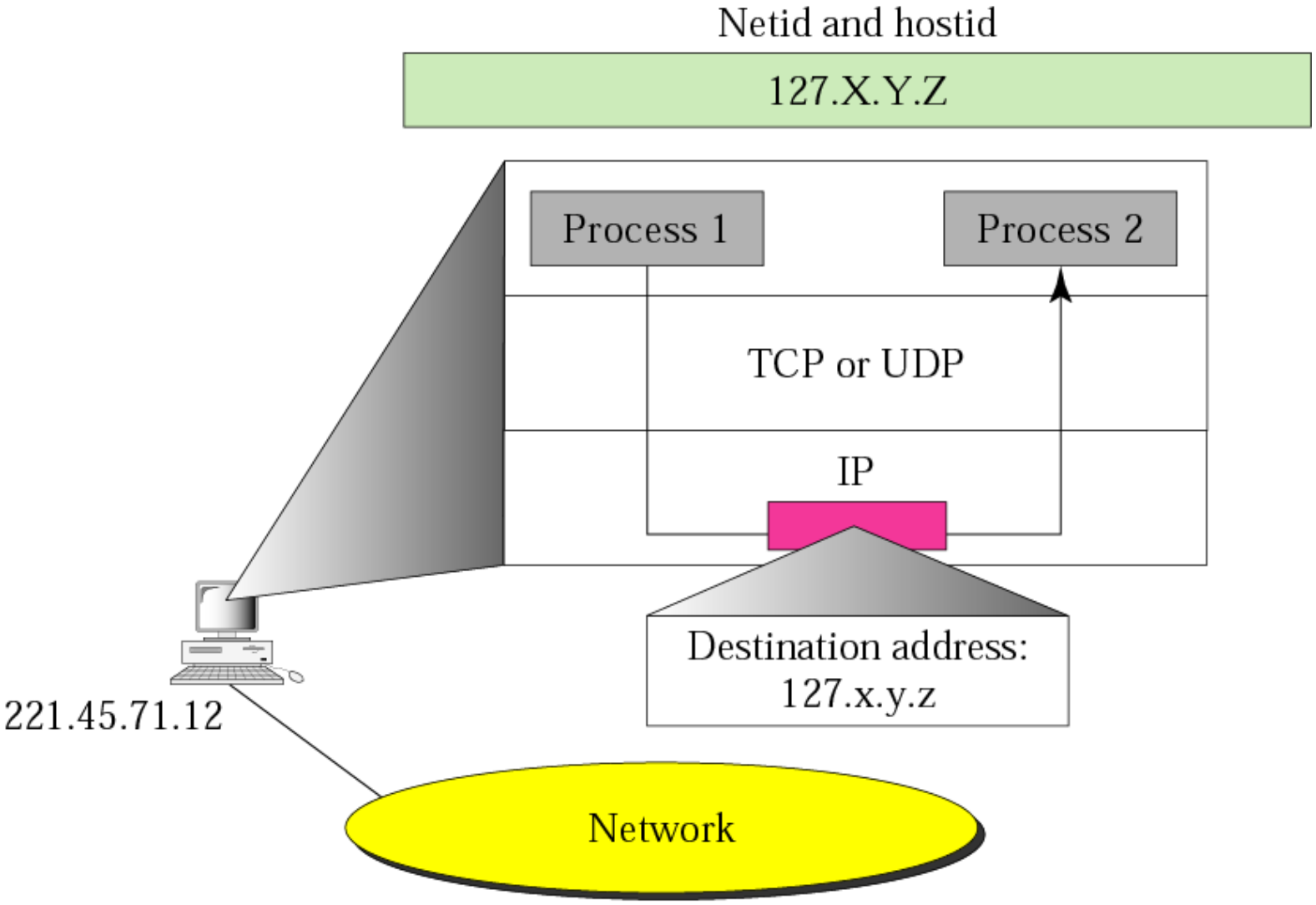
Loop back address

- IP address with first byte as 127[127.X.Y.Z]
- Used to test the s/w on a machine [Here the packet simply returns to the protocol s/w on the same machine]
- Eg. Ping appln to test if the process is able to receive and process a packet.
- Eg. Client process sending msg to server process on the same machine.

Special Addresses

Special Address	Netid	Hostid	Source or Destination
Network address	Specific	All 0s	None
Direct broadcast address	Specific	All 1s	Destination
Limited broadcast address	All 1s	All 1s	Destination
The host on this network	All 0s	All 0s	Source
Specific host on this network	All 0s	Specific	Destination
Loopback address	127	Any	Destination

Example of loopback address



A packet with a loopback address will not reach the network.

Unicast, Multicast, and Broadcast Addresses

Unicast communication is *one-to-one*.

Multicast communication is *one-to-many*.

Broadcast communication is *one-to-all*.

SUBNETTING

Note

IP addresses are designed with two levels of hierarchy.

Subnet Addresses

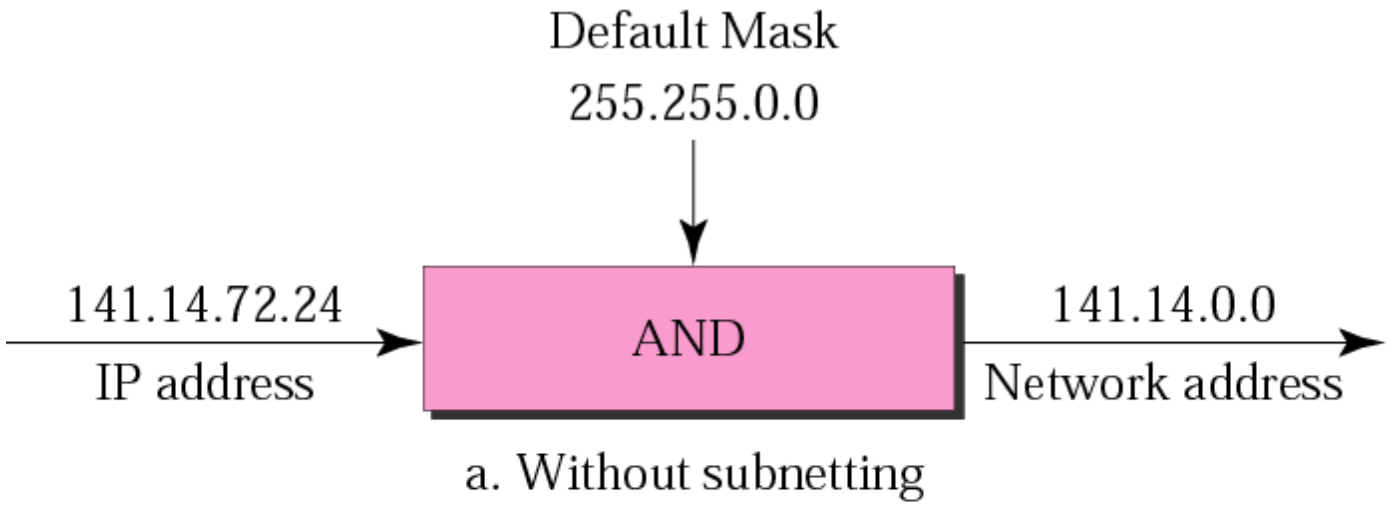
- An organization can subdivide it's host address space into groups called subnets.
- The subnet ID is generally used to group hosts based on the physical network topology.

Hierarchy concept in a telephone number

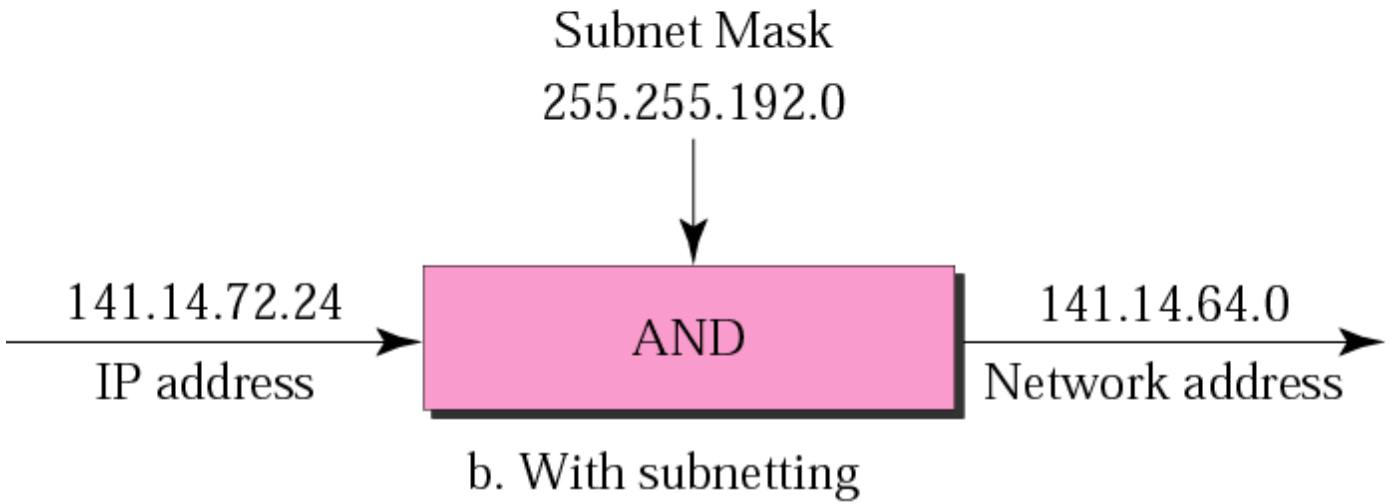
Two levels: Netid & Hostid

Three levels: Netid : subnetid : Hostid

Default mask and subnet mask

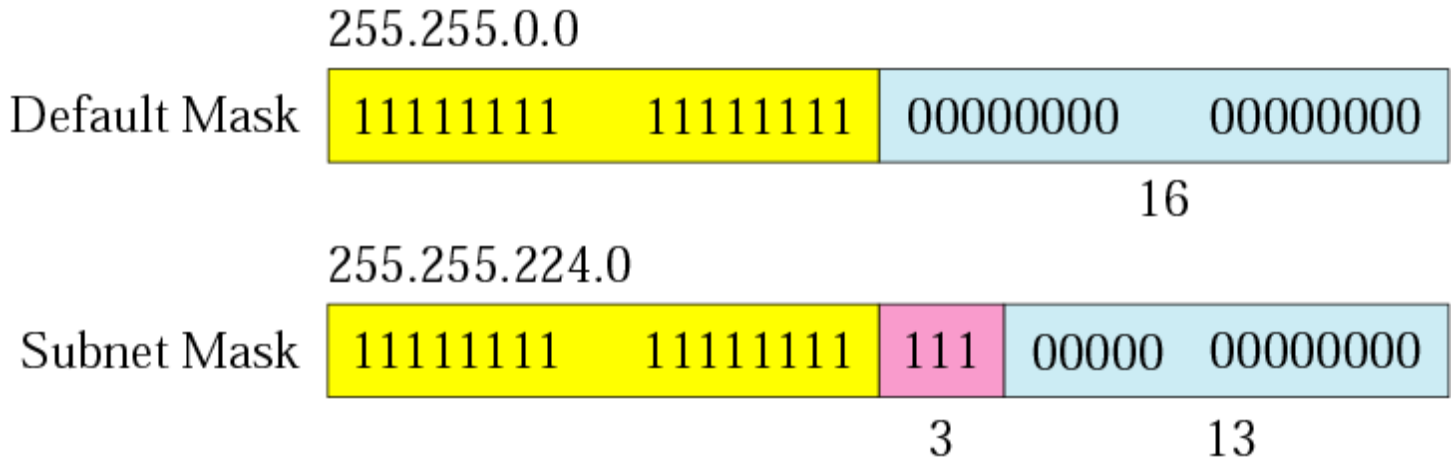


a. Without subnetting



b. With subnetting

Comparison of a default mask and a 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 15

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 1111**0000** **00000000**

11001000 00101101 0010**0000** **00000000**

The subnetwork address is **200.45.32.0**.

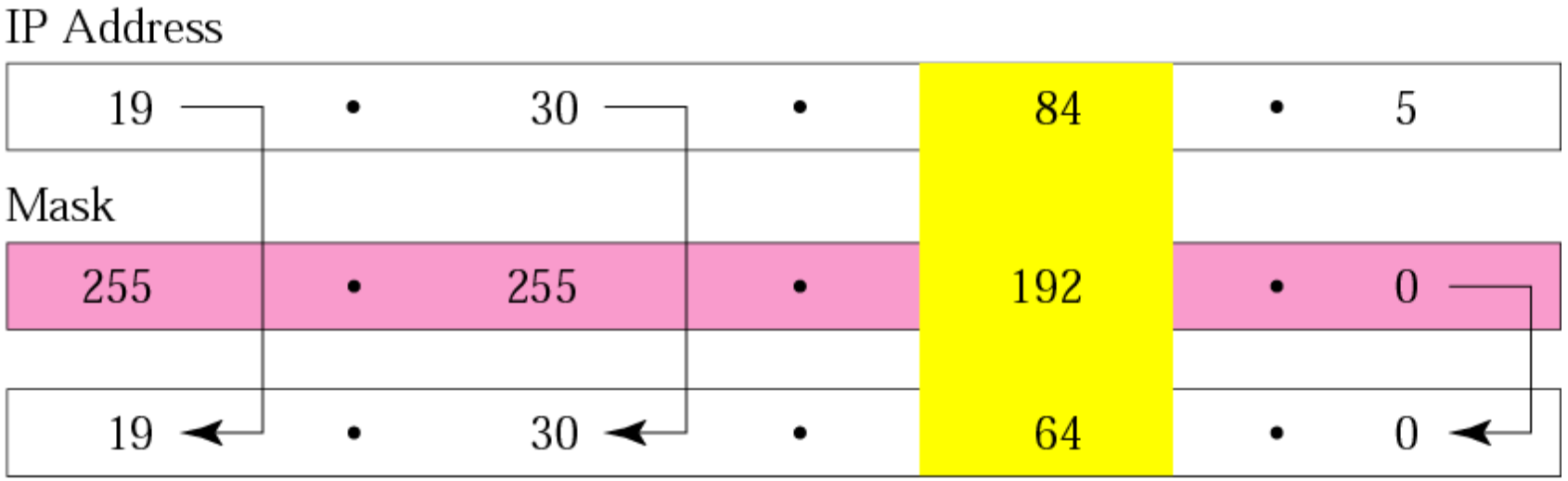
Short-Cut Method

** 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.

What is the subnetwork address if the destination address is 19.30.84.5 and the mask is 255.255.192.0?



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

Note

The number of subnets must be a power of 2.

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).

The total number of 0s is 5 (32 – 27).

Solution (Continued)

The mask is

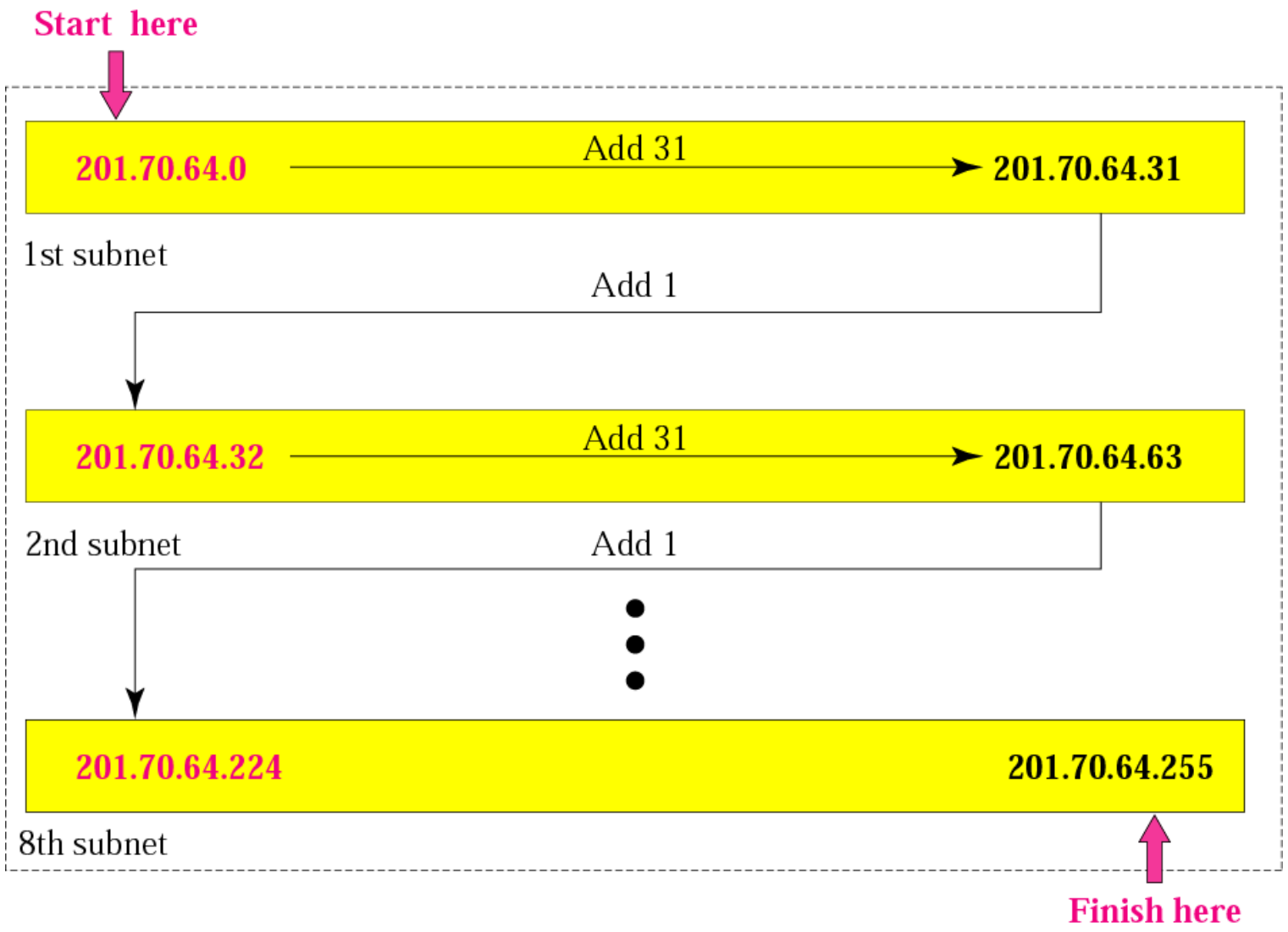
11111111 11111111 11111111 11100000

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.


Start here
201.70.64.0
Add 31
201.70.64.31
1st subnet
Add 1
201.70.64.32
Add 31
201.70.64.63
2nd subnet
Add 1
201.70.64.224
201.70.64.255
8th subnet
Finish here

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 – 26).

Solution (Continued)

The mask is

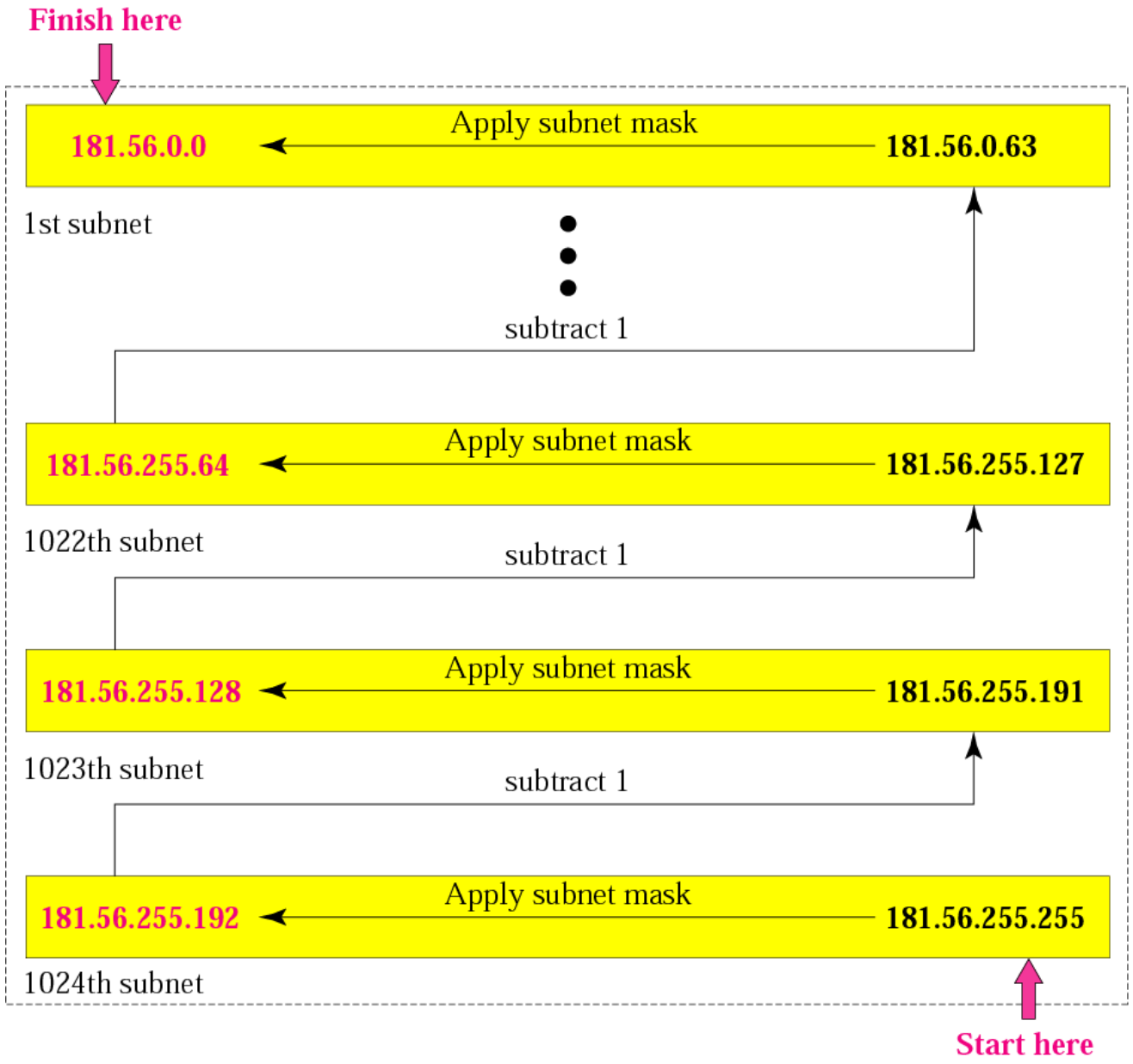
11111111 11111111 11111111 11000000

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) or 64.


Finish here
181.56.0.0
Apply subnet mask
181.56.0.63
1st subnet
subtract 1
181.56.255.64
Apply subnet mask
181.56.255.127
1022th subnet
subtract 1
181.56.255.128
Apply subnet mask
181.56.255.191
1023th subnet
subtract 1
181.56.255.192
Apply subnet mask
181.56.255.255
1024th subnet
Start here

SUPERNETTING

Comparison

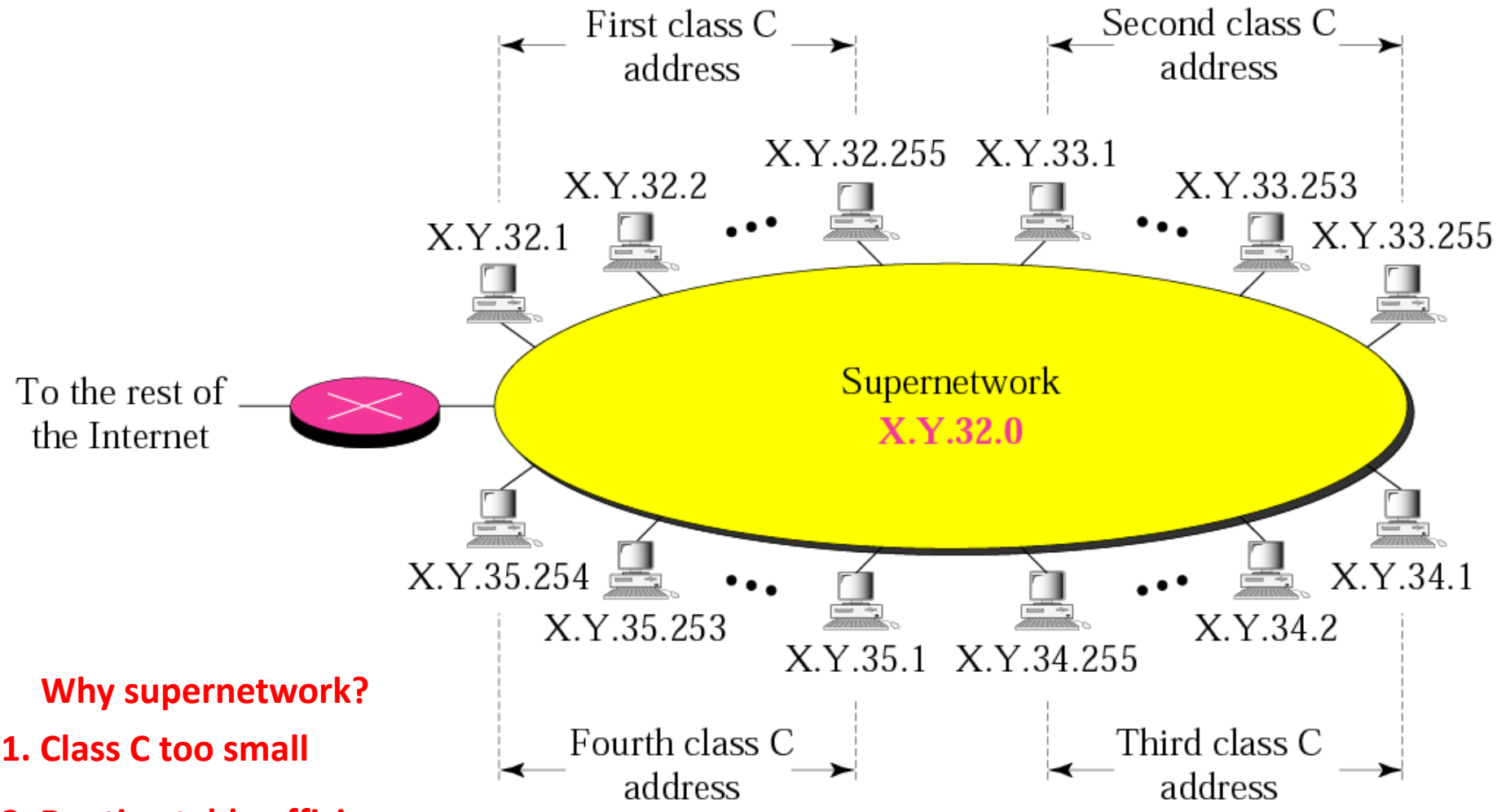
Subnetting

- 1’s are made more than the default mask
- A subnet mask divides a block into subblocks [Eg. SITE, SCSE, SMBS]

Supernetting

- 1’s are made less than the default mask
- A supernet combines n blocks into one superblock [Combining several blocks]

A supernetwork

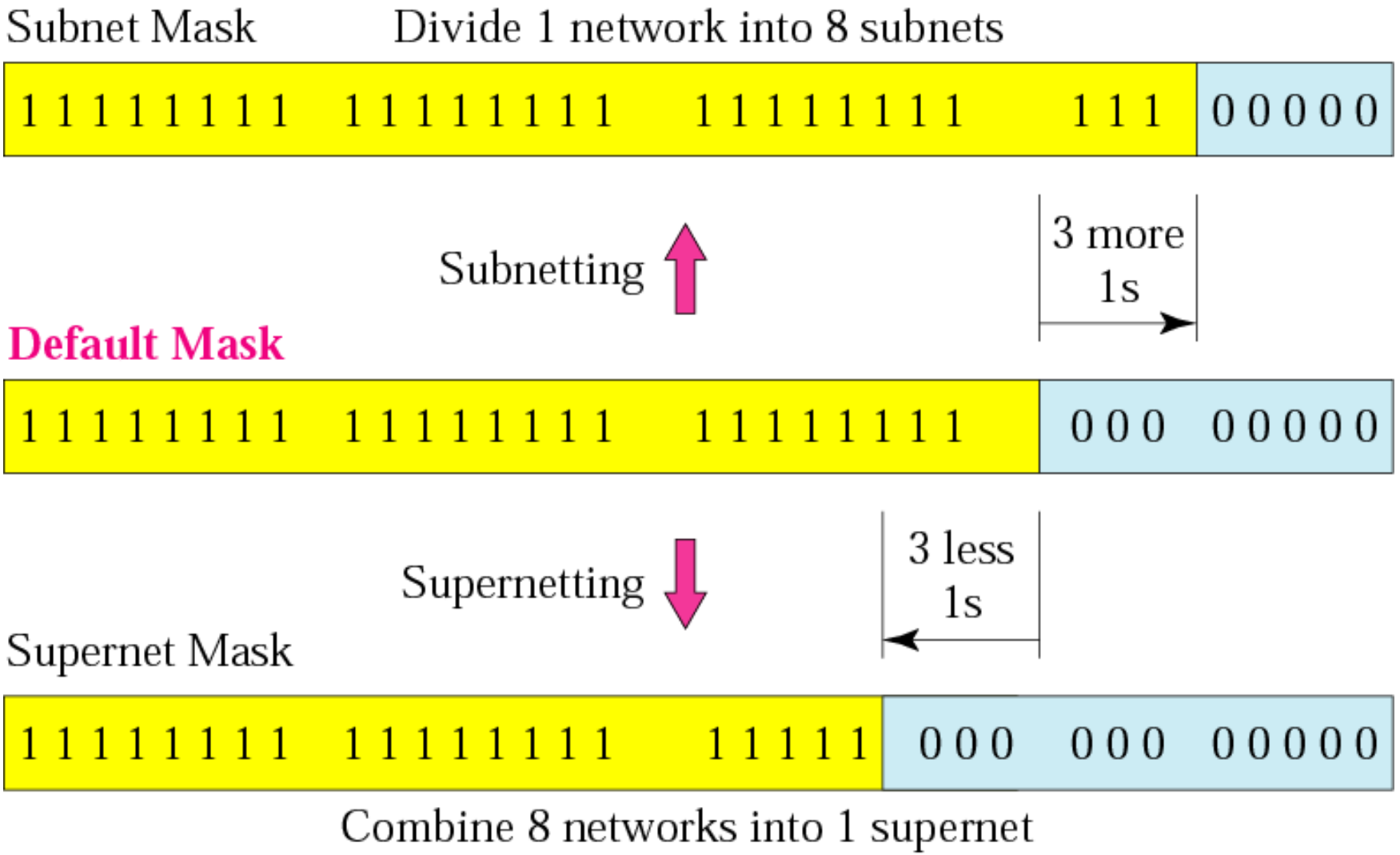


Why supernetwork?

1. Class C too small

2. Routing table efficiency

Comparison of subnet, default, and supernet masks



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

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

We apply the supernet mask to see if we can find the beginning address.

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.

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.

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*.

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

198.47.31.0 198.47.32.0 198.47.33.0 198.47.34.0

198.47.32.0 198.47.33.0 198.47.34.0 198.47.35.0

Solution

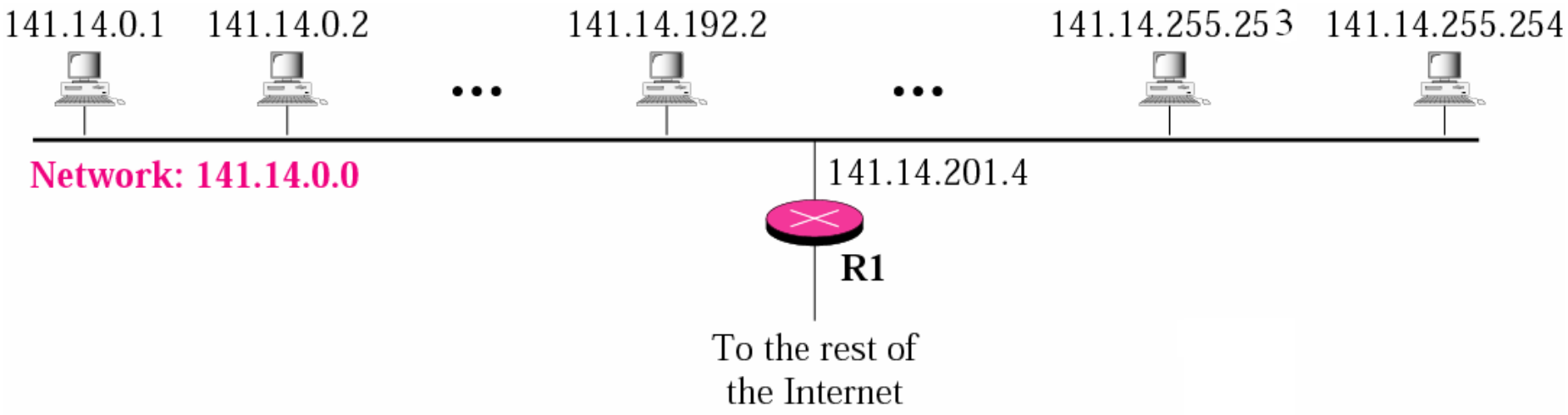
1: No, there are only three blocks.

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.

A network with two levels of hierarchy (not subnetted)



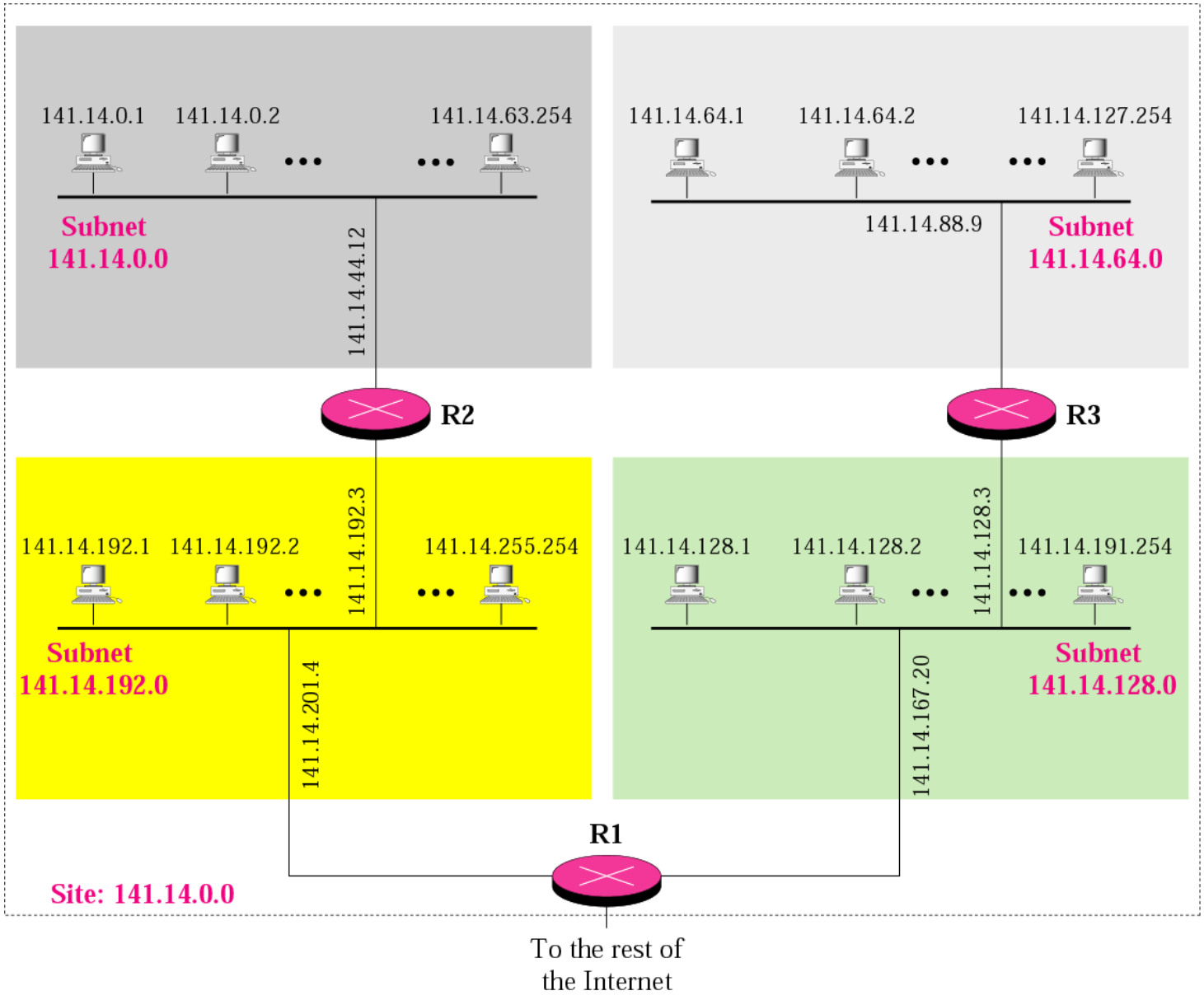
Why subnetting?

1. The transmissions of these hosts will affect one another.

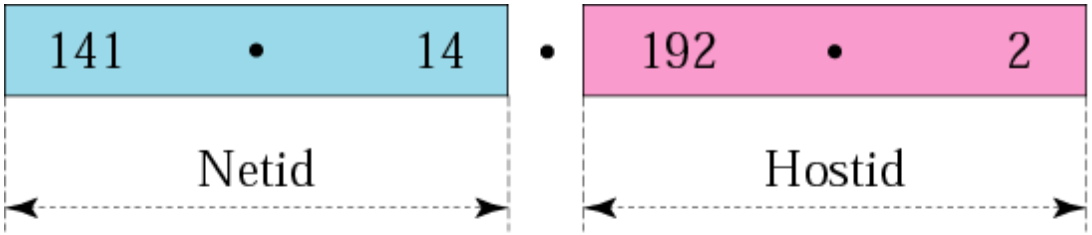
2. Class B too large, wasteful.

3. Not easy to manage. (e.g., where is host 141.14.190.1?)

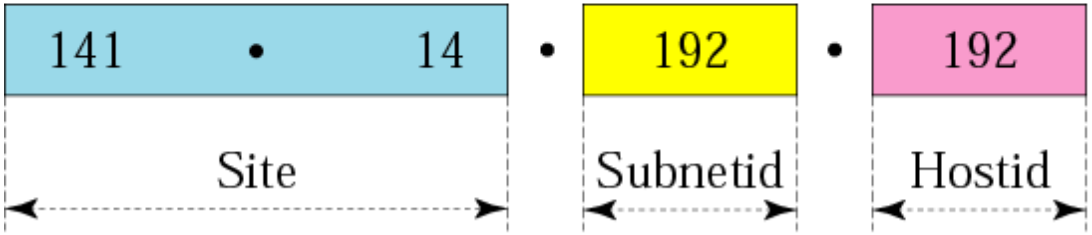
A network with three levels of hierarchy (subnetted)



Addresses in a network with and without subnetting



a. Without subnetting



b. With subnetting

The idea of subnetting and supernetting of classful addresses is almost obsolete.