# Chapter 4

# IP Addresses: Classful Addressing

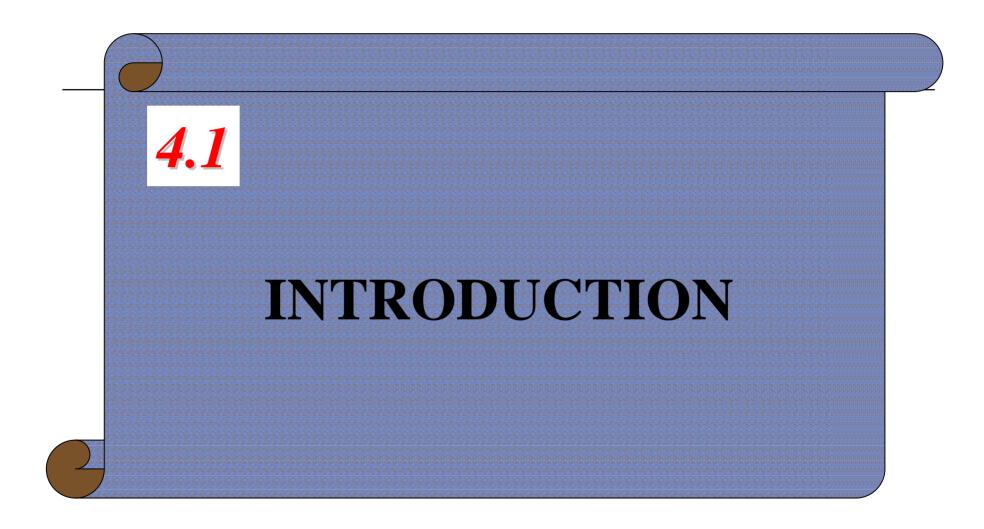
## Outlines

Introduction

Classful addressing

Other issues

A sample Internet



## Introduction

- IP address, or Internet Address
  - n 32-bit binary address
  - n Uniquely and universally defines the connection of a host or a router to the Internet
- Address Space
  - n Total number of addresses used by the protocol
  - n IPv4 uses 32-bit address and the address space is 2^32

#### Note

An IP address is a 32-bit address.

The IP addresses
are
unique.

# Address Space

```
addr1 addr15
addr2 addr41 addr226
addr31
```

## 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.

#### Note

## The address space of IPv4 is

232

or

4,294,967,296.

## Notation

Binary notation

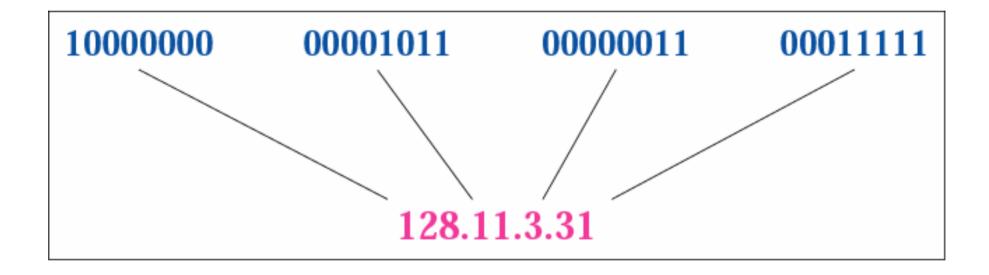
Dotted-decimal notation

Hexadecimal notation

## **Binary Notation**

01110101 10010101 00011101 11101010

#### **Dotted-Decimal Notation**



#### Hexadecimal Notation

0111 0101 1001 0101 0001 1101 1110 1010

**75** 

**95** 

**1D** 

EA

0x75951DEA

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

10000001 00001011 00001011 11101111



129.11.11.239

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

111.56.45.78



01101111 00111000 00101101 01001110

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

111.56.045.78



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

### Example 3 (continued)

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

221.34.7.8.20



We may not have more than four numbers in an IP address

### 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 3 (continued)

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

11100010.23.14.67



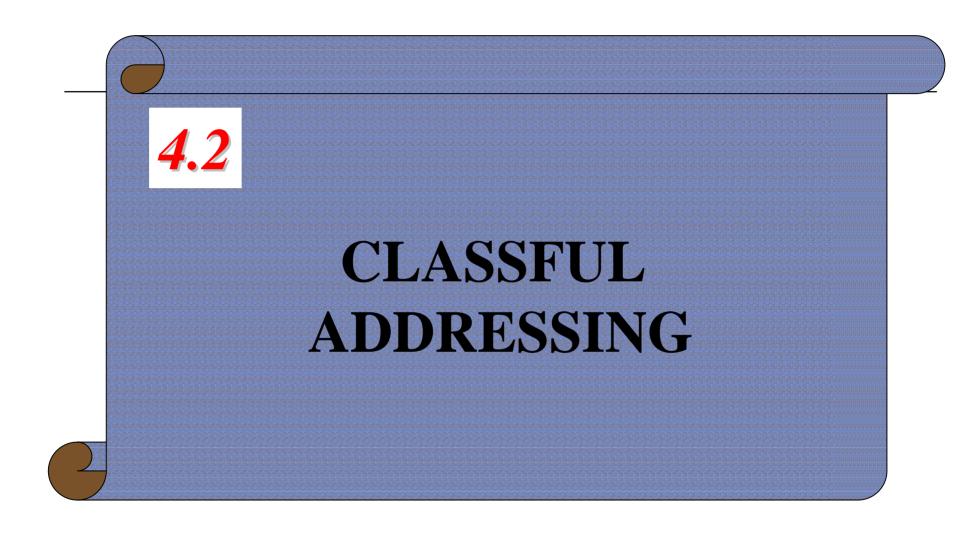
A mixture of binary notation and dotted-decimal notation is not allowed.

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

10000001 00001011 00001011 11101111



0X810B0BEF or 810B0BEF<sub>16</sub>



## Classful Addressing

• IP address space is divided into five classes:

A, B, C, D, E

n A: 1/2

**n** B: 1/4

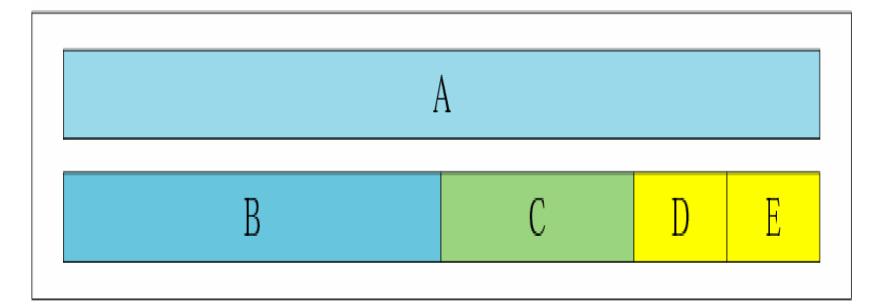
n C: 1/8

n D: 1/16

n E: 1/16

## Occupation of the Address Space

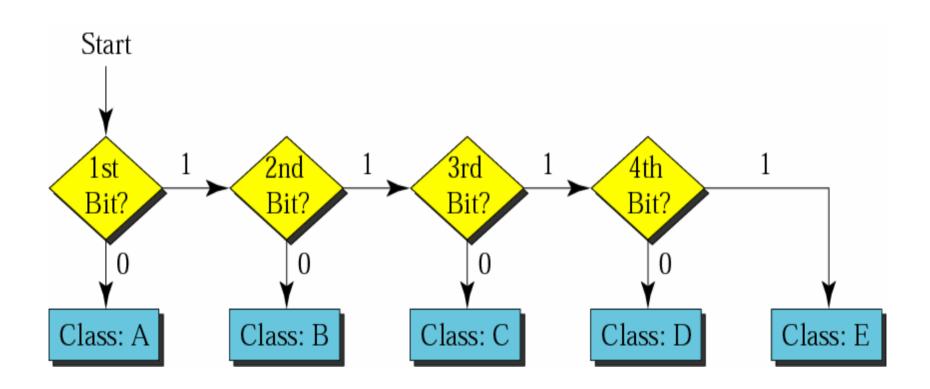
Address space



## 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



How can we prove that we have 2,147,483,648 addresses in class A?

# Solution

In class A, only 1 bit defines the class. The remaining 31 bits are available for the address. With 31 bits, we can have 2<sup>31</sup> or 2,147,483,648 addresses.

Find the class of the address:

**0**0000001 00001011 00001011 11101111



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

### Example 6 (Continued)

Find the class of the address:

**110**00001 10000011 00011011 11111111

Solution

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

## 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			

Find the class of the address:

**227**.12.14.87



The first byte is 227 (between 224 and 239); the class is D.

### Example 7 (Continued)

Find the class of the address:

**193**.14.56.22

Solution

The first byte is 193 (between 192 and 223); the class is C.

In Example 4 we showed that class A has  $2^{31}$  2,147,483,648) addresses. How can we prove this same fact using dotted-decimal notation?

# Solution

The addresses in class A range from 0.0.0.0 to 127.255.255.255. We notice that we are dealing with base 256 numbers here.

## Solution (Continued)

Each byte in the notation has a weight. The weights are as follows: 256<sup>3</sup>, 256<sup>2</sup>, 256<sup>1</sup>, 256<sup>0</sup>

Last address:  $127 \times 256^3 + 255 \times 256^2 + 255 \times 256^1 + 255 \times 256^0 = 2,147,483,647$ 

First address: = 0

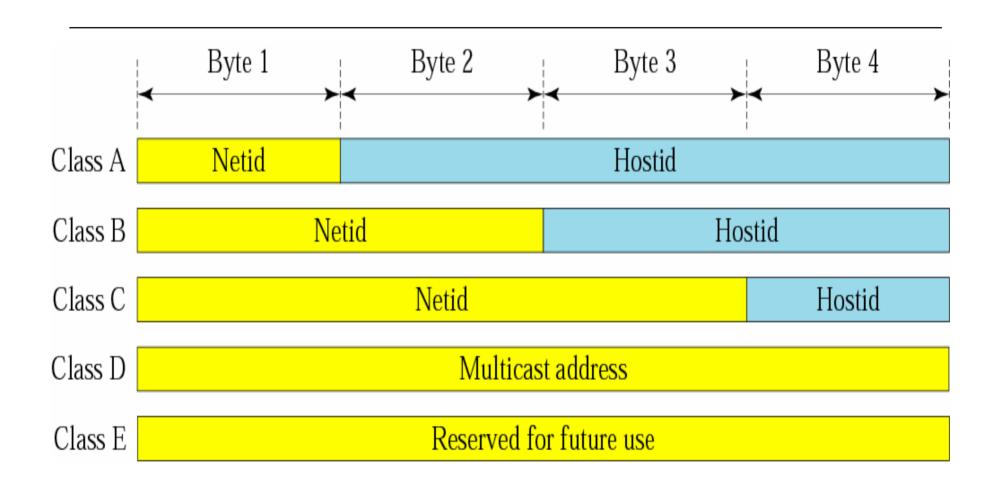
If we subtract the first from the last and add 1, we get 2,147,483,648.

## Netid and Hostid

- An IP address in classes A, B, C is divided into
  - n Netid
  - n Hostid

 Notably, classes D and E are not divided into netid and hostid

#### Netid and Hostid



### Classes and Blocks

• Each class is divided into a fixed number of blocks with each block having a fixed size

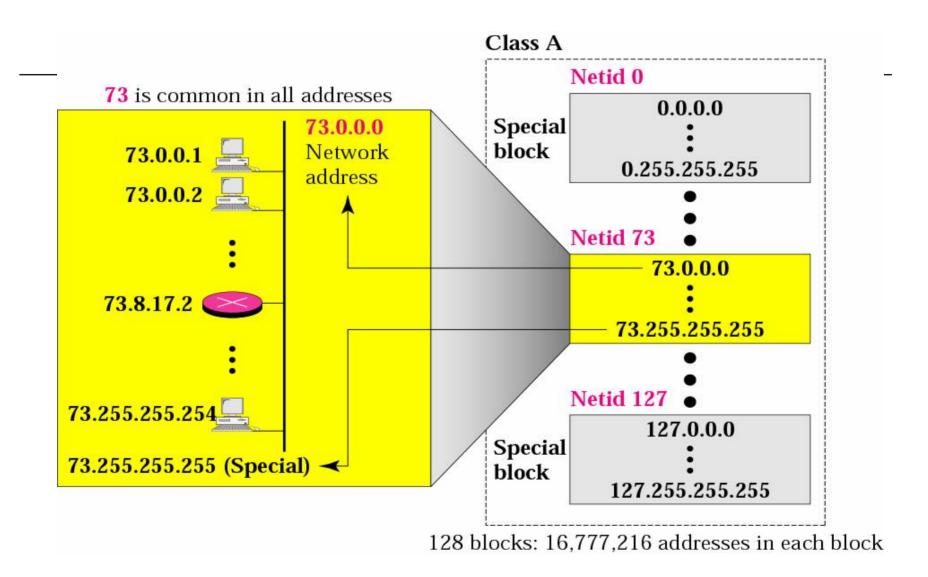
• The number of blocks is based on the *netid* 

• Each block's size is depends on the *hostid* 

### Class A

- Class A: divided into 128 blocks
  - n First block:  $0.0.0.0 \sim 0.255.255.255$
  - n ....
  - n Last block: 127.0.0.0 ~ 127.255.255.255
- Each block contains 16777216 addresses
  - n Too large than the needs of almost all organizations
- In each block, the first address, e.g., 73.0.0.0, is called the network address
  - n Identify the network of the organization, not individual hosts

#### Blocks in Class A

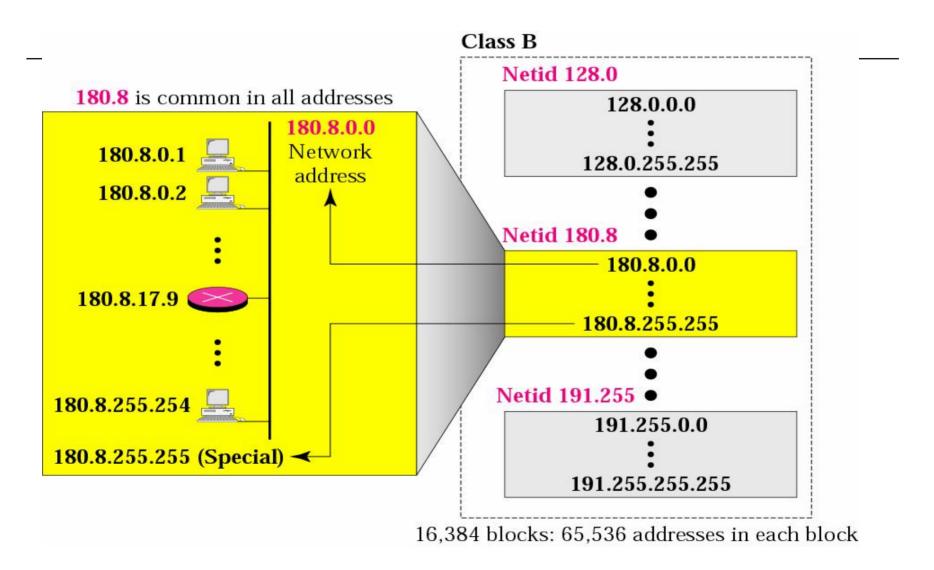


Millions of class A addresses are wasted.

#### Class B

- Class B: divided into 16,384 blocks
  - n First block: **128.0**.0.0 ~ **128.0**.255.255
  - n ....
  - n Last block: **191.255**.0.0 ~ **191.255**.255.255
- Each block contains 65,535 addresses
  - n larger than the needs of most mid-size organizations
- o In each block, the first address, e.g., 180.8.0.0, is called the network address
  - n Identify the network of the organization, not individual hosts

#### Blocks in Class B



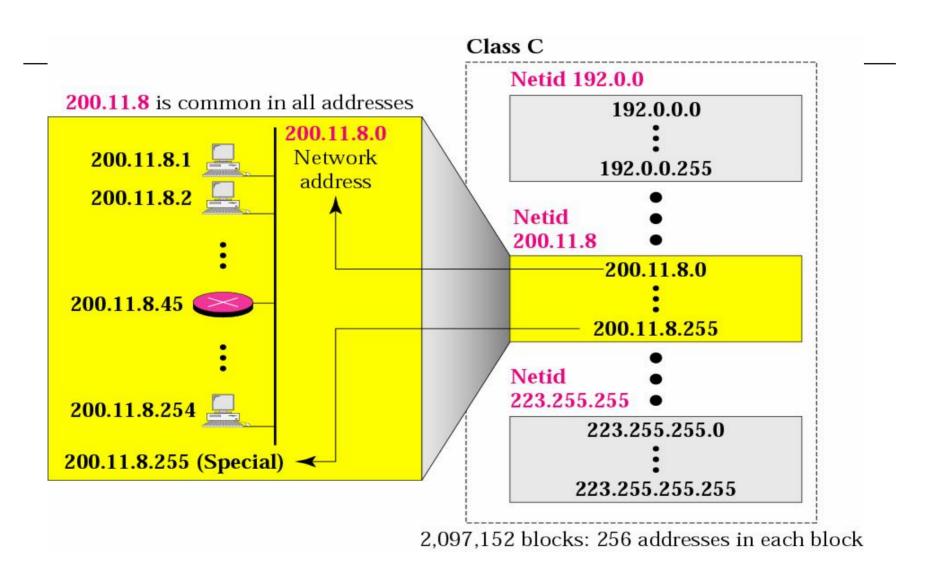
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Many class B addresses are wasted.

#### Class C

- Class C: divided into 2.097,152 blocks
  - n First block: **192.0.0**.0 ~ **128.0.0**.255
  - n ....
  - n Last block: **223.255.255.**0 ~ **223.255.255**.255
- Each block contains 256 addresses
  - n Most organizations do not want such a block
- o In each block, the first address, e.g., 200.11.8.0, is called the network address
  - n Identify the network of the organization, not individual hosts

#### Blocks in Class C



The McGraw-Hill Companies, Inc., 2000

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

#### Class D and Class E

- Class D
  - n Just one block
  - n Designed for multicasting and each address is used to identify one multicasting group
- Class E
  - n Just one block
  - n Designed for use as reserved addresses

Class D addresses

are used for multicasting;

there is only

one block in this class.

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. Routers route a packet based on the network address.

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

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

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



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.

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.

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.

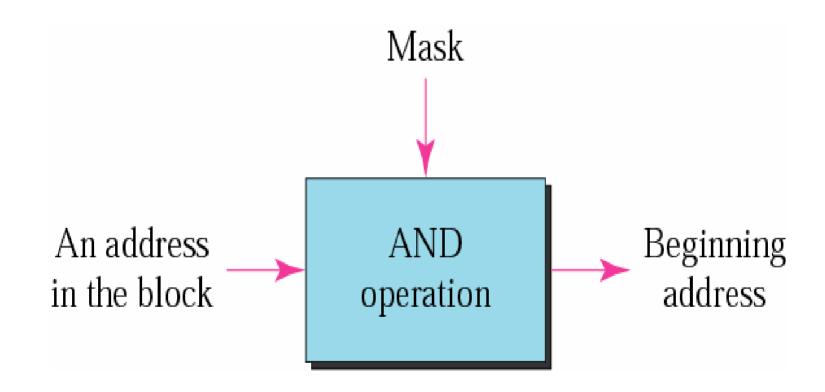
#### Mask

- If the network address is given
  - n We can obtain the block and block size
- However, if an address is given, how to find out the *network address*?
  - n First, find the *class* of the address
  - n Second, derive the *netid* and *hostid*
  - n Finally, network address is obtained by setting the hostid to zero.

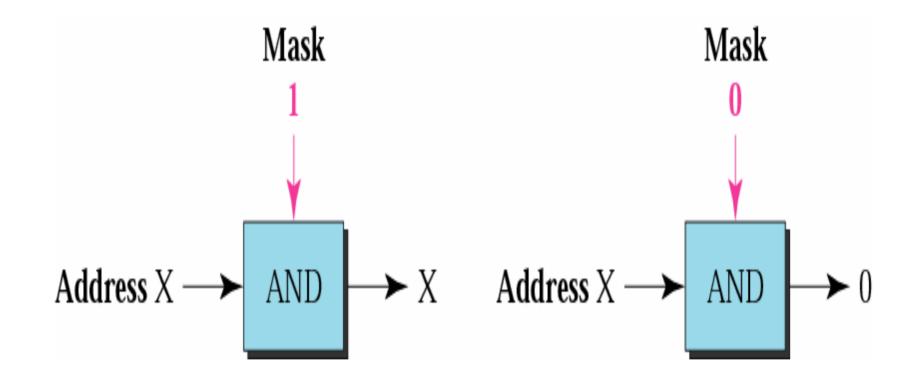
#### Mask

A mask is a 32-bit binary number that gives the first address in the block (the network address) when bitwise ANDed with an address in the block.

## Masking concept



## AND operation



#### Default Masks

- Class A
  - n Mask in binary: 1111111 00000000 00000000 00000000
  - n Mask in dotted-decimal: 255.0.0.0
- Class B
  - n Mask in binary: 11111111 11111111 00000000 00000000
  - n Mask in dotted-decimal: 255.255.0.0
- Class C
  - n Mask in binary: 11111111 11111111 1111111 00000000
  - n Mask in dotted-decimal: 255.255.255.0

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.

Given the address 23.56.7.91 and the default class A mask, 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.

Given the address 132.6.17.85 and the default class B mask, find the beginning address (network address).



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.

Given the address 201.180.56.5 and the class C default mask, 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.

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

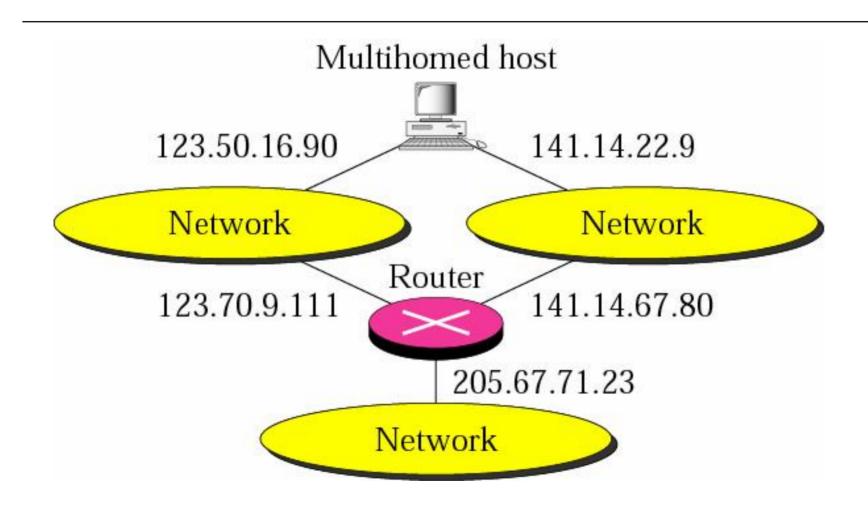


#### Multihomed Devices

- A computer that is connected to different networks is called a *multihomed* computer
  - n Have more than one address

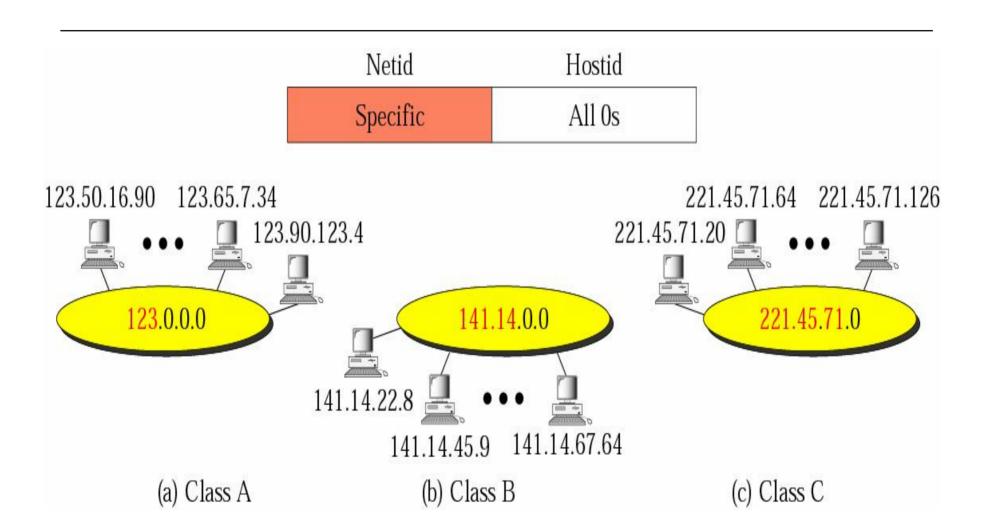
n Each possibly belonging to a different class

#### Multihomed Devices



## 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
This host on this network	All 0s	All 0s	Source
Specific host on this network	All 0s	Specifi c	Destination
Loopback address	127	Any	Destination



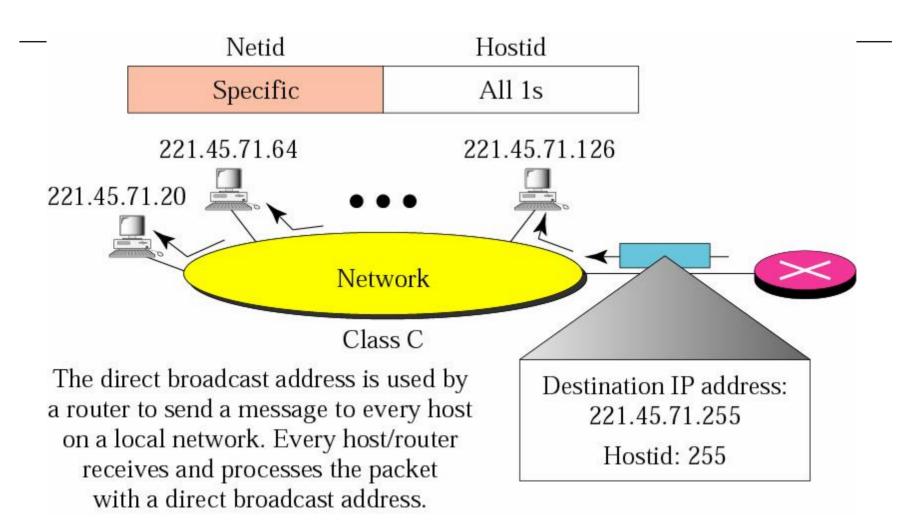
#### Direct Broadcast Address

• The *hostid* is all *1s* in classes A, B, and C

 Used by a router to send a packet to all host in a specific network

Can only be used as a destination address

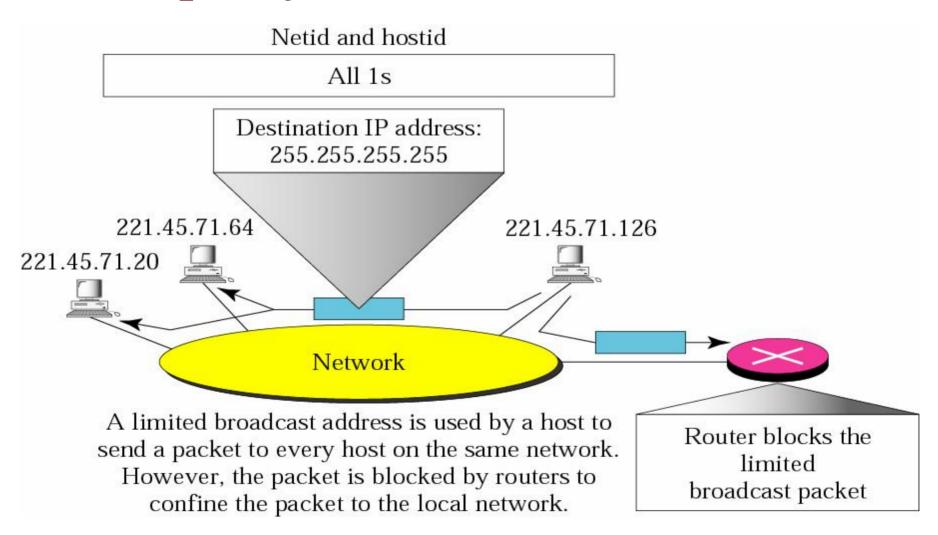
#### Example of Direct Broadcast Address



#### Limited Broadcast Address

- An address with all *Is* for the *netid* and *hostid* in classes A, B, and C
- Used by a host to send a packet to every other host in a network
- Routers will block a packet having this type of address to other networks
- Limited broadcast address belongs to class E

## Example of Limited Broadcast Address



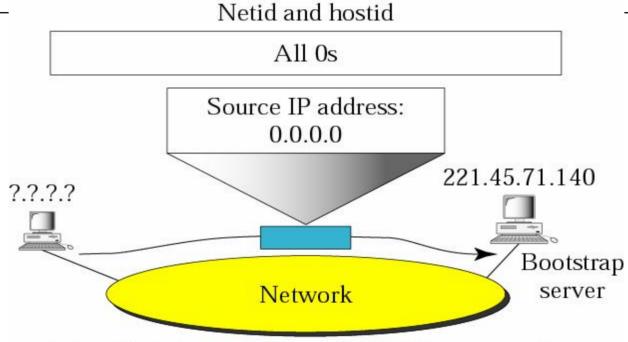
#### This Host on This Network

• An IP address is composed of all 0s

- Used by a host at bootstrap time when it does not know its IP address
  - n Source address: all 0s

n Destination address: limited broadcast address

## Example of This Host on This Network

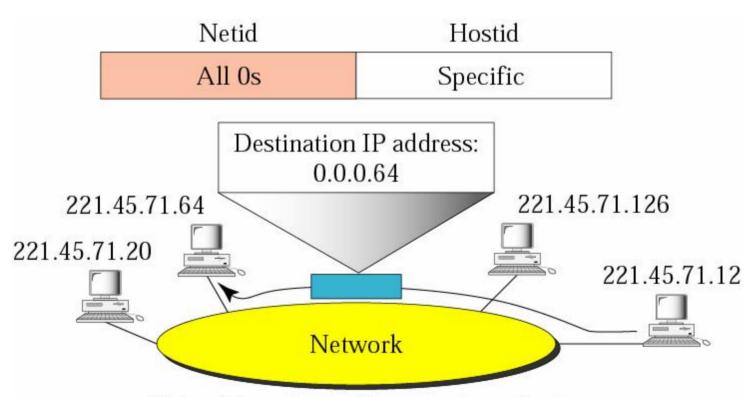


A host that does not know its IP address uses the IP address 0.0.0.0 as the source address and 255.255.255.255 as the destination address to send a message to a bootstrap server.

## Specific Host on This Network

- An IP address with a *netid* of all *0s*
- Used by a router or host to send a packet to another host on the same network
- Router will block this packet to other networks
- Only used for a destination address

## 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.

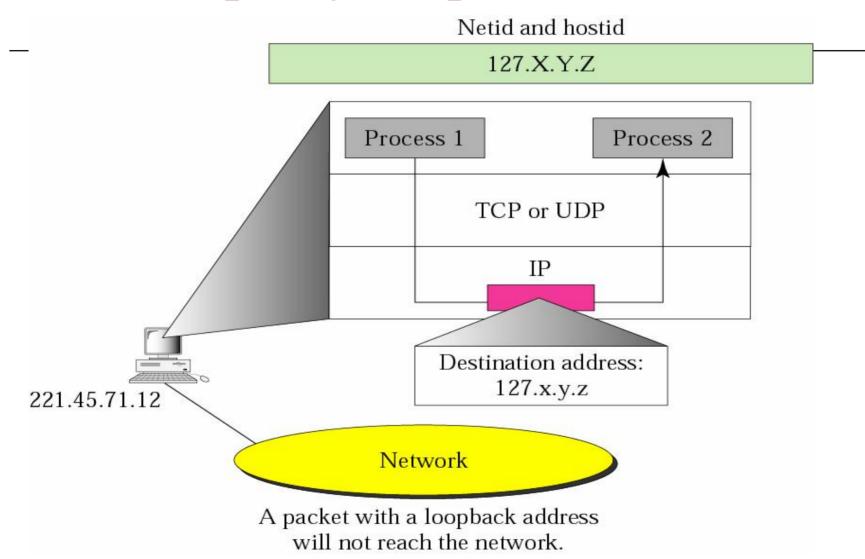
## Loopback Address

• An IP address with the first byte equal to 127

• This packet never leaves the machine

Used only as a destination address

## Example of Loopback Address



#### Private Addresses

- A number of blocks in each class are assigned for private use and not recognized globally.
- Used in
  - n Isolation
  - n In connection with network address translation

Class	Netid	Blocks
A	10.0.0	1
В	172.16 to 172.31	16
С	192.168.0 to 192.168.255	256

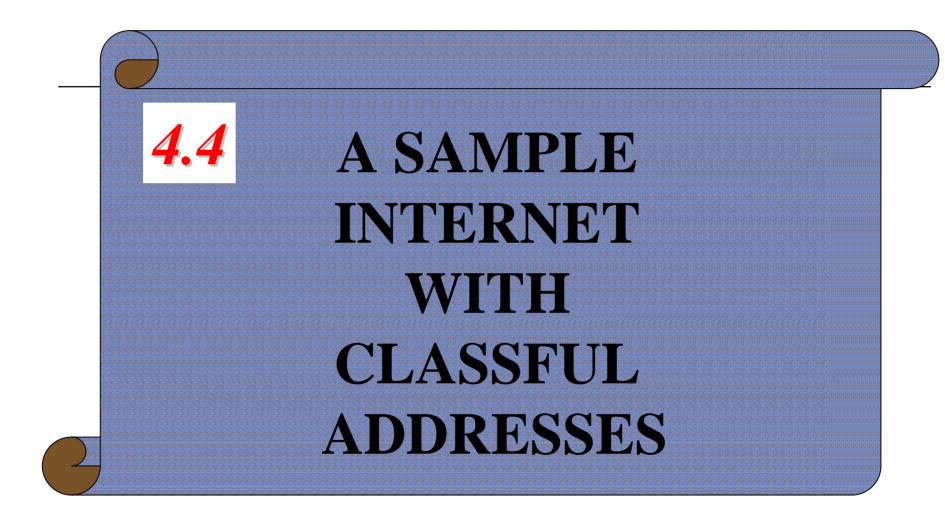
## Unicast, Multicast, and Broadcast Addresses

Unicast communication is one-to-one.

Multicast communication is one-to-many.

Broadcast communication is one-to-all.

# Multicast delivery will be discussed in depth in Chapter 14.



## Sample Internet

- A Token Ring LAN: 220.3.6.0: Class C
- An Ethernet LAN: 138.18.0.0: Class B
- An Ethernet LAN: 124.0.0.0: Class A
- A point-to-point WAN, for example a T-1 line
  - n Just connect two routers and no hosts
  - n To save addresses, no IP address is assigned
- A switch WAN, e.g., Frame Relay or ATM
  - n Connect to three network via three routers

F:----

Sample internet 134.18.10.88 134.18.0.0 134.18.68.44 200.78.6.92 200.78.6.14 220.3.6.0 Switched WAN R2 220.3.6.3 R1 200.78.6.0 220.3.6.1 220.3.6.23 134.18.14.121 R3 200.78.6.146 134.18.8.21 Point-to-point WAN Rest of the Internet R4 124.100.33.77 124.0.0.0 124.4.51.66 124.42.5.45