Logical Addressing

Adapted From

TCP/IP Protocol Suite, 4th Edition, Forouzan

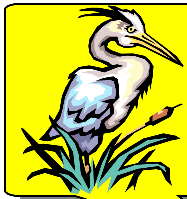
Computer Networks, 4th Edition, Tanenbaum

Classful
Logical Addressing

Logical Address

- The identifier used in the IP layer of the TCP/IP protocol suite to identify each device connected to the Internet is called the Internet address or IP address.
- An IP address is a 32-bit address that uniquely and universally defines the connection of a host or a router to the Internet.
- IP addresses are unique. They are unique in the sense that each address defines one, and only one, connection to the Internet.

Logical Address



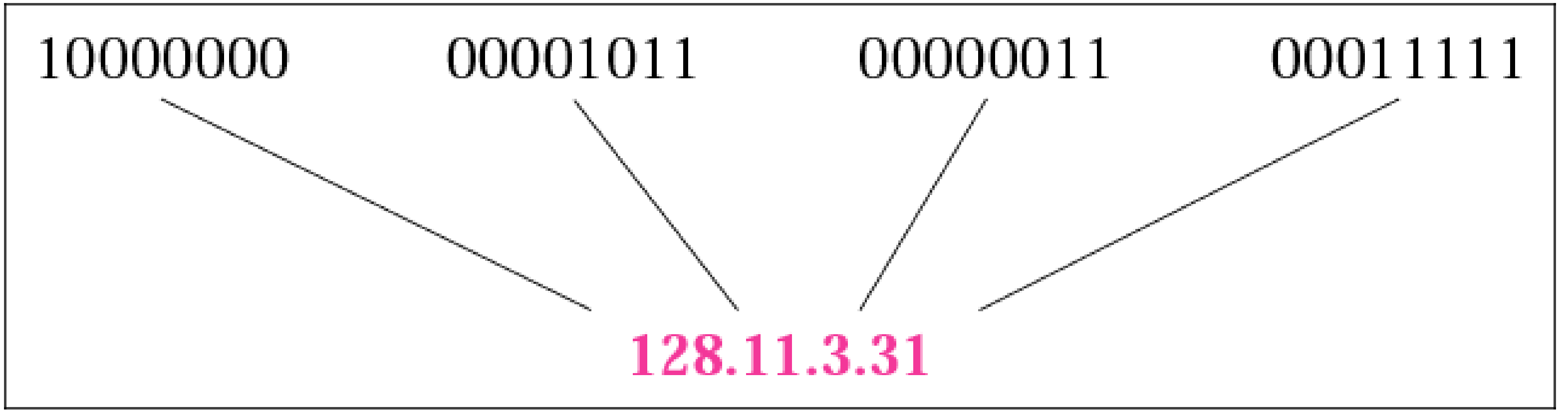
Note:

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

Logical Address

Notation:

1. Binary Notation
2. Dotted Decimal Notation



Logical Address

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

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

c. 11100111 11011011 10001011 01101111

d. 11111001 10011011 11111011 00001111

Solution

We replace each group of 8 bits with its equivalent decimal number (see Appendix B) and add dots for separation:

a. 129.11.11.239 b. 193.131.27.255
c. 231.219.139.111 d. 249.155.251.15

Logical Address

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

a. 111.56.45.78

b. 221.34.7.82

c. 241.8.56.12

d. 75.45.34.78

Solution

We replace each decimal number with its binary equivalent:

a. 01101111 00111000 00101101 01001110

b. 11011101 00100010 00000111 01010010

c. 11110001 00001000 00111000 00001100

d. 01001011 00101101 00100010 01001110

Logical Address

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

a. **10000001 00001011 00001011 11101111**

b. **11000001 10000011 00011011 11111111**

Solution

We replace each group of 4 bits with its hexadecimal equivalent (see Appendix B). Note that hexadecimal notation normally has no added spaces or dots; however, 0X (or 0x) is added at the beginning or the subscript 16 at the end to show that the number is in hexadecimal.

a. 0X810B0BEF or $810B0BEF_{16}$
b. 0XC1831BFF or $C1831BFF_{16}$

IP Addresses: Classlful Addressing

Classful Addressing

- IP addresses, when started a few decades ago, used the concept of classes. This architecture is called Classful addressing.

- In the mid-1990s, a new architecture, called classless addressing, was introduced and will eventually supersede the original architecture.

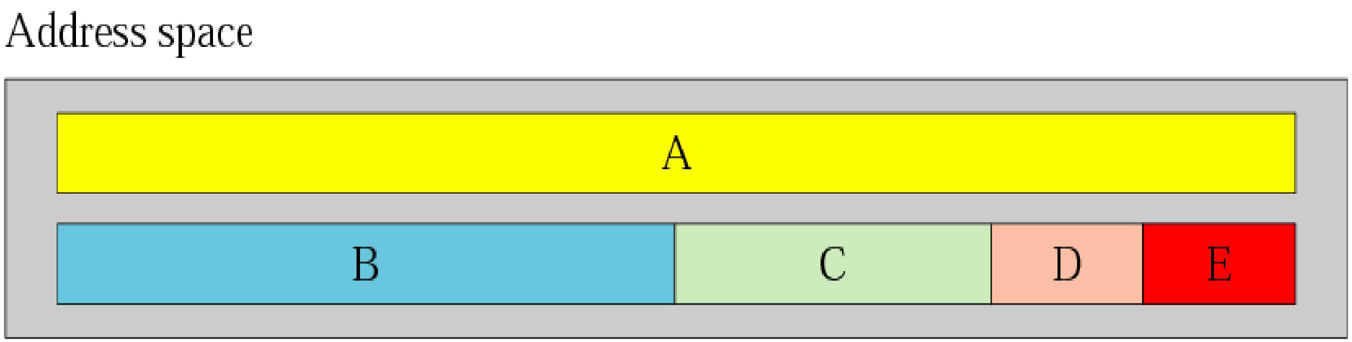
Classful Addressing

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**			

Classful Addressing

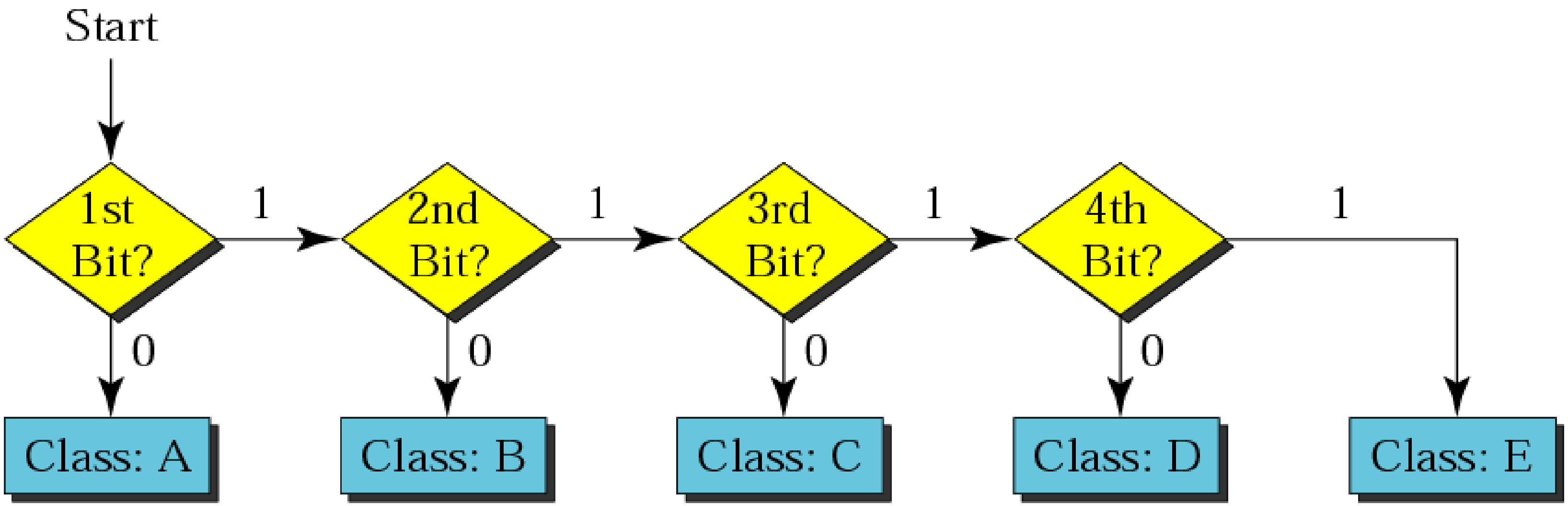
Occupation of the address space



Class	*Number of Addresses*	*Percentage*
A	$2^{31} = 2{,}147{,}483{,}648$	50%
B	$2^{30} = 1{,}073{,}741{,}824$	25%
C	$2^{29} = 536{,}870{,}912$	12.5%
D	$2^{28} = 268{,}435{,}456$	6.25%
E	$2^{28} = 268{,}435{,}456$	6.25%

Classful Addressing

Finding the address class



Classful Addressing

Example

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^{31} or 2,147,483,648 addresses.

Classful Addressing

Example

Find the class of each address:

a. 00000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

c. 10100111 11011011 10001011 01101111

d. 11110011 10011011 11111011 00001111

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 bit is 0; the second bit is 1. This is a class B address.

d. The first 4 bits are 1s. This is a class E address..

Classful Addressing

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**			

Classful Addressing

Example

Find the class of each address:

a. 227.12.14.87 **b.193.14.56.22** **c.14.23.120.8**
d. 252.5.15.111 **e.134.11.78.56**

Solution

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

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

c. The first byte is 14 (between 0 and 127); the class is A.

d. The first byte is 252 (between 240 and 255); the class is E.

e. The first byte is 134 (between 128 and 191); the class is B.

Classful Addressing

Example

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 need to show that the difference between these two numbers is 2,147,483,648.

We notice that we are dealing with base 256 numbers here. Each byte in the notation has a weight.

Classful Addressing

$$256^3, 256^2, 256^1, 256^0$$

Now to find the integer value of each number, we multiply each byte by its weight:

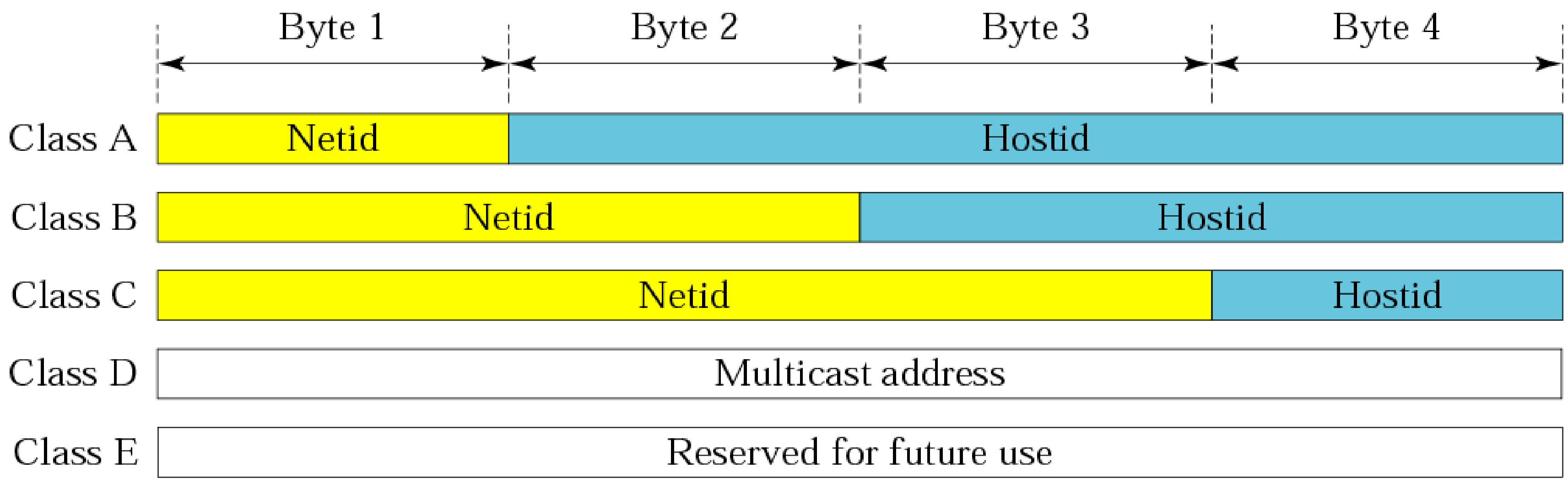
Last address: $127 \times 256^3 + 255 \times 256^2 + 255 \times 256^1 + 255 \times 256^0 = 2{,}147{,}483{,}647$

First address: $= 0$

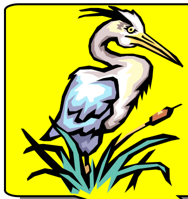
If we subtract the first from the last and add 1 to the result (remember we always add 1 to get the range), we get 2,147,483,648 or 231.

Classful Addressing

Netid and hostid



Logical Address

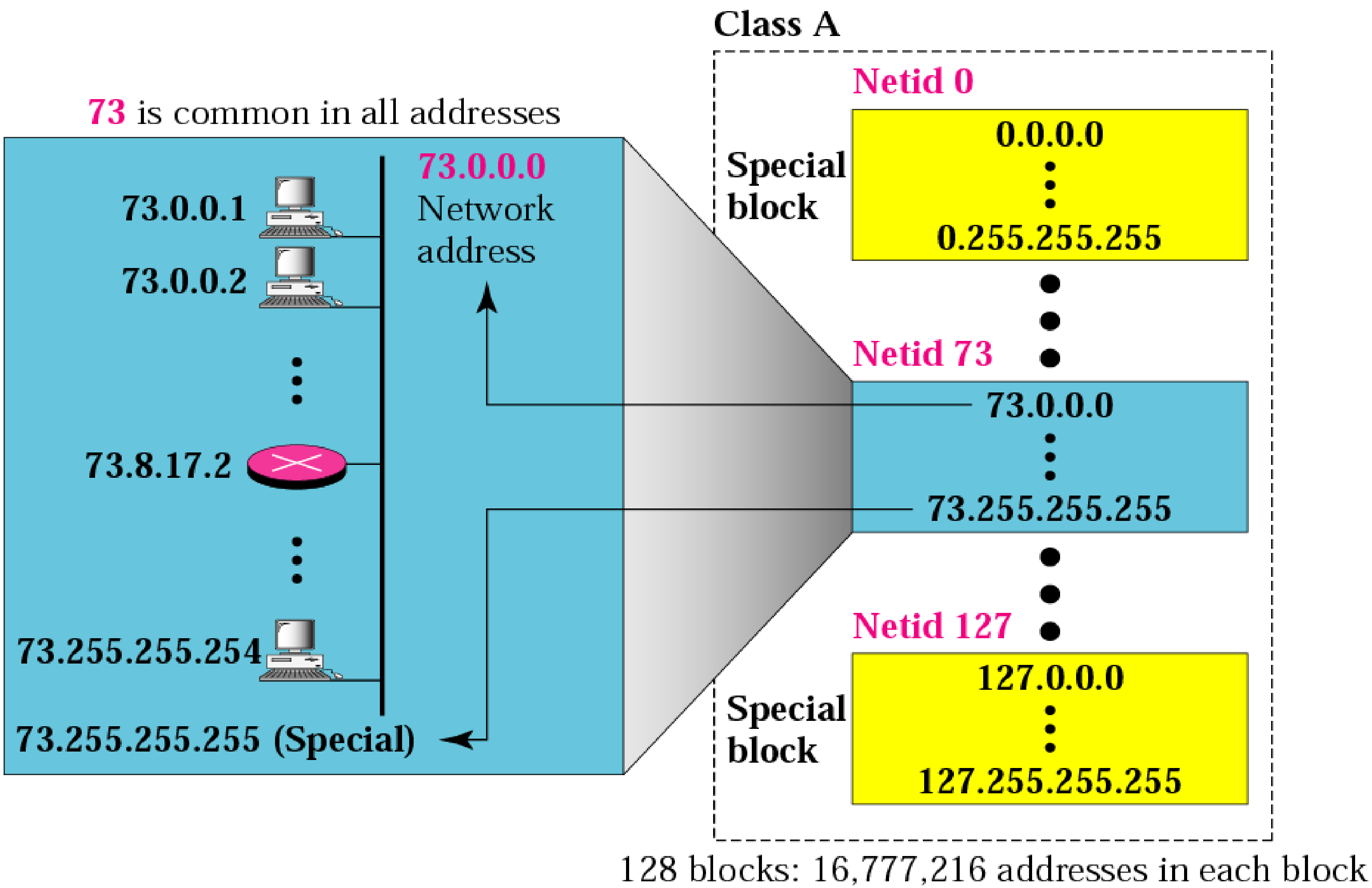


Note:

Millions of class A addresses are wasted.

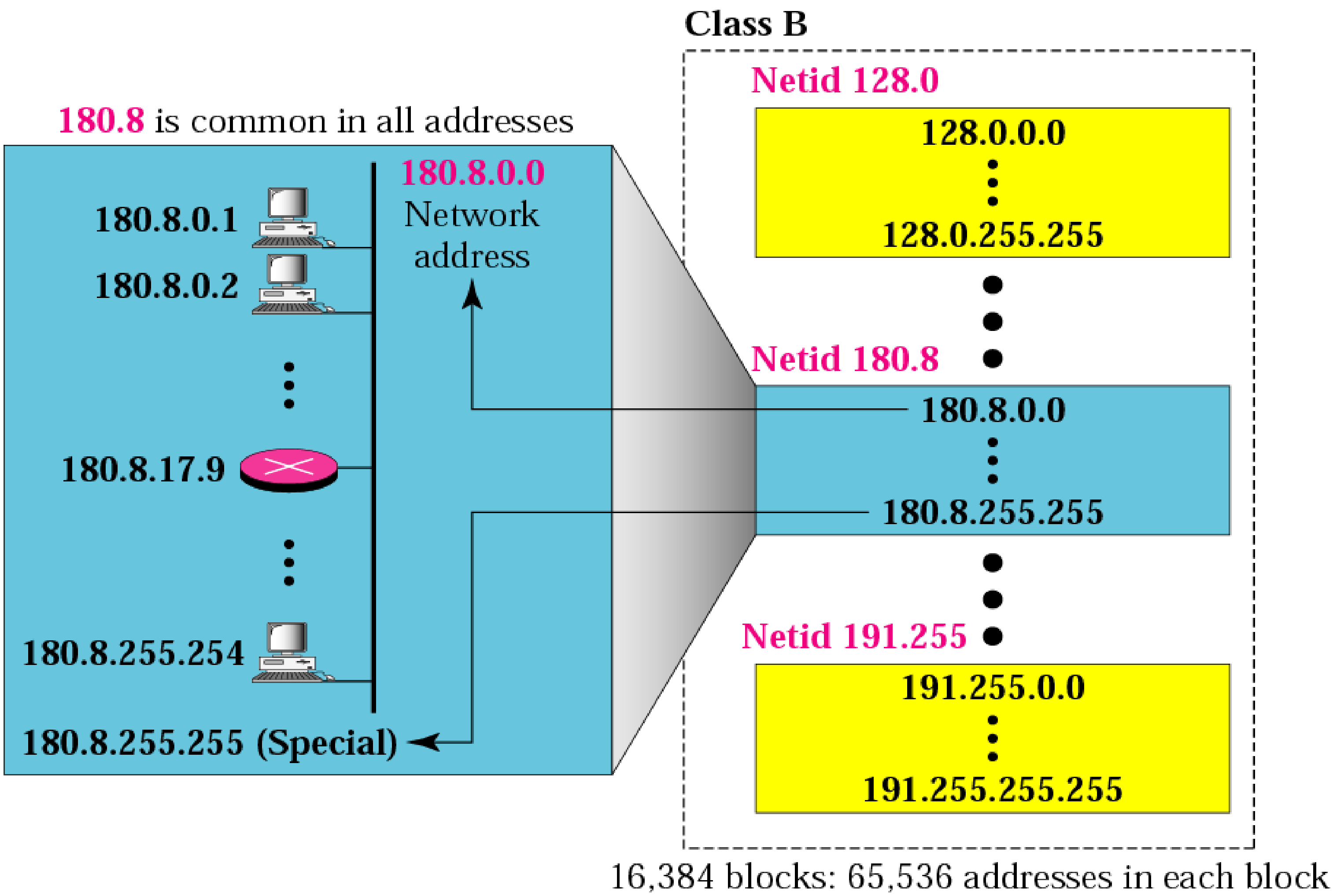
Classful Addressing

Blocks in class A

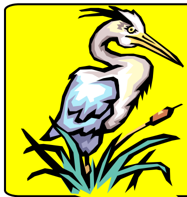


Classful Addressing

Blocks in class B



Logical Address

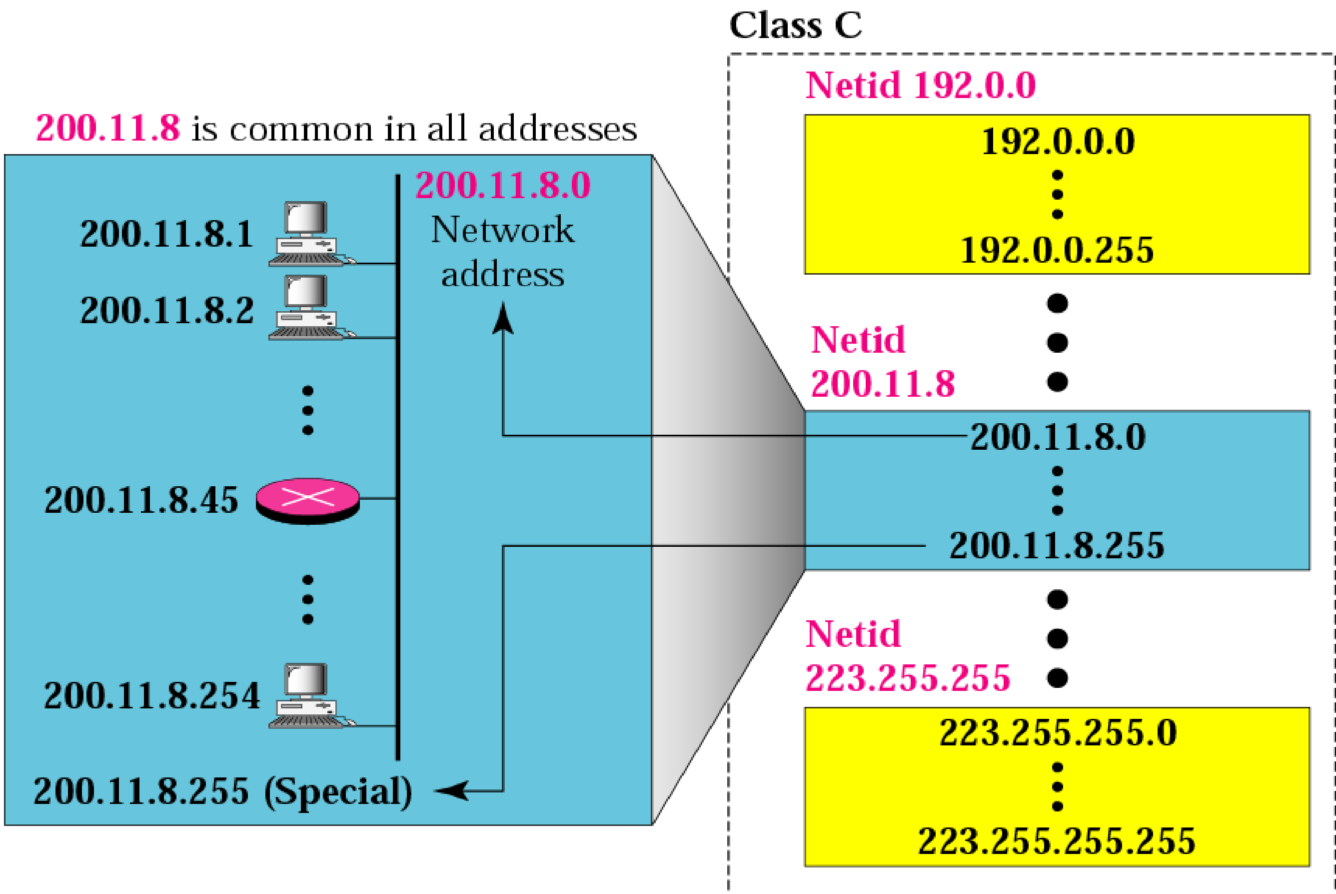


Note:

Many class B addresses are wasted.

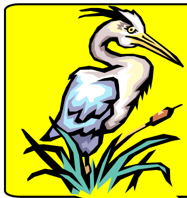
Classful Addressing

Blocks in class C



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

Logical Address



Note:

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

Logical Address

Example

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.

Logical Address

Example

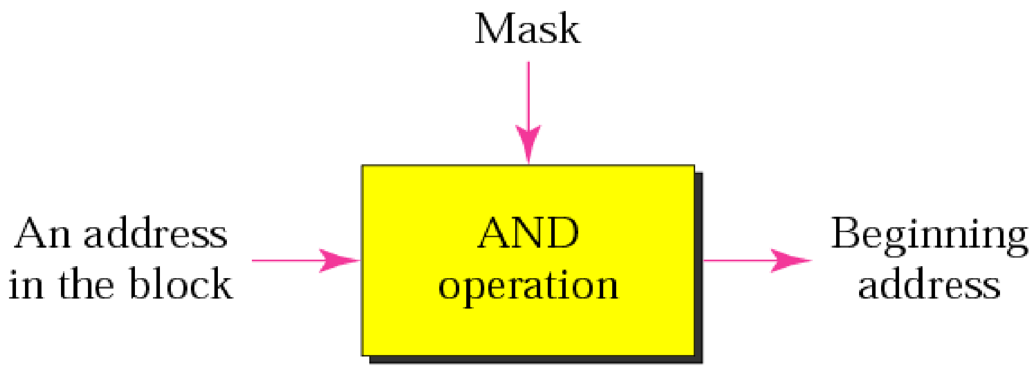
Given the network address 132.21.0.0, find the class, the block, and the range of the addresses.

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.

Logical Address

Masking Concept



Class	*Mask in binary*	*Mask in dotted-decimal*
A	**11111111** 00000000 00000000 00000000	**255.**0.0.0
B	**11111111 11111111** 00000000 00000000	**255.255.**0.0
C	**11111111 111111111 11111111** 00000000	**255.255.255.**0

Logical Address

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.

Logical Address

Example

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.

Logical Address

Example

Given the address 132.6.17.85, 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.

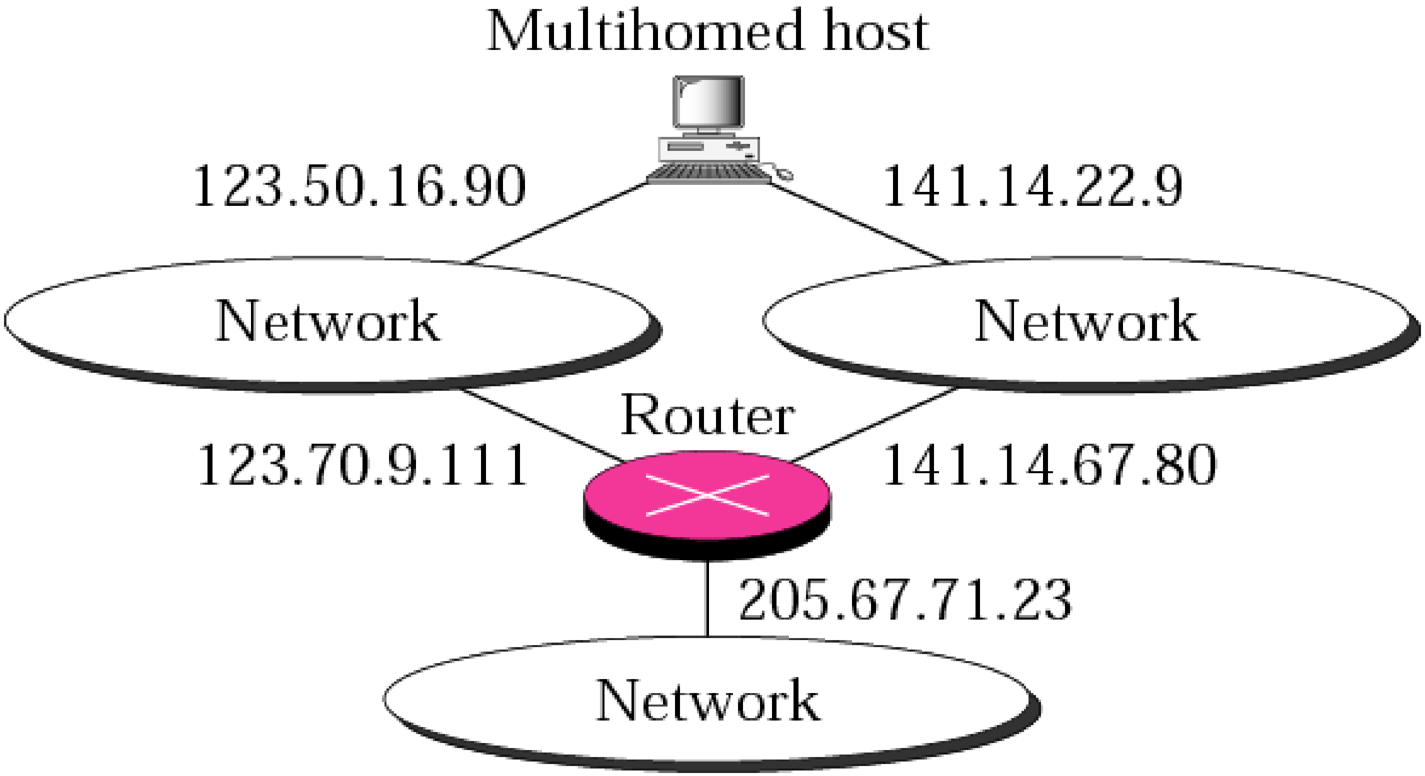
Logical Address

Note:

Note that we must not apply the default mask of one class to an address belonging to another class.

Other Issues

Multihomed devices



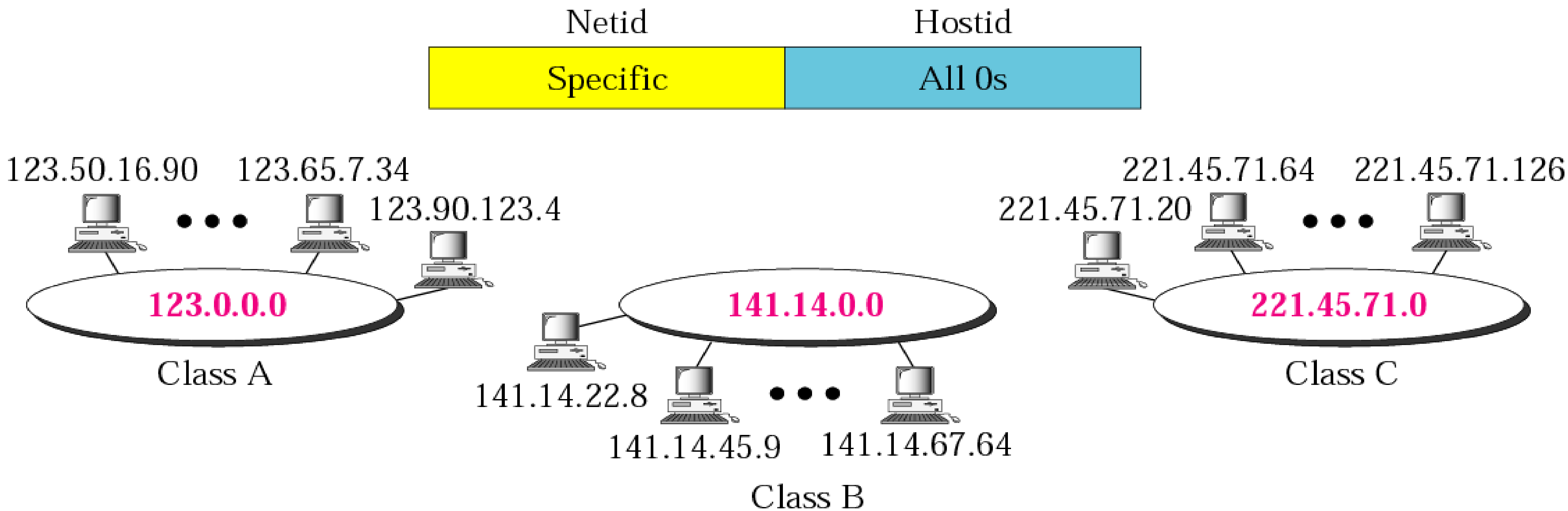
Other Issues

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	Specific	Destination
Loopback address	127	Any	Destination

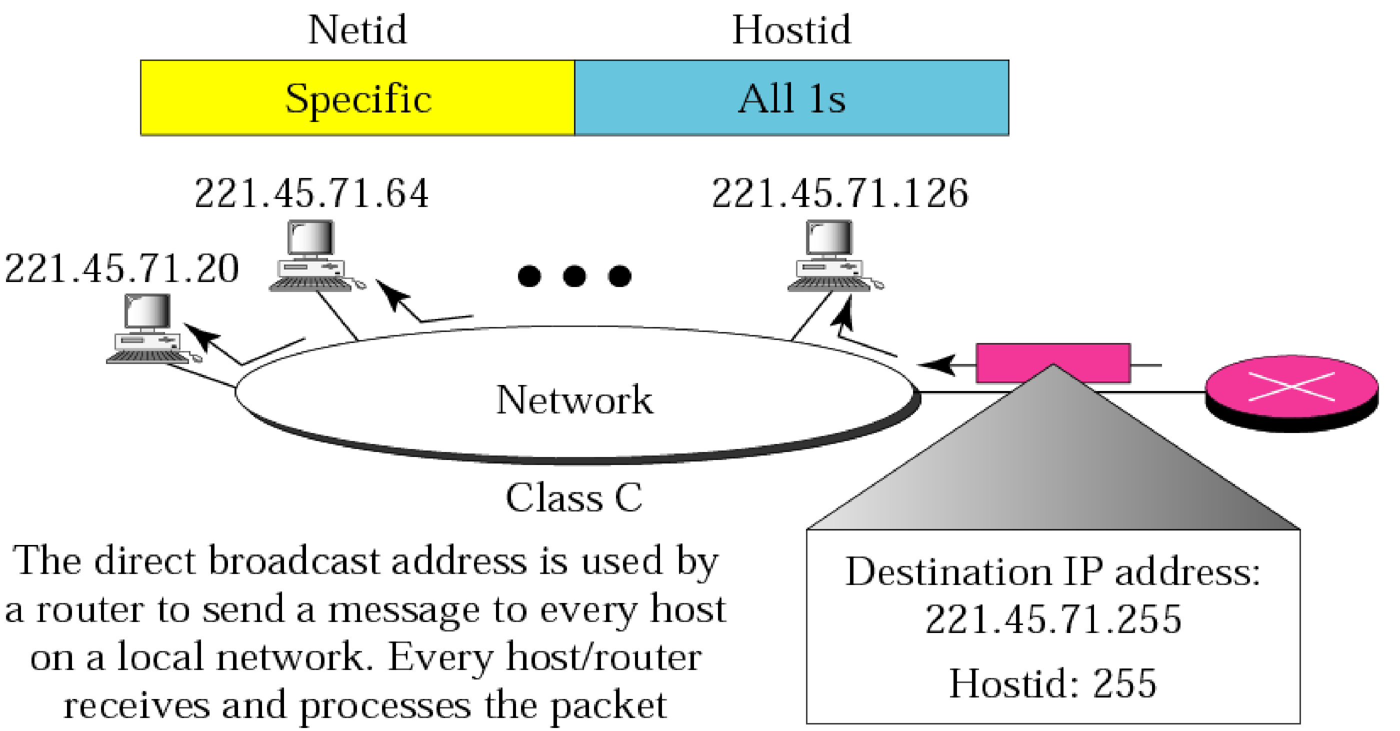
Other Issues

Network address



Other Issues

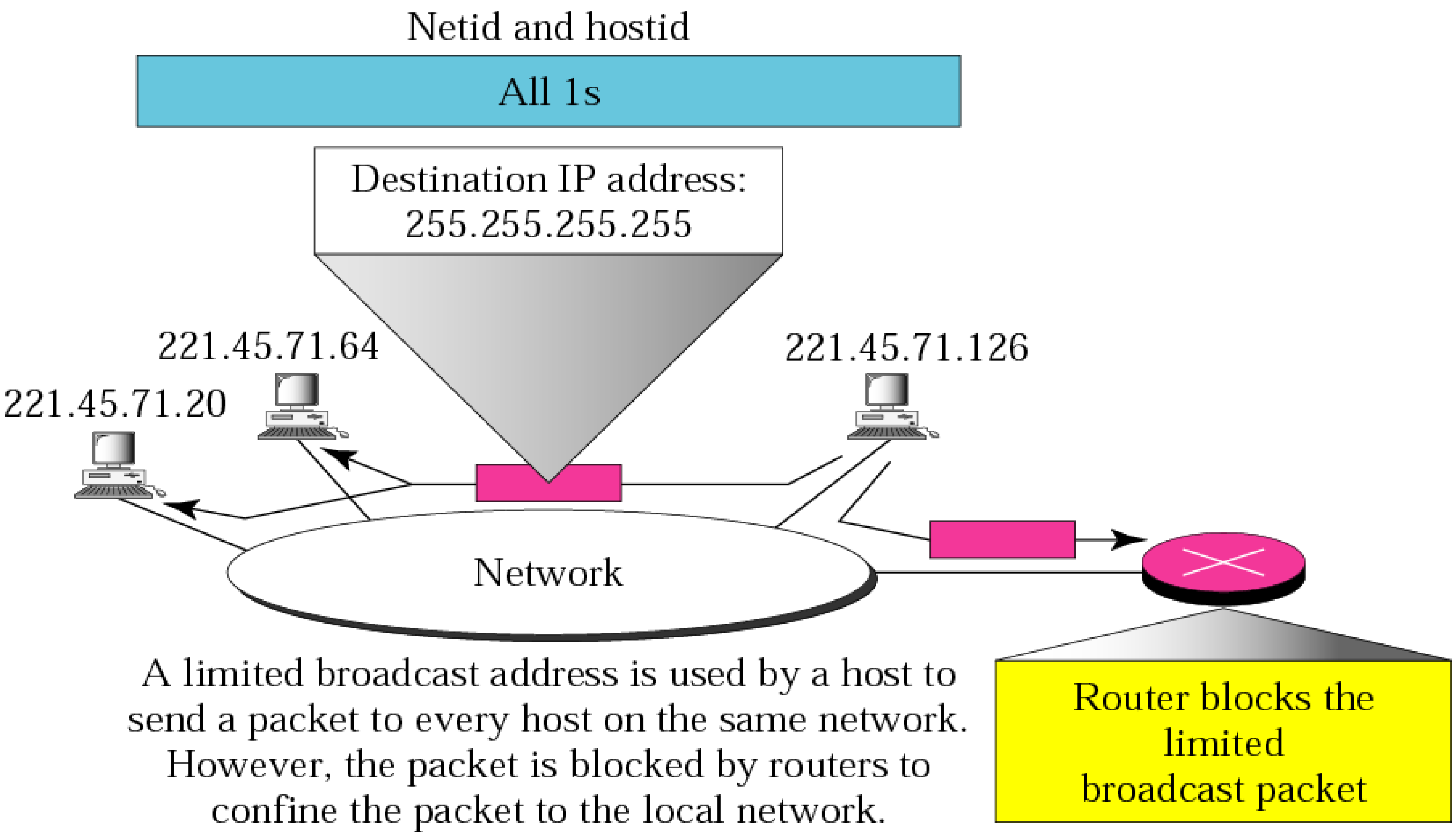
Example of direct broadcast address



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.

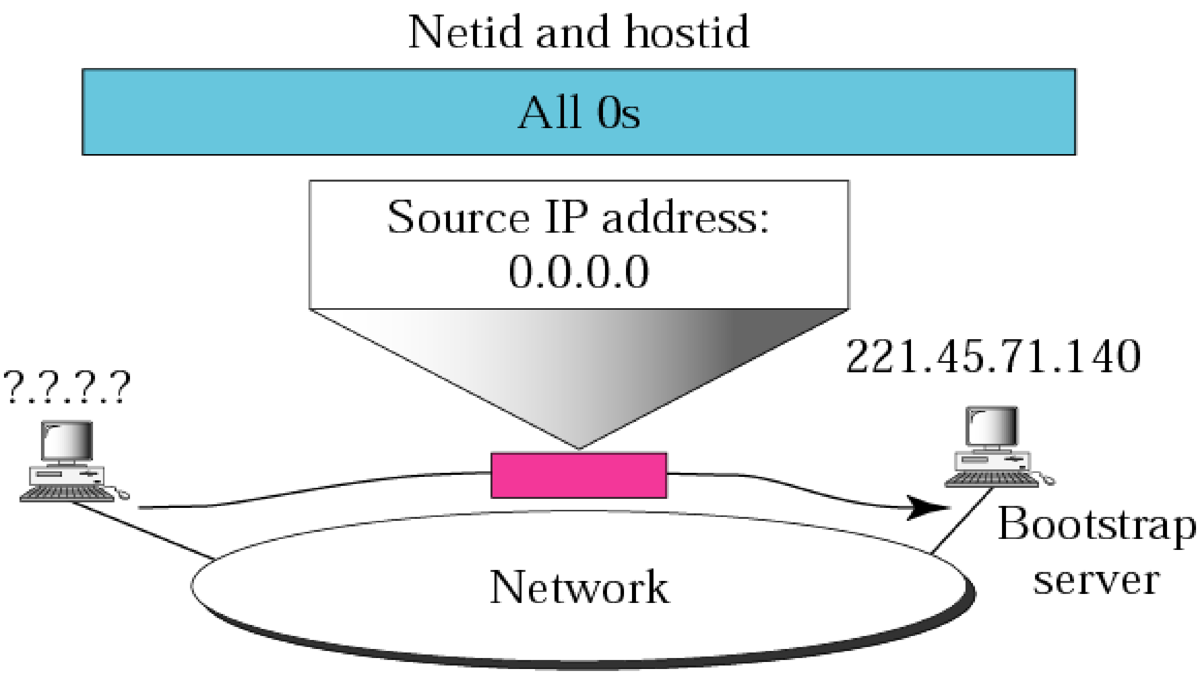
Other Issues

Example of limited broadcast address



Other Issues

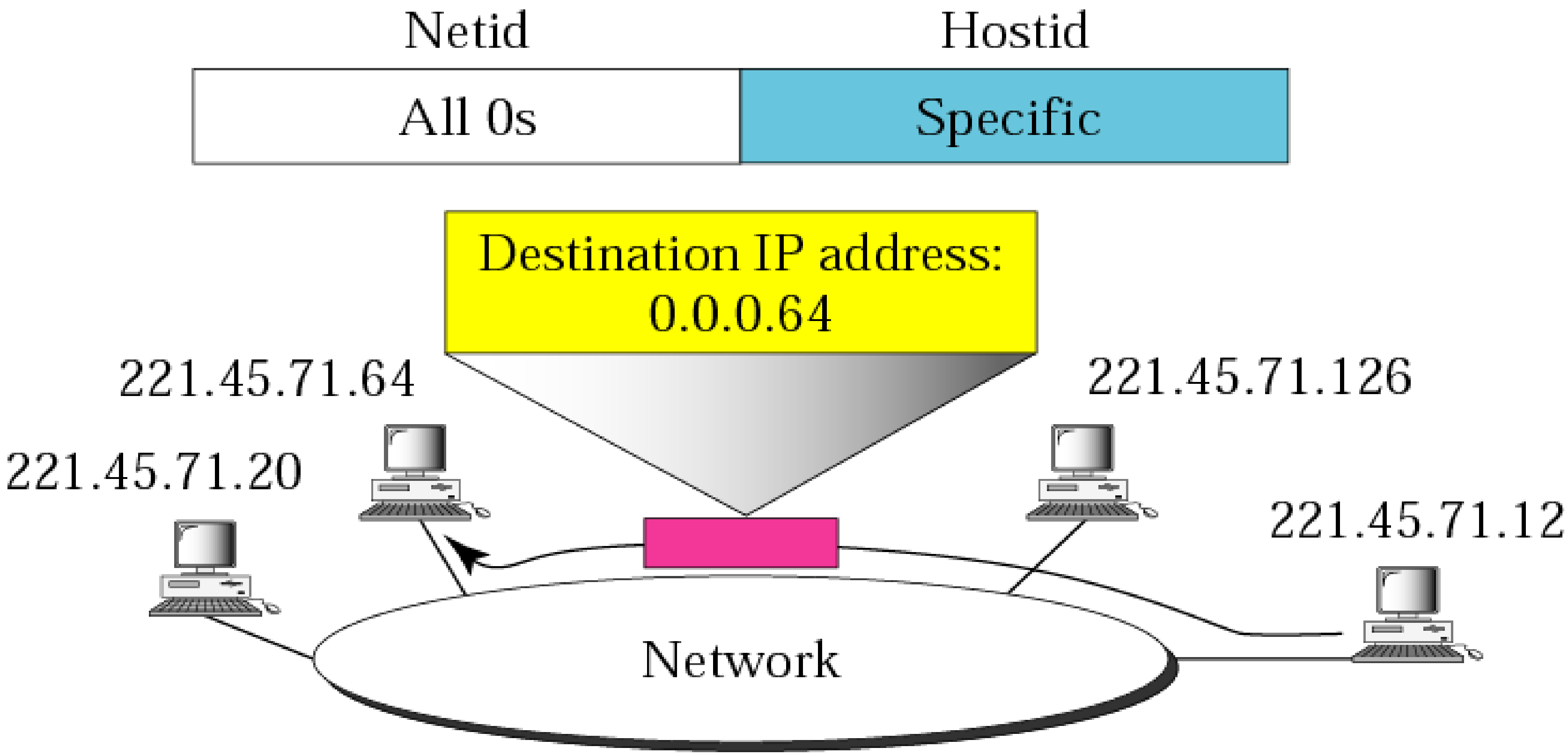
Examples of “this host on this network”



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.

Other Issues

Example of "specific host on this network"



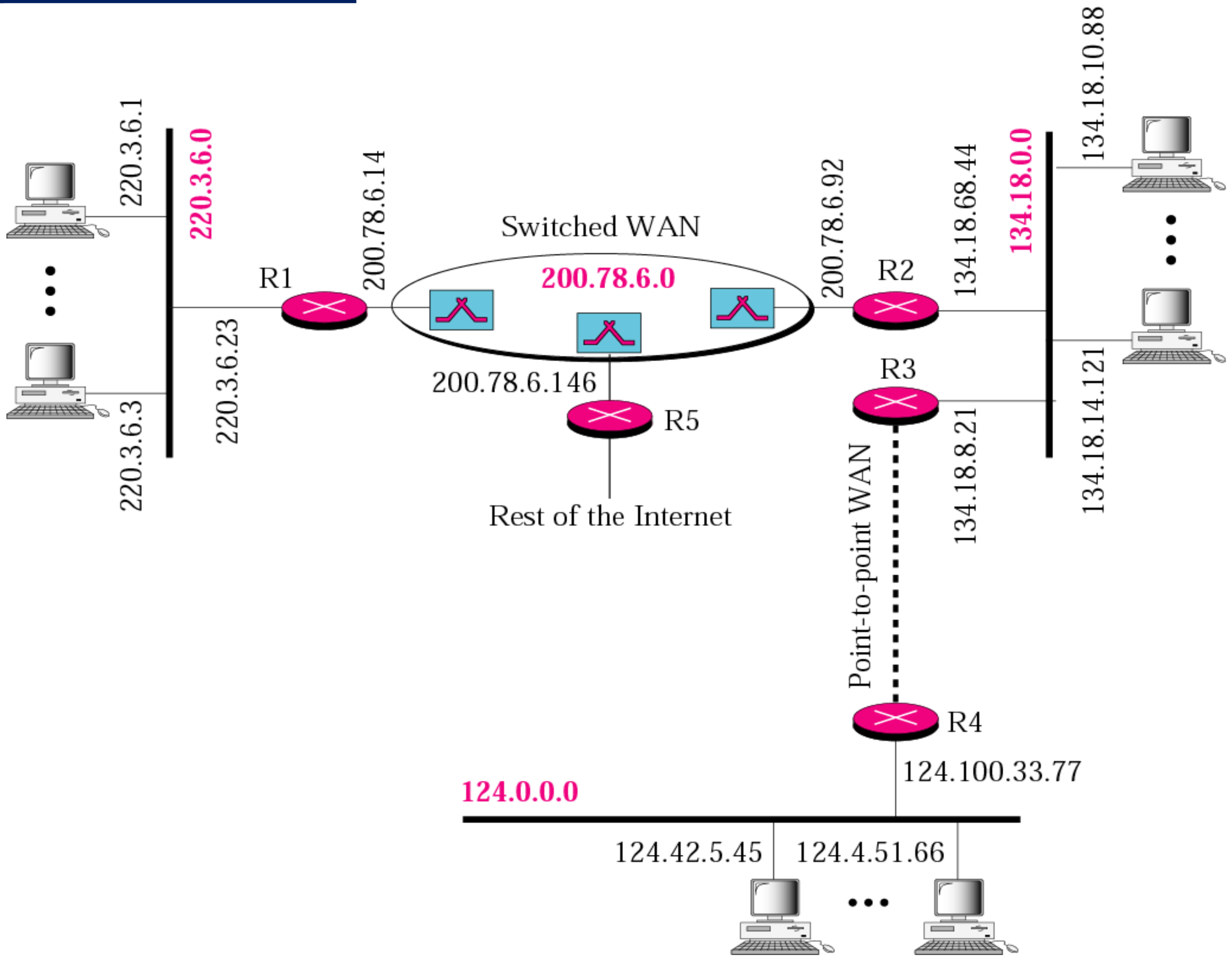
This address is used by a router or host to send a message to a specific host on the same network.

Other Issues

Addresses for private networks

Class	*Netids*	*Blocks*
A	10.0.0	1
B	172.16 to 172.31	16
C	192.168.0 to 192.168.255	256

Sample internet

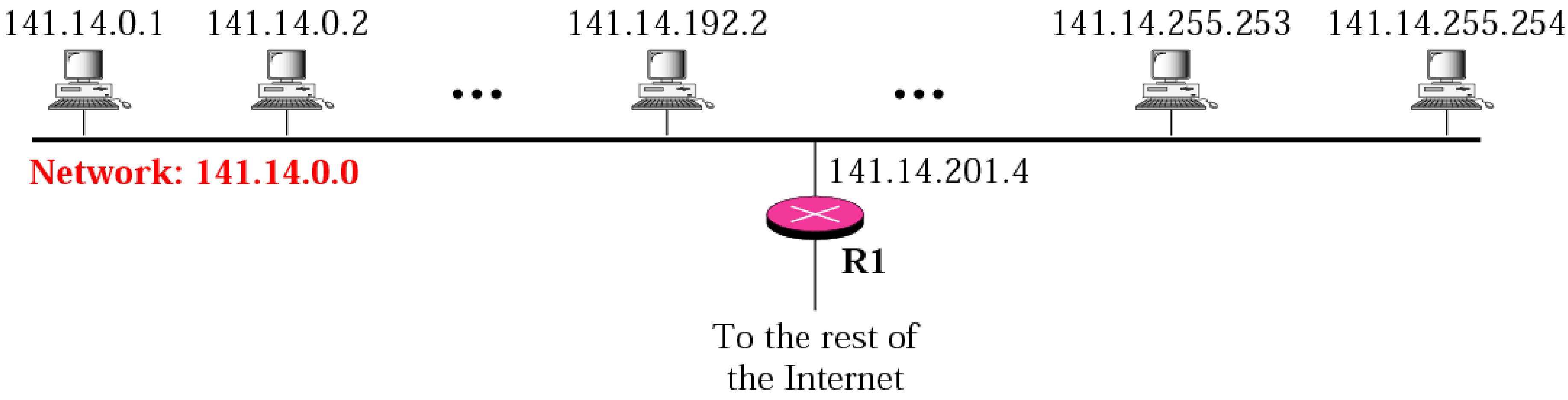


SUBNETTING AND SUPERNETTING

- In the previous sections, we discussed the problems associated with Classful addressing.
- Specifically, the network addresses available for assignment to organizations are **close to depletion.**
- This is coupled with the **ever-increasing demand** for addresses from organizations that want connection to the Internet.
- In this section we briefly discuss two solutions: **subnetting and supernetting**.

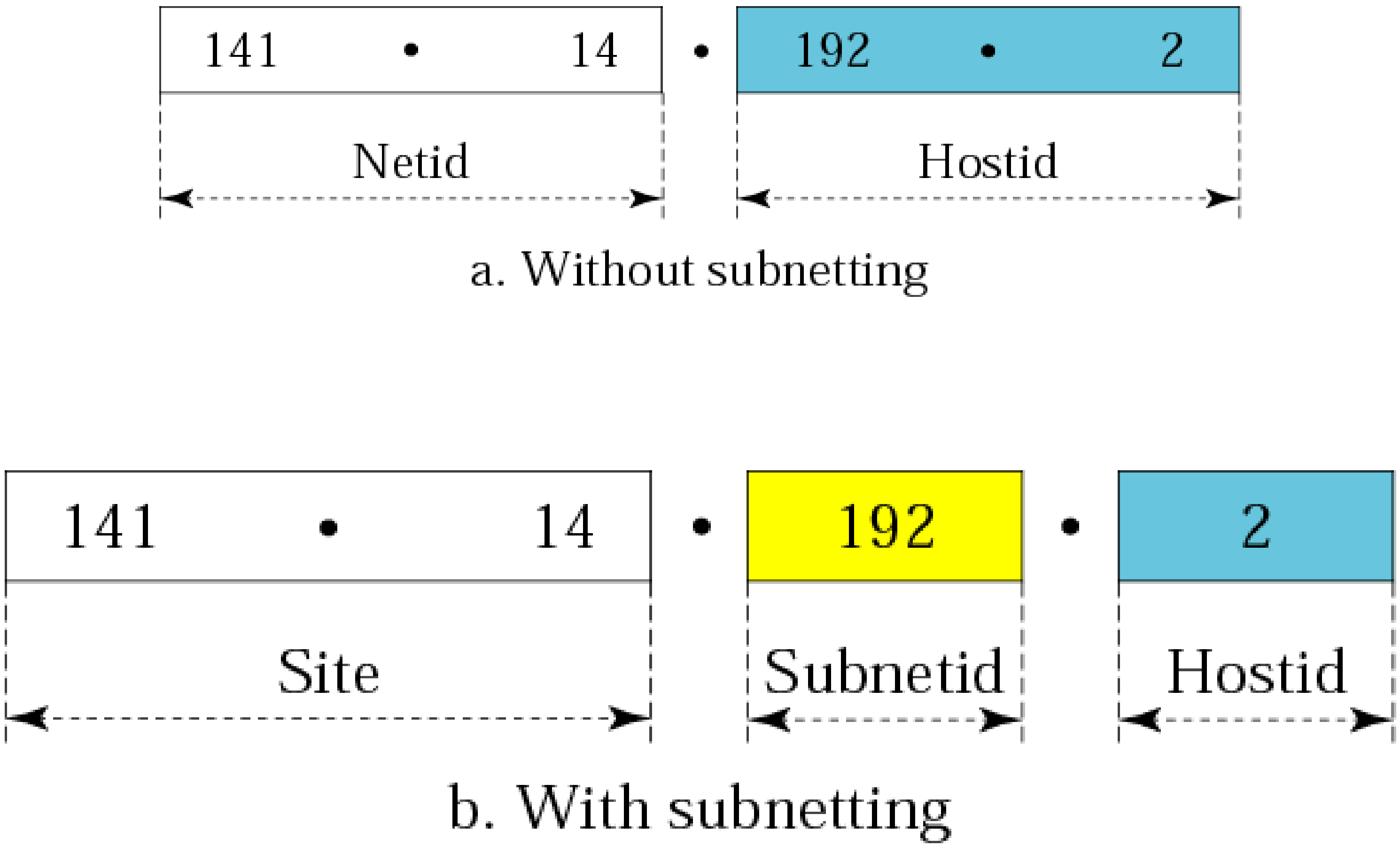
SUBNETTING

A network with two levels of hierarchy
(not subnetted)



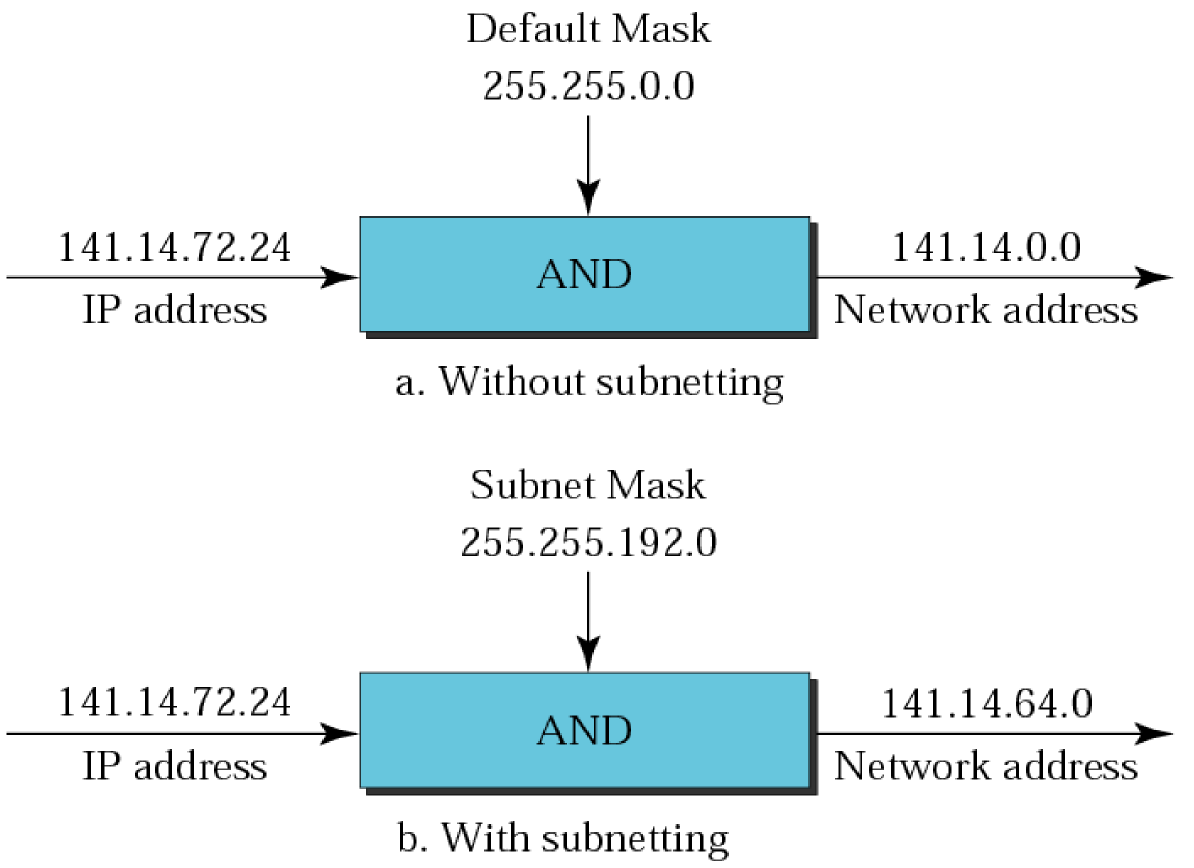
SUBNETTING

Addresses in a network with and without subnetting



SUBNETTING

Default mask and subnet mask



SUBNETTING

Example

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

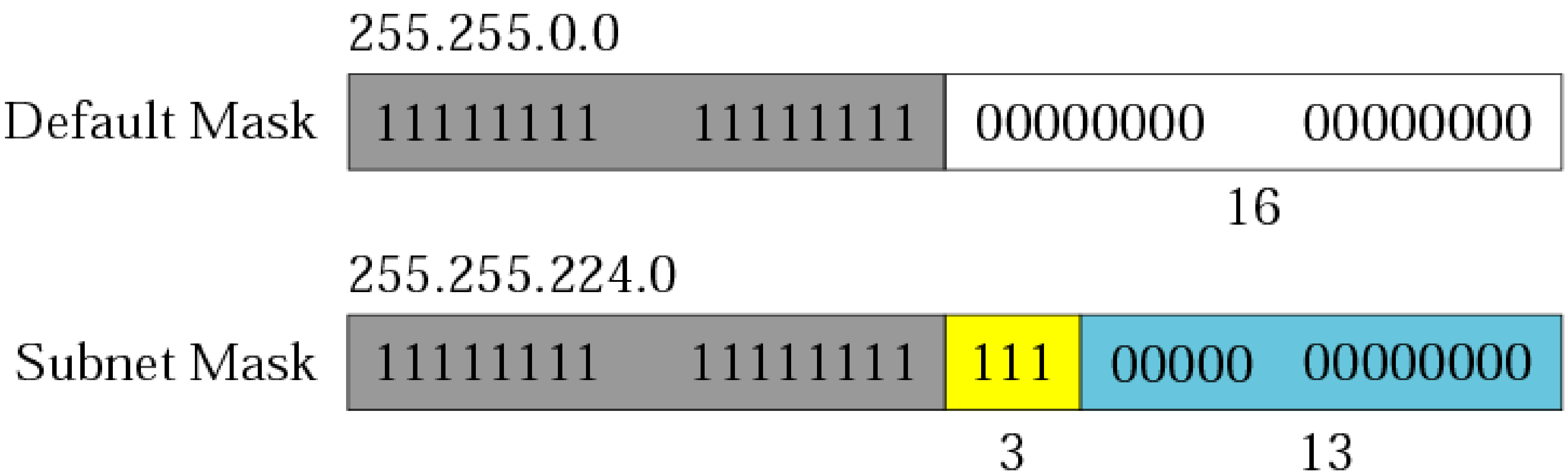
Solution

We apply the AND operation on the address and the subnet mask.

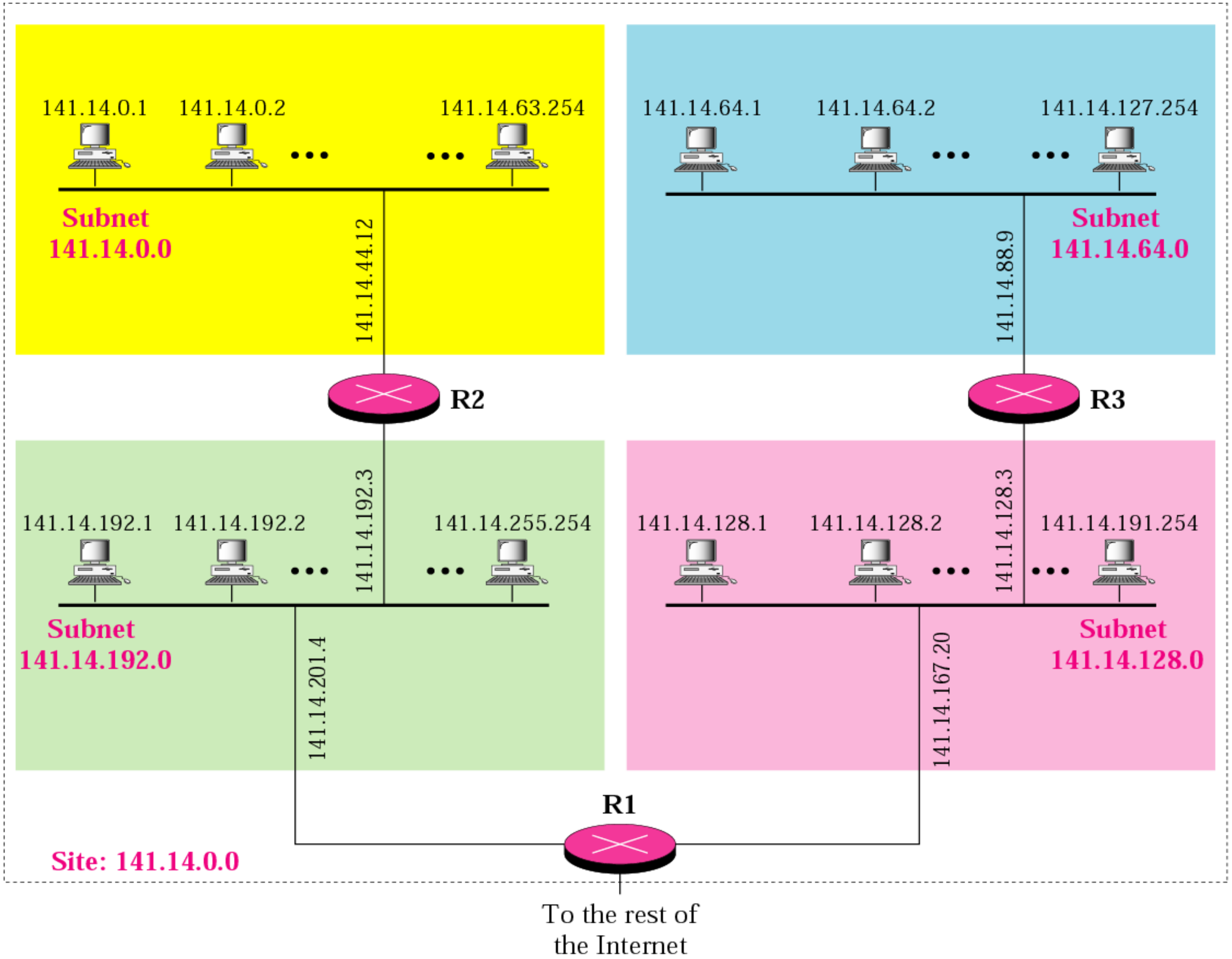
Address	→ *11001000 00101101 00100010 00111000*
Subnet Mask	→ *11111111 11111111 11110000 00000000*
Subnetwork Address	→ *11001000 00101101 00100000 00000000.*

SUBNETTING

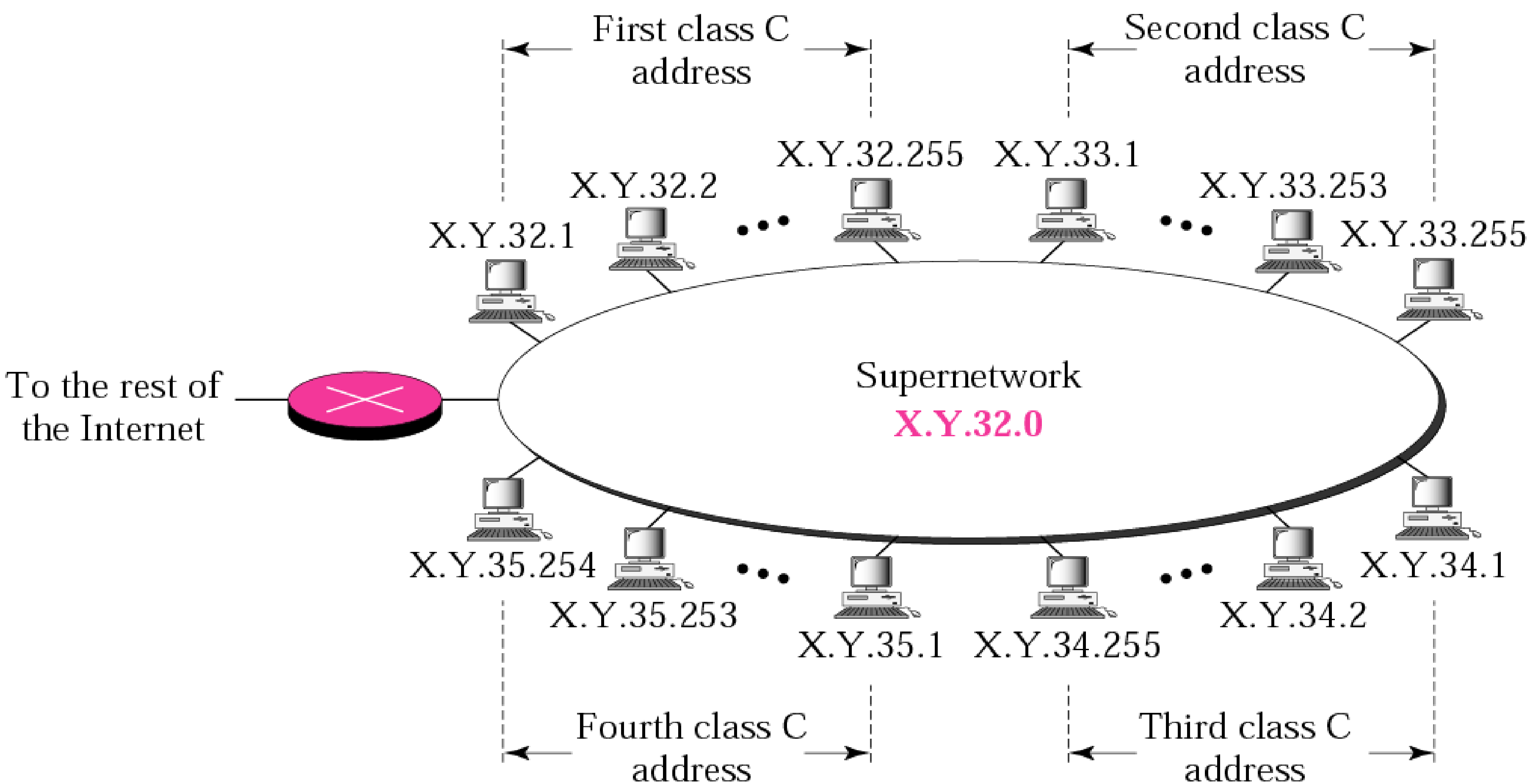
Comparison of a default mask and a subnet mask



A network with three levels of hierarchy (subnetted)



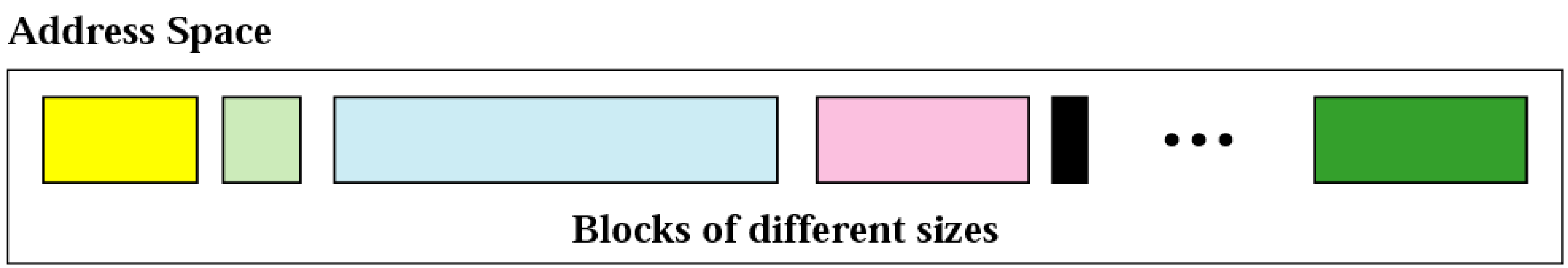
SUPERNETTING



IP Addresses: Classless Addressing

Classless Addressing

- No of Class A and Class B addresses are wasted.
- In classless addressing variable-length blocks are assigned that belong to no class.
- In this architecture, the entire address space (2^{32} addresses) is divided into blocks of different sizes.
- Restriction on block allocation.



Variable-Length Blocks

Classless Addressing

Example

Which of the following can be the beginning address of a block that contains 16 addresses?

a. *205.16.37.32* ***b.*** *190.16.42.44*
c. *17.17.33.80* ***d.****123.45.24.52*

Solution

Only two are eligible (a and c). 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.

Classless Addressing

CIDR Notation: **x.y.z.t/n**

Prefix lengths:

/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

Classless Addressing

Example

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, which means that we must keep the first 27 bits as it is and change the remaining bits to 0s. The following shows the process:

Address in binary: *10100111 11000111 10101010 010****10010***

Keep the left 27 bits: *10100111 11000111 10101010 010****00000***

Result in CIDR notation: 167.199.170.64/27

Classless Addressing

Example

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.

Classless Addressing

Example

Using the first method, find the last address in the block if one of the addresses is 140.120.84.24/20.

Solution

The prefix length is 20, which means that we must keep the first 20 bits as it is and change the remaining bits to 1's. The following shows the process:

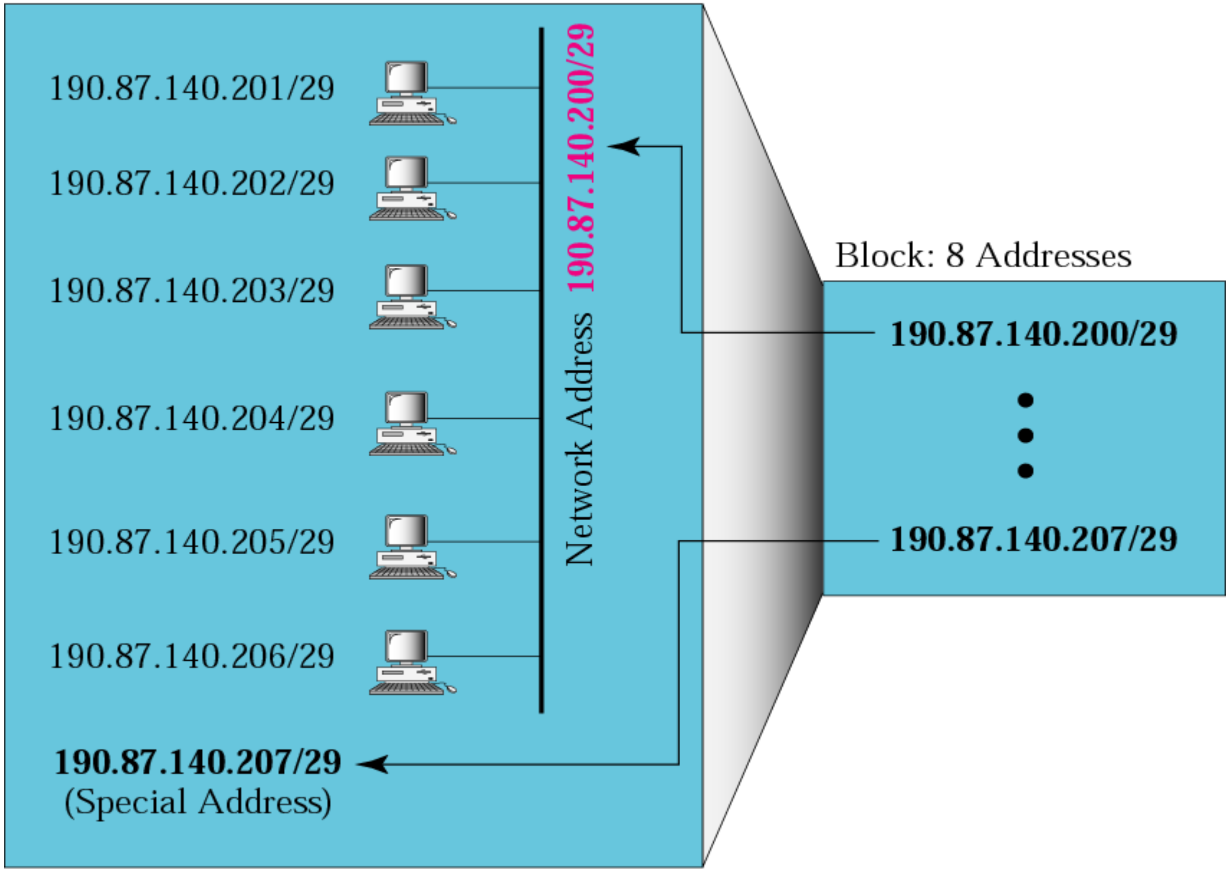
*Address in binary: 10001100 01111000 0101**0100 00011000***

*Keep the left 20 bits: 10001100 01111000 0101**1111 11111111***

*Result in CIDR notation: **140.120.95.255/20***

Classless Addressing

Draw the block diagram of the network having one of the IP address is 190.87.140.200/29.



Subnetting in Classless Addressing

- **When an organization is granted a block of addresses, it can create subnets to meet its needs.**
- **The prefix length increases to define the subnet prefix length.**

Example

An organization is granted the block 130.34.12.64/26. The organization needs 4 subnets. What is the subnet prefix length?

Solution

We need 4 subnets, which means we need to add two more 1s ($\log_2 4 = 2$) to the site prefix. The subnet prefix is then /28.

IP Addresses

CIDR – Classless InterDomain Routing

Example 1

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:

a. The first group has 64 customers; each needs 256 addresses.

b. The second group has 128 customers; each needs 128 addresses.

c. The third group has 128 customers; each needs 64 addresses.

Design the subblocks and find out how many addresses are still available after these allocations.

IP Addresses

CIDR – Classless InterDomain Routing

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. The addresses are:

1st Customer	190.100.0.0/24	190.100.0.255/24
2nd Customer	190.100.1.0/24	190.100.1.255/24
. . .		
64th Customer	190.100.63.0/24	190.100.63.255/24
Total = 64 × 256 = 16,384		

CIDR – Classless InterDomain Routing

Solution

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:

1st Customer	190.100.64.0/25	190.100.64.127/25
2nd Customer	190.100.64.128/25	190.100.64.255/25
. . .		
128th Customer	190.100.127.128/25	190.100.127.255/25

Total = 128 × 128 = 16,384

CIDR – Classless InterDomain Routing

Solution

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 $32 - 6 = 26$. The addresses are:

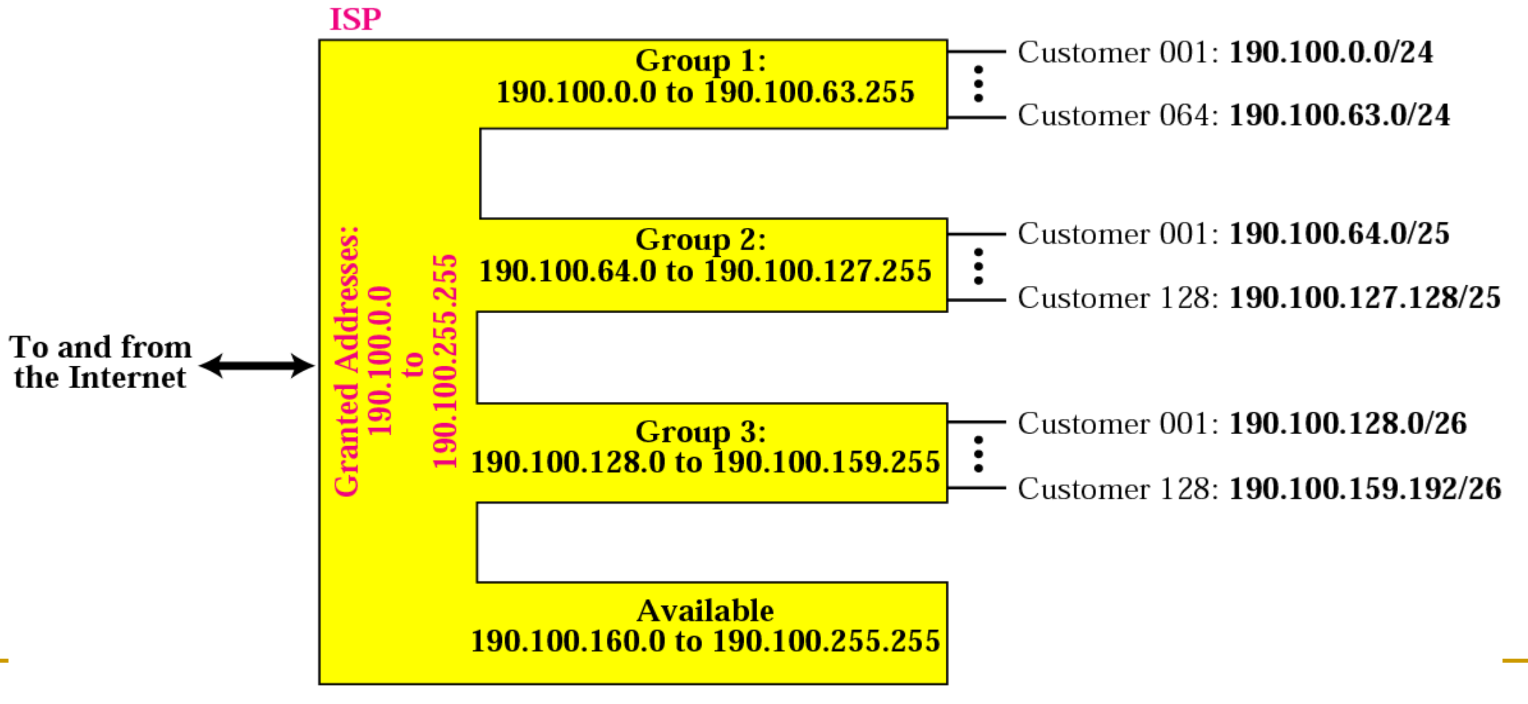
1st Customer	190.100.128.0/26	190.100.128.63/26
2nd Customer	190.100.128.64/26	190.100.128.127/26
. . .		
128th Customer	190.100.159.192/26	190.100.159.255/26

Total = 128 × 64 = 8,192

CIDR – Classless InterDomain Routing

Solution

Number of granted addresses to the ISP	:	**65,536**
Number of allocated addresses by the ISP	:	**40,960**
Number of available addresses	:	**24,576**



IP Addresses

CIDR – Classless InterDomain Routing

Example 2

An organization is granted the block 16.0.0.0. The administrator wants to create 500 subnets.

A. Find the subnet mask.

B. Find the number of address in each subnet.

C. Find the first and last address in the first subnet.

D. Find the first and last and address in the last subnet.

Solution

A. $\log_2 500 = 8.95$ Extra 1s = 9 Possible subnets: 512 **Mask: /17**

B. $2^{32-17} = 2^{15}$ = **32,768 Addresses per subnet**

CIDR – Classless InterDomain Routing

Solution

C. Find the first and last address in the first subnet:

First subnet:
The first address is the beginning address of the block.

first address in subnet 1:	**16**	.	**0**	.	**0**	.	**0**

To find the last address, we need to write 32,767 (one less than the number of addresses in each subnet) in base 256 (0.0.127.255) and add it to the first address (in base 256).

first address in subnet 1:	**16**	.	**0**	.	**0**	.	**0**
number of addresses:	**0**	.	**0**	.	**127**	.	**255**
last address in subnet 1:	**16**	.	**0**	.	**127**	.	**255**

CIDR – Classless InterDomain Routing

Solution

D. Find the first and last address in the last subnet:

Last subnet (Subnet 500):

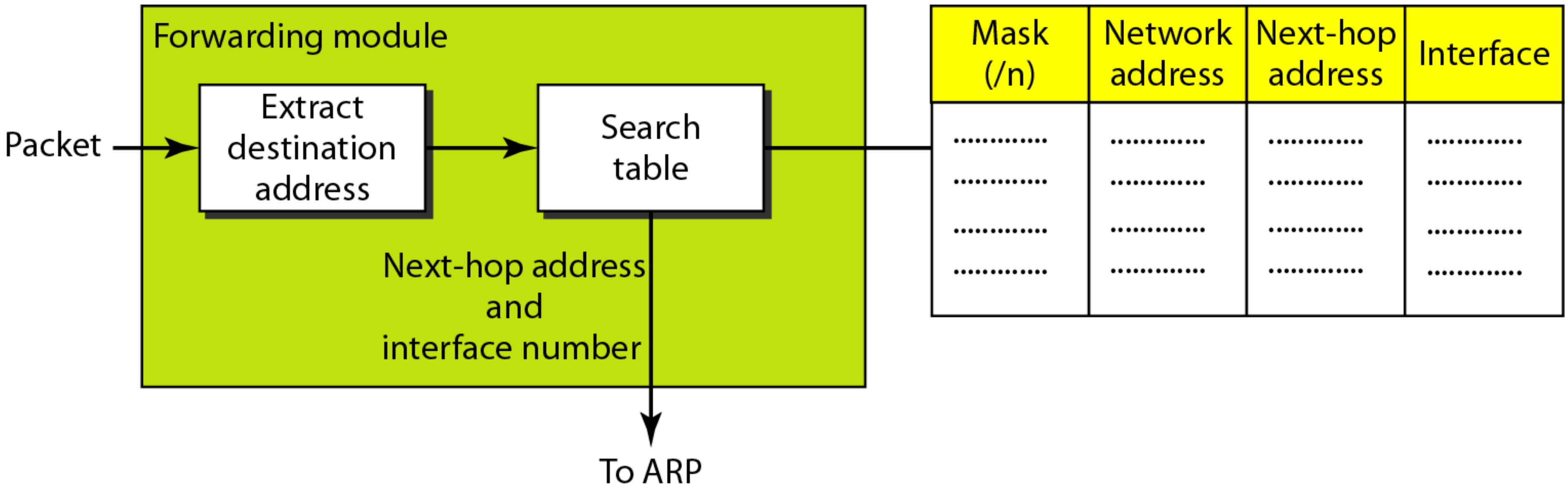
Note that the subnet 500 is not the last possible subnet; it is the last subnet used by the organization. To find the first address in subnet 500, we need to add 16,351,232 (499 × 32678) in base 256 (0. 249.128.0) to the first address in sub-net 1.

first address in subnet 1	**16**	.	**0**	.	**0**	.	**0**
number of addresses:	**0**	.	**249**	.	**128**	.	**0**
first address in subnet 500:	**16**	.	**249**	.	**128**	.	**0**

Now we can calculate the last address in subnet 1024.

first address in subnet 500:	**16**	.	**249**	.	**128**	.	**0**
number of addresses:	**0**	.	**0**	.	**127**	.	**255**
last address in subnet 500:	**16**	.	**249**	.	**255**	.	**255**

CIDR – Classless InterDomain Routing Techniques



CIDR – Classless InterDomain Routing Techniques

Example 22.1

Make a routing table for router R1, using the configuration in Figure 22.6.

Solution

Table 22.1 shows the corresponding table.

CIDR – Classless InterDomain Routing Techniques

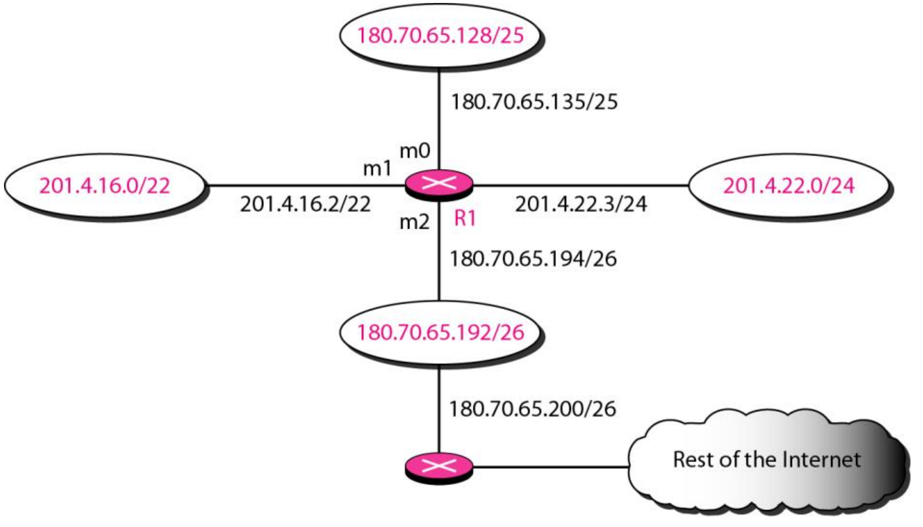


Figure 22.6

Configuration for Example 22.1

Mask	*Network Address*	*Next Hop*	*Interface*
/26	180.70.65.192	—	m2
/25	180.70.65.128	—	m0
/24	201.4.22.0	—	m3
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

CIDR – Classless InterDomain Routing Techniques

Example 22.2

Show the forwarding process if a packet arrives at R1 in Figure 22.6 with the destination address 180.70.65.140.

Solution

The router performs the following steps:

1. The first mask (/26) is applied to the destination address. The result is 180.70.65.128, which does not match the corresponding network address.

2. The second mask (/25) is applied to the destination address. The result is 180.70.65.128, which matches the Corresponding network address. The next-hop address and the interface number m0 are passed to ARP for further processing.

IP Addresses

Network Address Translation

- IP addresses are limited.
- Dynamic assignment of IP addresses, with dial up connectivity, may work well for home users and limited number of customers.
- For business customers, the limits will quickly be exceeded.
- ADSL makes the matter worst.
- The long term solution is for the whole internet to migrate to IPv6, but it takes years to complete this task.
- The quick fix came in the form of **Network Address Translation(NAT)**.

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IP Addresses

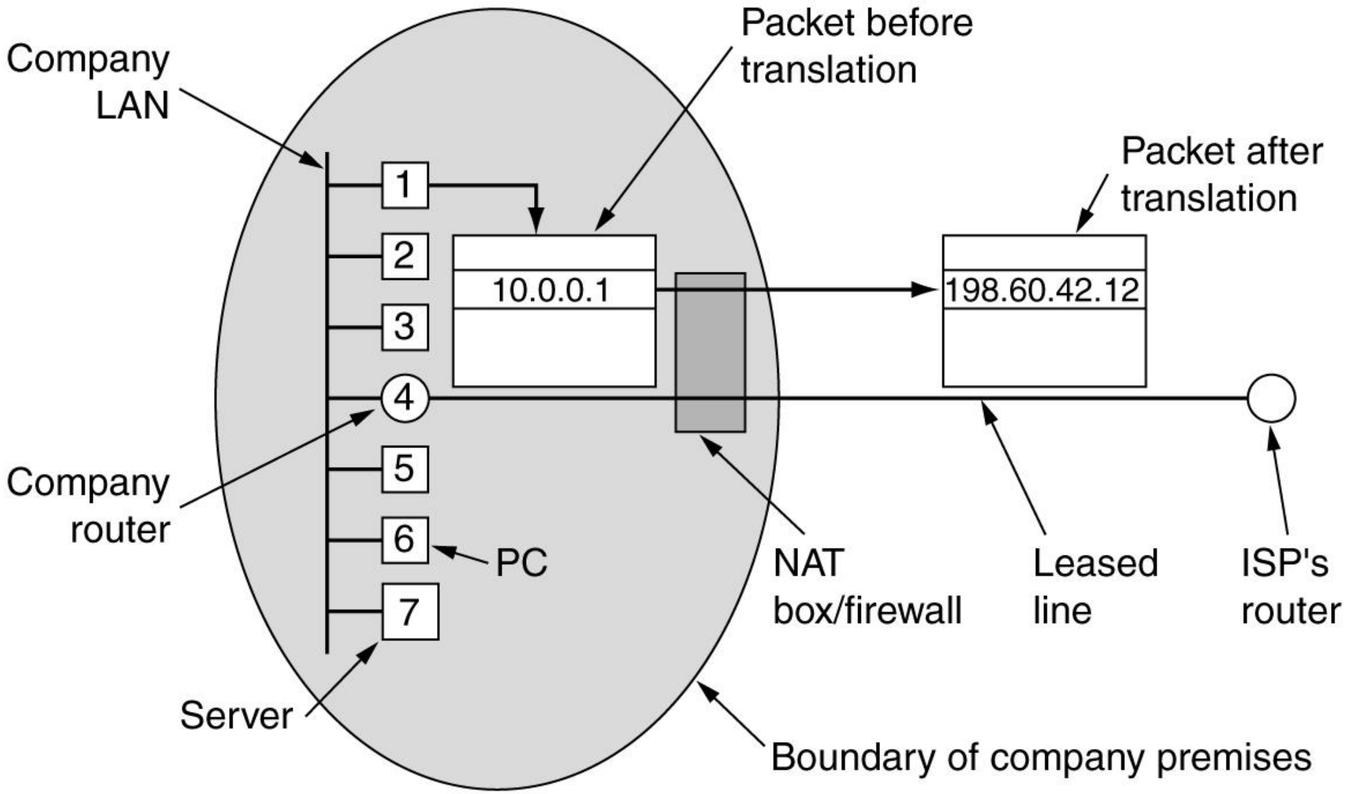
Network Address Translation

- The basic idea behind NAT is to assign single (or at most less number of) real IP address to a company.
- Within the company, each computer gets a unique IP address from the private blocks of IP range.
- When a packet exits the company and goes to the ISP, address translation takes place.
- Three reserved range are;

Class	*Netids*	*Blocks*
A	10.0.0	1
B	172.16 to 172.31	16
C	192.168.0 to 192.168.255	256

IP Addresses

Network Address Translation



<u>Placement and operation of a NAT box</u>