Internet Protocol (IP)

Lecture 20
BDS-7A
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SMI

Network Layer

Network layer is concerned with getting packets from the source **all the way** to the destination (**end-end to transmission**)

> May require many hops at intermediate routers (**multiple hops**),

> Its primary function is **routing**

> Network layer should provide either connection oriented or connectionless service

Network layer protocols

> Protocols which route data from one hop to another hop between two end hosts in a network

Core Network layer protocol

> **IP: A connectionless unreliable protocol ,**

> **ARP**: Resolves IP addresses to MAC addresses,

> **ICMP**: Diagnostics and error reporting,

> **IGMP**: Management of group multicast

Internet Protocol (IP)

IP ADDRESSES

An IP address uniquely and universally defines the connection of a device (a computer or a router) to the Internet
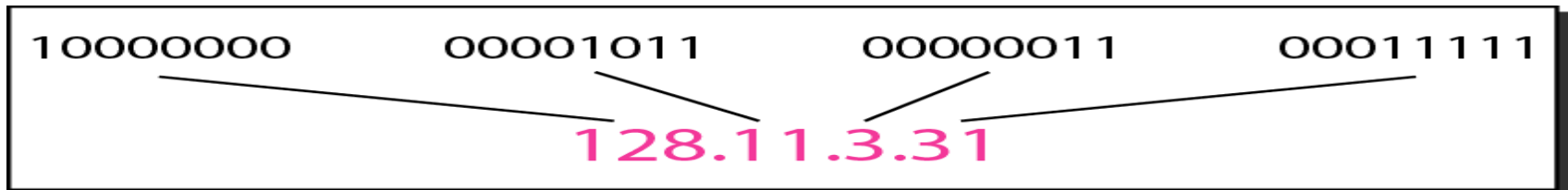
Types of IP addresses in active use
➢ IP version 4 (IPv4)
➢ IP version 6 (IPv6)

Types of IP ADDRESSES

IP version 4 (IPv4)
- Initially deployed on Jan 1, 1983
- Still most commonly used version
- A 32 bit address in length
- Expressed as four 8 bit Octets separated by **a period symbol** (Dotted decimal notation)
  - 192.2.3.50
- Its **address space** is 2^{32} or **4,294,967,296**

10000000	00001011	00000011	00011111

128.11.3.31

Types of IP ADDRESSES

IP version 6 (IPv6)

➤ Its deployment started in 1999

➤ 128 bit numbers

➤ conventionally expressed using hexadecimal strings

➤ *2001:0db8:582:ae33::29*

➤ *Apparently Address space is* **2^{128}**

IPv4 Addresses (classful)

IPv4 classes in binary and dotted-decimal notation

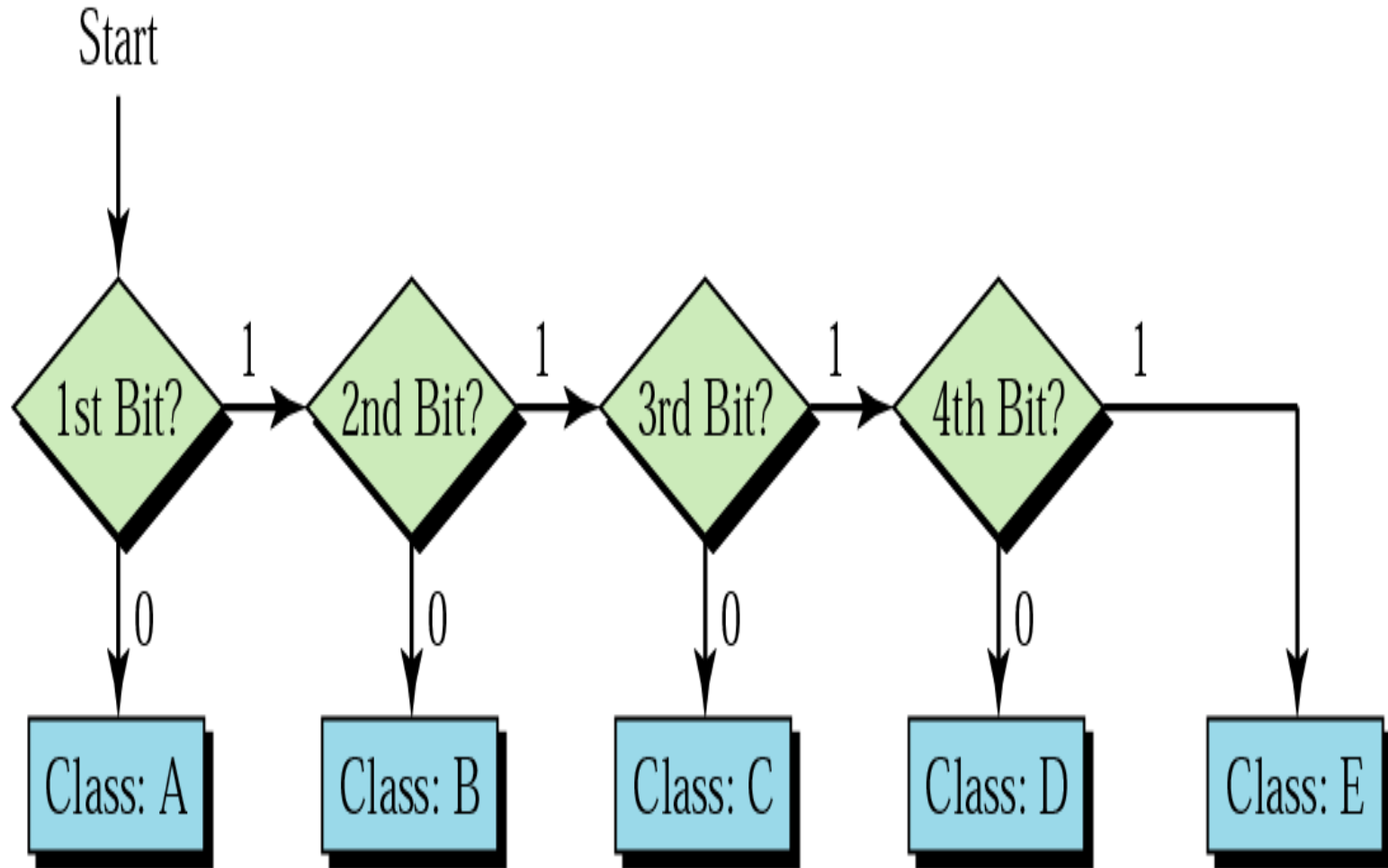## The address space is divided into five classes: A, B, C, D, and E

a. 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			

b. Dotted-decimal notation

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

Finding the Class

Start

IPv4 ADDRESSES

IP address is divided into two parts

➤ **Prefix** defines the network (Network ID or **Net ID):**
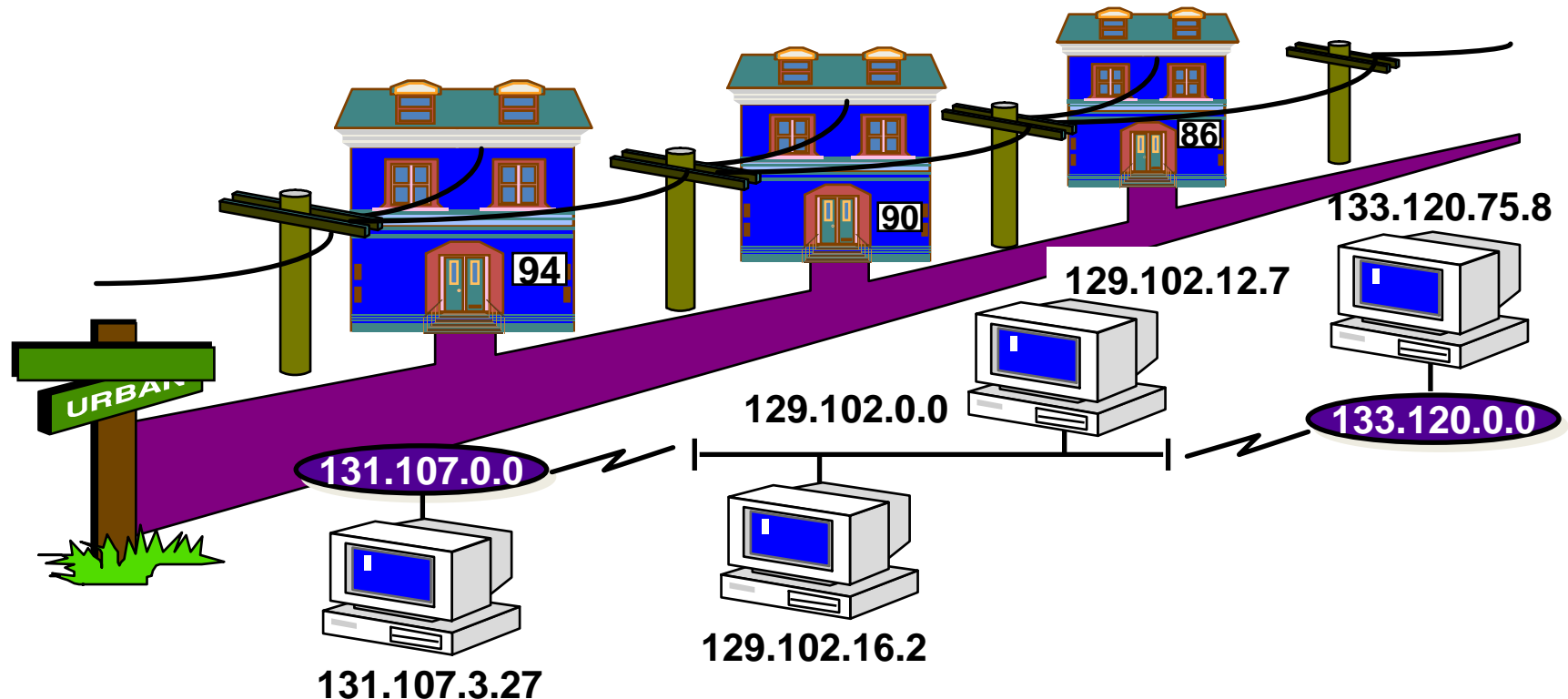 ➤ like street address

➤ **Suffix (Host ID)** defines the node (connection of a device to the network):
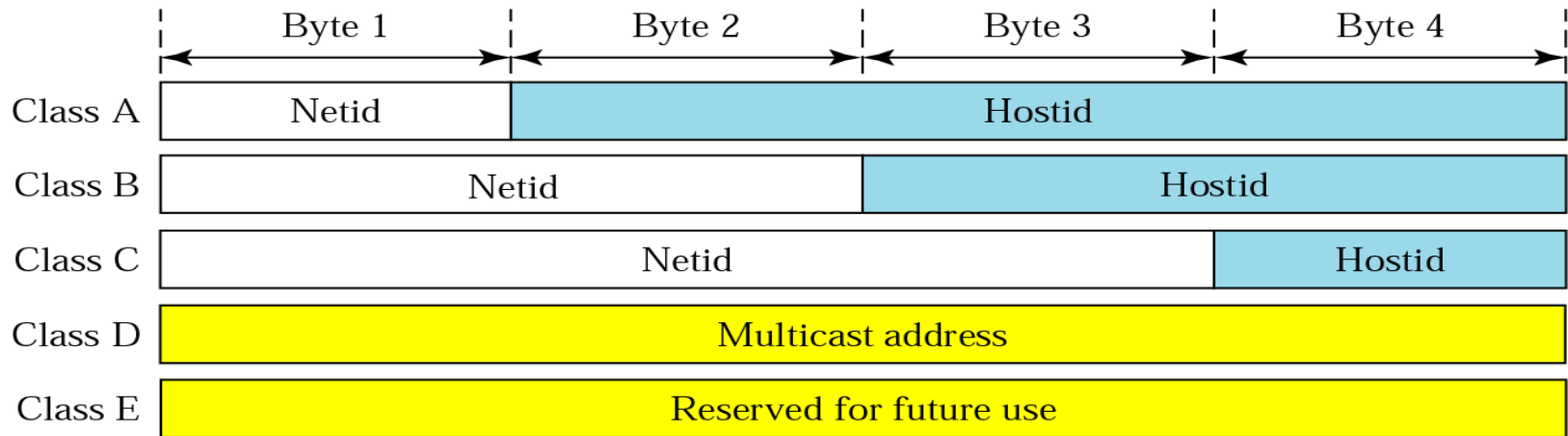 ➤ Like house or building number

➤ A **host** is a device that has a network interface card (NIC) connected to a network

IPv4 ADDRESSES

➢ If a device has **two** network interfaces, it should be considered **two separate hosts**

➢ Each host that is attached to a TCP/IP network must have a **unique IP address**

Netid and Hostid

	Byte 1	Byte 2	Byte 3	Byte 4
Class A	Netid	Hostid		
Class B	Netid		Hostid	
Class C	Netid			Hostid
Class D	Multicast address			
Class E	Reserved for future use			

➢**Hostid: cannot be all 0s**

   ➢If host portion is all 0s, represents a **network** address.

➢**Hostid: cannot be all 1s**

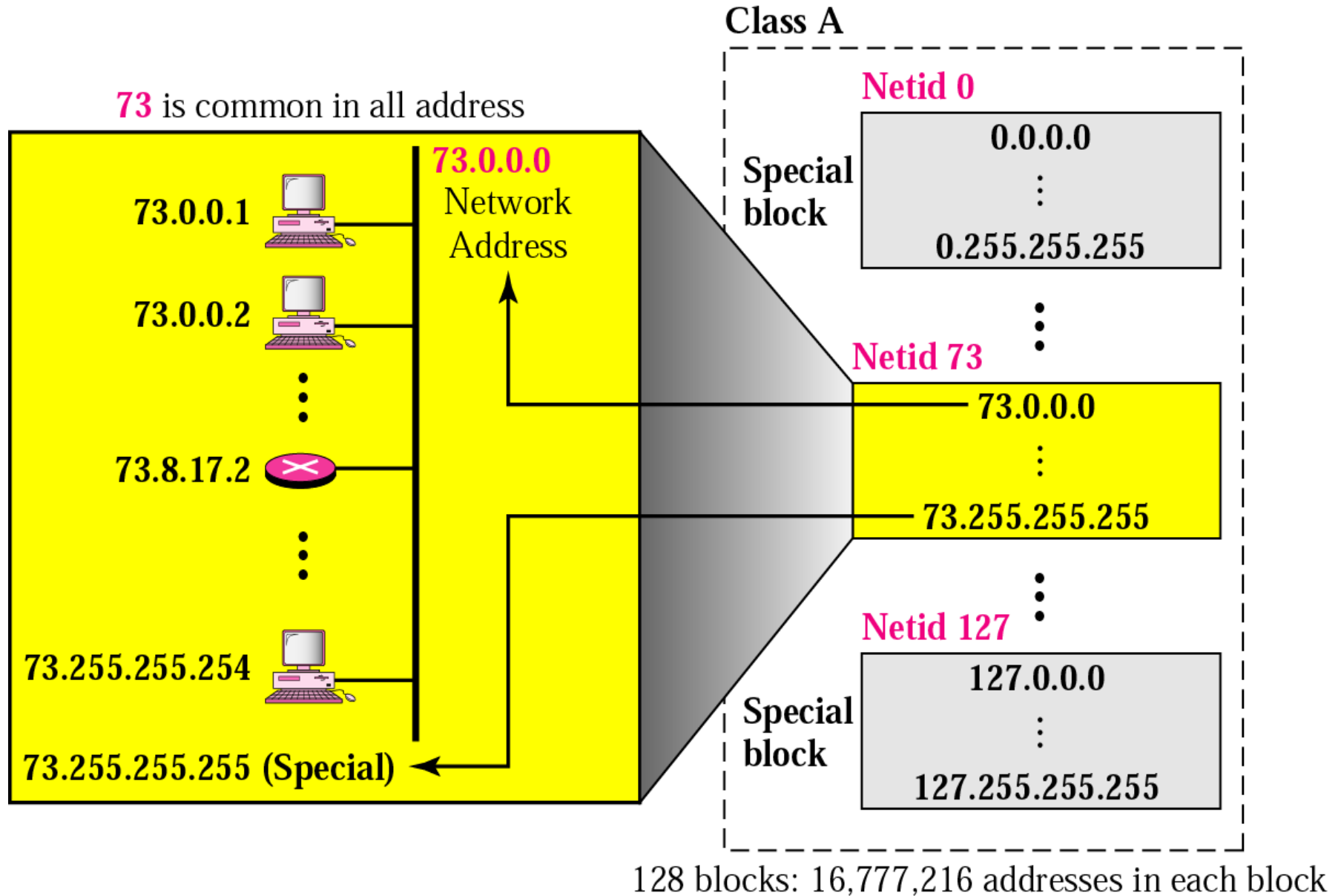   ➢If host portion is all 1s, represents **broadcast** address.

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

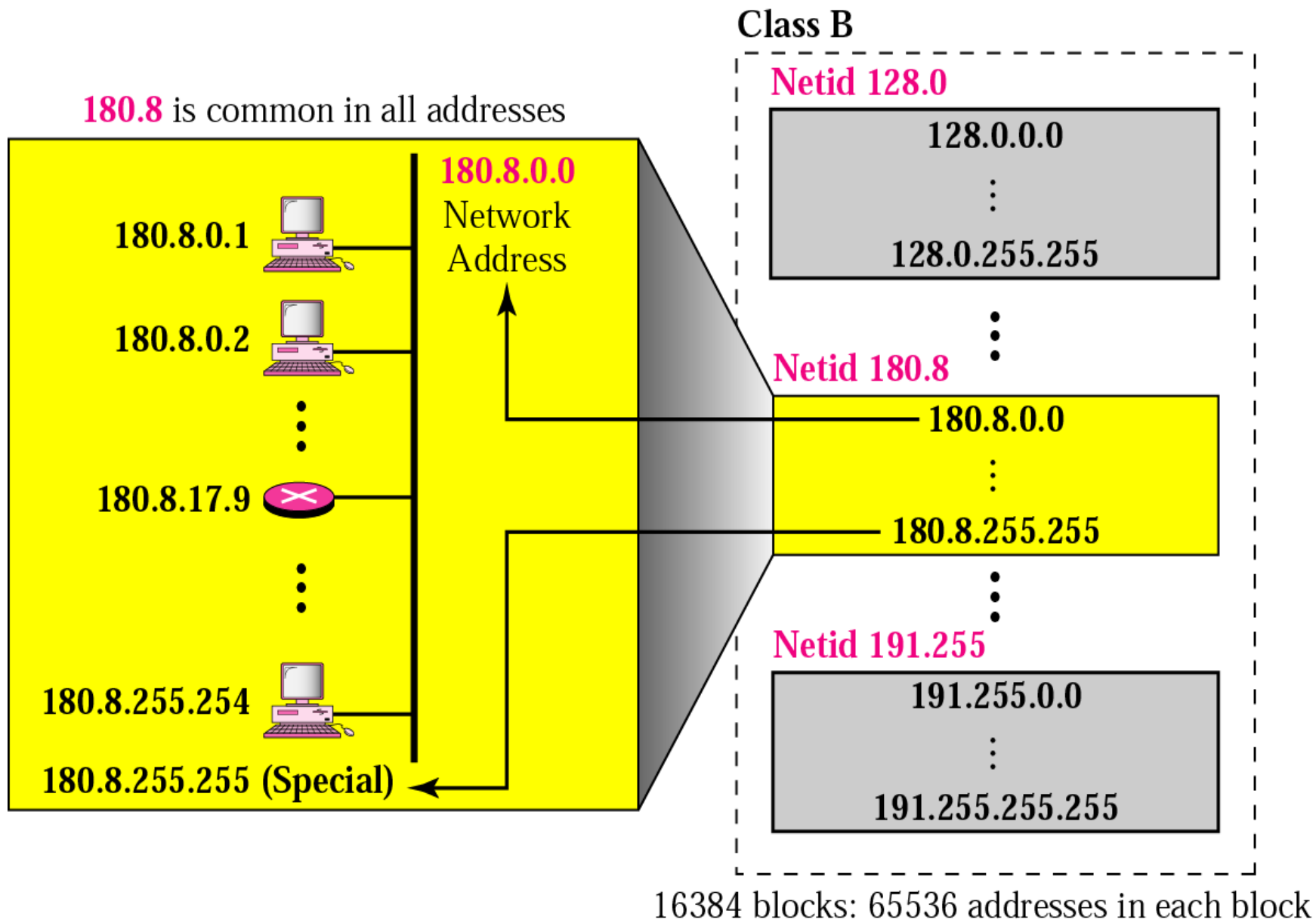# Class A Address

➢First bit: always 0. Remaining bits can be either 0s or 1s.

➢Range of first octet is 00000000 to 01111111

   ➢Network addresses cannot be all 0s (**0.0.0.0** through **0.255.255.255**): nodes attempting to use them will be unable to communicate properly on the Internet

   ➢127 is reserved for **loopback testing**

➢**126 valid Class A network IDs**: 1.x.y.z to 126.x.y.z

Class A Address

73 is common in all address

73.0.0.1
73.0.0.2
73.8.17.2
73.255.255.254
73.255.255.255 (Special)

73.0.0.0
Network Address

Class A

Netid 0

Special block

0.0.0.0
⋮
0.255.255.255

Netid 73

73.0.0.0
⋮
73.255.255.255

Netid 127

Special block

127.0.0.0
⋮
127.255.255.255

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

Blocks in class B

180.8 is common in all addresses

180.8.0.0
Network Address

180.8.0.1

180.8.0.2

180.8.17.9

180.8.255.254

180.8.255.255 (Special)

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

16384 blocks: 65536 addresses in each block

Blocks in Class C

Class C

Netid 192.0.0

192.0.0.0
⋮
192.0.0.255

Netid 200.11.8

200.11.8.0
⋮
200.11.8.255

Netid 223.255.255

223.255.255.0
⋮
223.255.255.255

200.11.8 is common in all addresses

200.11.8.0
Network
Address

200.11.8.1

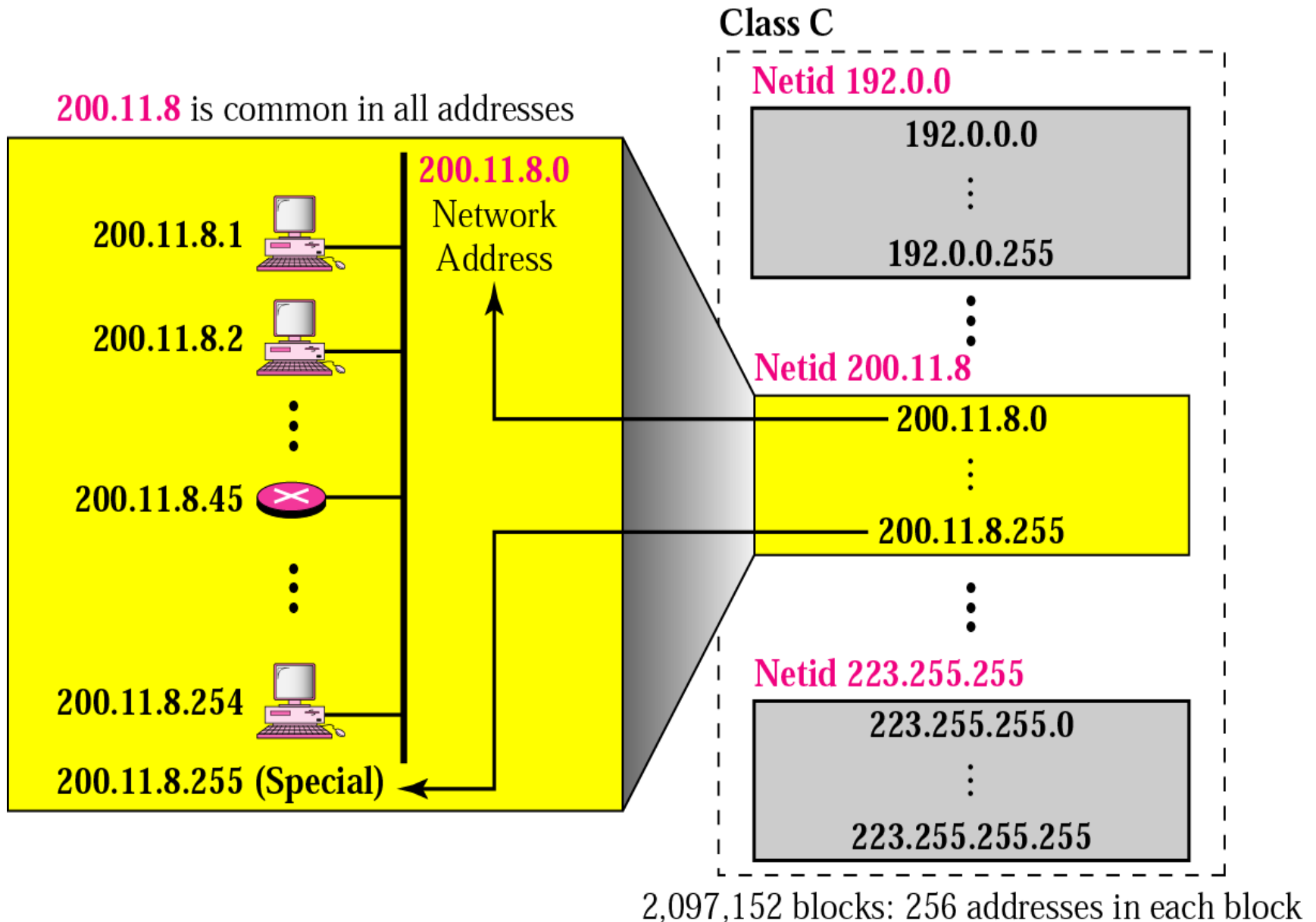200.11.8.2

200.11.8.45

200.11.8.254

200.11.8.255 (Special)

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

➢ **Class D addresses** (from 224.x.y.z to 239.x.y.z) are used for multicasting

  ➢method of sending a single packet to multiple hosts

➢ **Class E addresses** (from 240.x.y.z to 255.x.y.z)

  ➢experimental address range

  ➢Not used in actual networks

Network Address

The **first address** is called the **network address**
- different from a **netid** and
- contains **both netid and hostid**
  - with **0s** for the **hostid**

➤It defines the **organization network** (to connect to the rest of world)

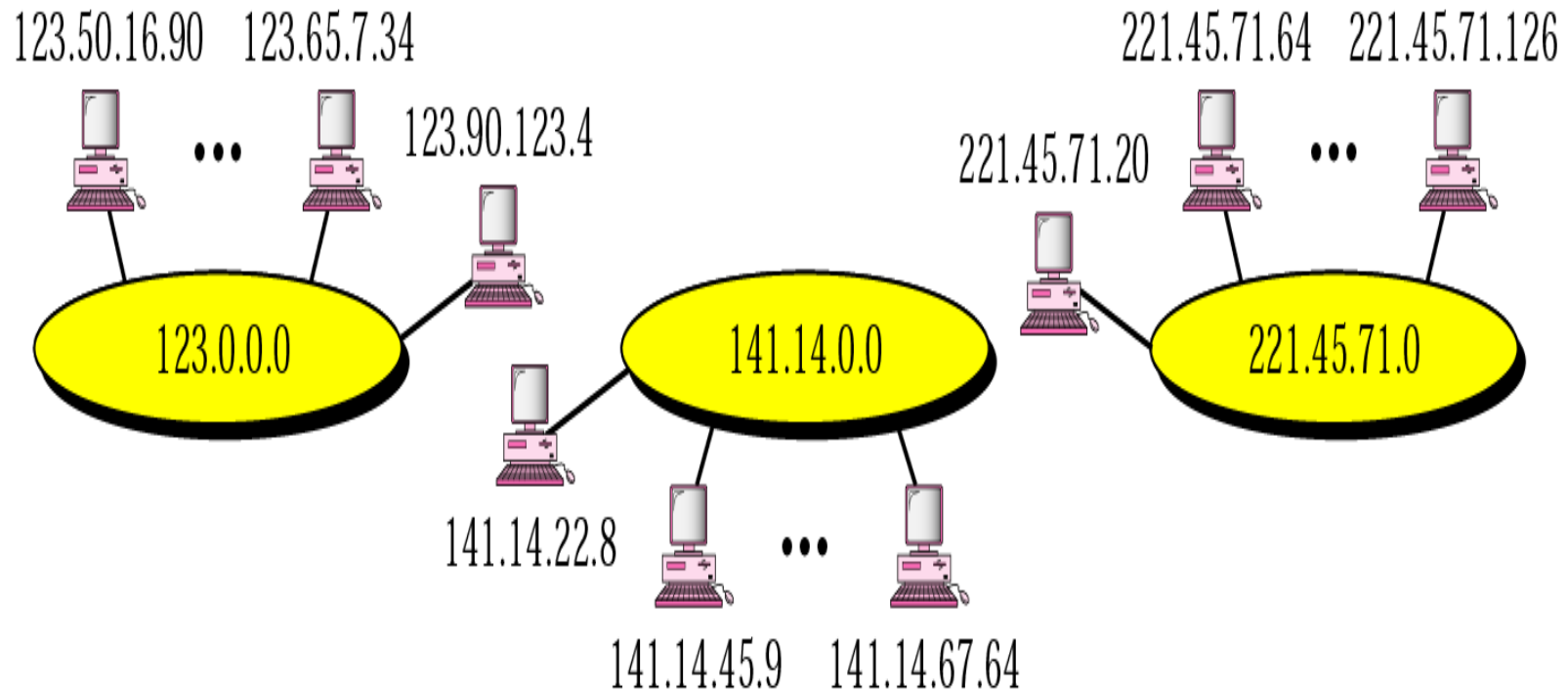   ➤The **organization network** is **connected** to the **Internet** via a **router**.

➤The router has **two addresses**.

    ➤One belongs to the **granted block**;

    ➤the other belongs to the network that is **at the other side of the router**.

Network Address

Netid	Hostid
Specific	All 0s

123.50.16.90   123.65.7.34

123.90.123.4

• • •

123.0.0.0

141.14.22.8

141.14.0.0

141.14.45.9   141.14.67.64

• • •

221.45.71.64   221.45.71.126

221.45.71.20

• • •

221.45.71.0

a. Class A   b. Class B   c. Class C

Examples: Network Address

➢ **Question:** Given the address **23.56.7.91**, find the **network address**.

➢ **Answer:** Replacing the host-id bytes (56.7.91) with 0s. So, the network address is **23.0.0.0**.

➢ **Question:** Given the address **132.6.17.85**, find the **network address**
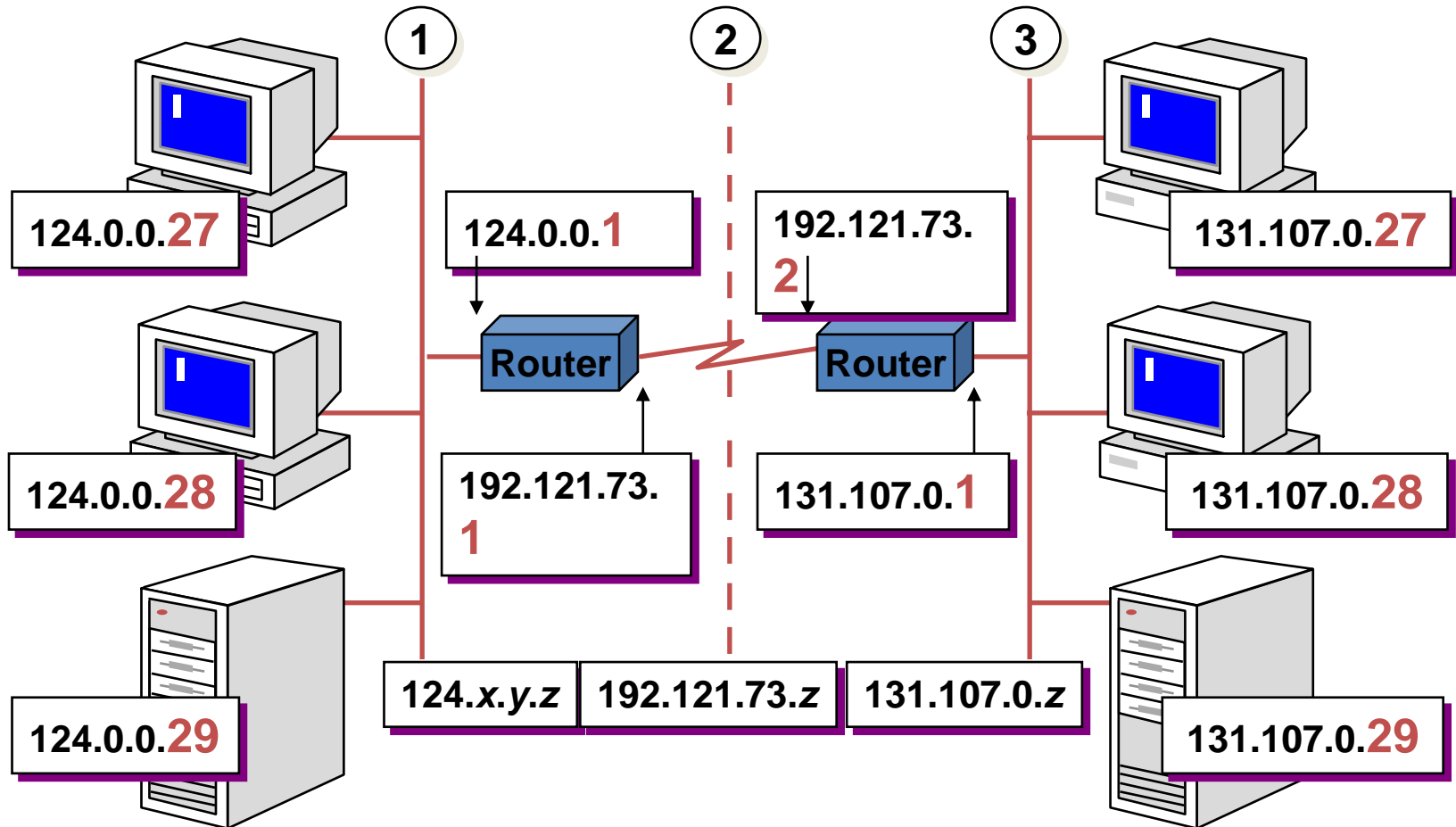
➢ **Answer:** We can find the network address by replacing the hostid bytes (17.85) with 0s.

Thus, the network address is **132.6.0.0.**

Address Class Summary

	Number of Networks	Number of Hosts per Network	Range of Network IDs (First Octet)
Class A	126	16,777,214	1 – 126
Class B	16,384	65,534	128 – 191
Class C	2,097,152	254	192 – 223

Assigning Host IDs

Remember the following

Network address: If all the bits in the host part are "0", that represents the network id

First usable IPv4 address: If all the bits in the host part are "0" except the last bit

Last usable IPv4 address : If all the bits in the host part are "1" except the last bit

Broadcast address: If all the bits in the host part are "1"

Reserved, Private addresses

Private address block:
Class A: 10.0.0.0 to 10.255.255.255 [16777216] (Private use networks)
Class B: 172.16.0.0 to 172.31.255.255 [1048576]
Class C: 192.168.0.0 to 192.168.255.255 [65536]

Reserved:
Class A: 0.0.0.0 to 0.255.255.255 & 127.0.0.0 to 127.255.255.255 (LB)
Administered by RIRs: Examples
128.0.0.0 to 128.0.255.255 & 191.255.0.0 to 191.255.255.255
192.0.0.0 to 192.0.0.255 --------196.-.-.-, 198.-.-.-

What is Subnet Mask?

IPv4 address has two components, the network part and the host part.

The purpose of subnet mask is to identify which part is the **network part** and which part is the **host part**.

Subnet mask: A 32 bit number where
- all the bits of the network part are shown as **1** and
- all the bits of the host part are represented as **0**.

For example, for a **Class C Network**, 192.168.10.0, the subnet mask is **255.255.255.0**

Subnet and Sub-netting

➢A logical, visible subdivision of an IP network is called **subnet** or **subnetwork:**

　➢It is created by dividing the host identifier

➢**Sub-netting** is the practice of dividing a network into two or more networks

➢**Sub-netting** is done by taking the bits from host part and adding it to the network part

Subnet and Sub-netting

In sub-netting, a class A or class B or class C block is divided into several subnets

- each subnet with larger prefix length than the original network).

➢**For example,** divide the **class A** into **four subnets**, (take two bits from host id part in order to obtain subnets).

   ➢then each subnet will have prefix length as 10

Class C – 1 bit sub-netting

Consider class C network 192.168.10.0 (subnet mask is 255.255.255.0)

❖ If we include one bit from the host part to the network part, the subnet mask changes into 255.255.255.128 (for 1 bit sub-netting)

❖ The single bit can have two values in last octet, either 0 or 1

❖ 11000000.10101000.00001010.**0** | 0000000
11111111.11111111.11111111.**1** | 0000000

❖ So the network 192.168.10.0 is divided into two networks with a single bit sub-netting,

❖ each network has 128 total addresses of which 126 are usable

❖ two are used in each subnet to represent the network address and broadcast address.

Class C – 1 bit sub-netting

SN No.	Description	Binaries	Decimal
1	Network Address	11000000.10101000.00001010.00000000	192.168.10.0
	First usable address	11000000.10101000.00001010.00000001	192.168.10.1
	Last usable address	11000000.10101000.00001010.01111110	192.168.10.126
	Broadcast Address	11000000.10101000.00001010.01111111	192.168.10.127
2	Network Address	11000000.10101000.00001010.10000000	192.168.10.128
	First usable address	11000000.10101000.00001010.10000001	192.168.10.129
	Last usable address	11000000.10101000.00001010.11111110	192.168.10.254
	Broadcast Address	11000000.10101000.00001010.11111111	192.168.10.255

Class C – 2 bit sub-netting

SN No.	Description	Binaries	Decimal
1	NA	11000000.10101000.00001010.**00**000000	192.168.10.0
	1st	11000000.10101000.00001010.00000001	192.168.10.1
	Last	11000000.10101000.00001010.00111110	192.168.10.62
	BA	11000000.10101000.00001010.**00**111111	192.168.10.63
2	NA	11000000.10101000.00001010.**01**000000	192.168.10.64
	1st	11000000.10101000.00001010.01000001	192.168.10.65
	Last	11000000.10101000.00001010.01111110	192.168.10.126
	BA	11000000.10101000.00001010.**01**111111	192.168.10.127
3	NA	11000000.10101000.00001010.**10**000000	192.168.10.128
	1st	11000000.10101000.00001010.10000001	192.168.10.129
	Last	11000000.10101000.00001010.10111110	192.168.10.190
	BA	11000000.10101000.00001010.**10**111111	192.168.10.191
4	NA	11000000.10101000.00001010.**11**000000	192.168.10.192
	1st	11000000.10101000.00001010.11000001	192.168.10.193
	Last	11000000.10101000.00001010.11111110	192.168.10.254
	BA	11000000.10101000.00001010.11111111	192.168.10.255

Class C – 3 bit sub-netting

SN No.	Description	Binaries	Decimal
1	NA	11000000.10101000.00001010.**000**00000	192.168.10.0
	1st	11000000.10101000.00001010.00000001	192.168.10.1
	Last	11000000.10101000.00001010.00011110	192.168.10.30
	BA	11000000.10101000.00001010.**000**11111	192.168.10.31
2	NA	11000000.10101000.00001010.**001**00000	192.168.10.32
	1st	11000000.10101000.00001010.00100001	192.168.10.33
	Last	11000000.10101000.00001010.00111110	192.168.10.62
	BA	11000000.10101000.00001010.**001**11111	192.168.10.63
		……………	
8	NA	11000000.10101000.00001010.**111**00000	192.168.10.224
	1st	11000000.10101000.00001010.11100001	192.168.10.225
	Last	11000000.10101000.00001010.11111110	192.168.10.254
	BA	11000000.10101000.00001010.**111**11111	192.168.10.255

Class B – 1 bit sub-netting

Consider class B network 172.16.0.0 (subnet mask is 255.255.0.0)

❖ If we include one bit from the host part to the network part, the **subnet mask** changes into 255.255.128.0 (with 1 bit sub-netting)

❖ The single bit can have two values in last octet, either 0 or 1

❖ 10101100.00010000.**0** | 0000000.00000000
    11111111.11111111.**1** | 0000000.00000000

❖ So the network 172.16.0.0 is divided into two networks with single bit sub-netting,
  ❖ each network has 32768 total addresses of which 32766 are usable, two are used in each subnet to represent the network address and broadcast address.

Class B – 1 bit sub-netting

SN No.	Description	Binaries	Decimal
1	Network Address	10101100.00010000.00000000.00000000	172.16.0.0
	First address	10101100.00010000.00000000.00000001	172.16.0.1
	Last address	10101100.00010000.01111111.11111110	172.16.127.254
	Broadcast Address	10101100.00010000.01111111.11111111	172.16.127.255
2	Network Address	10101100.00010000.10000000.00000000	172.16.128.0
	First address	10101100.00010000.10000000.00000001	172.16.128.1
	Last address	10101100.00010000.11111111.11111110	172.16.255.254
	Broadcast Address	10101100.00010000.11111111.11111111	172.16.255.255

Class B – 2 bit sub-netting

SN No.	Description	Binaries	Decimal
1	NA	10101100.00010000.**00**000000.00000000	172.16.0.0
	1st	10101100.00010000.**00**000000.00000001	172.16.0.1
	Last	10101100.00010000.**00**111111.11111110	172.16.63.254
	BA	10101100.00010000.**00**111111.11111111	172.16.63.255
2	NA	10101100.00010000.**01**000000.00000000	172.16.64.0
	1st	10101100.00010000.**01**000000.00000001	172.16.64.1
	Last	10101100.00010000.**01**111111.11111110	172.16.127.254
	BA	10101100.00010000.**01**111111.11111111	172.16.127.255
3	NA	10101100.00010000.**10**000000.00000000	172.16.128.0
	1st	10101100.00010000.**10**000000.00000001	172.16.128.1
	Last	10101100.00010000.**10**111111.11111110	172.16.191.254
	BA	10101100.00010000.**10**111111.11111111	172.16.191.255
4	NA	10101100.00010000.**11**000000.00000000	172.16.192.0
	1st	10101100.00010000.**11**000000.00000001	172.16.192.1
	Last	10101100.00010000.**11**111111.11111110	172.16.192.254
	BA	10101100.00010000.**11**111111.11111111	172.16.192.255

Example: Route 193.205.102.36

193	205	102	36
1 1 0 0 0 0 0 1	1 1 0 0 1 1 0 1	0 1 1 0 0 1 1 0	0 0 1 0 0 1 0 0

Class C address;
Outside private domain routed with mask 255.255.255.0

network			host
193	205	102	36
1 1 0 0 0 0 0 1	1 1 0 0 1 1 0 1	0 1 1 0 0 1 1 0	0 0 1 0 0 1 0 0

Inside private domain, administrator has set netmask 255.255.255.248

255	255	255	248
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

Hence, route to subnet address and then to host id, computed as:

network			subnet	host
1 1 0 0 0 0 0 1 1 1 0 0 1 1 0 1 0 1 1 0 0 1 1 0			0 0 1 0 0	1 0 0
193.205.102.32 /29				4

Classless Addressing

➢ **Classless addressing**

    ➢ uses a variable number of bits for the network and host portions of the address (**variable-length blocks)**

    ➢ treats the IP address as a 32 bit stream of ones and zeroes,

    ➢ where the boundary between network and host portions can fall anywhere between bit 0 and bit 31.

Classless Addressing

➢ **Classless addressing**

➢ How to find the prefix length if an address is given?

➢ As prefix length is not inherent in the address

    ➢ Need to separately give the length of the prefix

➢ So, Prefix length is added to the address, separated by a slash

Format of classless address

The notation is informally referred to as slash notation and formally as *classless inter-domain routing or CIDR*

$$\mathbf{x.y.z.t/n}$$

Table   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

Classful addressing is a special case of classless 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 1: 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 is and change the remaining bits (5) to 0s. The following shows the process:

Address in binary: 10100111 11000111 10101010 01010010
Keep the left 27 bits: 10100111 11000111 10101010 01000000
Result in CIDR notation: 167.199.170.64/27

Example 2: What is the first address in the block if one of the addresses is 140.120.84.24/20? Number of addresses, first and last useable IPs in block? Broadcast address?

Answer: The first address is 140.120.80.0/20

IP Address

140	.	120	.	84	.	24

/n

8	8	4	0

First Address

140	.	120	.	80	.	0

84	0 1 0 1 0 1 0 0
Keep left 4 bits	**0 1 0 1** 0 0 0 0

Result in decimal: 80

	128	64	32	16	8	4	2	1
Write 84 as sum of:	0	64	0	16	0	4	0	0

Select only leftmost 4:	0	64	0	16

Add to find the result: 80

Example 4: find the first and last address in the block if one of the addresses is 140.120.84.24/20.

Answer: The **first** address is **140.120.80.0/20** (set all bits of host part to 0)
The **last** address is **140.120.95.255/20** (set all bits of host part to 1)

Another way to find the last address:

Add the **mask complement** to the **beginning address** to find the **last address**.

```
      140 . 120 . 80 .   0
        0 .   0 . 15 . 255
      -----------------------------
      140 . 120 . 95 . 255
```

Example 5: Find the block if one of the addresses is 190.87.140.202/29.

Solution: To find the **first** address, we notice that the mask (/29) has five 1s in the last byte.

So write the last byte as powers of 2 and retain only the leftmost five:

202	➡ **128 + 64 + 0 + 0 + 8 + 0 + 2 + 0**
The leftmost 5 numbers are ➡	**128 + 64 + 0 + 0 + 8**
The first address is **190.87.140.200/29**	

The number of addresses is 2^{32-29} or 8.

To find the last address, use the complement of the mask. The mask has twenty-nine 1s; the complement has three 1s. The complement is 0.0.0.7. Add this to the first address to get 1**90.87.140.207/29**. So, the first address is 190.87.140.200/29, the last address is 190.87.140.207/29. There are only 8 addresses in this block.

Previous Example: Network Configuration

Network Organization

190.87.140.201/29

190.87.140.202/29

190.87.140.203/29

190.87.140.204/29

190.87.140.205/29

190.87.140.206/29

190.87.140.207/29
(Special Address)

Network Address **190.87.140.200/29**

Block: 8 Addresses

190.87.140.200/29

190.87.140.207/29
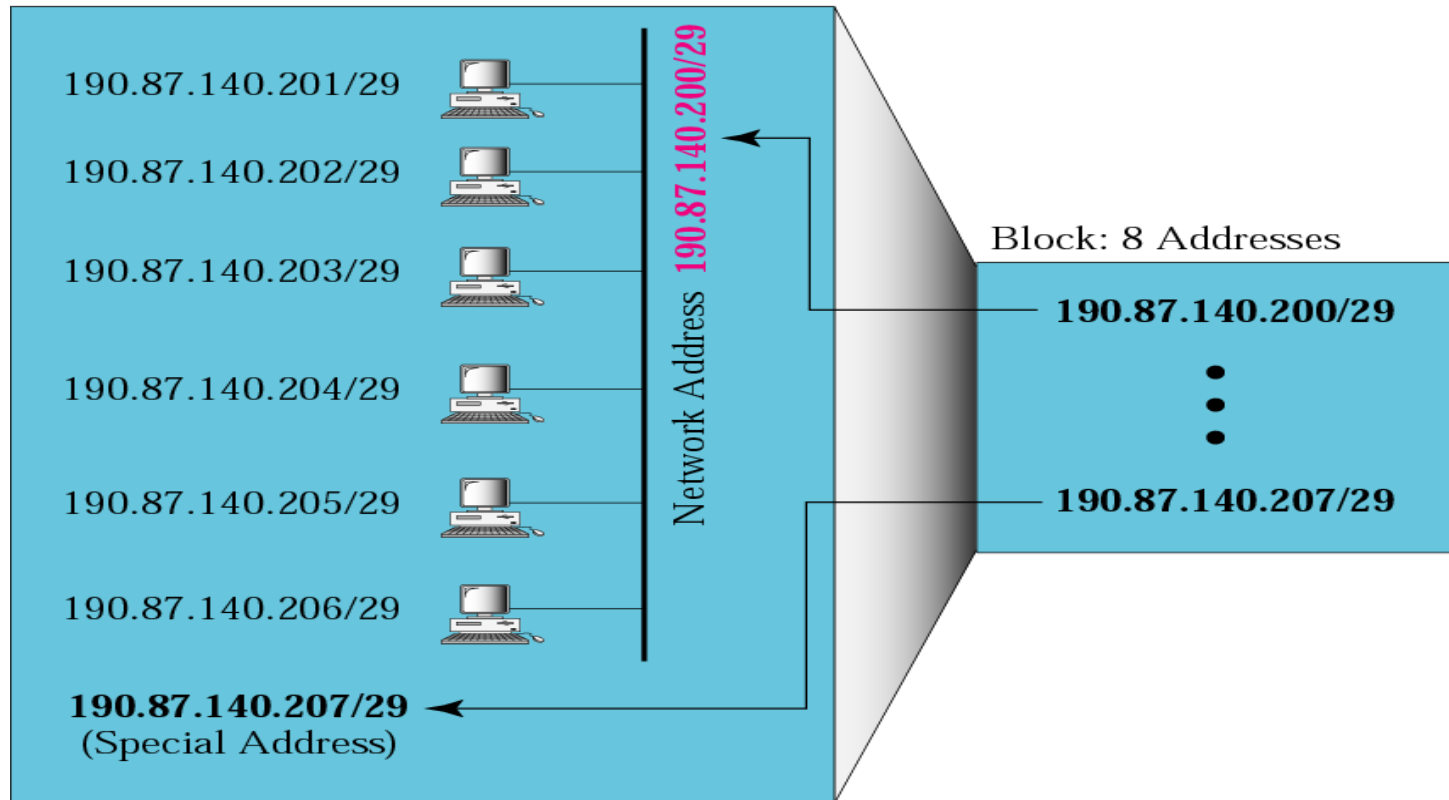
In classless addressing, the last address in the block does not necessarily end in 255.

➢In classless addressing, an address can belong to many blocks (depending on value of prefix associated with that block).

➢For example, consider the address **230.8.24.56**

➢It can belong to many blocks

Prefix length	Block	
	From	To
16	230.8.0.0	230.8.255.255
20	230.8.16.0	230.8.31.255
26	230.8.24.0	230.8.24.63
27	230.8.24.32	230.8.24.63
29	230.8.24.56	230.8.24.63
31	230.8.24.56	230.8.24.57

Variable Length Subnet Mask (VLSM)

➢ VLSM is a way of further sub-netting a subnet.

➢ we can allocate IPv4 addresses to the subnets by the exact need by using VLSM

➢ VLSM allows us to use more than one subnet mask within the same network address space.

➢ In classful addressing, we can divide a network only into subnets with equal number of IPv4 addresses.

➢ VLSM allows to create subnets from a single network with unequal number of IPV4 addresses
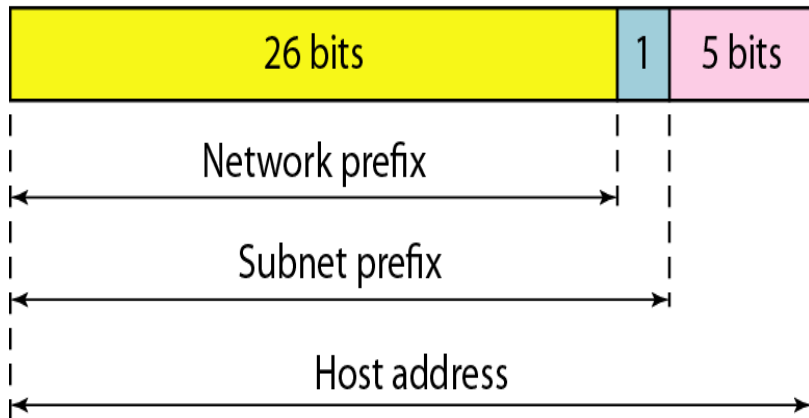
Variable Length Subnet Mask (VLSM)

➢ Suppose we want to divide 192.168.10.0 (a Class C network) into four networks each with unequal number of address as per the following requirements:

      Subnet A : 126 IPv4 Addresses.
      Subnet B : 62 IPv4 Addresses.
      Subnet C : 30 IPv4 Addresses.
      Subnet D : 30 IPv4 Addresses.

➢ Such division is not possible in classful addressing, since it divides the network equally,

➢ **but it is possible with VLSM.**

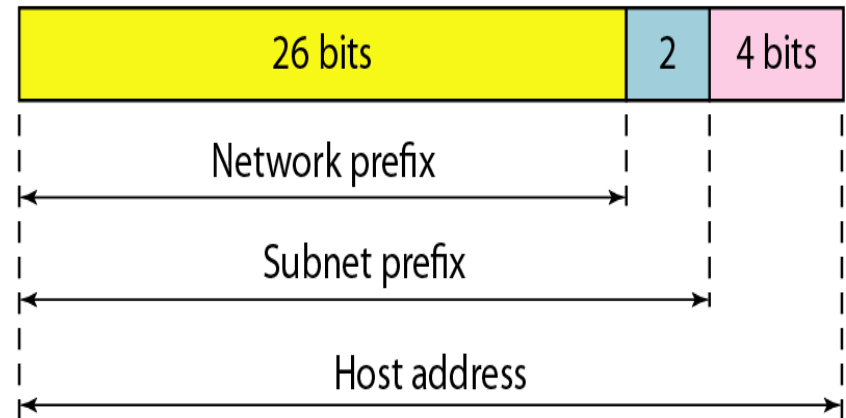# Two-level hierarchy in an IPv4 address
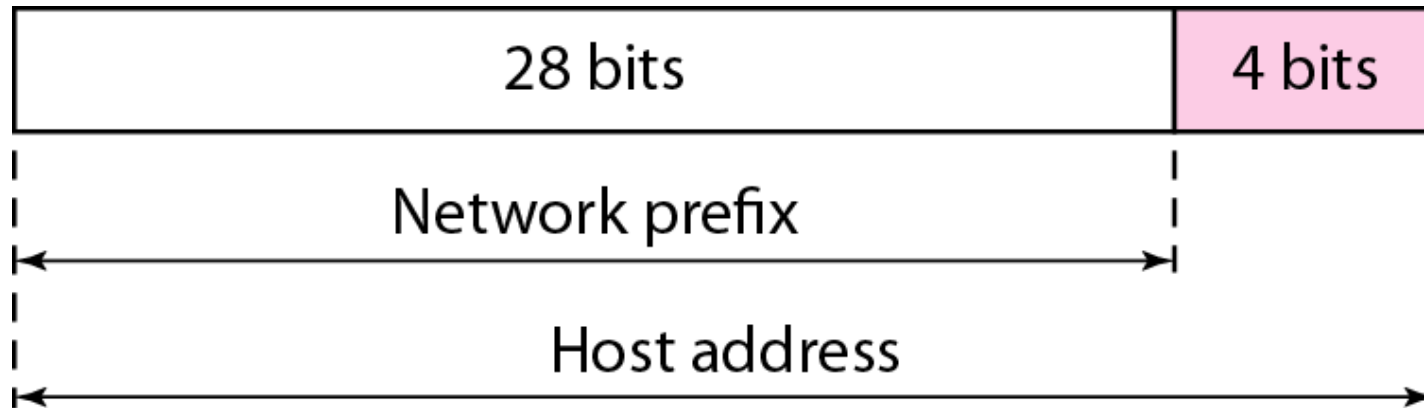
Three-level hierarchy in an IPv4 address

Variable Length Subnet Mask (VLSM)

Division of **192.168.10.0/24 (original network)** into four networks **with VLSM.**

FIRST DIVISION

▪ Divide into two networks equally with 128 addresses (126 usable) using subnet mask 255.255.255.128

1. 192.168.10.0/25 [255.255.255.128]
   ➤ 11000000.10101000.00001010.00000000 [in binary]
   11111111.11111111.11111111.10000000 [subnet mask]

2. 192.168.10.128/25 [255.255.255.128]
   ➤ 11000000.10101000.00001010.10000000
   11111111.11111111.11111111.10000000 [subnet mask]

Variable Length Subnet Mask (VLSM)

SECOND DIVISION

- Divide second subnet 192.168.10.128/25 (obtained from first division) again into two networks,

- Each with 64 addresses (62 usable) using subnet mask 255.255.255.192

  1. 192.168.10.128/26 [255.255.255.192]

     ➢ 11000000.10101000.00001010.10000000 [in binary]
       11111111.11111111.11111111.11000000 [subnet mask]

  2. 192.168.10.192/26 [255.255.255.192]

     ➢ 11000000.10101000.00001010.11000000
       11111111.11111111.11111111.11000000 [subnet mask]

Variable Length Subnet Mask (VLSM)

THIRD DIVISION

- Divide second subnet 192.168.10.192/26 (obtained from second division) again into two networks,
- each with 32 addresses (30 usable) using subnet mask 255.255.255.224

    1. 192.168.10.192/27 [255.255.255.224]
        ➢ 11000000.10101000.00001010.11000000   [in binary]
          11111111.11111111.11111111.11100000   [subnet mask]

    2. 192.168.10.224/27 [255.255.255.224]
        ➢ 11000000.10101000.00001010.11100000
          11111111.11111111.11111111.11100000   [subnet mask]

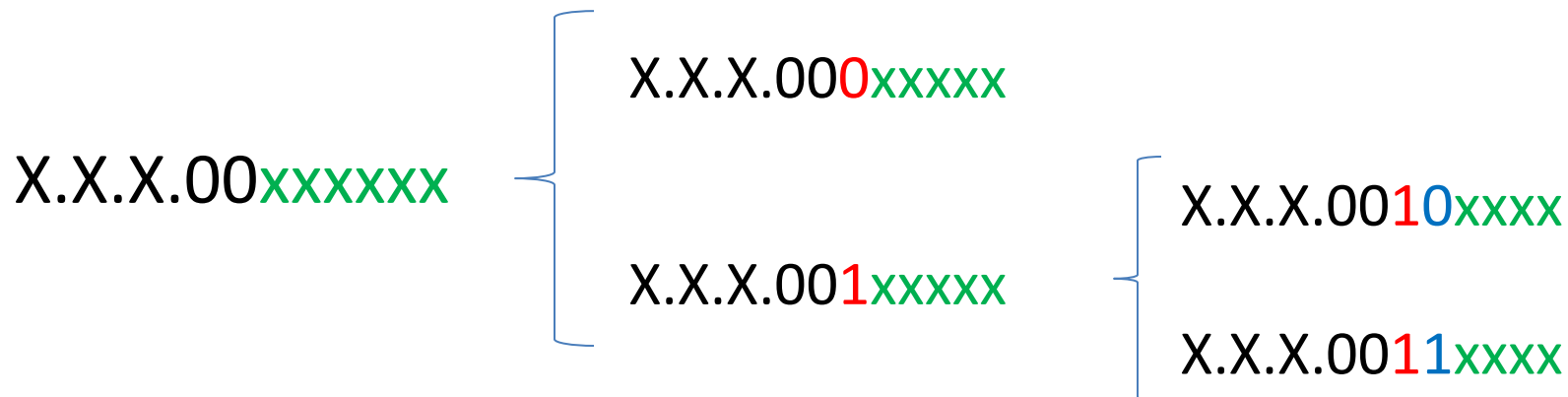- So, splitting of 192.168.10.0/24 into four subnets using VLSM with unequal number of addresses is done

Example 2:

An organization is granted a block of addresses starting with 17.12.14.0/26 (64 addresses).

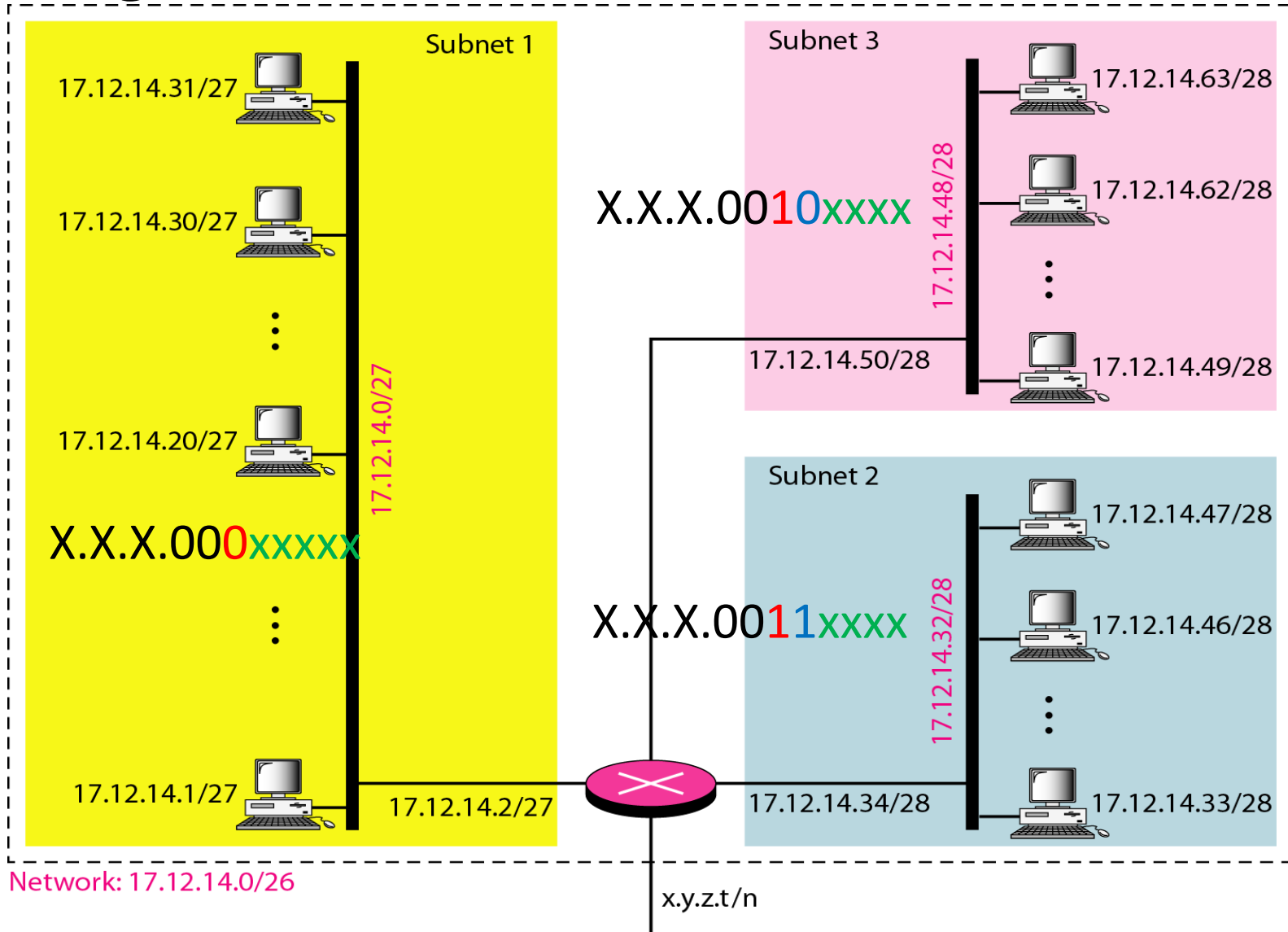The organization needs to have three sub-blocks of addresses to use in its three subnets:
- one sub-block of 32 addresses, and
- two sub-blocks of 16 addresses each.

Design the sub-blocks and find out how many addresses are still available after these allocations.

X.X.X.00xxxxxx

X.X.X.000xxxxx

X.X.X.001xxxxx

X.X.X.0010xxxx

X.X.X.0011xxxx

Solution of Example 2:
Configuration and addresses in a sub-netted network

Subnet 1

17.12.14.31/27

17.12.14.30/27

17.12.14.20/27

17.12.14.0/27

X.X.X.000xxxxx

17.12.14.1/27

17.12.14.2/27

Subnet 3

17.12.14.63/28

17.12.14.62/28

X.X.X.0010xxxx

17.12.14.48/28

17.12.14.50/28

17.12.14.49/28

Subnet 2

17.12.14.47/28

17.12.14.32/28

X.X.X.0011xxxx

17.12.14.46/28

17.12.14.34/28

17.12.14.33/28

Network: 17.12.14.0/26

x.y.z.t/n

Example 3:

An organization is granted a block of addresses starting with 14.24.74.0/24.

The organization needs to have three sub-blocks of addresses to use in its three subnets:
- one sub-block of 10 addresses,
- one sub-block of 60 addresses, and
- one sub-block of 120 addresses.

Design the sub-blocks and find out how many addresses are still available after these allocations.

Solution to Example 3:
There are $2^{32-24} = 256$ addresses in this block. The first address is 14.24.74.0/24 and last address is 14.24.74.255/24 .

Assign addresses to sub-blocks starting with the largest and ending with the smallest one.

➢ Mask n1 for the **first** (largest) subnet 2^{32-n1} must be 128 (a number with power of 2 nearest to 120). **So n1 = 25.** We allocate 128 addresses instead of 120 to this subnet

    ➢The first address in this subnet is 14.24.74.0/25 and last address is 14.24.74.127/25

Solution (previous example 3 continue)

➤ Mask for the **second subnet** 2^{32-n2} must be 64 (a number with power of 2 nearest to 60). **So n2 = 26**

    ➤ The first address in this subnet is 14.24.74.128/26 and last address is 14.24.74.191/26

➤ Mask for the **third subnet** 2^{32-n3} must be 16 (a number with power of 2 nearest to 10). So **n3 = 28**

    ➤ The first address in this subnet is 14.24.74.192/28 and last address is 14.24.74.207/28

➤ So we have 128+64+16 = 208 addresses in all three sub-blocks.

    ➤ Therefore, 48 address are still left in reserve.

Example

An ISP is granted a block of addresses starting with 190.100.0.0/16 (65,536 addresses). 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 sub-blocks and find out how many addresses are still available after these allocations.

Example (continued)

Solution

Group 1

For this group, each customer needs 256 addresses.
This means that 8 ($\log_2 256$) bits are needed to define each host.
The prefix length is then 32 − 8 = 24.

Example (continued)

X.X.00000000.x

X.X.00000001.x

...

X.X.00111111.x

...

Solution

Group 1: 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

Example (continued)

X.X.*01000000*.*0*-------
X.X.*01000000*.*1*-------
...
X.X.*01111111*. *0*-------
X.X.*01111111*. *1*------
...

Group 2

For this group, each customer needs 128 addresses. This means that 7 ($\log_2 128$) bits are needed to define each host. 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 = $128 \times 128 = 16,384$		

Example (continued)

Group 3

For this group, each customer needs 64 addresses. This means that 6 ($log_2 64$) bits are needed to each host. The prefix length is then $32 - 6 = 26$. The addresses are

Example (continued)

X.X.10000000.00------
X.X.10000000.01------
X.X.10000000.10------
X.X.10000000.11------
...
X.X.10011111. 10-------
X.X. 10011111. 11-------
...

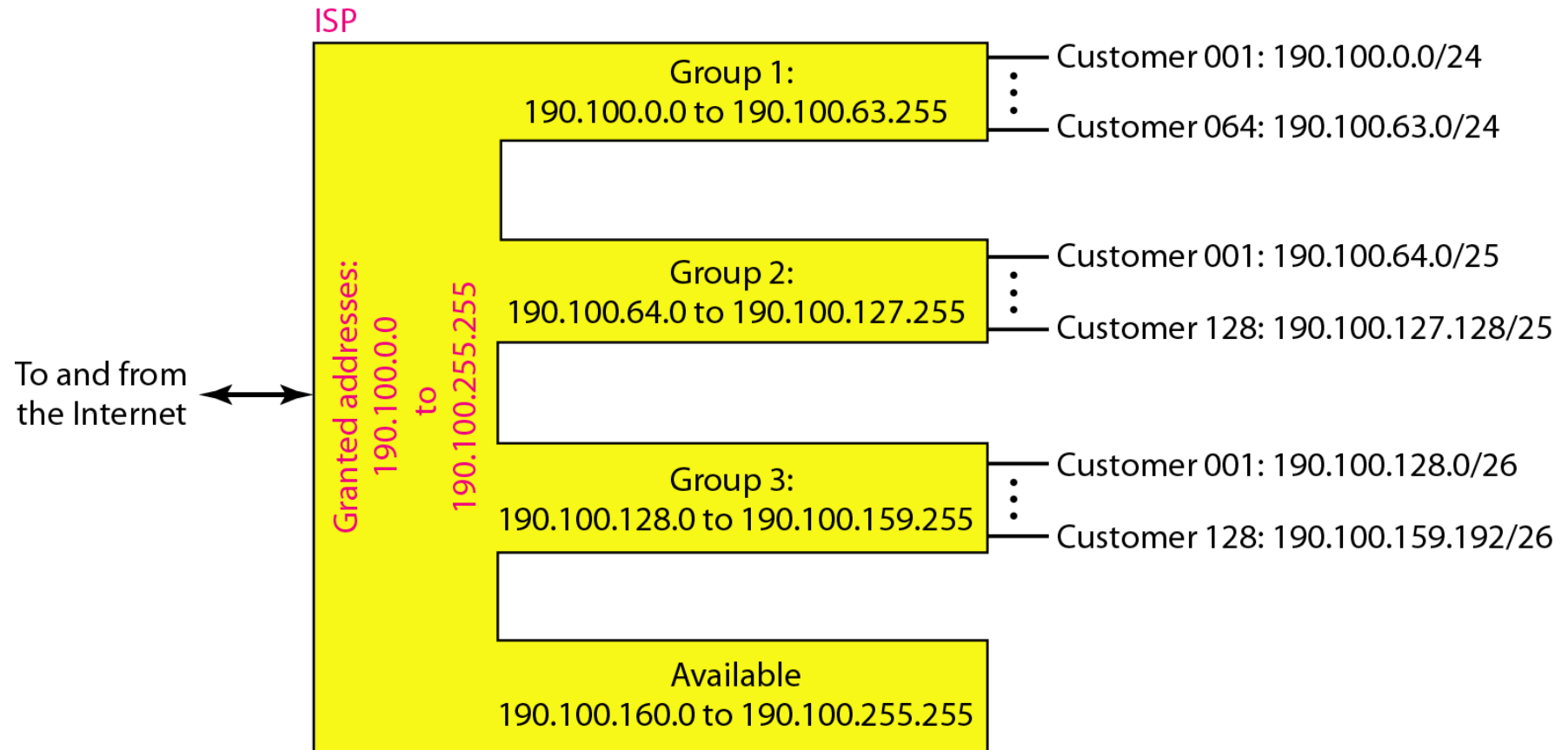|		
1st Customer:	190.100.128.0/26	190.100.128.63/26
2nd Customer:	190.100.128.64/26	190.100.128.127/26
. . .		
128th Customer:	190.100.159.192/26	190.100.159.255/26
Total = 128 × 64 = 8192		

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

Figure: An example of address allocation and distribution by an ISP

Address depletion and IPv6

Classless addressing is a short term solution to solve the address depletion problem

➢ Uses the same address space but change the distribution of addresses to provide a fair share to each organization.

➢ Still uses the IPv4 addresses (class privilege was removed from the distribution)

Address depletion and IPv6

➢ Despite all short-term solutions, address depletion is still a long-term problem for the Internet.

➢ This and other problems in the IP protocol itself have been the motivation for already devised **IPv6**.
   ➢ **The long-range** solution
   ➢ The larger address space is obtained by **increasing the length of IP addresses** (128 bits)

➢ It means that **format of IP** packets need to be changed

IPv6 ADDRESSES

128 bits = 16 bytes = 32 hex digits

| 1111110111101100 | ... | 1111111111111111 |

FDEC : 0074 : 0000 : 0000 : 0000 : B0FF : 0000 : FFFF

Abbreviated IPv6 addresses

Original

| FDEC | : | 0074 | : | 0000 | : | 0000 | : | 0000 | : | B0FF | : | 0000 | : | FFF0 |

Abbreviated

| FDEC | : | 74 | : | 0 | : | 0 | : | 0 | : | B0FF | : | 0 | : | FFF0 |

More abbreviated

| FDEC | : | 74 | :: | B0FF | : | 0 | : | FFF0 |

Gap
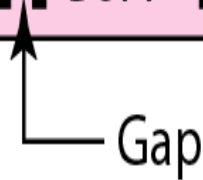
EXAMPLE

Expand the address 0:15::1:12:1213 to its original.

Solution

We first need to align

➢ the left side of the double colon to the left of the original pattern and

➢ the right side of the double colon to the right of the original pattern

in order to find how many 0s we need to replace the double colon.

```
XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX
 0:   15:                    :    1:   12:1213
```

This means that the original address is.

```
0000:0015:0000:0000:0000:0001:0012:1213
```