IP Addressing

By Amit Patel

IP Address

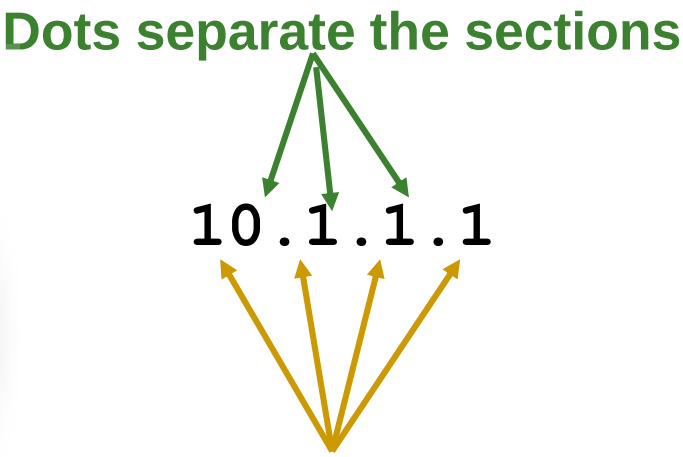
- A Unique **32-bit address.**
- **Used by** computers to communicate over a computer network.
- **Known as : Logical Address**
- It is a software address assigned to each machine on network.
- **Why Need? : Necessary for Universal communication services that are independent of underlying networks.**
- **Used In : Universal Addressing System**
- **Universal Addressing System** is one where each host can be identified uniquely regardless of the underlying physical network.

IP Address

- Used at **Network layer** of OSI Model.
- Designed to allow a host on one network to communicate with host on a different network.
- We can **change IP Address** but **can't change MAC Address** because it is hard coded on NIC.

IP Address

- IP addresses are written in *dotted* ***Decimal*** format and **Binary** format.
- **Four sections** are separated by dots.
- Each section contains a number between 0 to 255.
- Each section is known as **OCTET.**



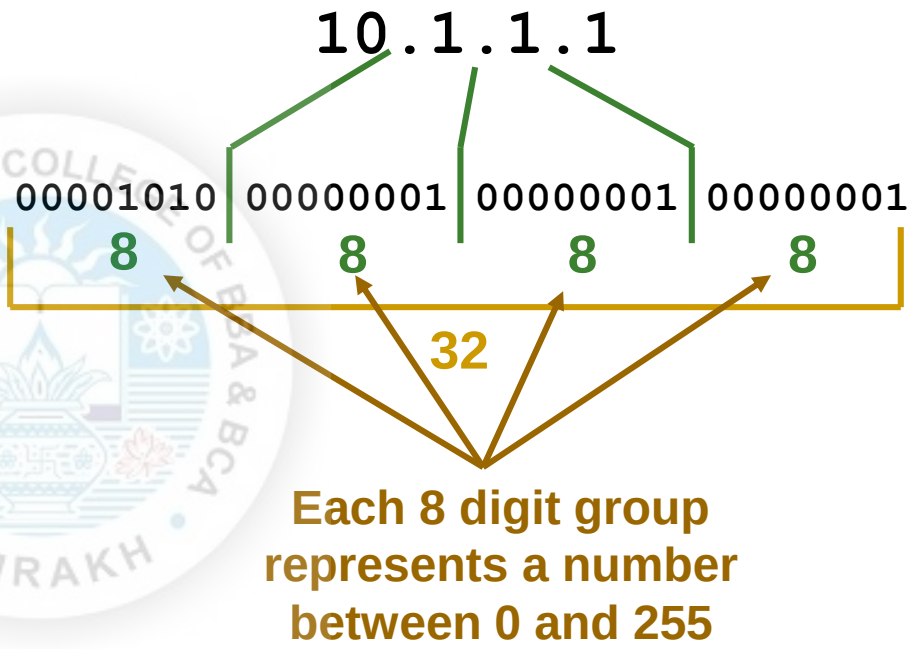
00001010. 00000001 .0000001. 00000001

IP Addressing

- **Why is each section a number between 0 and 255?**
  - Computers operate in binary, humans operate in decimal.
  - Computers treat IP addresses as a single large 32 digit binary number, but this is hard for people to do.
  - So, we split them up into four smaller sections so we can remember and work with them better

IP Addressing

- 32/4 == 8.
- But, computers number starting at 0, so to make a space of 256 numbers, we number from 0 to 255.



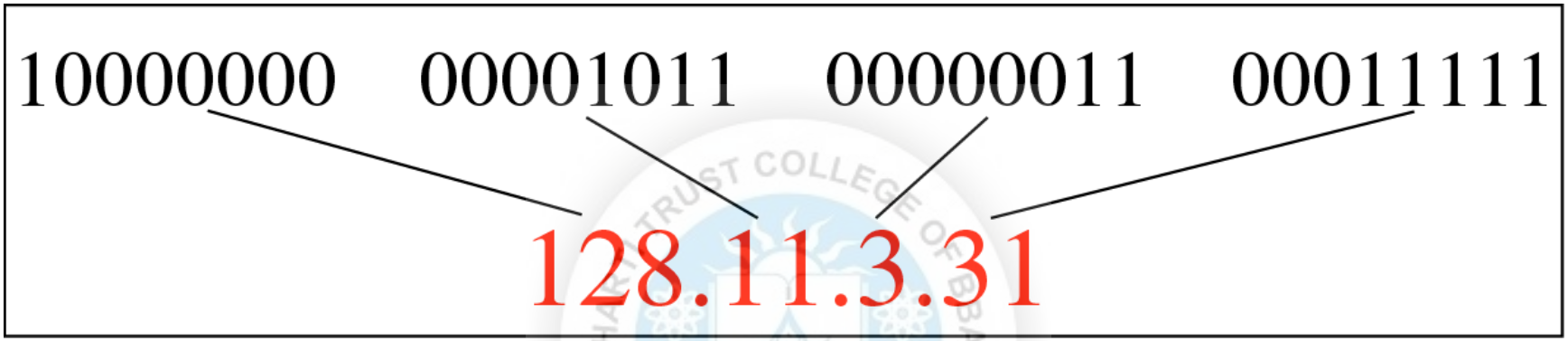
Address Space

- **Definition:** A protocol such as IPv4 that defines range of addresses which is also called as address space.
- An address space is the **total number of addresses** used by the protocol.
- The address space in a protocol That uses N-bits to define an address is: 2^N
- IPv4 uses **32-bit addresses**, which means that the address space is 2^{32} or 4,294,967,296 (more than **4 billion**).
- This means that, theoretically, more than 4 billion devices as mentioned above could be connected to the Internet.

IP Addressing

- Each IP address has two fundamental parts:
  - **Network Number or Address:**
    - Uniquely identify each network.
    - This number is common to all computers on the same network and define the network group the computer belong to.
  - **Host Number or Address:**
    - Consist number that are unique to each computer on the network.
    - Useful to uniquely identify each computer on the network.

IP Address



128.11 : Network Address

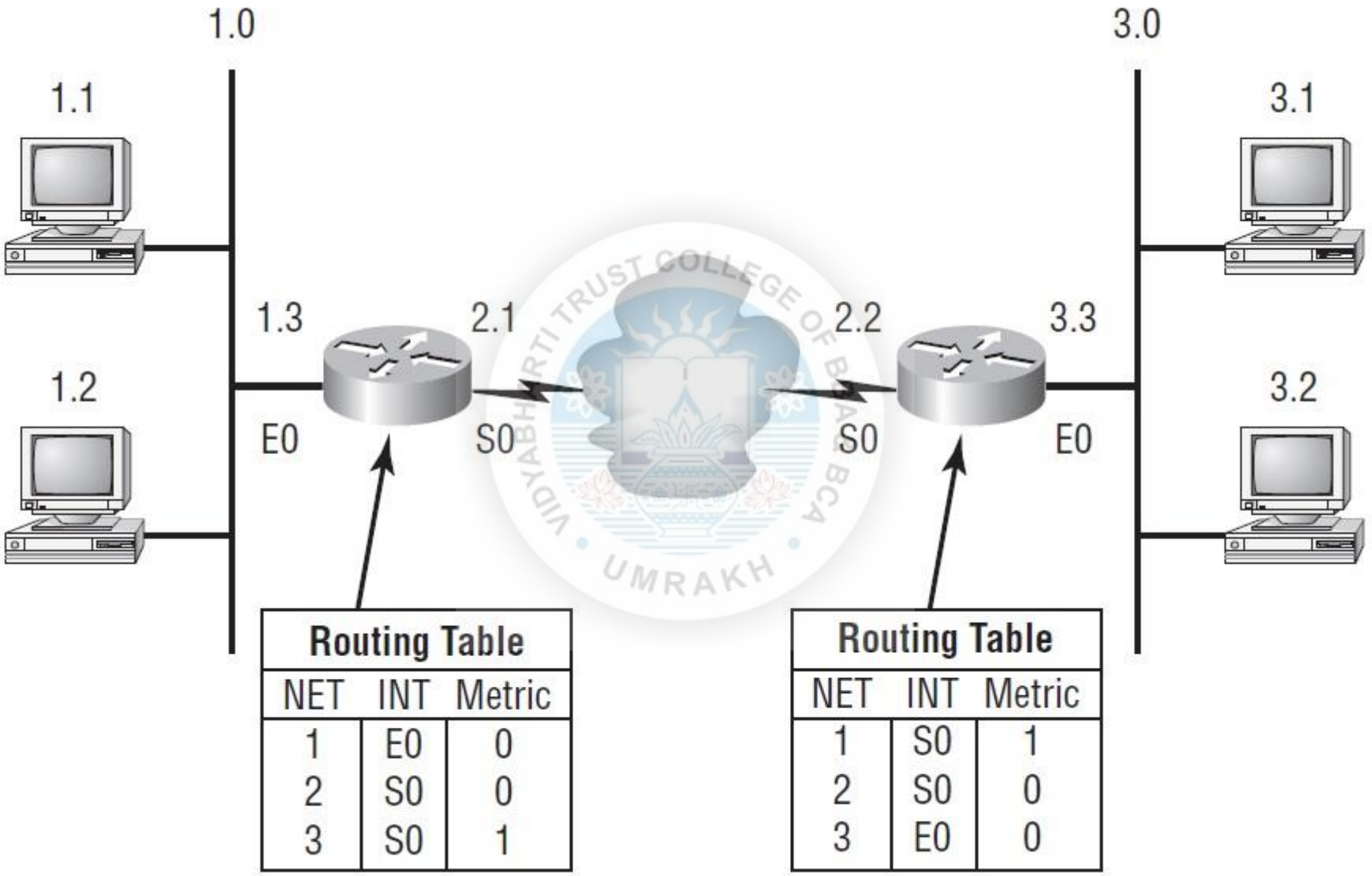
3.31 : Host Address

IP Addressing

- **It is structure or hierarchical Address.**
  - IP address is used in routing.
  - If every machine has unique address then all router on the internet would need to store the address of each and every machine on the internet.
  - This make router inefficient.
  - **Solution :** 32 bit is divided into two parts.
    - Network Address
    - Host Address

IP Address

- Benefit or Function of Hierarchical Scheme
  - Prevent Duplication of Address
  - Support modular design and scalability
  - Route aggregation.
  - Control access, monitor security and performance.



Routing Table

NET	INT	Metric
1	E0	0
2	S0	0
3	S0	1

Routing Table

NET	INT	Metric
1	S0	1
2	S0	0
3	E0	0

MAC vs IP address

MAC address	IP address
Functions at data link layer	Functions at network layer
It is a physical address	It is a logical address
It is fixed	It changes with the relocation of device from one network to another
It is a 48 bit address	It is a 32 bit address

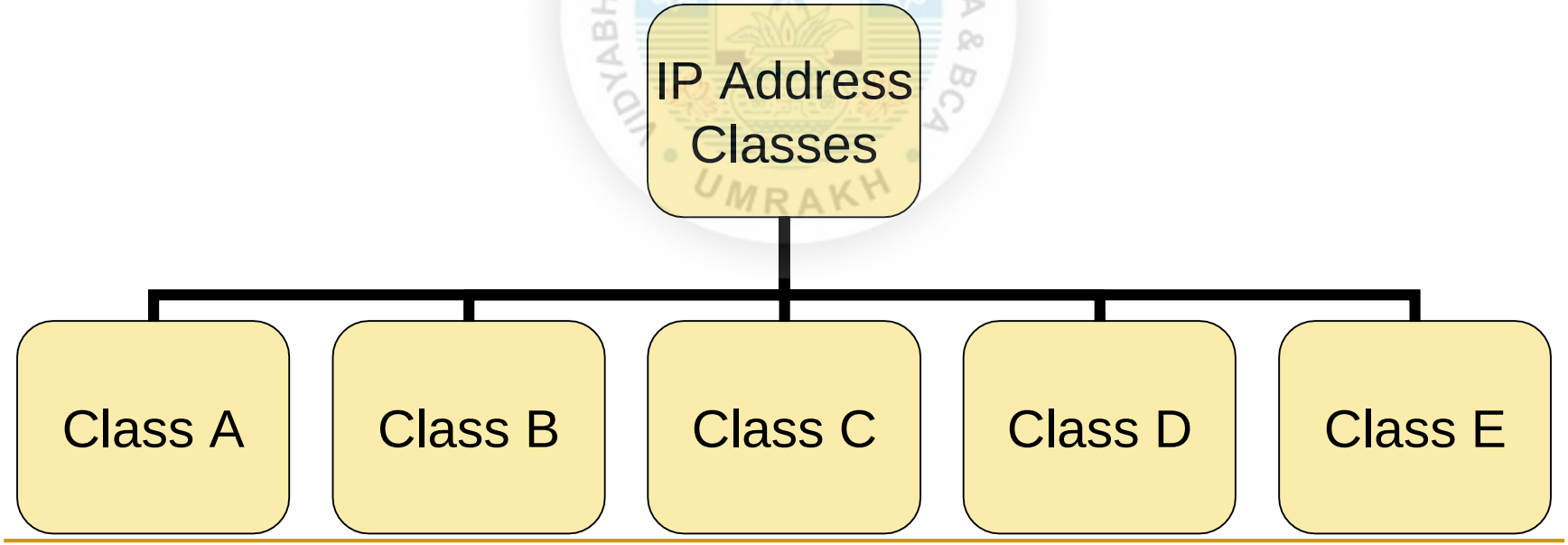
Classful Addressing

- IPv4 addressing **used the concept of classes**, this architecture is called classfull addressing.
- In classfull addressing, the address space is divided into five classes: A, B, C, D, and E.
- The class of an address defines which portion of the address identifies the Network number and which portion identifies the Host.
- If the address is given in binary notation, **the first few bits can immediately tell us the class of the address.**
- If the address is given in decimal-dotted notation, **the first byte defines the class.**

Classful IP Addressing - I

IP addresses are divided into classes so that they can be assigned to a particular business, government or other entity based on size and need.

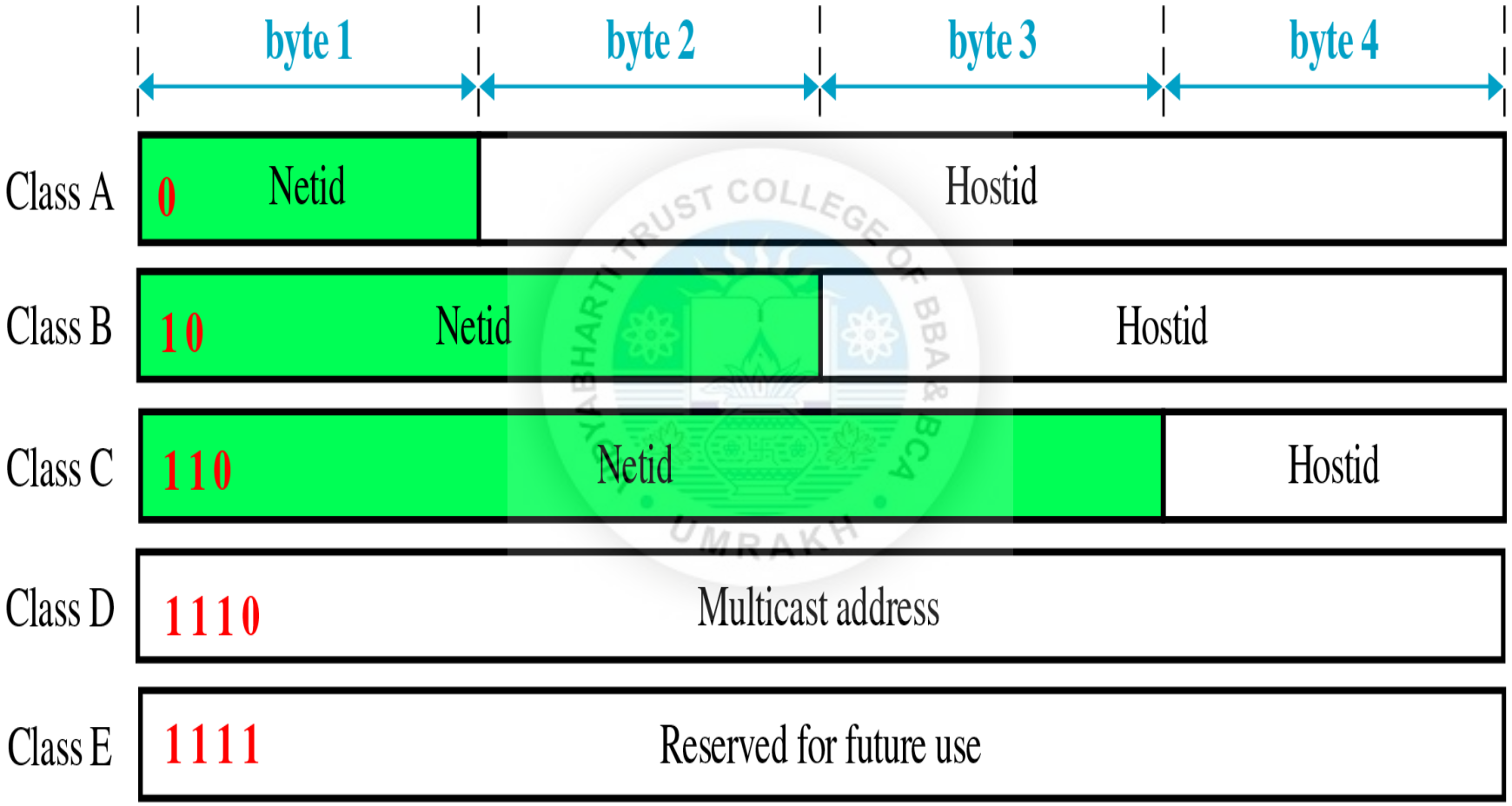
There are five IP classes plus certain special addresses



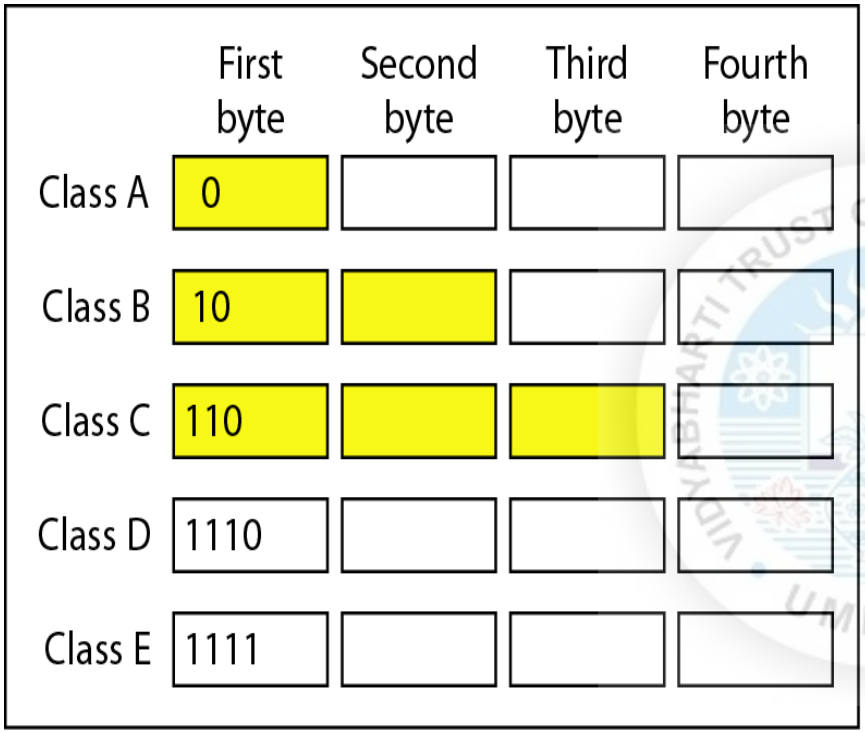
IP Address

An Internet address is made of four bytes (32 bits) that define a host's connection to a network.

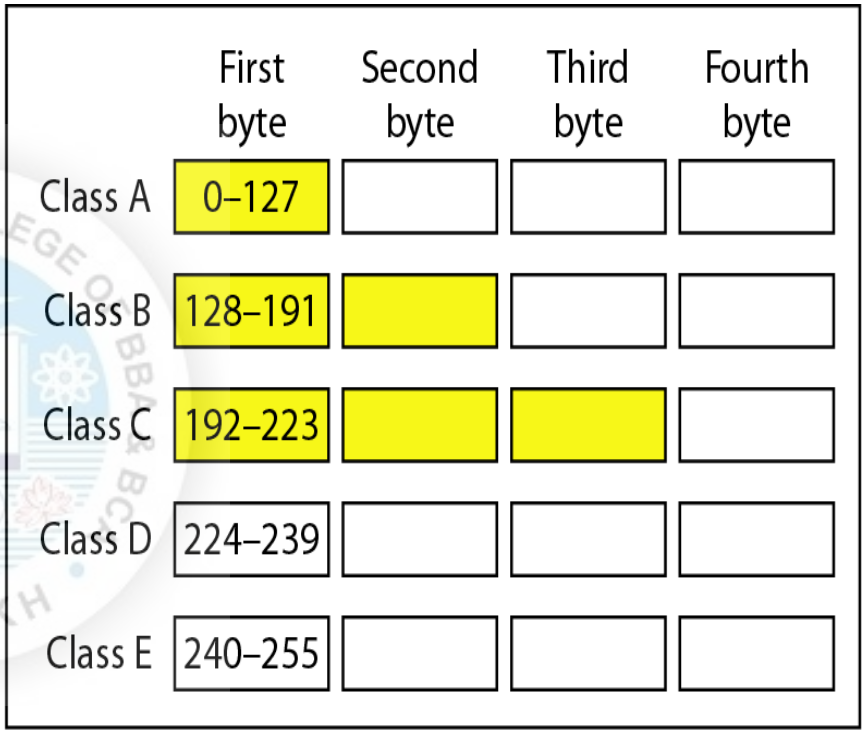
IP Address



Decimal – Binary Notation

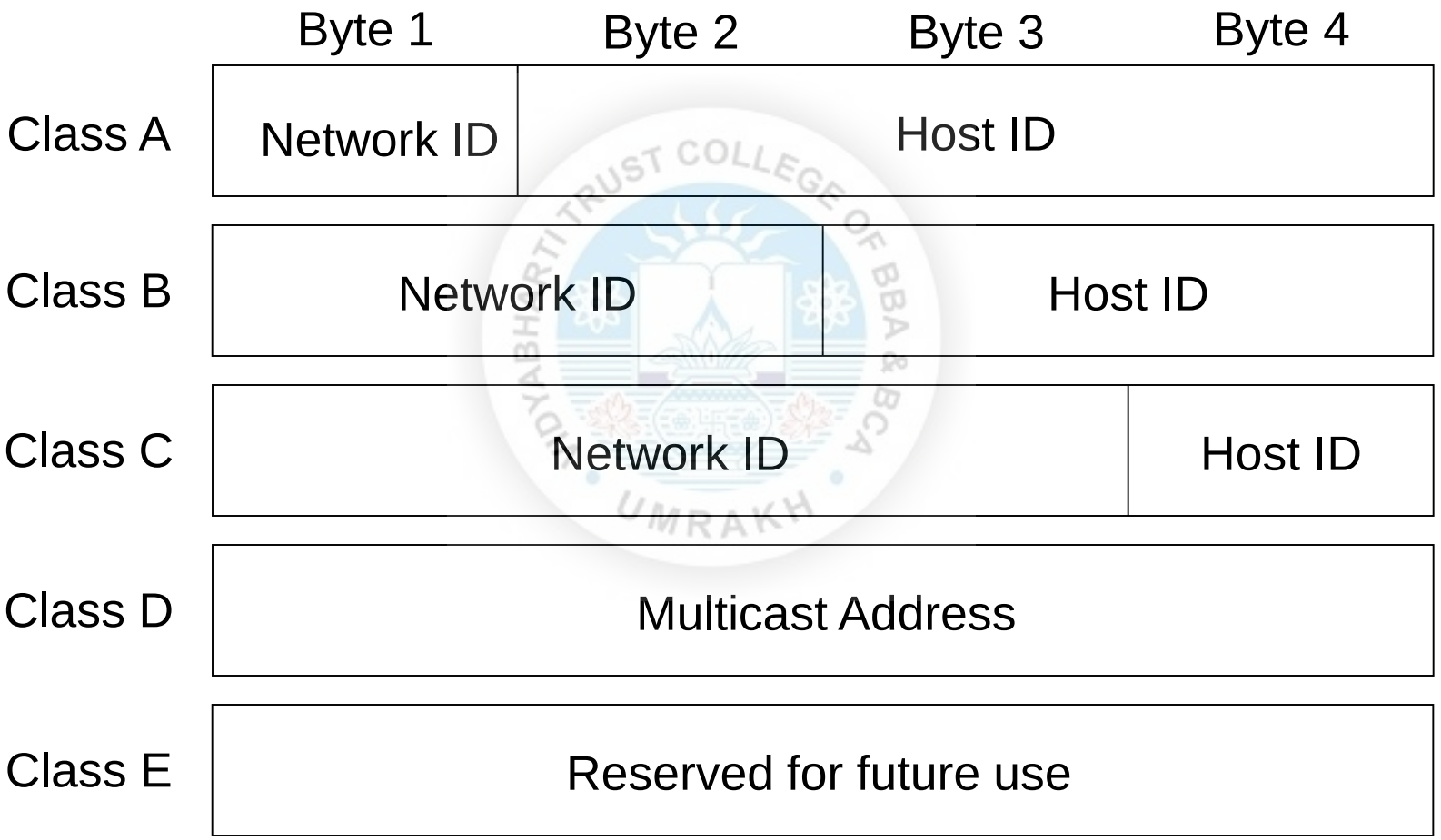


a. Binary notation

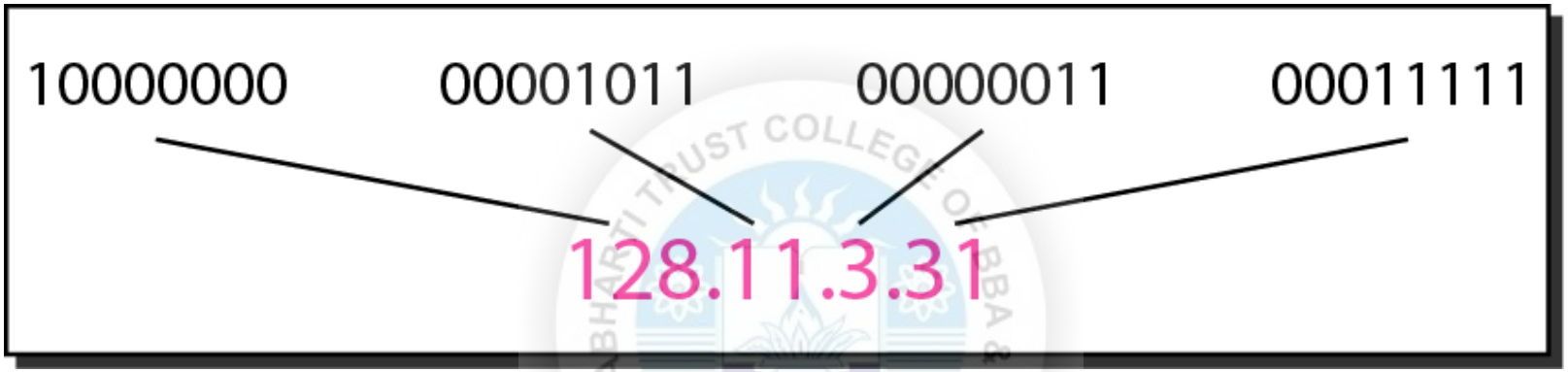


b. Dotted-decimal notation

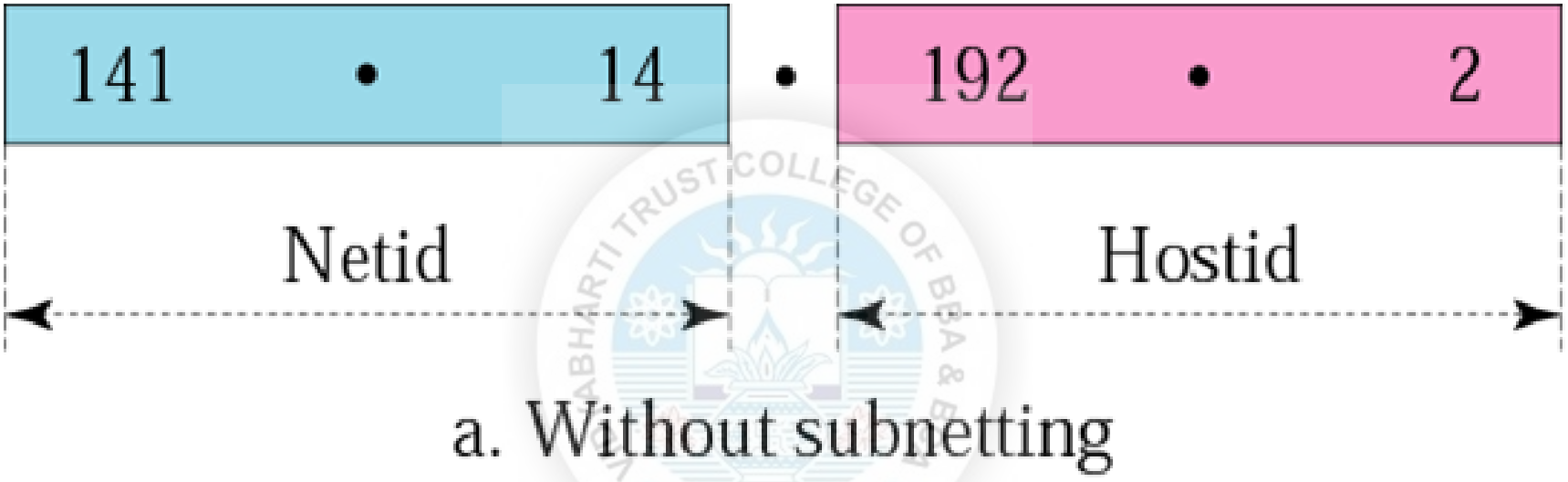
Classful IP Addressing - II



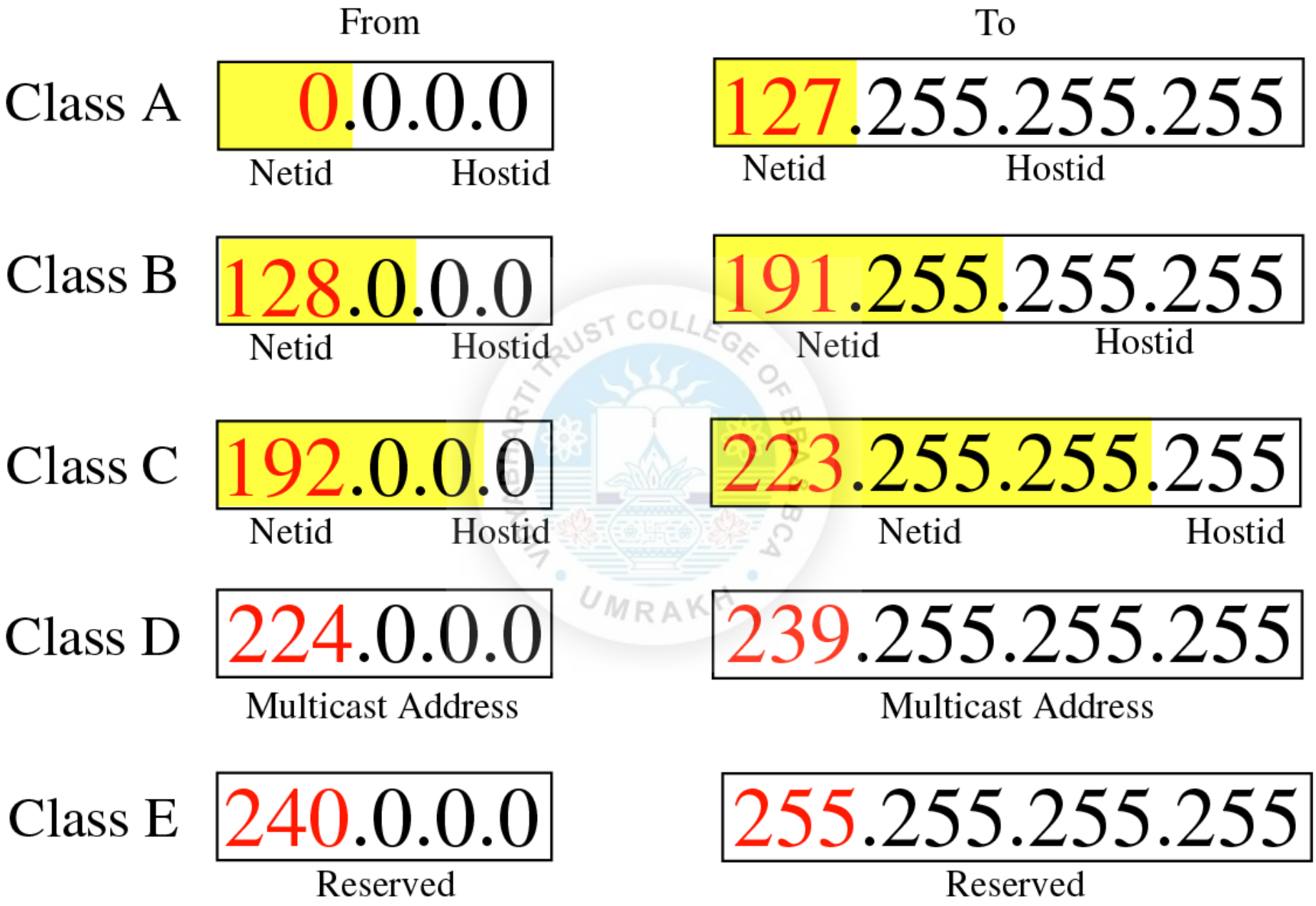
Find Class from IP Address

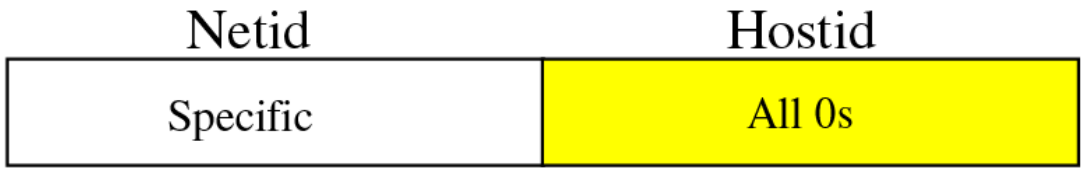


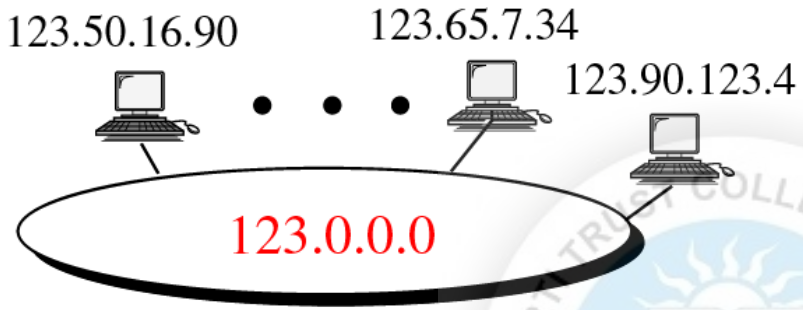
IP Address



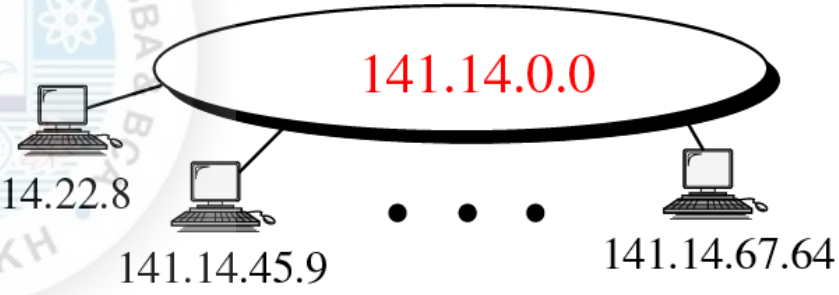
a. Without subnetting



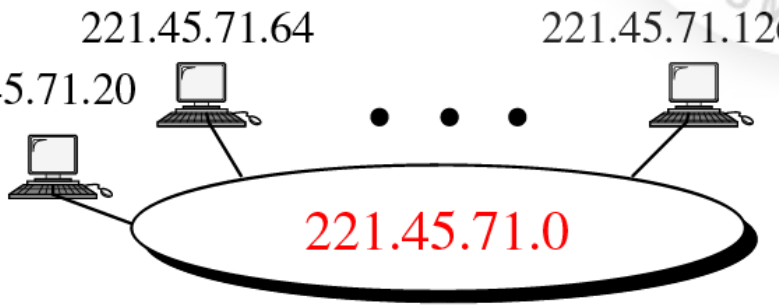




(a) Class A



(b) Class B



(c) Class C

Change Binary to Decimal Notation

Change the following IPv4 addresses from binary notation to dotted-decimal notation.

a. 10000001 00001011 00001011 11101111

b. 11000001 10000011 00011011 11111111

Solution

- ***We replace each group of 8 bits with its equivalent decimal number and add dots for separation.***

a. 129.11.11.239

b. 193.131.27.255

Find Error If Any

a. 111.56.045.78
b. 221.34.7.8.20
c. 75.45.301.14
d. 11100010.23.14.67

Solution

- *a. There must be no leading zero (045).*
- *b. There can be no more than four numbers.*
- *c. Each number needs to be less than or equal to 255.*
- *d. A mixture of binary notation and dotted-decimal notation is not allowed.*

Find Class of IP Address

Find the class of each address.

- *a.* 00000001 00001011 00001011 11101111
- *b.* 11000001 10000011 00011011 11111111
- *c.* 14.23.120.8
- *d.* 252.5.15.111

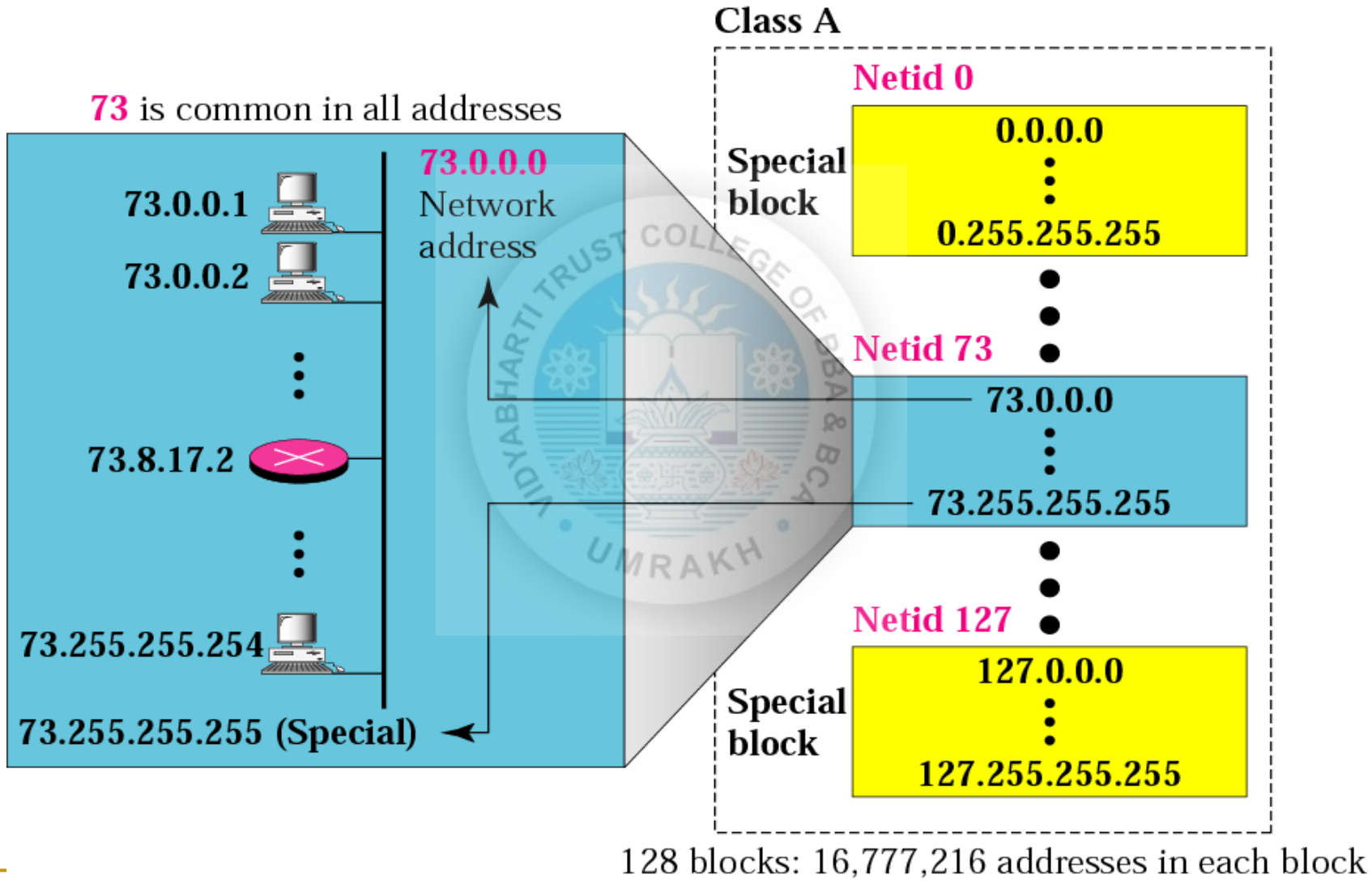
Solution

- *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.*

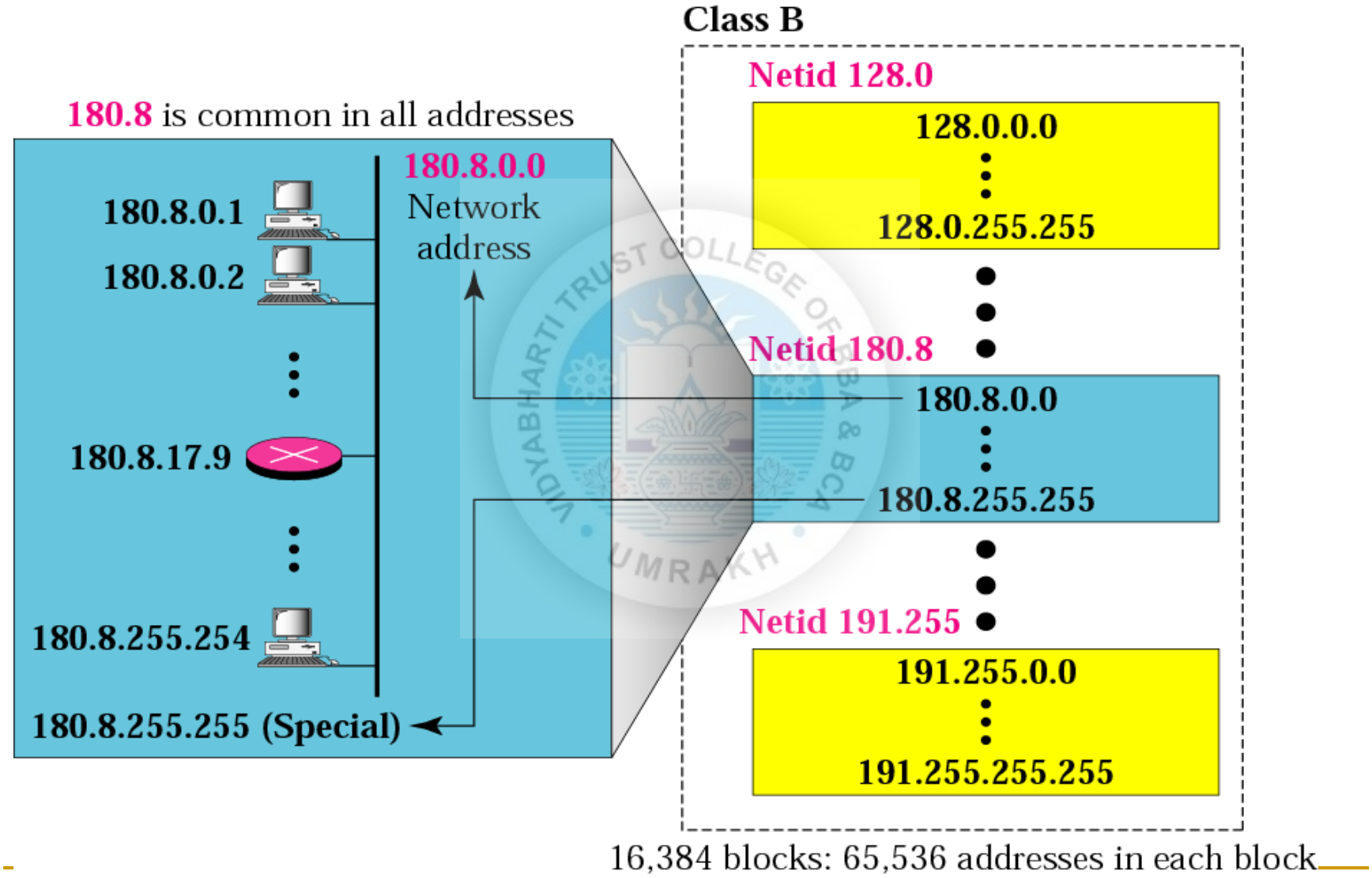
Address Per Classes

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%

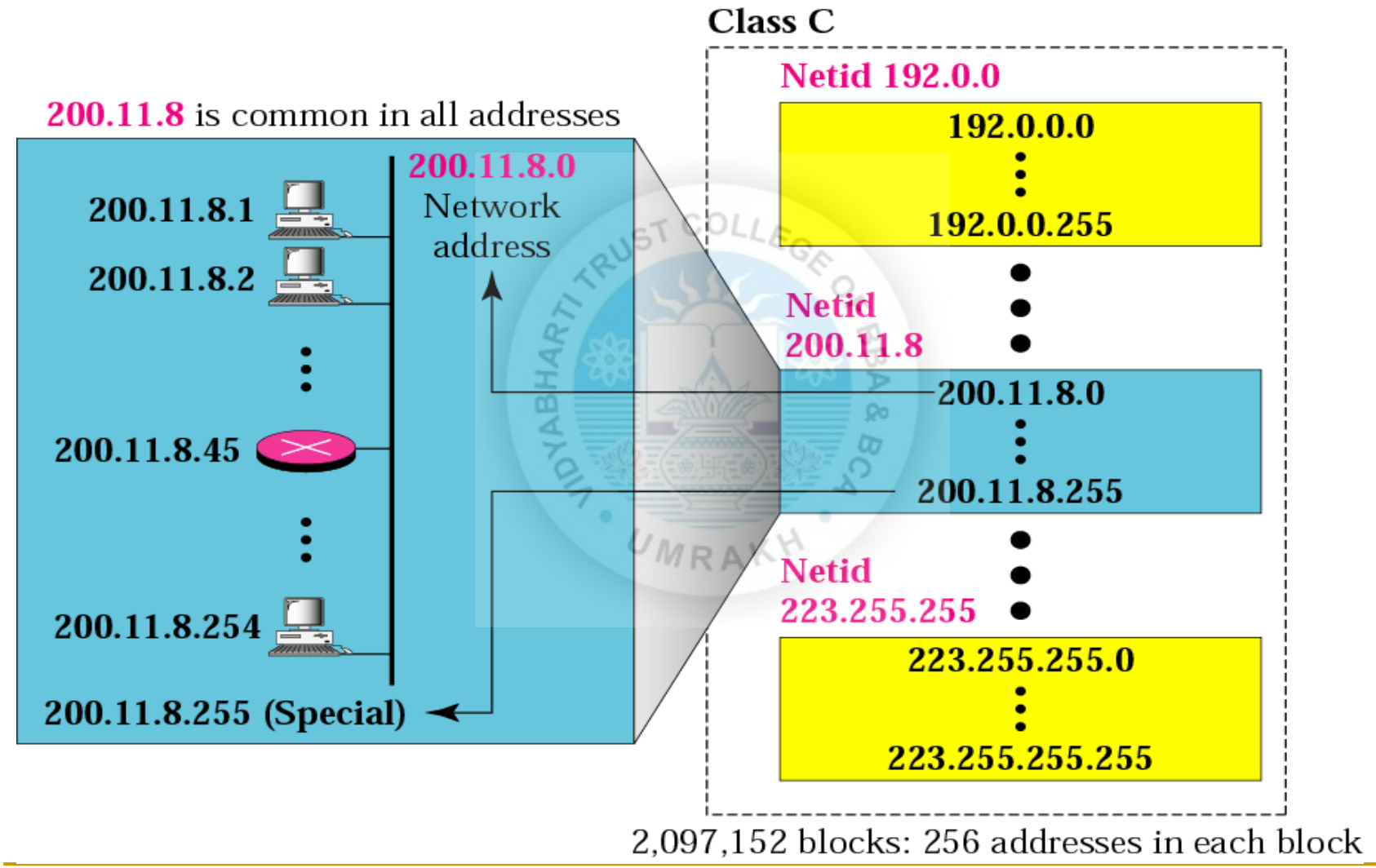
Class A : Available Net ID & Host ID



Class B : Available Net ID & Host ID



Class C : Available Net ID & Host ID



- Given the network address 17.0.0.0, find the class, the net id, and the range of the addresses.

- Given the network address 220.34.76.0, find the class, the net id, and the range of addresses

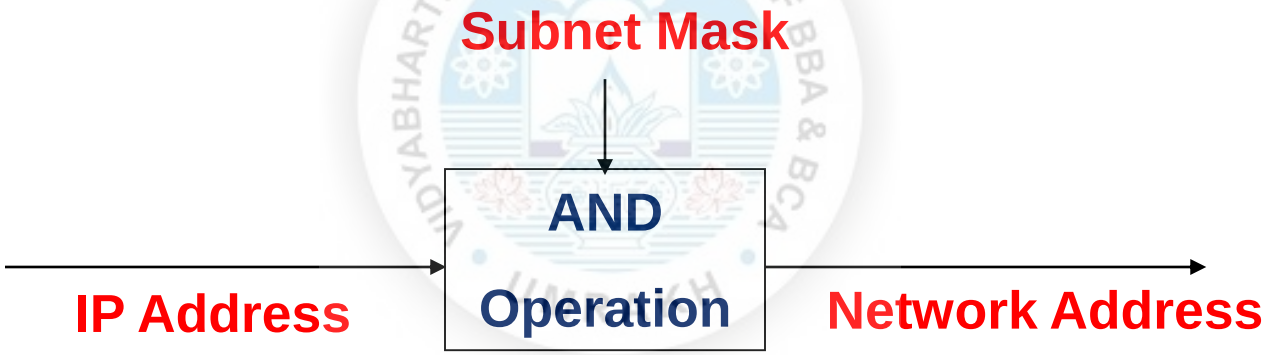
Solution

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

The class is C, the block is 220.34.76, and the range of addresses is 220.34.76.0 to 220.34.76.255

Subnet Mask

- Subnet mask is used to **differentiate Network ID and Host ID In IP.**
- Each class has **Default Subnet Mask in classful Addressing.**
- To differentiate , perform **AND** operation with IP Address and Subnet Mask.



"32 bit value that allow recipient of IP packets to distinguish the network id and host id portion of the IP Address."

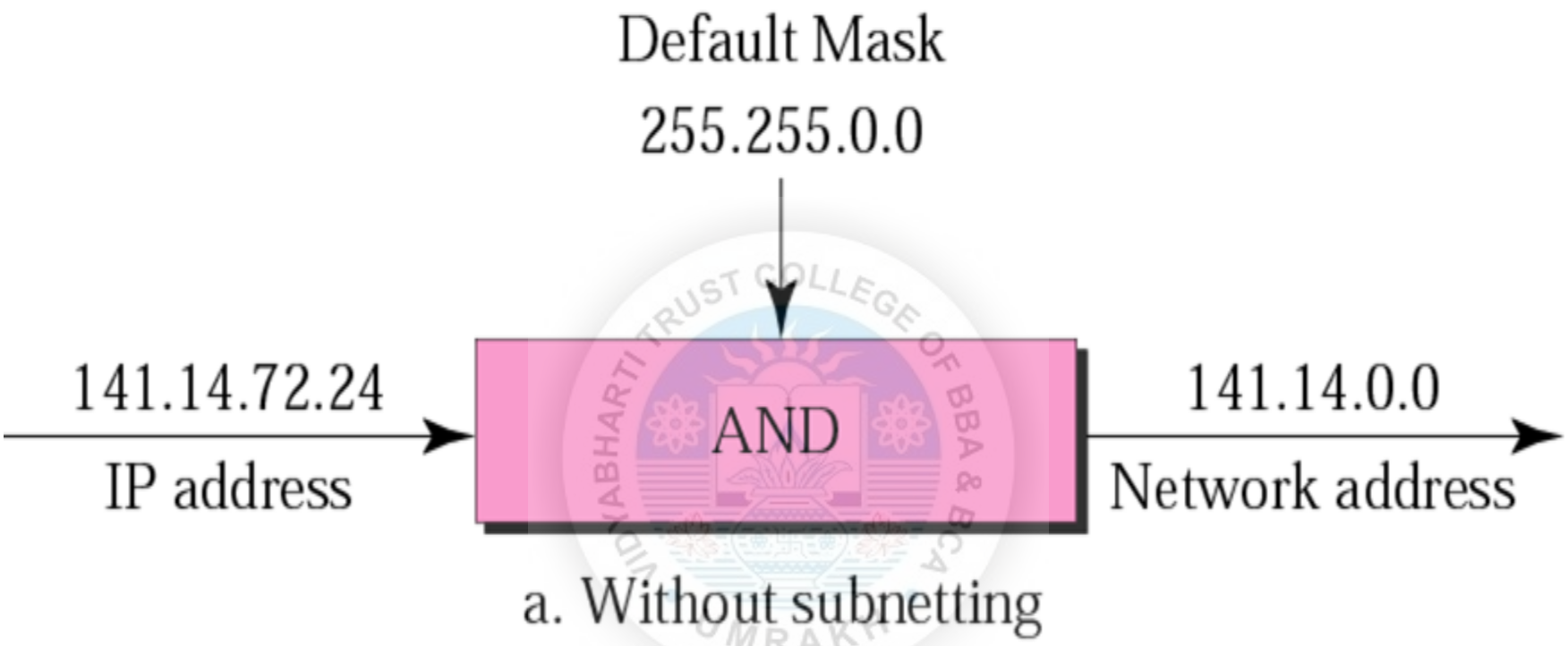
Default Subnet Mask

- Class A, B and C contains 1s in network ID fields for default subnet mask.
- The bits of the subnet mask are defined as follows:

  All bits that correspond to the **network ID are set to 1.**

  All bits that correspond to the **host ID are set to 0.**

Address Class	Bits Used for Subnet Mask				Dotted Decimal Notation
Class A	11111111	00000000	00000000	00000000	255.0.0.0
Class B	11111111	11111111	00000000	00000000	255.255.0.0
Class C	11111111	11111111	11111111	00000000	255.255.255.0



a. Without subnetting

Address Class	1st Octet Decimal Range	1st Octet High Order Bits	Network/Host ID (N=Network, H=Host)	Default Subnet Mask	Number of Networks	Hosts per Network (Usable Addresses)
A	1 – 126 *	0	N.H.H.H	255.0.0.0	126 (2^7 – 2)	16,777,214 (2^{24} – 2)
B	128 – 191	10	N.N.H.H	255.255.0.0	16,382 (2^{14} – 2)	65,534 (2^{16} – 2)
C	192 – 223	110	N.N.N.H	255.255.255.0	2,097,150 (2^{21} – 2)	254 (2^8 – 2)
D	224 – 239	1110	Reserved for Multicasting			
E	240 – 254	11110	Experimental; used for research			

** Class A address 127 cannot be used and is reserved for loopback and diagnostic functions.*

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

What is the network address if the destination address is 200.45.34.56 and the subnet mask is 255.255.255.0?

Solution

11001000	00101101	00100010	00111000
11111111	11111111	11111111	00000000
11001000	00101101	00100010	00000000

The network address is 200.45.34.0.

How to find Network ID?

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.

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.

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.

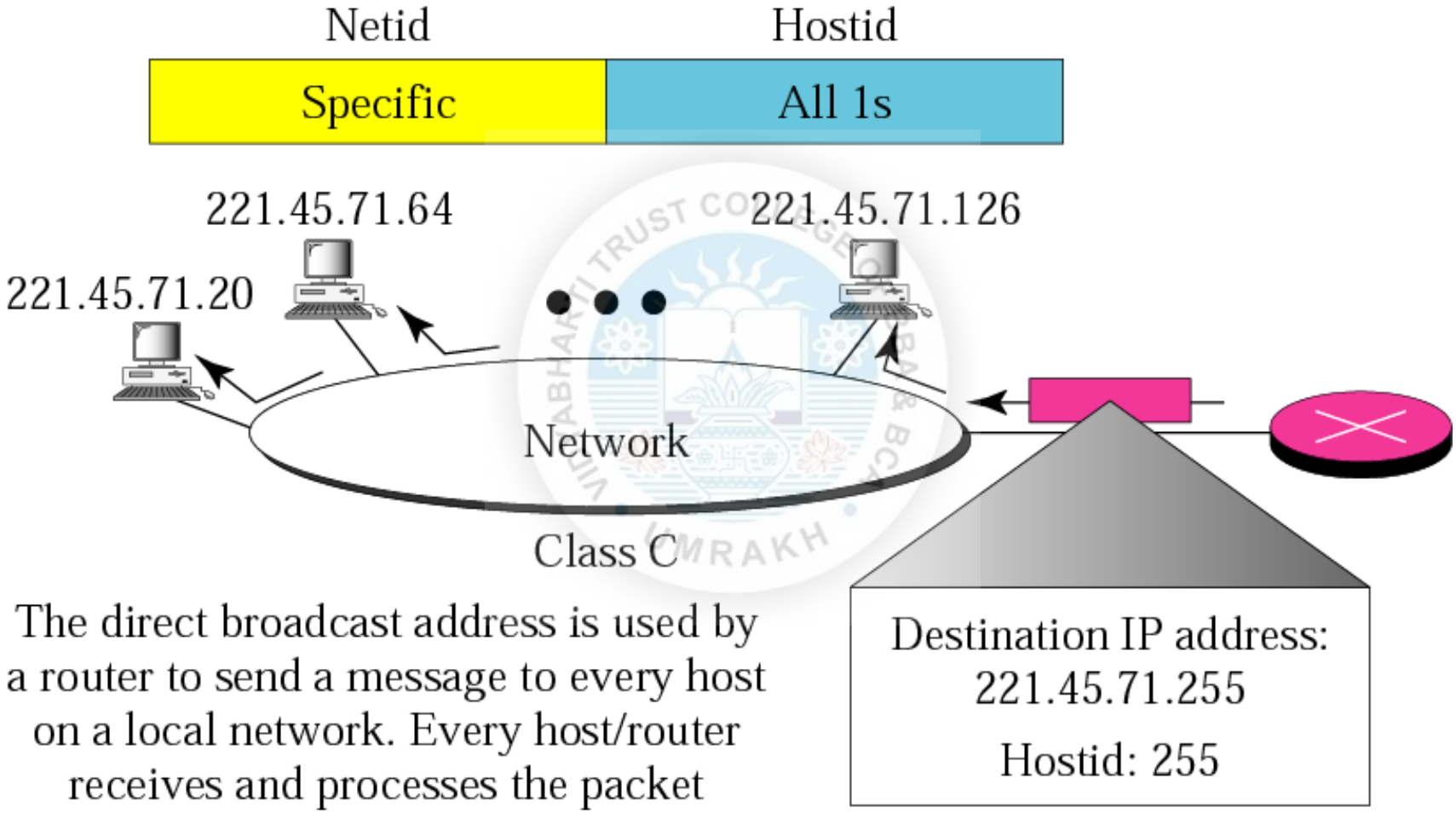
Multihomed Devices

- A computer that is connected to different networks is called a *multihomed* computer and will have more than one address.
- Each possibly belonging to a different class.
- Routers are multihomed Device.

Special Addresses

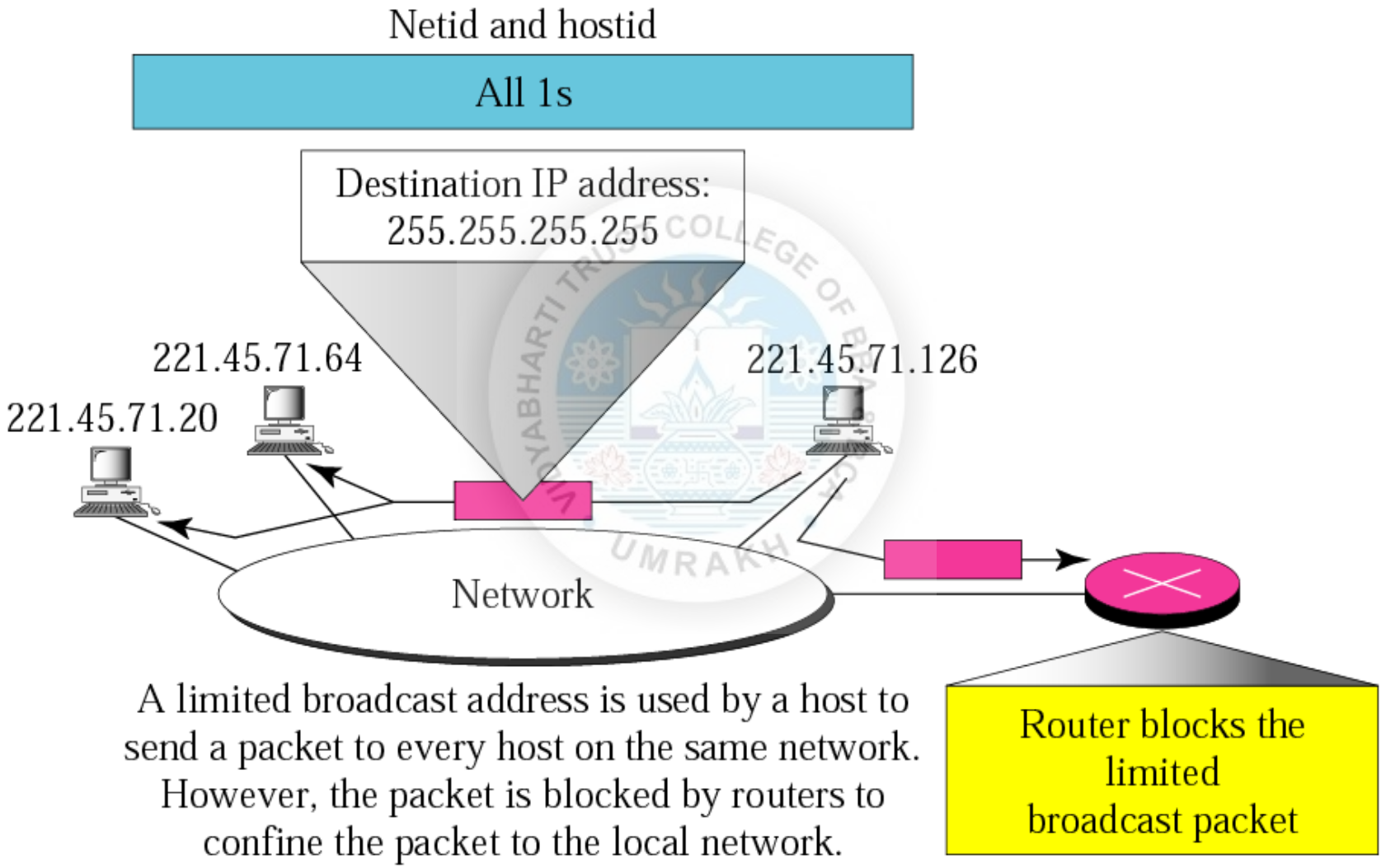
Special Address	*Netid*	*Hostid*	*Source or Destination*
Network address	Specific	All 0s	None
Direct broadcast address	Specific	All 1s	Destination
Limited broadcast address	All 1s	All 1s	Destination
This host on this network	All 0s	All 0s	Source
Specific host on this network	All 0s	Specific	Destination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

Direct Broadcast Address

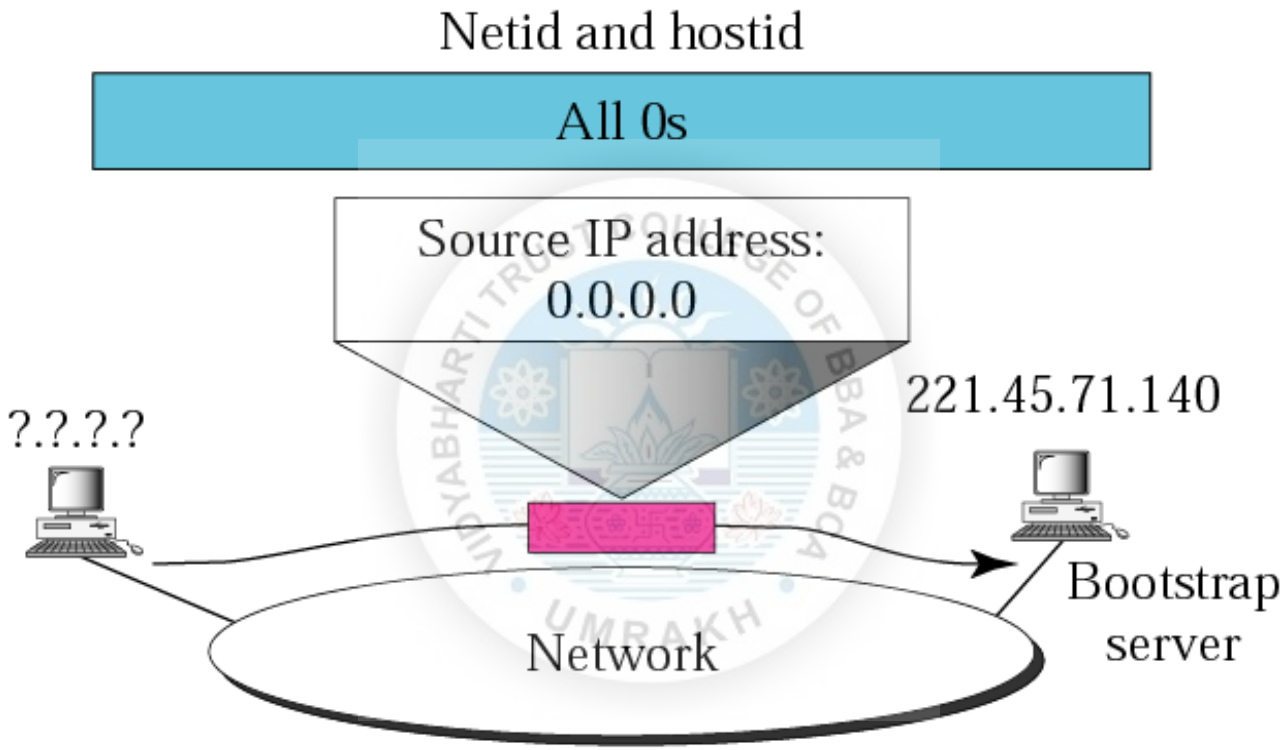


The direct broadcast address is used by a router to send a message to every host on a local network. Every host/router receives and processes the packet with a direct broadcast address.

Limited Broadcast Address

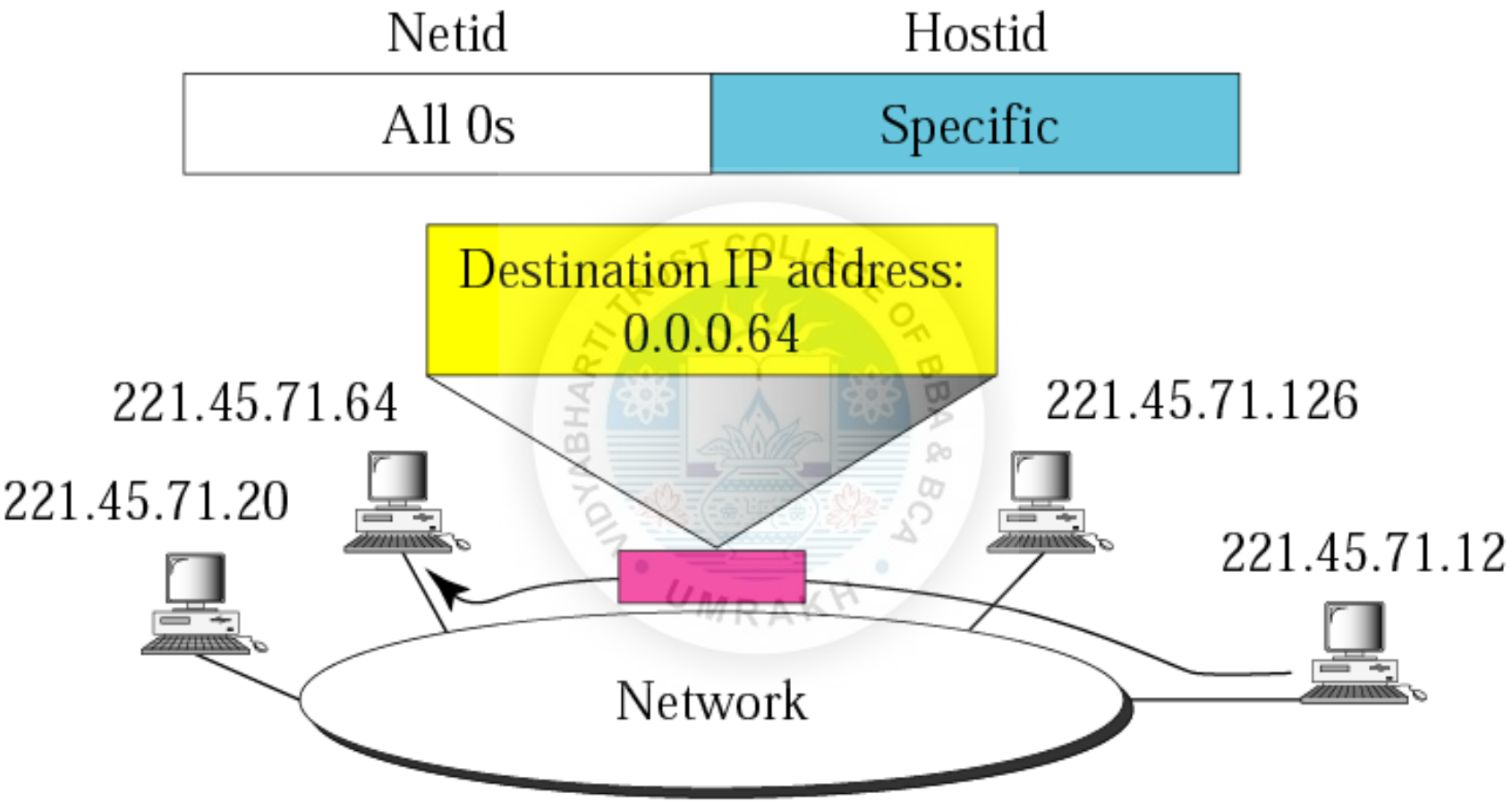


This Host On This Network



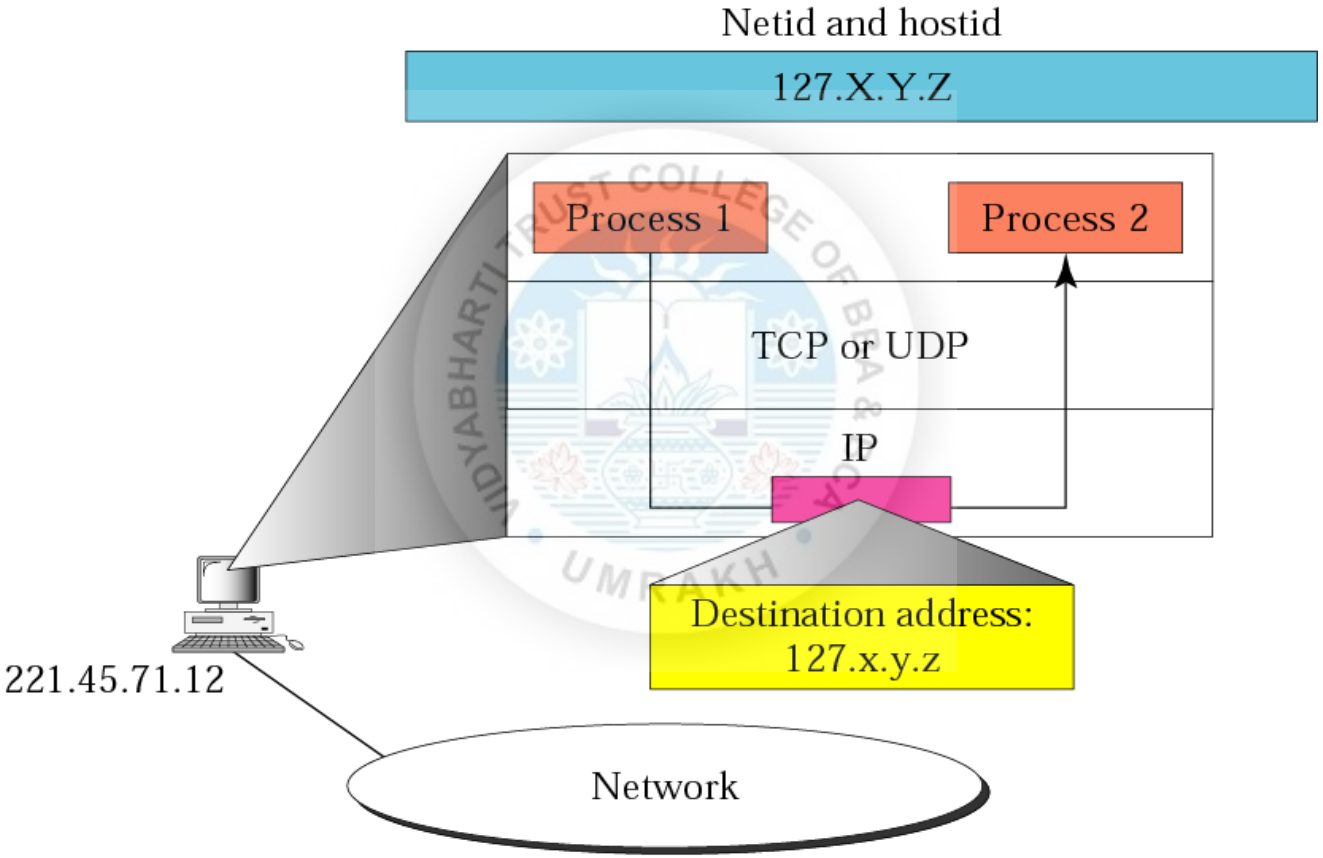
A host that does not know its IP address uses the IP address 0.0.0.0 as the source address and 255.255.255.255 as the destination address to send a message to a bootstrap server.

Specific Host On This Network



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

LoopBack Address



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

Private IP Address

- Used by anyone on Private Network.
- Are not routable .
- Can not access from internet.
- Save IP Address Space.
- Internet Assigned Numbers Authority (IANA) has reserved certain IP addresses as private addresses for **use with internal web sites or intranets.**
- These are also referred to as **RFC 1918 addresses.**
- If every host on network as real routable ip address , we would have run out of IP Address space.

Private IP Address

- **Used for computer not directly connected with internet.**
- **Used by company for internal network**

CLASS	RESERVED ADDRESS SPACE	Available Address
A	10.0.0.0 - 10.255.255.255	16,777,216
B	172.16.0.0 - 172.31.255.255	1,048,576
C	192.168.0.0 - 192.168.255.255	65,536

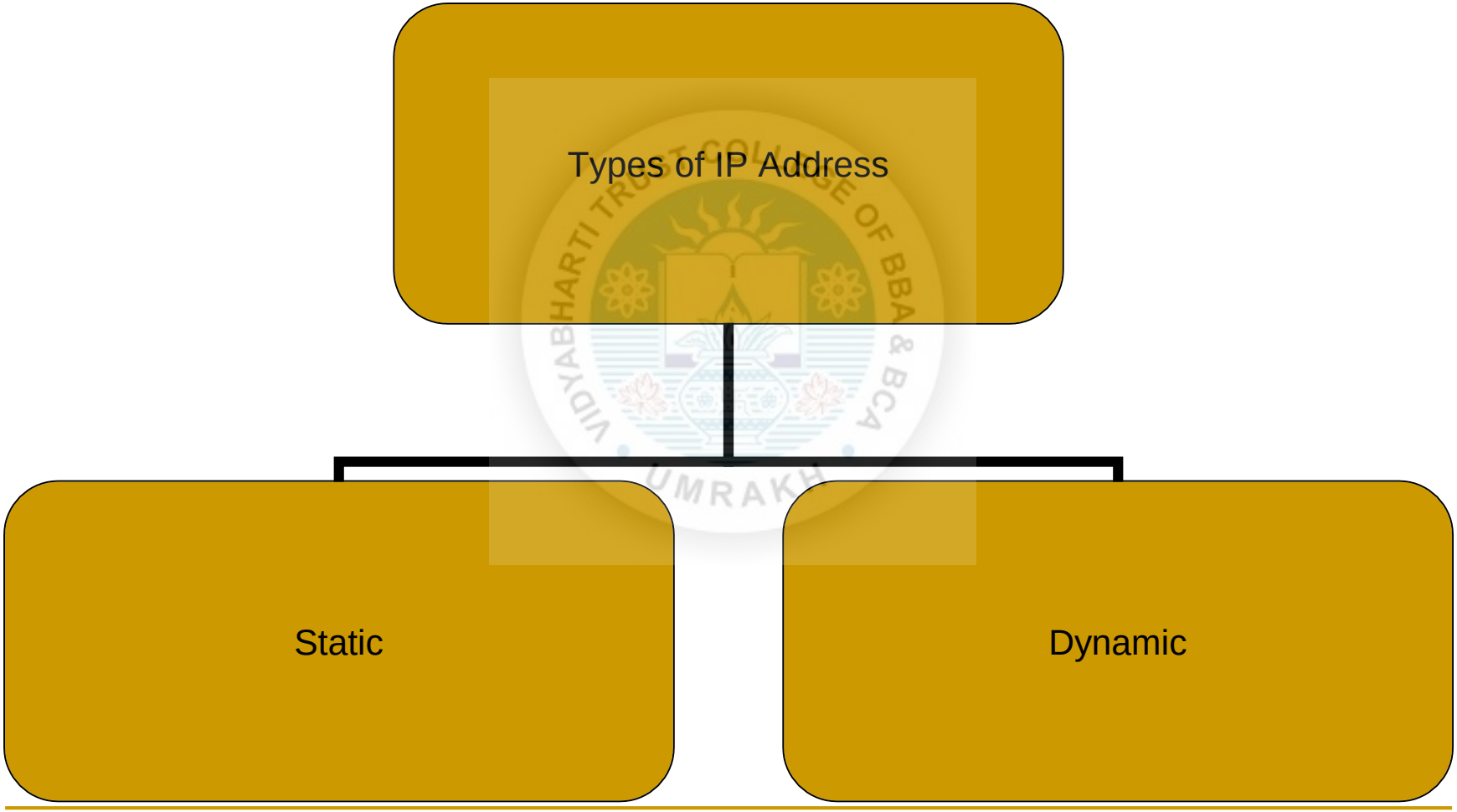
LoopBack Address

- 127.0.0.1 is a Loopback Address
- Use:
  - A host can use this to send message back to itself.
  - Primarily for Troubleshooting and network testing.
- It check if the TCP/IP protocol stack on machine is working properly or not.
- 127.0.0.0 to 127.255.255.255 reserve for loopback address.

Public IP Address

- A public IP address is any valid address, or number, that can be **accessed over the Internet.**
- Internet standards groups, such as the **Internet Assigned Numbers Authority (IANA),** are the organizations **responsible for registering IP ranges** and assigning them to organizations, such as Internet Service Providers (ISPs).

Types of IP Address.



Static IP Address

- Manually input by network administrator
- Manageable for small networks
- Requires careful checks to avoid duplication

Dynamic IP Address

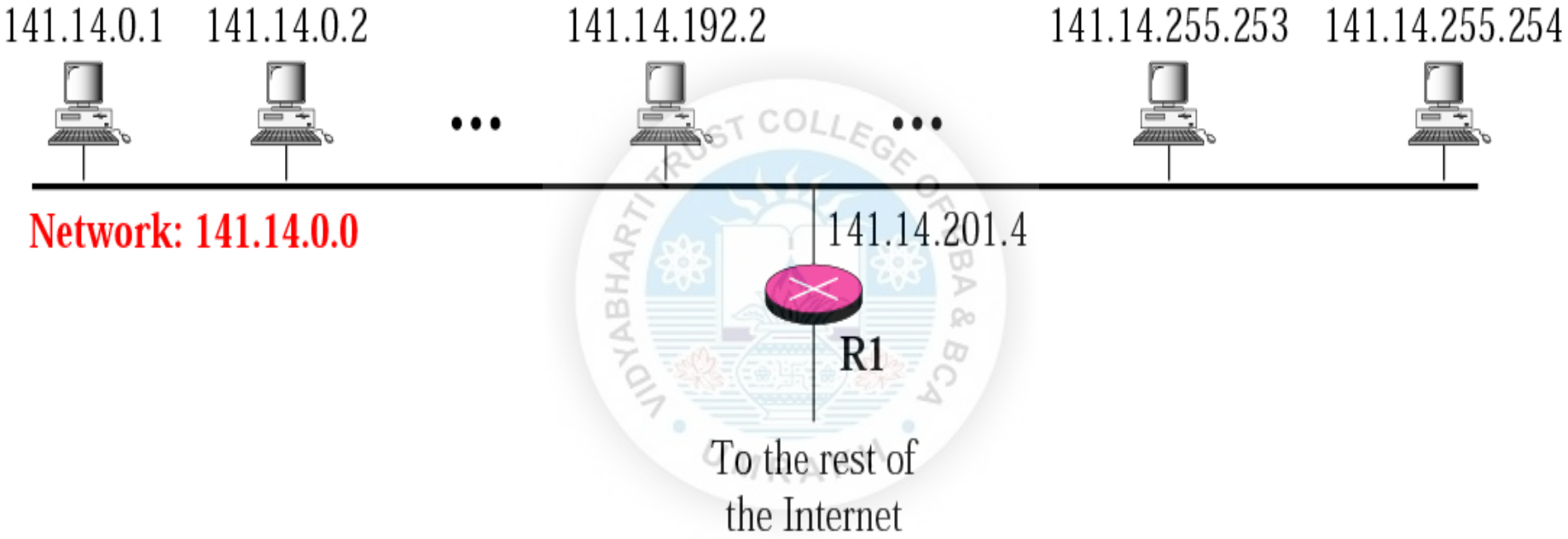
- Assigned by server when host boots
- Derived automatically from a range of addresses
- Duration of ‘lease’ negotiated, then address released back to server
- Example: DHCP server is used to assigned ip address dynamically.

Unicast, Multicast and Broadcast Addresses

- Used to achieve communication on the Internet
- Unicast address uniquely identifies a host in a network and belongs to class A, B and C
- Multicast address defines an address for a group and belongs to class D
- Broadcast address allows user to send data packet to all machines on a given network and is last address of that network

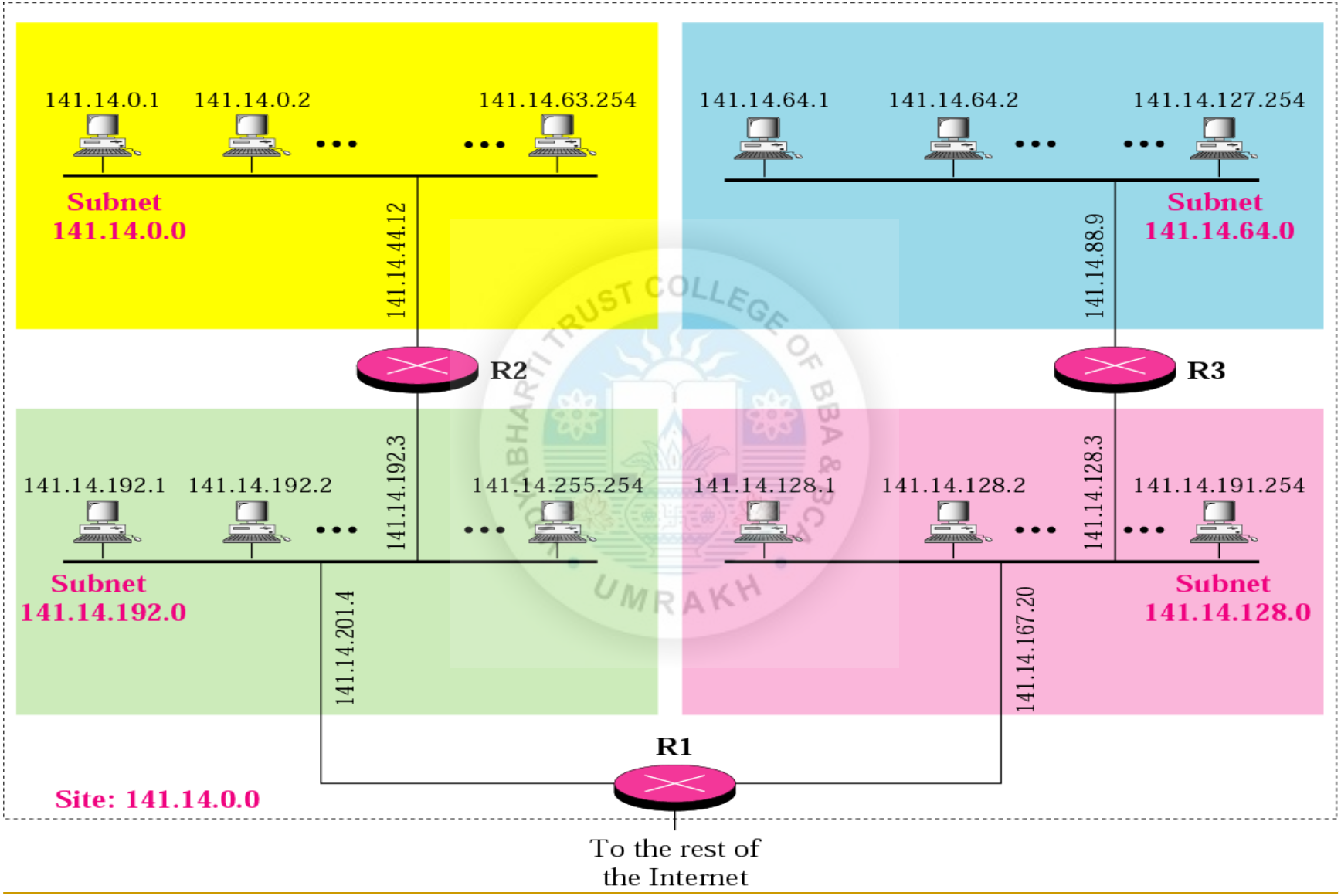
IP addresses are designed with two levels of hierarchy:

netid and host id.



This network (141.14.0.0) is a class B and can have 2^16 hosts.

What if we break the network into 4 subnets?



IP Subnetting

- Allows you to divide a network into smaller sub-networks.
- Use **parts of the host IDs as a sub network** for subnetting purpose
- Each subnet has its own sub-network address.
- Subnet can be created within Class A, B, or C based networks.
- Subnetting allows you to create multiple logical networks that exist within a single Class A, B, or C network.
- If you do not subnet, you are only able to use one network from your Class A, B, or C network

Continue…

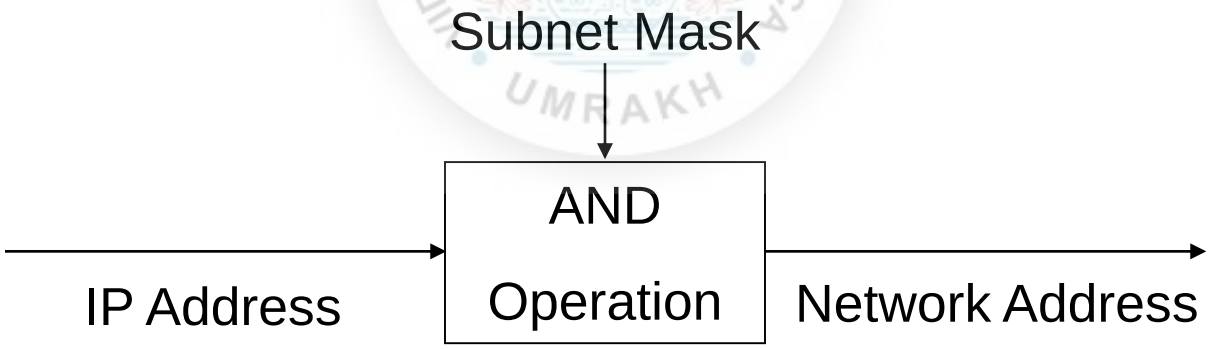
- In order to subnet a network, extend the natural mask using some of the bits from the host ID portion of the address to create a subnetwork ID.
- For example, given a Class C network of 204.17.5.0 which has a natural mask of 255.255.255.0, you can create subnets in this manner:

Why Need Subnetting?

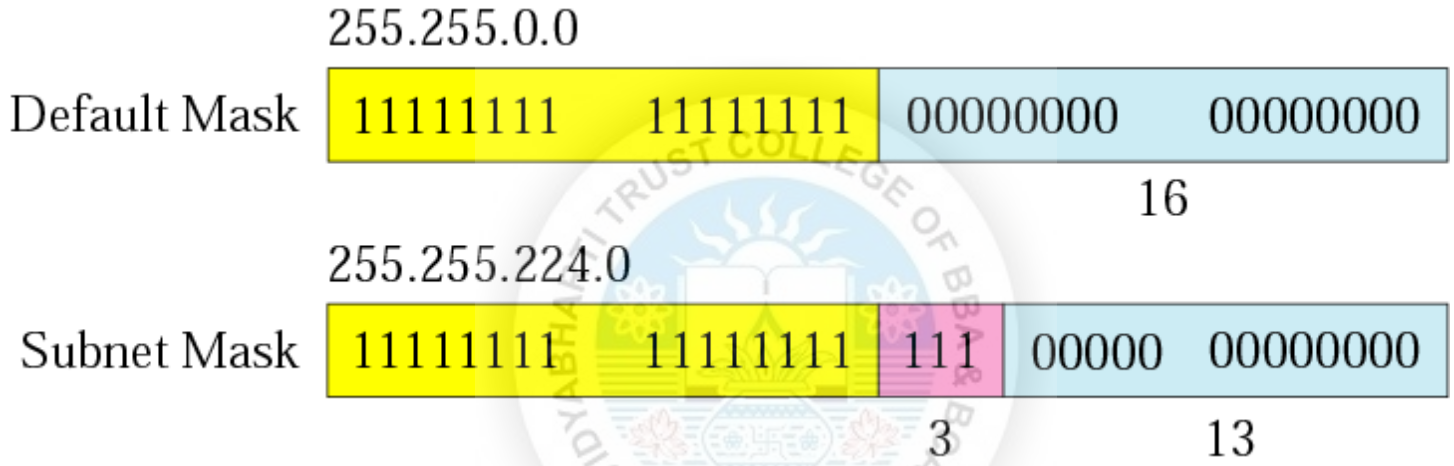
- Classes A and B have a large number of hosts corresponding to each network ID.
- It may be desirable to subdivide the hosts in Class C subnets.
- Often, there is a limitation on the number of hosts that could be hosted on a single network segment
  - The limitation may be imposed by concerns related to the management of hardware.
- A **subnet mask is used** to facilitate the flow of traffic between the different subnets and the outside network (hops).
- A **Hop** is the distance a data packet travels form one node to the other

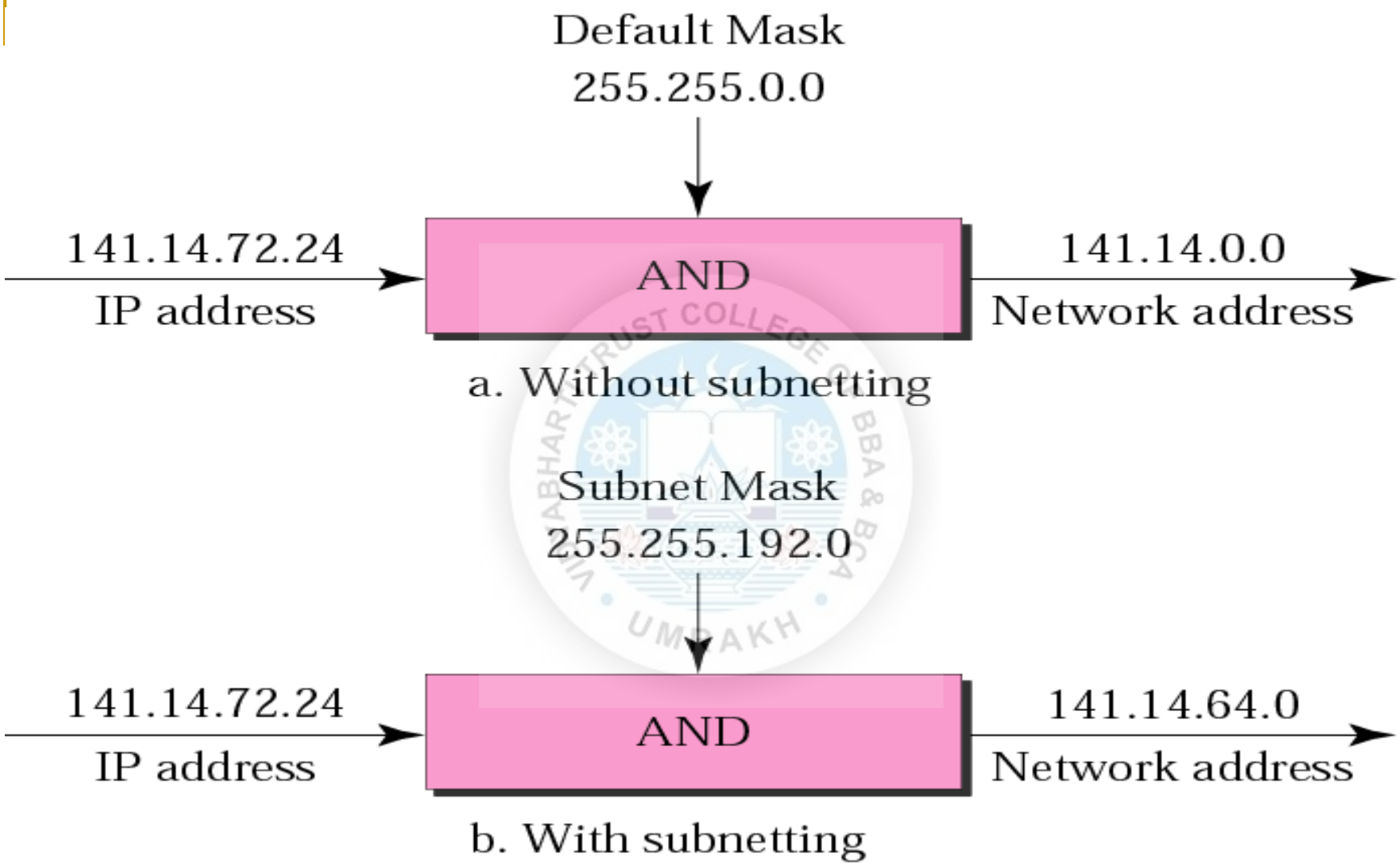
Subnet Mask

- Specifies part of IP address used to identify a subnetwork.
- Subnet mask when logically ANDed with IP address provides 32-bit network address

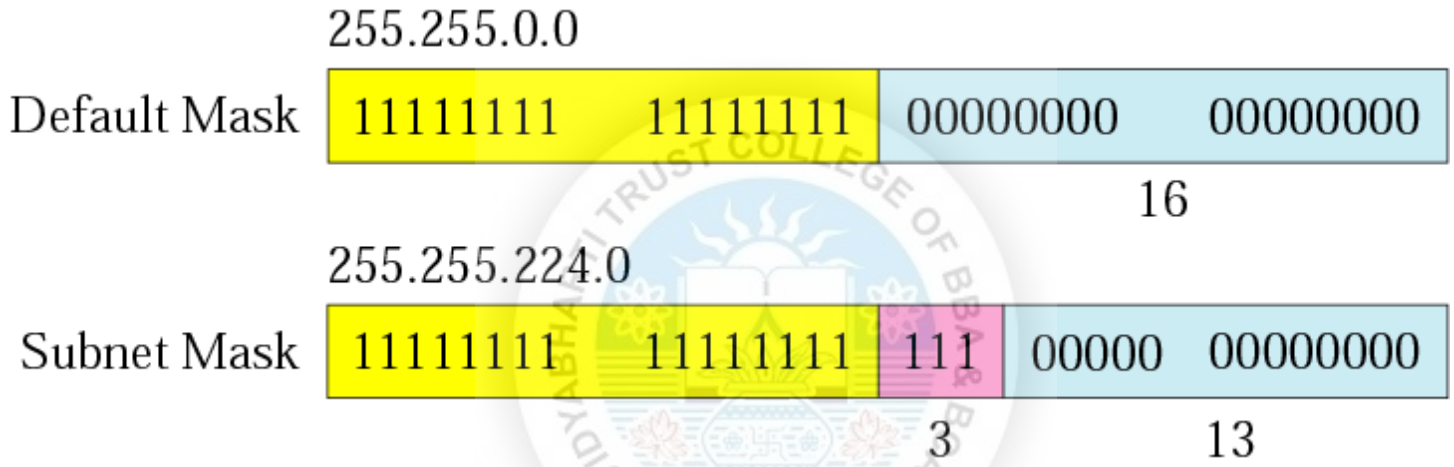


Comparison : Default Vs Subnet Mask





Subnet Mask



Continue….

204.17.5.0 :11001100.00010001.00000101.00000000

255.255.255.224 :11111111.11111111.11111111.11100000

----------|sub|-------

Continue…

- By extending the mask to be 255.255.255.224, you have taken three bits (indicated by "sub") from the original host portion of the address and used them to make subnets.
- With these three bits, it is possible to create eight subnets(2^3 **= 8)** .
- With the remaining five host ID bits, each subnet can have up to 32 host addresses, 30 of which can actually be assigned to a device *since host ids of all zeros or all ones are not allowed.*

Continue…

- 204.17.5.0 255.255.255.224 host address range 1 to 30
- 204.17.5.32 255.255.255.224 host address range 33 to 62
- 204.17.5.64 255.255.255.224 host address range 65 to 94
- 204.17.5.96 255.255.255.224 host address range 97 to 126
- 204.17.5.128 255.255.255.224 host address range 129 to 158
- 204.17.5.160 255.255.255.224 host address range 161 to 190
- 204.17.5.192 255.255.255.224 host address range 193 to 222
- 204.17.5.224 255.255.255.224 host address range 225 to 254

Continue…

- The more host bits you use for a subnet mask, the more subnets you have available.
- However, the more subnets available, the less host addresses available per subnet.

Try It

- If you have network 172.16.0.0 ,then you know that its natural mask is 255.255.0.0 or 172.16.0.0/16. Extending the mask to anything beyond 255.255.0.0 means you are subnetting.
- If you use a mask of 255.255.248.0 (/21), how many subnets and hosts per subnet does this allow for?

Continue..

172.16.0.0 : 10101100.00010000.00000000.00000000

255.255.248.0 : 11111111.11111111.11111000.00000000

----------| sub |----------

- You are using five bits from the original host bits for subnets.
- This allows you to have 32 subnets (2^5).
- After using the five bits for subnetting, you are left with 11 bits for host addresses. This allows each subnet so have 2048 host addresses (2^{11}-2), 2046 of which could be assigned to devices.

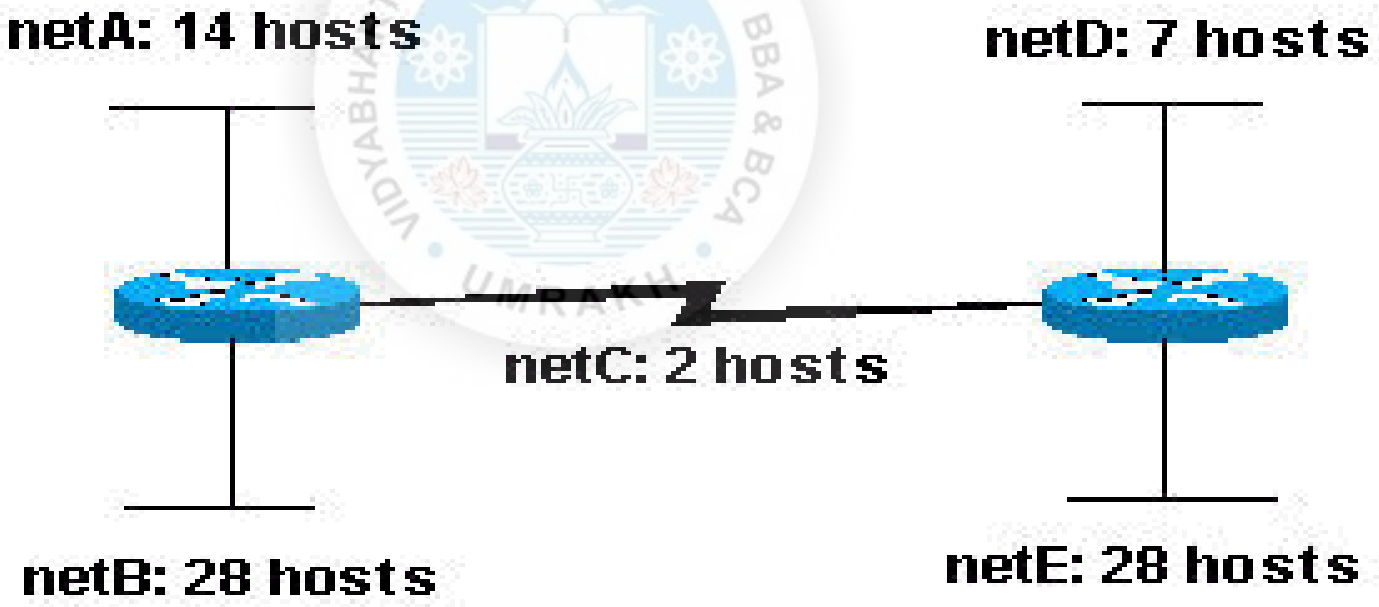
Try It

- Device A: 172.16.17.30/20
- Device B: 172.16.28.15/20

- Your task is to determine if these devices are on the same subnet or different subnets.

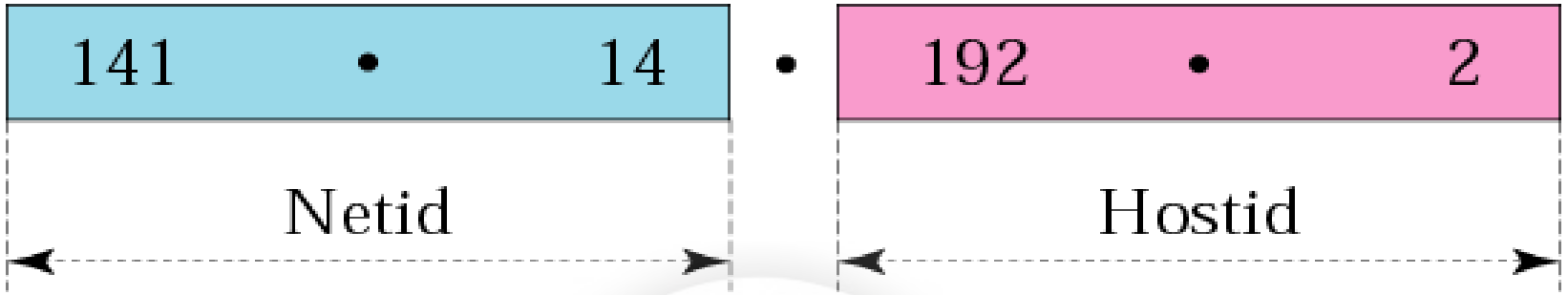
Try It

- Given the Class C network of 204.15.5.0/24, subnet the network in order to create the network in Figure with the host requirements shown.

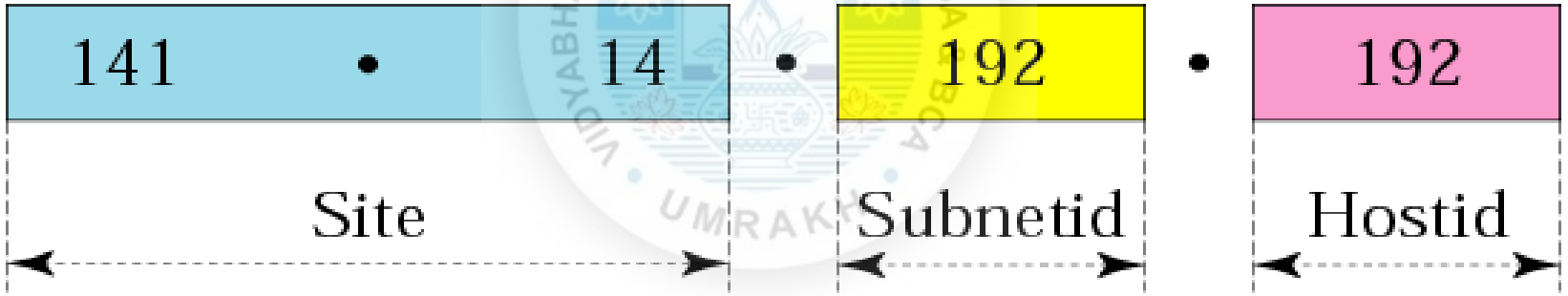


Continue…

- Looking at the network shown in Figure 3, you can see that you are required to create five subnets. The largest subnet must support 28 host addresses.
- You can start by looking at the subnet requirement. In order to create the five needed subnets you would need to use three bits from the Class C host bits. Two bits would only allow you four subnets (2^2).
- Since you need three subnet bits, that leaves you with five bits for the host portion of the address. So $2^5 = 32$ (30 usable) host id we use. This meets the requirement.



a. Without subnetting



b. With subnetting

Finding the Subnet Address

Given an IP address, we can find the subnet address by applying 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 1

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 00100000 00000000

The subnetwork address is 200.45.32.0.

Short-Cut Method

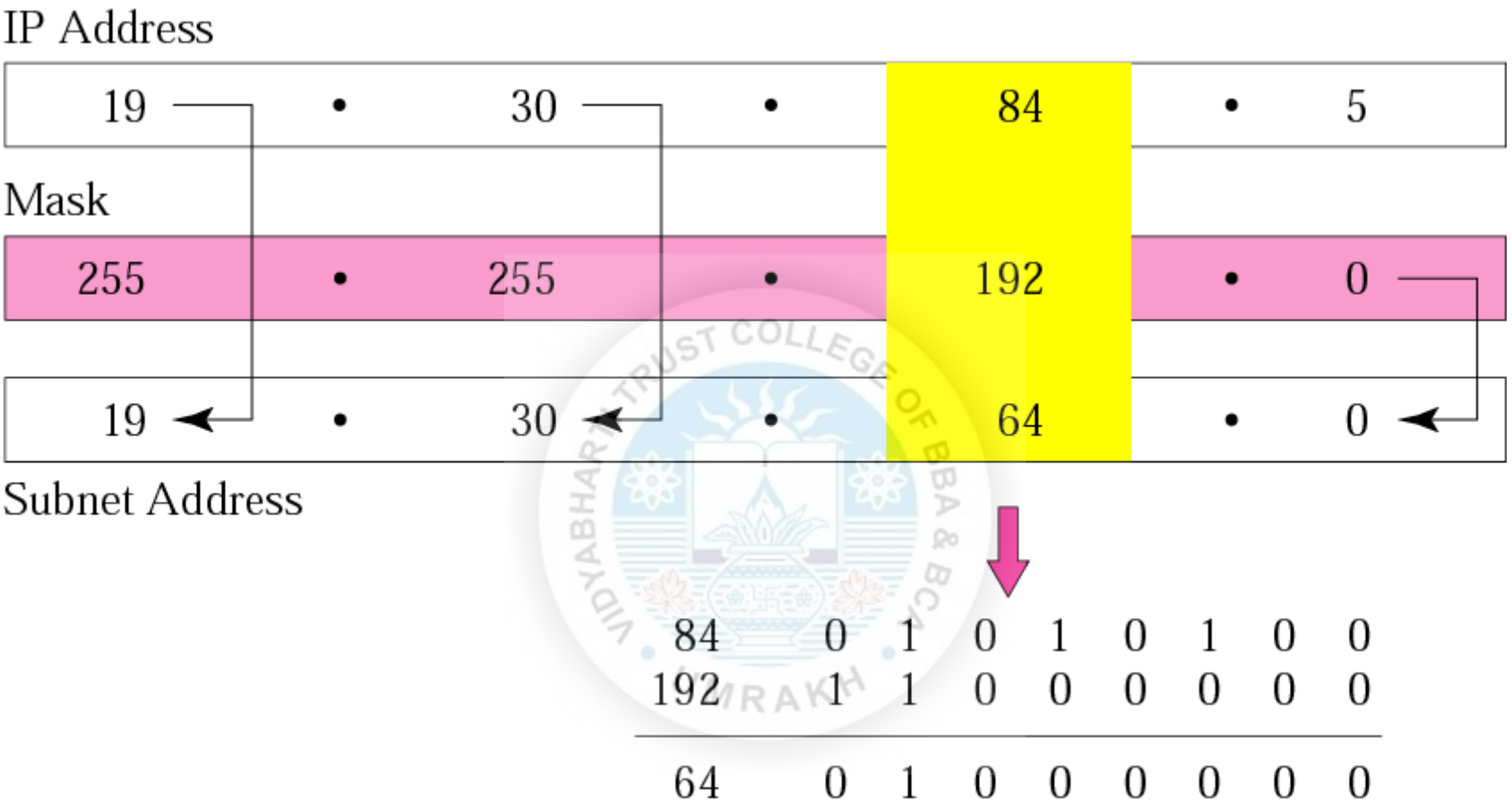
** If the byte in the mask is 255, copy the byte in the address.

** If the byte in the mask is 0, replace the byte in the address with 0.

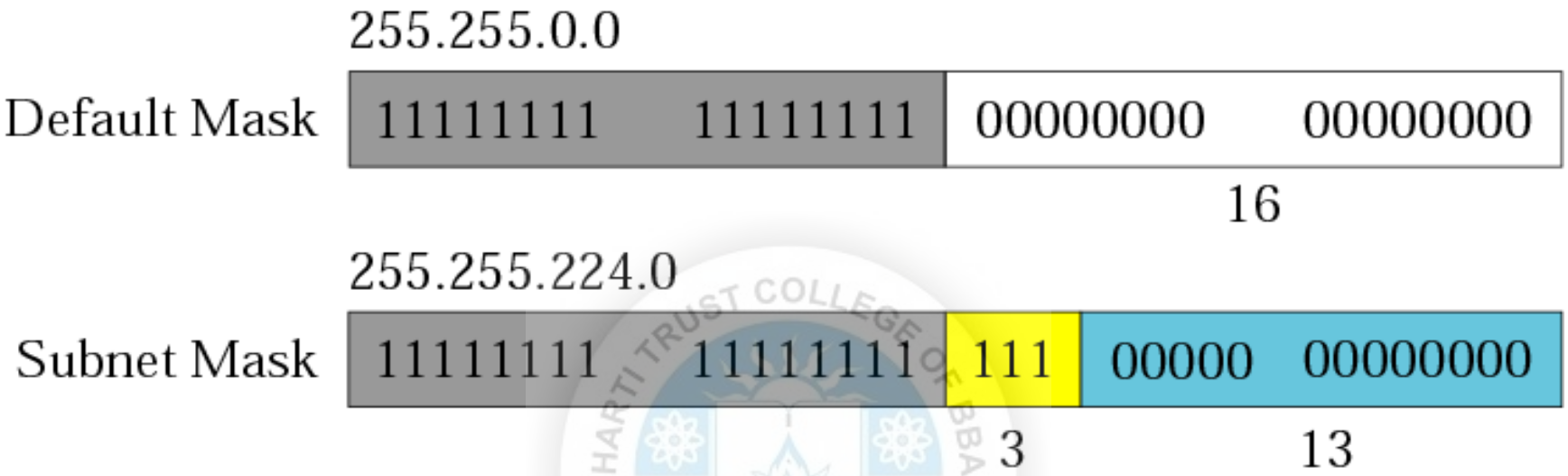
** If the byte in the mask is neither 255 nor 0, we write the mask and the address in binary and apply the AND operation.

Example 2

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



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



With this subnet mask, you have 3 bits for the subnet address (the yellow portion) which equals 8 addresses, leaving 13 bits for the Hostid (the blue portion) which equals 2^13 hosts.

Note

The number of subnets must be a power of 2.

Example 3

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). The mask is

Solution (Continued)

11111111 11111111 11111111 11100000

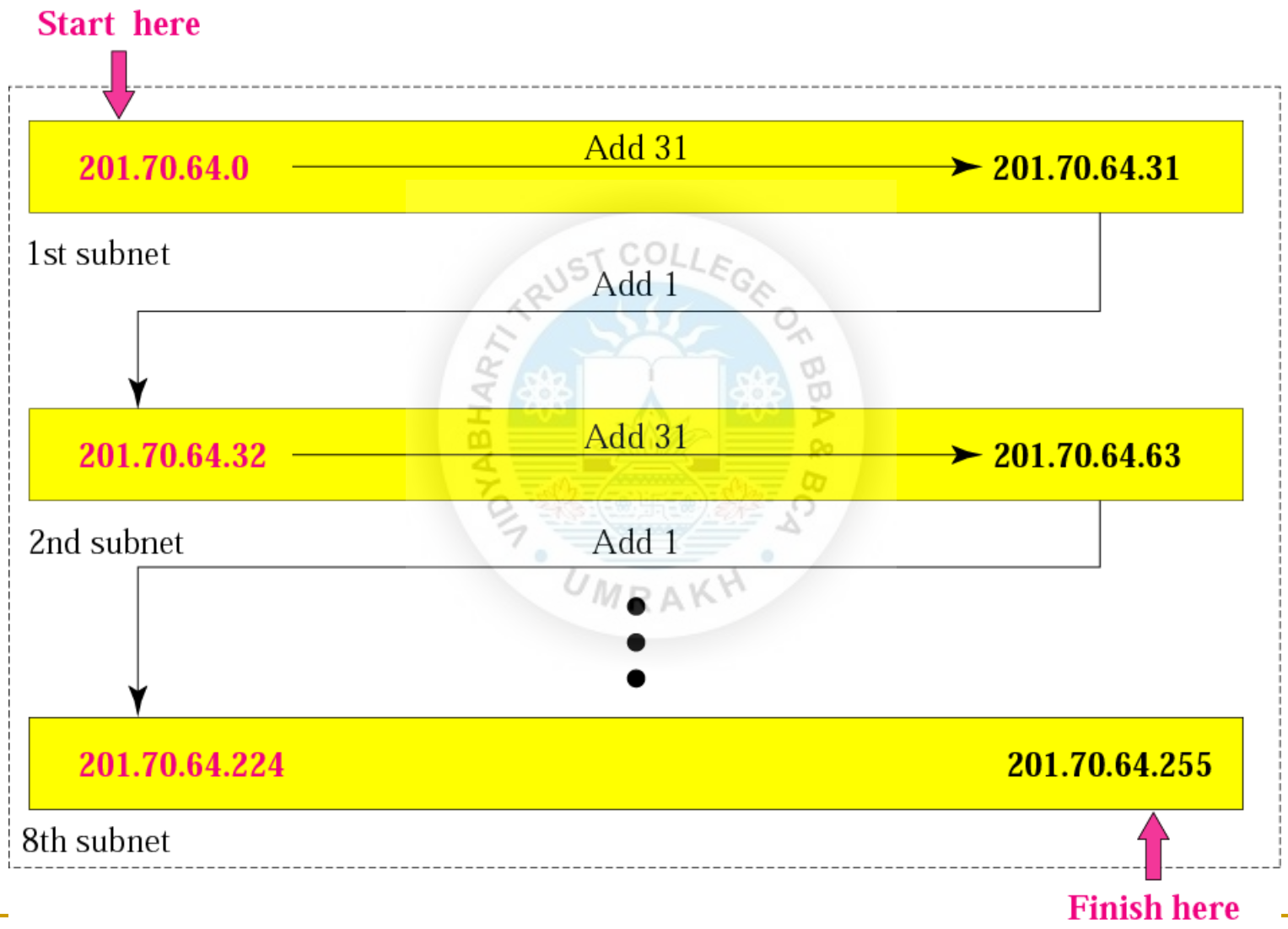
or

255.255.255.224

The number of subnets is 8.

The number of addresses in each subnet is 2^5

(5 is the number of 0s) or 32.



Example 4

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).

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.