CN (IT-3001)

Network Layer: IP Addressing

Prof. Amit Jha

School of Electronics Engineering (SOEE)

KIIT Deemed to be University

Objectives

- The objective of this module is to discus following concepts…
    1. IP Addressing
    2. Subnetting
    3. Supernetting

Logical addressing/IP addressing

- **Motivation:** The MAC address does not work if packet to be transmitted from one network to other network.

Thus, we need other addressing method, IP address, which can be used to remove limitations of MAC address.

Recent Development: IPTV

IPv4 Addressing

- It is a 32-bit address that *uniquely* and *universally* defines the connection of a device to the Internet.
- Two devices on the Internet can never have the same address at the same time.
- On the other hand, if a device operating at the network layer has *m* connections to the Internet, it needs to have *m* addresses, e.g., Router.
- **Address Space:**

- The address space of IPv4 is 2^{32}= 4,294,967,296.
- So, if there were no restrictions, we can have more than 4 billion devices on the Internet theoretically. However, this number is much less practically.

IPv4 Addressing: Notations

- Two notations: Binary notation and dotted-decimal notation.
- **Binary Notation:** In this, address is displayed as 32 bits. So, IPv4 address in this case referred to as a 32-bit address or a 4-bytes address.

00001010 00000000 01001001 00010111

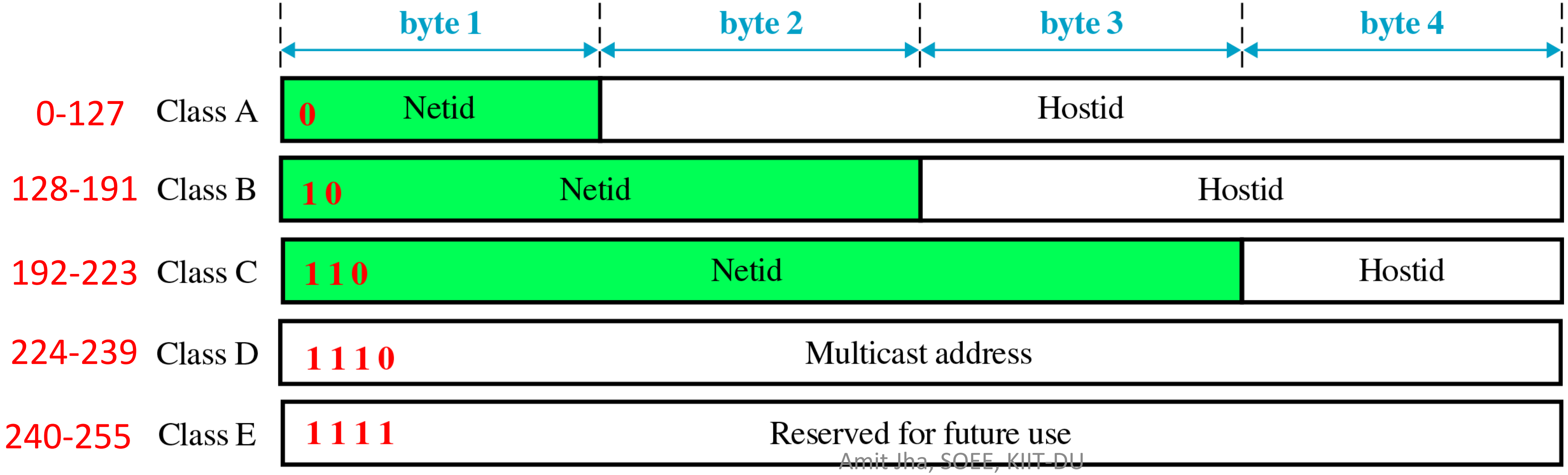
- **Dotted-Decimal Notation:** It is compact and easy to read.

00001010 00000000 01001001 00010111

10.0.73.23

IPv4 Addressing: Classful Addressing

- Total address space is divided into five classes, A, B, C, D, E.
- In binary notation, the first few bits can immediately tell us the class of the address.
- In dotted-decimal notation, the first byte defines the class.



IPv4 Addressing: Class Ranges

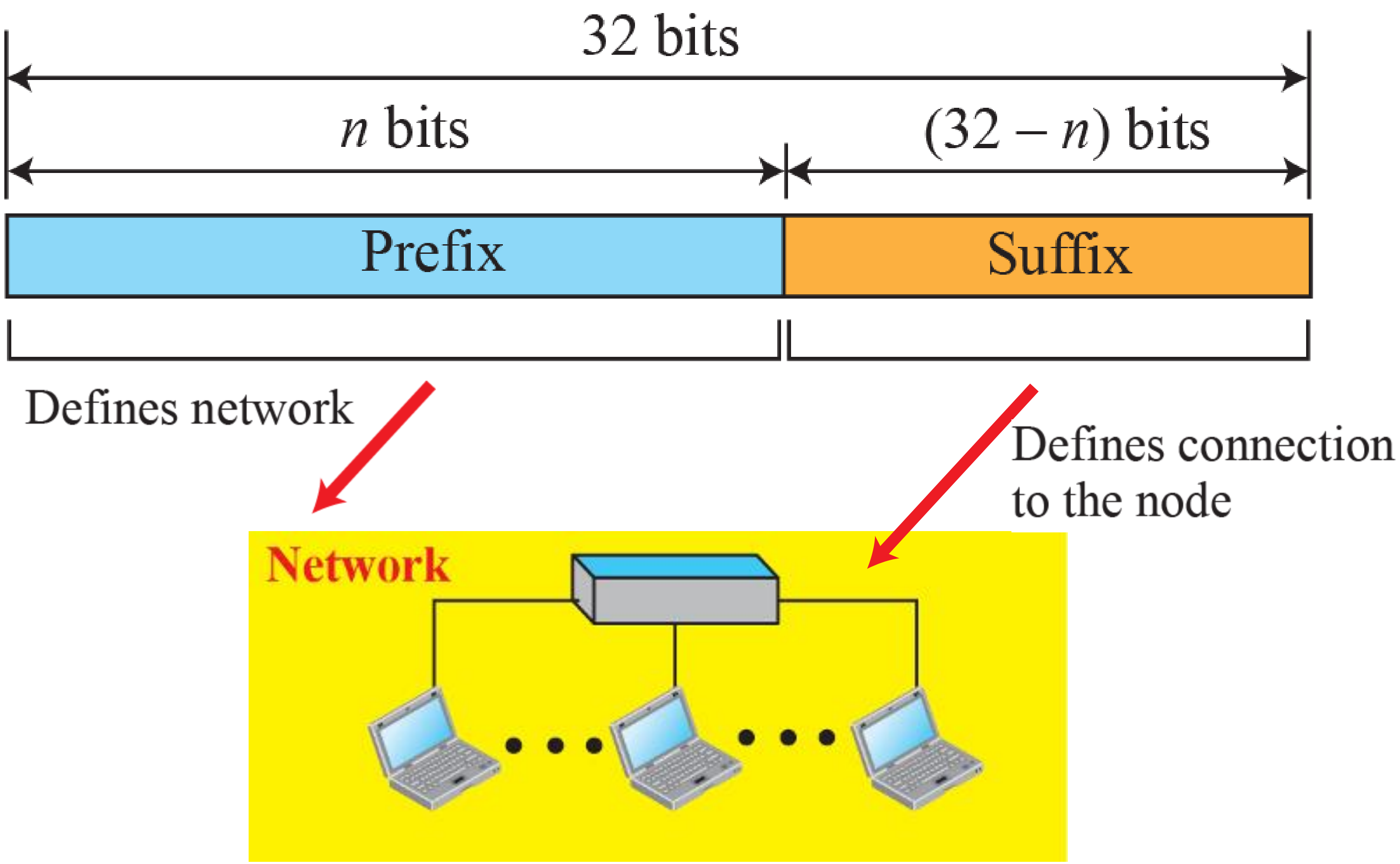
	From	To	Total # Networks Possible	Total # Hosts Possible	Application
Class A	0.0.0.0 (Netid, Hostid)	127.255.255.255 (Netid, Hostid)	2^{7}=128	2^{24}=16,777,216	Unicast
Class B	128.0.0.0 (Netid, Hostid)	191.255.255.255 (Netid, Hostid)	2^{14}=16,384	2^{16}=65,536	Unicast
Class C	192.0.0.0 (Netid, Hostid)	223.255.255.255 (Netid, Hostid)	2^{21}=2,097,152	2^{8}=256	Unicast
Class D	224.0.0.0 (Group address)	239.255.255.255 (Group address)	2^{0}=1	2^{28}=268,435,456	Multicast
Class E	240.0.0.0 (Undefined)	255.255.255.255 (Undefined)	2^{0} =1	2^{28}=268,435,456	Reserved

- **Netid and Hostid:** Netid and Hostid stand for network address and host address respectively. Netid is called *prefix* and Hostid is called *suffix*.
- **Mask:** It is a 32-bit numbers made of contiguous 1s followed by contiguous 0s. In classful addressing, mask is predetermined number, thus referred to as a *default mask.*
- **Classless Interdomain Routing (CIDR):** It gives the number of bits used as a mask. In the address ***a.b.c.d* /*n*,** *n* represents number of masking bits.

Default masks for classful addressing

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

Hierarchy in addressing



Classful addressing is not an efficient method of IPv4 addressing…….

Class A addresses were designed for large organizations with a large number of attached hosts or routers. Class B addresses were designed for mid size organizations, and class C for small organizations.

Let us say, when KIIT has established, it was given a class C address. So, in the starting, KIIT could have used this class C address to accommodate 256 hosts, approximately all it could have. Due to the exponential growth of KIIT, it now need to have more than 10000 hosts. But, as per the class C, it can handle at max 256 hosts only if it could have used classful addressing.

Note: In Classful addressing, either a large part of the available addresses are wasted or we are unable to accommodate all hosts.

Classless Addressing & Block Allocation

- In this scheme, there are no classes, but the addresses are still granted in blocks. This is done by the ICANN.
- However, ICANN does not normally allocate addresses to individual Internet users. It assigns a large block of addresses to an IP.
- In classless addressing, when an entity, small or large, needs to be connected to the Internet, it is granted a block (range) of addresses by ISP.
- The size of the block depends upon the size of entity.
- For proper operation of the CIDR, three restrictions need to be applied to the allocated block. They are as follows:-
  - **Restriction:**
    1. The addresses in a block must be contiguous, one after another.
    2. The number of addresses in a block **N** must be a power of 2.
    3. The first address must be evenly divisible by the number of addresses.

HYU 4.6: Why all three restrictions need to be followed to allocate the block of IP addresses?

Example 4.7: An Example of classless address with Block Allocation

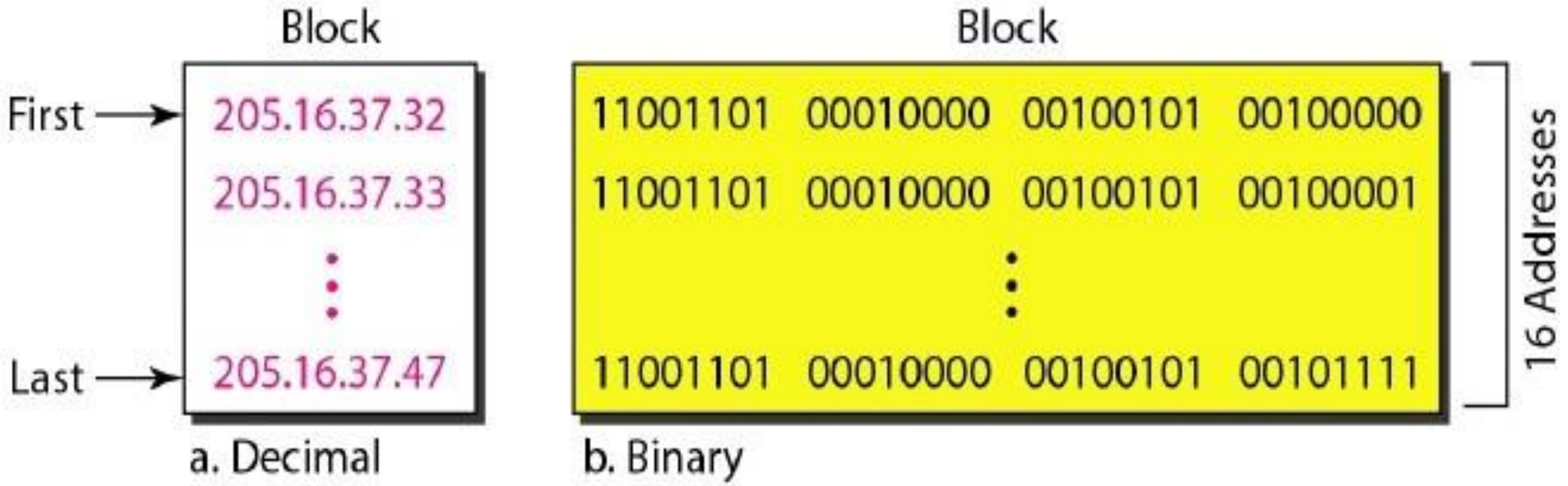


Fig: *A block of 16 addresses granted to a small organization*

Note: The above addressing obeys all three restrictions.

Classless Addressing: CIDR

- The address and the $/n$ notation completely define the whole block (the first address, the last address, the number of addresses, and the network address).
- **Number of Address:** It can be found out by using the formula 2^{32-n}.
- **First Address:** The first address in the block can be found by setting the right most 32- n bits to 0s.
- **First address** can also be found out by doing 'AND' operation of any one of the given/known address with Mask.
- **Last Address:** The last address in the block can be found by setting the right most 32- n bits to 1s.
- **Network Address:** The first address in the class, however, is normally (not always) treated as a network address.
- **Mask:** It is obtained by making leftmost n bits as 1s.

Example 4.8: If in an organization, one of the address is 205.16.37.39/28 then find out, its mask, network address, the first address, and the last address.

Sol: Here, n=28. 205.16.37.39 in binary 11001101 00010000 00100101 00100111

Mask = 11111111 11111111 11111111 11110000 or **255.255.255.240**

First address: 32-n=32-28=4, so make rightmost 4 bits as 0s.

so the first address is 11001101 00010000 00100101 00100000 or **205.16.37.32/28**

Last address: make rightmost 4 bits 1s.

11001101 00010000 00100101 00101111 or **205.16.37.47/28**

Network address: 205.16.37.32/28 ← First address

The network address can also be found out as (**Given address AND Mask**)

e.g.,

11001101 00010000 00100101 00100111 } AND Operation
11111111 11111111 11111111 11110000

11001101 00010000 00100101 00100000 = 205.16.37.32/28

Example 4.9: If in an organization, one of the address is 167.199.170.82/27 then find out, its mask, network address, the first address, and the last address.

Sol: Here, n=27. 167.199.170.82 in binary 10100111 11000111 10101010 01010010

Mask = 11111111 11111111 11111111 11100000 or **255.255.255.224**

First address: 32-n=32-27=5, so make rightmost 5 bits as 0s.

so the first address is 10100111 11000111 10101010 01000000 or **167.199.170.64/27**

Last address: make rightmost 5 bits 1s.

10100111 11000111 10101010 01011111 or **167.199.170.95/27**

Network address: 167.199.170.64/27 ← First address

The network address can also be found out as (**Given address AND Mask**)

e.g.,

$$\left.\begin{array}{cccc} 10100111 & 11000111 & 10101010 & 01010010 \\ 11111111 & 11111111 & 11111111 & 11100000 \end{array}\right\} \text{AND Operation}$$

$$\begin{array}{cccc} 10100111 & 11000111 & 10101010 & 01000000 \end{array} = 167.199.170.64/27$$

Example 4.10: An ISP has requested a block of 1000 addresses. Determine the prefix length and verify whether the firs address is divisible by total no of addresses or not. Also, note whether it follows all three restrictions of block allocation or not.

Answer:- Since 1000 is not a power of 2, 1024 addresses are granted. The prefix length is calculated as $n = 32 - \log_2 1024 = 22$. Assume that an available block, 18.14.12.0/22, is granted to the ISP. It can be seen that the first address in decimal is 302,910,464, which is divisible by 1024.

Note: *18.14.12.0 = 00010010. 00001110. 00001100. 00000000 → 302910464 (combining all bytes together)*

What is the concept of *subnet*?

The process of dividing a *larger network* into *smaller number* of sub networks is known as *subnet*.

Blind Rule: **Borrow from the Host ID, thus subnetting increases the number of 1s in the mask (prefix).**

Subnetting

- More level of hierarchy can be created using subnetting.
- An organization (or an ISP) that is granted a range of addresses may divide the range into several subranges and assign each subrange to a subnetwork (or subnet).
- Note that nothing stops an organization from creating more levels, i.e.,
    - A subnetwork can be divided into several sub-subnetworks.
    - A sub-subnetwork can be divided into several sub-sub-subnetworks. And so on..
-

Designing of Subnets

Subnet should be designed properly to felicitate routing of packets.

- Let total number of addresses granted to the organization is **N**, the prefix length is *n*, the assigned number of addresses to each subnetwork is $\boldsymbol{N_{sub}}$ and the prefix length for each subnetwork is $\boldsymbol{n_{sub}}$. Then following rules is applied.
  - The number of addresses in each subnetwork should be power of 2.
  - The prefix length of each subnetwork is found using $\boldsymbol{n_{sub} = 32 - log_2\,(N_{sub})}$.
  - The starting address in each subnetwork should be divisible by the number of addresses in the subnetwork. This can be achieved if we first assign addresses to the larger subnetwork.

Few Key points to Remember for Subnet

- **For a subnet,**
  - A subnet with **subnet id (prefix id) bits as all zeros** is not used→ because this is not allowed by most of the router, however, some of the routers like Cisco Systems devices allow the use of these subnets when the **id subnet zero** command is configured.
  - Similarly, a subnet with subnet id bits as all ones is not allowed → however, some of the devices may allow to use these subnetworks.
- In a subnet,
  - Host id with **all host id (suffix id) bits set to zero** is not allowed as host IP address → this is because, this results in first IP address in that subnet which is generally a network (subnetwork here) address.
  - Host id (suffix id) with **all host id bits set to one** is not allowed as host IP address → this is because, this results in the broadcast address in that network (subnetwork here).

Example 4.11:- Given the Class C network of 204.15.5.0/24, subnet the network in order to create the network as shown in figure 3 with the host requirements depicted therein.

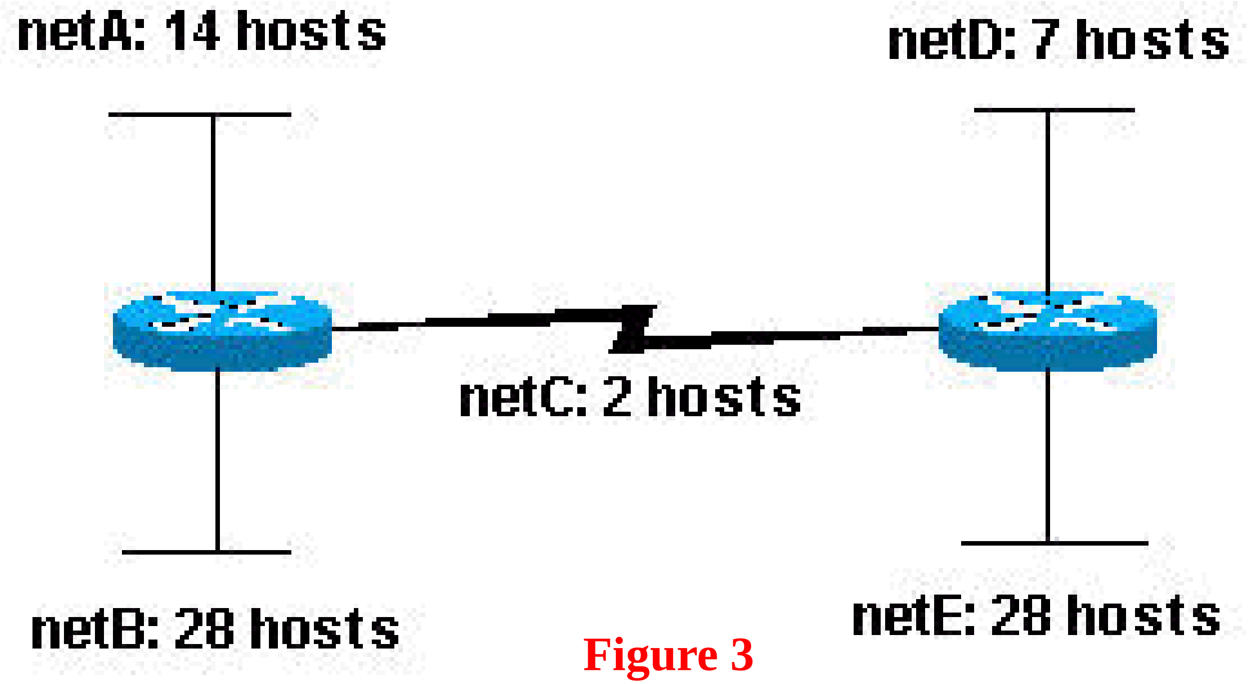


Figure 3

Solution:- you can see that you are required to create five subnets. The largest subnet must support 28 host addresses.

Is this possible with a Class C network? and if so, then how?

Lets design the subnet by first answering the following points:-

How many subnets we need?

Ans:- five

How many bits we need to borrow at least from the host id ?

Ans:- three bits

Note:- Two bits would only allow you four subnets (2^2).

How many hosts does this support?

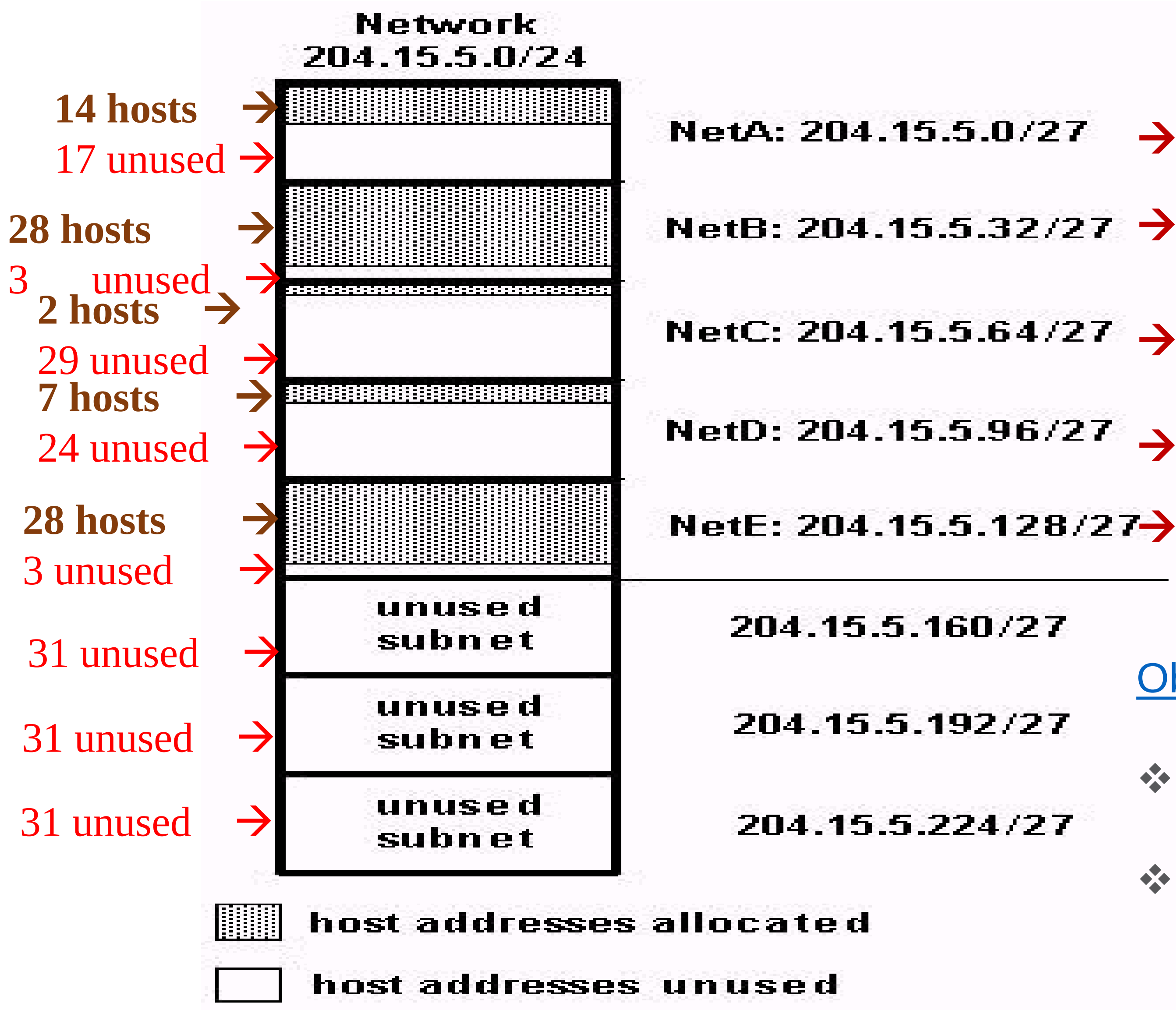
Ans:- $2^5 = 32$ (30 usable). *since host ids of all zeros or all ones are not allowed* (it is very important to remember this).

Let us now create the subnetworks… ….

Name of Subnet	Mask	Network Address	Range of IP Address	Remark
netA	255.255.255.224	204.15.5.**0**/27	204.15.5.00000000/27 = 204.15.5.0/27 204.15.5.00000001/27 = 204.15.5.1/27 204.15.5.00000010/27 = 204.15.5.2/27 : : 204.15.5.00011110/27 = 204.15.5.30/27 204.15.5.00011111/27 = 204.15.5.31/27	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used
netB	255.255.255.224	204.15.5.**32**/27	204.15.5.00100000/27 = 204.15.5.32/27 204.15.5.00100001/27 = 204.15.5.33/27 204.15.5.00100010/27 = 204.15.5.34/27 : : 204.15.5.00111110/27 = 204.15.5.62/27 204.15.5.00111111/27 = 204.15.5.63/27	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used
netC	255.255.255.224	204.15.5.**64**/27	204.15.5.01000000/27 = 204.15.5.64/27 204.15.5.01000001/27 = 204.15.5.65/27 204.15.5.01000010/27 = 204.15.5.66/27 : : 204.15.5.01011110/27 = 204.15.5.94/27 204.15.5.01011111/27 = 204.15.5.95/27	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used

Name of Subnet	Mask	Network Address	Range of IP Address	Remark
netD	255.255.255.224	204.15.5.**96**/27	204.15.5.01100000/27 = 204.15.5.**96**/27 204.15.5.01100001/27 = 204.15.5.**97**/27 204.15.5.01100010/27 = 204.15.5.**98**/27 : : 204.15.5.01111110/27 = 204.15.5.**126**/27 204.15.5.01111111/27 = 204.15.5.**127**/27	→ Can not be used → First host address → 2^{nd} Host address : : → Last host address → Can not be used
netE	255.255.255.224	204.15.5.**128**/27	204.15.5.10000000/27 = 204.15.5.**128**/27 204.15.5.10000001/27 = 204.15.5.**129**/27 204.15.5.10000010/27 = 204.15.5.**130**/27 : : 204.15.5.10011110/27 = 204.15.5.**158**/27 204.15.5.10011111/27 = 204.15.5.**159**/27	→ Can not be used → First host address → 2^{nd} Host address : : → Last host address → Can not be used

Used Vs Unused IP Address



→ 14 hosts, 1 Network Address and 17 unused out of 32

→ 28 hosts, 1 Network Address and 3 unused out of 32

→ 2 hosts, 1 Network Address and 29 unused out of 32

→ 7 hosts, 1 Network Address and 24 unused out of 32

→ 28 hosts, 1 Network Address and 3 unused out of 32

Observations:-

- NetA, NetC, and NetD have a lot of unused host address space.
- It is possible that this was a deliberate design accounting for future growth, but in many cases this is just wasted address space due to the fact that the same subnet mask is used for all the subnets.

Question:- How can we avoid unnecessary wastage of IP addresses in designing subnetworks?

Ans:-

By using Variable Length Subnet Masks (VLSM), we can avoid the unnecessary wastage of IP addresses. VLSM allows us to use different masks for each subnet, thereby using address space efficiently.

VLSM (Variable Length Subnet Mask)

- Here, instead of allocating the same subnet mask for all the subnets, **different subnet mask** will be applicable for different network depending upon the requirement of the subnetworks.
- To Understand, let us solve the same example using VLSM as discussed in the next slide.
- ***Note:-*** *In previous example, the mask was same for all the subnets.*
- **Summary:-**
- **In VLSM→** Masking bits will be decided as per the requirements of the subnets (i.e., number of host addresses in subnet).
- **Without VLSM→** The masking bit will be decided as per the number of subnets and not on the # host.

Example 4.12:- Given the Class C network of 204.15.5.0/24, subnet the network in order to create the network as shown in figure 3 with the host requirements depicted therein. Use VLSM.

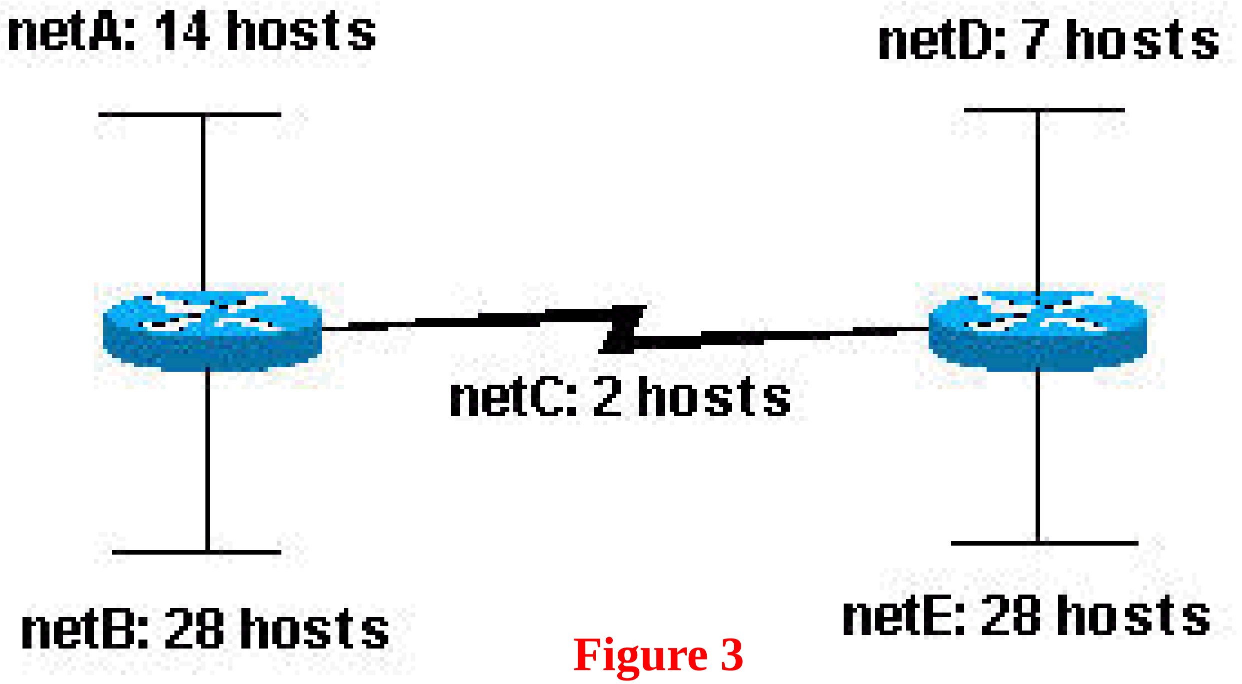


Figure 3

Solution

Determine what mask allows the required number of hosts.

- **netA:** requires a /28 (255.255.255.240) mask to support 14 hosts
- **netB:** requires a /27 (255.255.255.224) mask to support 28 hosts
- **netC:** requires a /30 (255.255.255.252) mask to support 2 hosts
- **netD*:** requires a /28 (255.255.255.240) mask to support 7 hosts
  - Note:- * a /29 (255.255.255.248) would only allow 6 usable host addresses therefore netD requires a /28 mask.
- **netE:** requires a /27 (255.255.255.224) mask to support 28 hosts

Address Assignment:- The easiest way to assign the subnets is to assign **the largest first.** For example, you can assign in this manner:

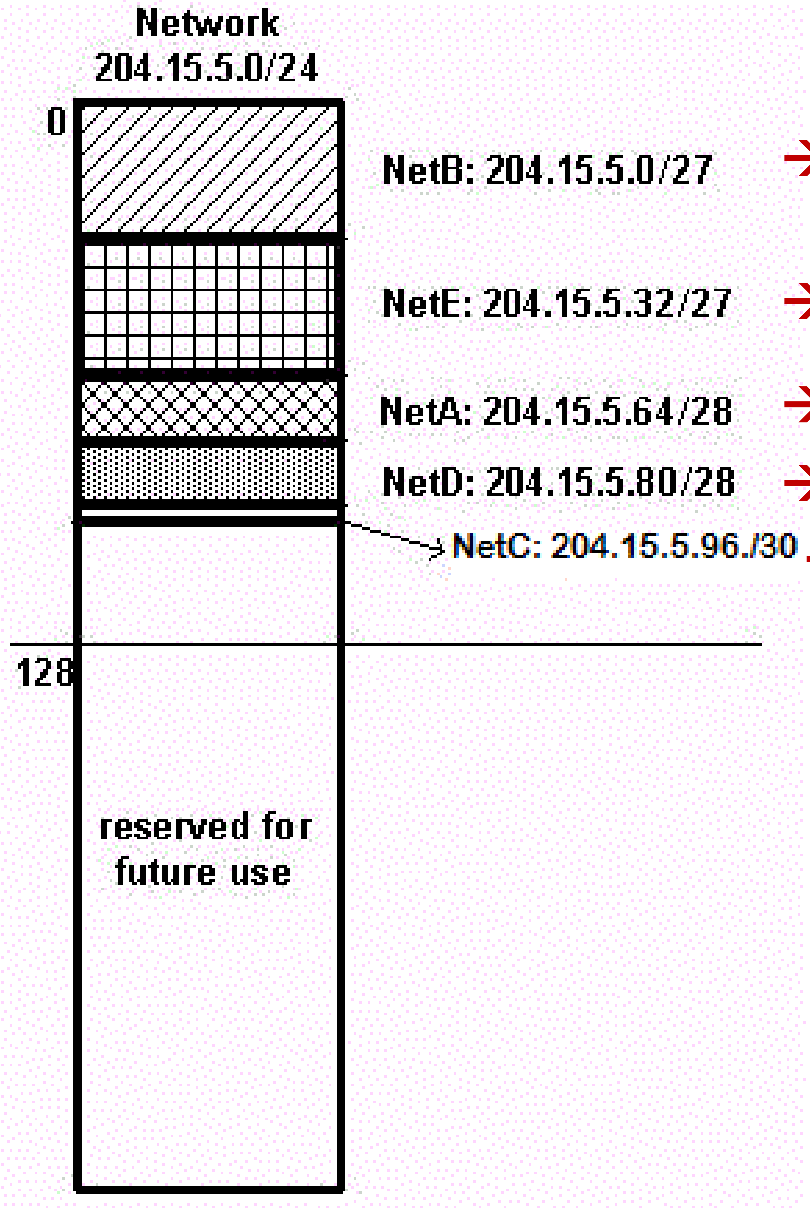
✓ netB: 204.15.5.**0**/27 host address range 1 to 30,
✓ **netE:** 204.15.5.**32**/27 host address range 33 to 62,
✓ **netA:** 204.15.5.**64**/28 host address range 65 to 78,
✓ **netD:** 204.15.5.**80**/28 host address range 81 to 94,
✓ **netC:** 204.15.5.**96**/30 host address range 97 to 98.

A complete network design is shown in the next slide.

Name of Subnet	Mask	Network Address	Range of IP Address	Remark
netB (28 Hosts)	255.255.255.224	204.15.5.**0**/27	204.15.5.00000000/27 = 204.15.5.0/27 204.15.5.00000001/27 = 204.15.5.1/27 204.15.5.00000010/27 = 204.15.5.2/27 : : 204.15.5.00011110/27 = 204.15.5.30/27 204.15.5.00011111/27 = 204.15.5.31/27	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used
netE (28 Hosts)	255.255.255.224	204.15.5.**32**/27 *Note: 0+2^5= 32*	204.15.5.00100000/27 = 204.15.5.32/27 204.15.5.00100001/27 = 204.15.5.33/27 204.15.5.00100010/27 = 204.15.5.34/27 : : 204.15.5.00111110/27 = 204.15.5.62/27 204.15.5.00111111/27 = 204.15.5.63/27	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used
netA (14 Hosts)	255.255.255.240	204.15.5.**64**/28 *Note: 32+2^5= 64*	204.15.5.01000000/28 = 204.15.5.64/28 204.15.5.01000001/28 = 204.15.5.65/28 204.15.5.01000010/28 = 204.15.5.66/28 : : 204.15.5.01001110/28 = 204.15.5.78/27 204.15.5.01001111/28 = 204.15.5.79/27	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used

Name of Subnet	Mask	Network Address	Range of IP Address	Remark
netD (7 Hosts)	255.255.255.240	204.15.5.**80**/28 *Note: 64+2^4= 80*	204.15.5.01010000/28 = 204.15.5.**80**/28 204.15.5.01010001/28 = 204.15.5. **81**/28 204.15.5.01010010/28 = 204.15.5. **82**/28 : : 204.15.5.01011110/28 = 204.15.5. **94**/28 204.15.5.01011111/28 = 204.15.5.**95**/28	→ Can not be used → First host address → 2nd Host address : : → Last host address → Can not be used
netC (2 Hosts)	255.255.255.252	204.15.5.**96**/30 *Note: 80+2^4= 96*	204.15.5.01100000/30 = 204.15.5.**96**/30 204.15.5.01100001/30 = 204.15.5.**97**/30 204.15.5.01100010/30 = 204.15.5.**98**/30 204.15.5.01100011/30 = 204.15.5.**99**/30	→ Can not be used → First host address → 2nd Host address → Can not be used

Used Vs Unused IP Address



→ 28 hosts, 1 Network Address and 3 unused out of 32

→ 28 hosts, 1 Network Address and 3 unused out of 32

→ 14 hosts, 1 Network Address and 1 unused out of 16

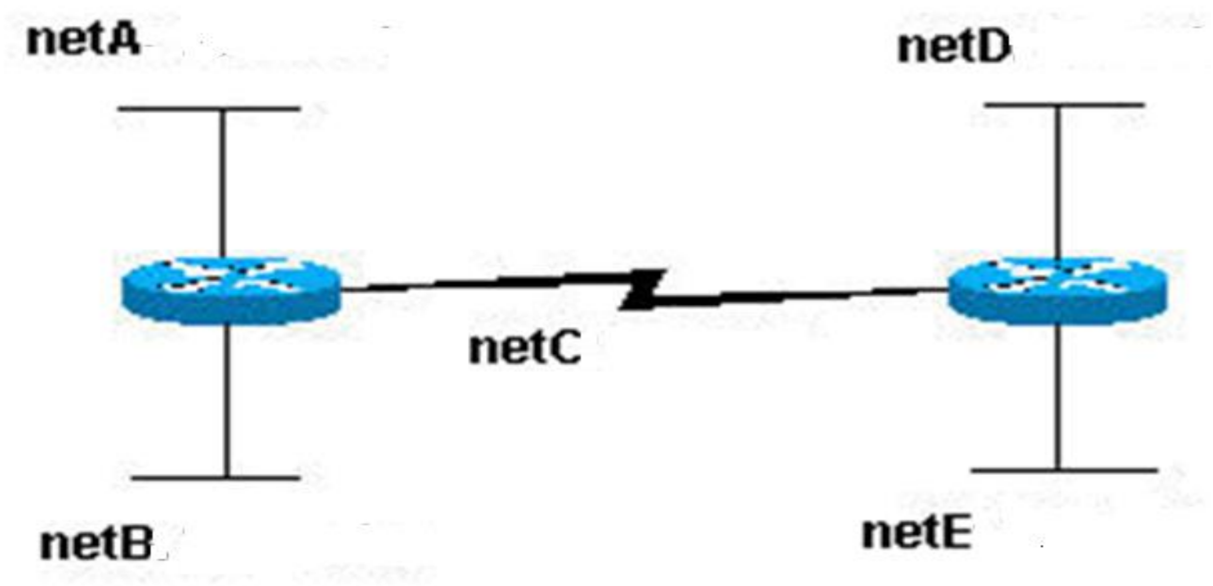
→ 7 hosts, 1 Network Address and 8 unused out of 16

→ 2 hosts, 1 Network Address and 1 unused out of 4

Observations:-

- NetA, NetC, and NetD have a lot of unused host address space.
- It is possible that this was a deliberate design accounting for future growth, but in many cases this is just wasted address space due to the fact that the same subnet mask is used for all the subnets.

- **HYU 4.7:**- Consider the ISP has provided you a Class C IP address 204.15.5.0/24. Now you want to create five subnetworks with name and number of hosts as follows: **Network *A*** with 126 hosts **Network *B*** with 62 hosts, **Network *C*** with 30 hosts, **Network *D*** with 14 hosts, and **Network *E*** with 14 hosts as shown in the diagram below. For the scenario elaborated above, design the network by focusing on the following points:
  1. Network Address and subnet mask of each sub network.
  2. Distribution of IP addresses for the host in each sub network.
  3. The total unused IP addresses.
  4. % of wastage of IP addresses.
  5. Clearly state assumptions (if any).



HYU 4.8:- An organization is granted a block of address with the beginning address 14.24.74.0/24. The organization needs to have three subblocks of addresses to use in its three subnets:

- One subblock of 10 addresses
- One subblock of 60 addresses and
- One subblock of 120 addresses

Design the subnetworks. Also, calculate the total unused IP addresses. Textbook solution

Example 4.13:- Consider the IP addresses of two devices given below. Identify, whether these devices are connected on same or different network.

DeviceA: 172.16.17.30/20 DeviceB: 172.16.28.15/20

Solution:-

Determine the Subnet for DeviceA:

172.16.17.30 → 10101100.00010000.00010001.00011110

Subnet Mask → 11111111.11111111.11110000.00000000 = 255.255.240.0

Subnet = 10101100.00010000.00010000.00000000 = 172.16.16.0

In this case, Device A belongs to subnet 172.16.16.0.

Determine the Subnet for DeviceB:

172.16.28.15 → 10101100.00010000.00011100.00001111

Subnet Mask → 11111111.11111111.11110000.00000000 = 255.255.240.0

Subnet = 10101100.00010000.00010000.00000000 = 172.16.16.0

From these determinations, DeviceA and DeviceB have addresses that are part of the same subnet.

Example 4.14:-

- Consider an organization is given the block **17.12.14.0/26**, which contains 64 addresses. The organization has three offices and needs to divide the addresses into three sub-blocks of 32, 16, and 16 addresses. How can this be done?

Solution

The first office can use a subnet mask n_1, s.t $2^{32-n_1} = 32$. So, n_1=27.

So, first office subnet mask becomes 255.255.255.224

1st address: 17.12.14.0/27; last address: 17.12.14.31/27

Thus, subnet 1 address = 17.12.14.0/27

The second office can use a subnet mask n_2, s.t $2^{32-n_2} = 16$. So, n_2=28.

So, second office subnet mask becomes 255.255.255.240

Any address in subnet 2, say **17.12.14.35/28**, can give us its address;

1st address: 17.12.14.32/28; last address: 17.12.14.47/28

Thus, subnet 2 address: 17.12.14.32/28

Similarly, for the third office, subnet mask $n_3 = 28$.

So, third office subnet mask becomes 255.255.255.240

Any address in subnet 3, say 17.12.14.50/28, can give us its address;

1st address: 17.12.14.48/28; last address: 17.12.14.63/28

Thus, subnet 3 address: 17.12.14.48/28.

Note→ All the addresses are included.

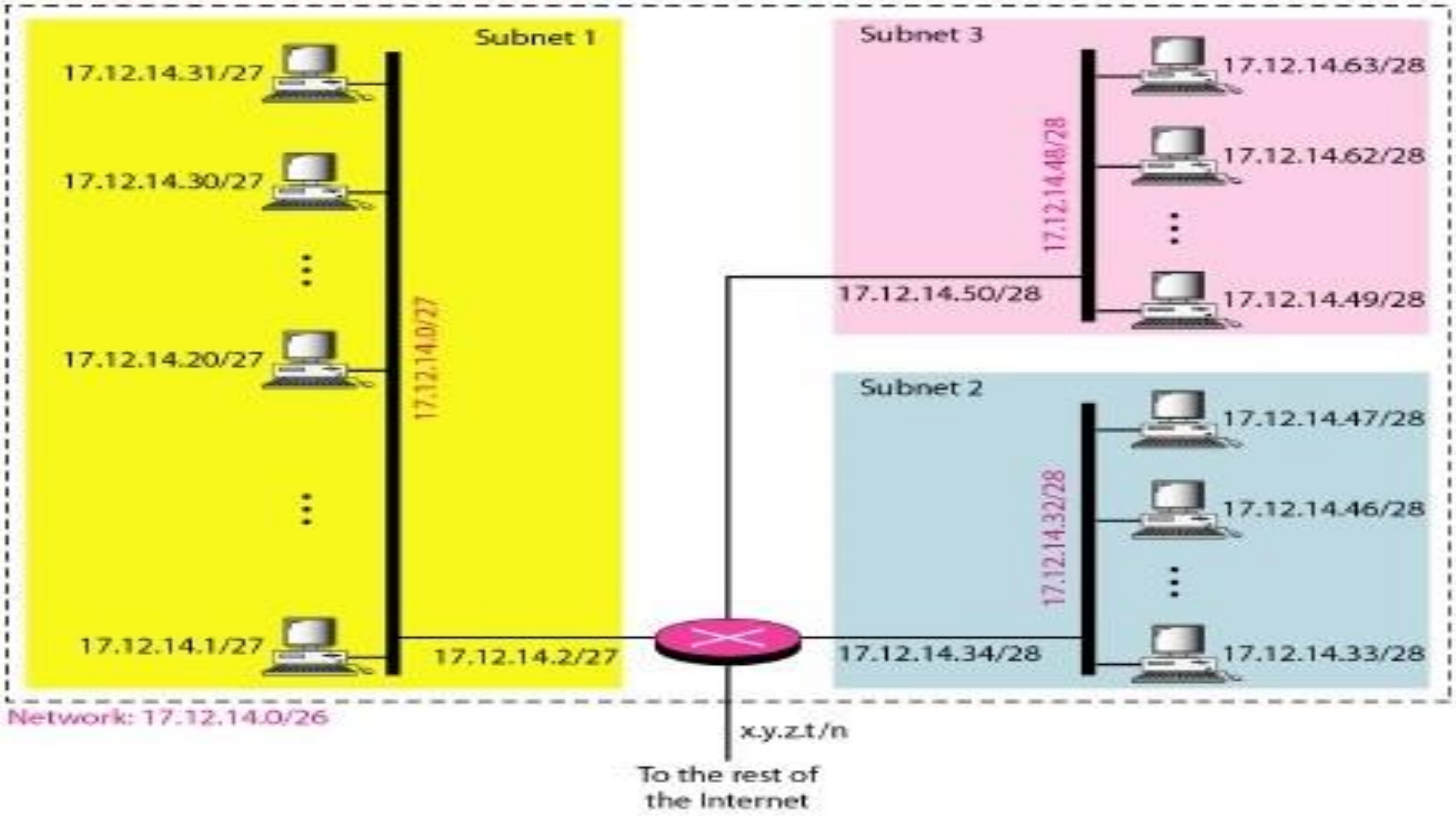


Fig: Configuration and Addresses in a Subnetted Network

Routing Table

Destination	Next Node	Interface
17.12.14.0/27	17.12.14.0/27	17.12.14.2/27
17.12.14.1/27 . . . 17.12.14.31/27	-------same-------	-------same--------
17.12.14.32/28 17.12.14.33/28 . . . 17.12.14.47/28	17.12.14.32/28 -------same-------	17.12.14.34/28 -------same-------
17.12.14.48/28 17.12.14.49/28 . . . 17.12.14.63/28	17.12.14.48/28 -------same-------	17.12.14.50/28 -------same-------

HYU 4.9:-

Problem: 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 subblocks and find out how many addresses are still available after these allocations.

Brain Exercise: Observe the number of unused addresses .

HYU 4.10:-

Problem: Assume you are going for a start-up. The ISP has allocated to you 162.12.0.0 as an IP address. But you want to create seven offices at Bhubaneswar, Mumbai, Patna, Kolkata, Guwahati, Pune, and Delhi consisting of 7800 hosts each.

As you have studied DCN course, you do not want to hire any one as a network engineer. Design the network by keeping the following points in mind.

a) Mask and Network address for each office.

b) Pool of IP addresses

c) First and last address

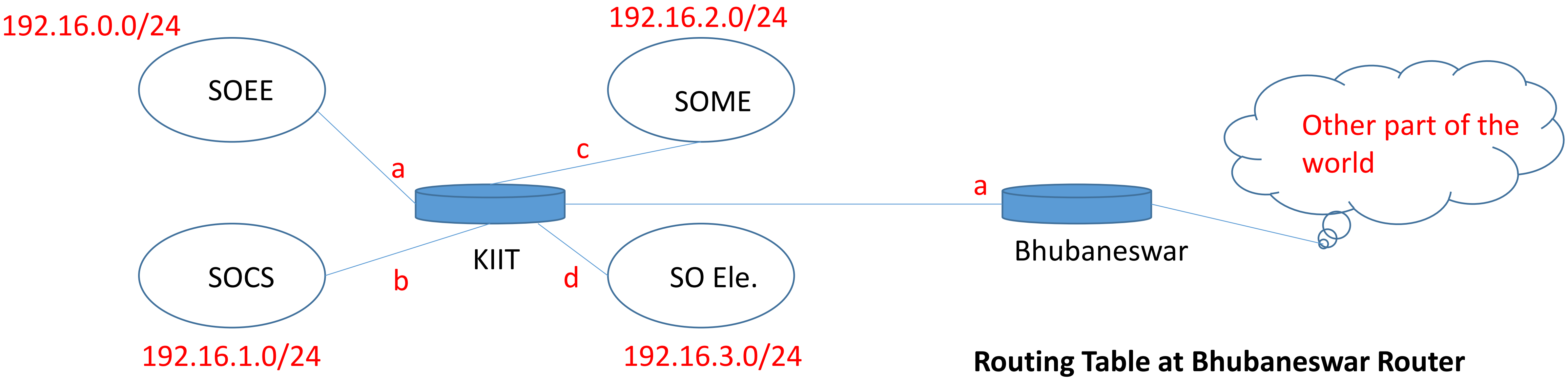
d) Broadcast address

Brain Exercise: Repeat the this Homework if you don't wish to choose 162.12.0.0 as an IP address for any of the subnetworks and observe the number of unused addresses .

Give me a Solution !!!!!!!!!!

- Assume, your friend is sending a message from Alaska to you in Bhubaneswar using Internet. Can you guess how many entries will be there in routing table to which your friend is connected?

Supernetting or aggregation



Routing Table at Bhubaneswar Router

Network address	Mask	Interface
192.16.0.0/24	255.255.255.0	a
192.16.1.0/24	255.255.255.0	a
192.16.2.0/24	255.255.255.0	a
192.16.3.0/24	255.255.255.0	a
For Other Part	Of	The world

Routing Table at KIIT Router

Network address	Mask	Interface
192.16.0.0/24	255.255.255.0	a
192.16.1.0/24	255.255.255.0	b
192.16.2.0/24	255.255.255.0	c
192.16.3.0/24	255.255.255.0	d

Note: From the routing table at Bhubaneswar, it is clear that it will have all information of routing table at KIIT along with routing information of other part of the world.

Thus we need supernetting to reduce the burden of routers by combining several small networks into a super network.

Key point for Supernet

- It has to follow the CIDR restrictions.
- Networks to be supernetted must be of same size; otherwise choose those which are of same size and repeat.
- **Blind Rule:** Borrow from the network id, thus in supernetting decreases the number of 1s in the mask.

Solution:

Supernet Mask: As four networks are to be combined with n= 24 each. Thus for supernet, the value of n becomes = 22

Thus supernet Mask = **11111111.11111111.11111100.00000000 = 255.255.252.0**

First Network address: take any one of the given network address and make 32-22=10 right most bits 0.

Thus we get **192.16.0.0/22** as first network address.

Alternate Solution: Take any one of the given network address and do 'AND' operation with mask.

	192. 16. 2. 0
AND	255. 255. 252. 0
	192. 16. 0. 0

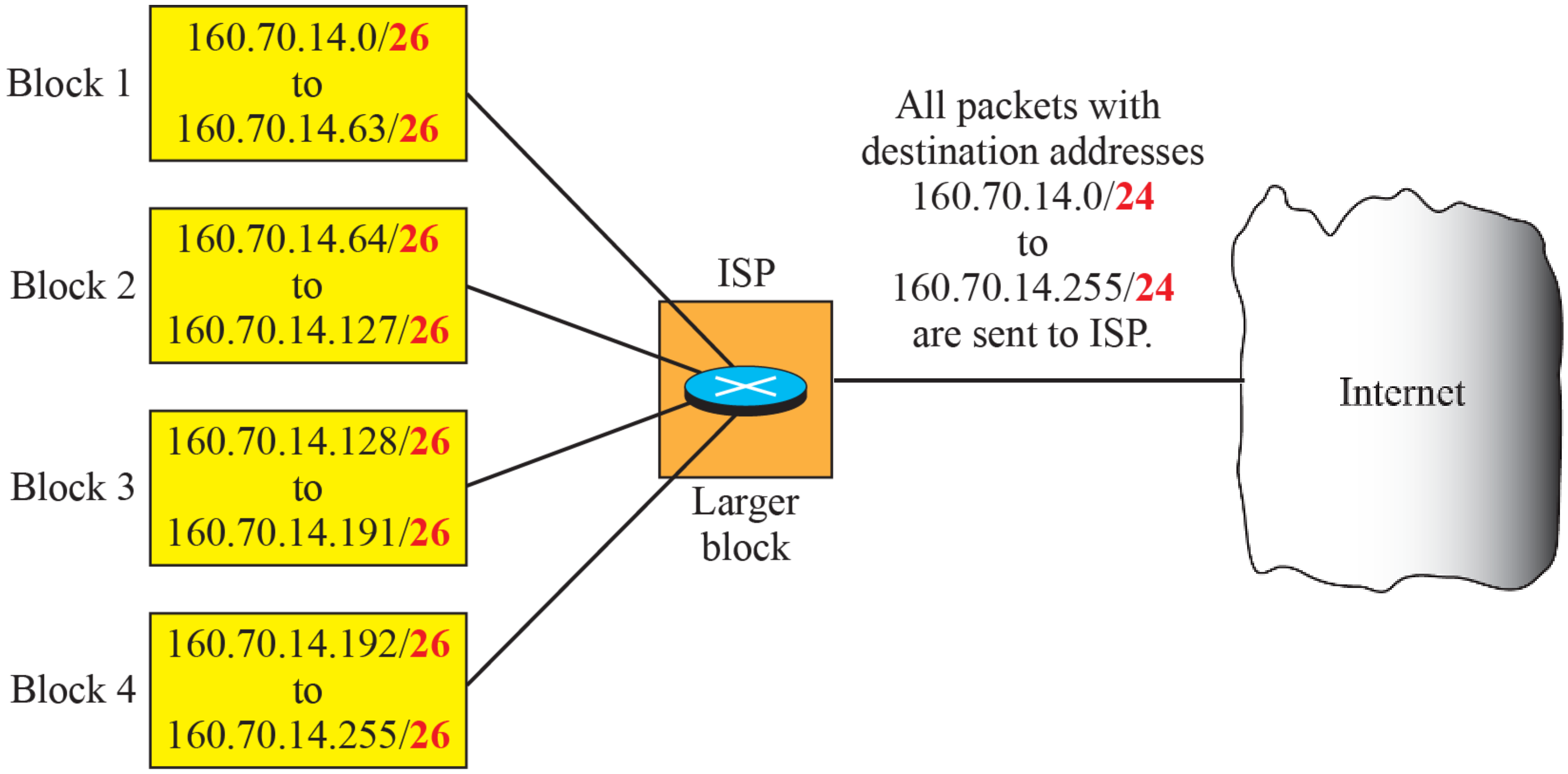
First Network address

Routing Table at Bhubaneswar Router

Network address	Mask	Interface
192.16.0.0/22	255.255.252.0	a
For Other Part	**Of**	**The world**

Example 4.15:- Figure 4.37 shows how four small blocks of addresses are assigned to four organizations by an ISP. The ISP combines these four blocks into one single block and advertises the larger block to the rest of the world. Any packet destined for this larger block should be sent to this ISP. It is the responsibility of the ISP to forward the packet to the appropriate organization.

Analogy:- *This is similar to routing we can find in a postal network. All packages coming from outside a country are sent first to the capital and then distributed to the corresponding destination.*

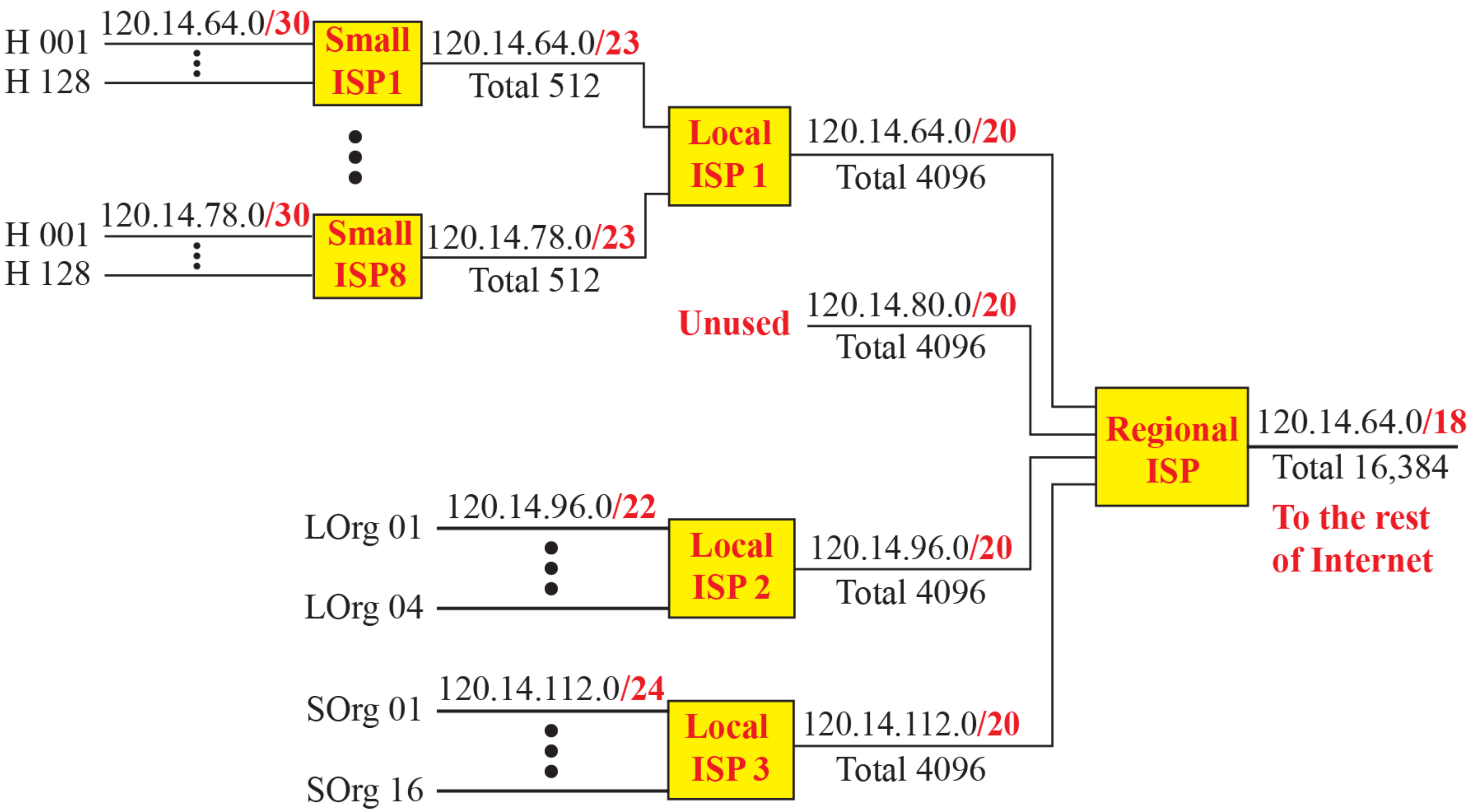


HYU 4.11:-

- Assume 16 networks with network addresses from 192.16.32.0/24 to 192.16.47.0/24 are connected to router R1 which itself is connected to router R2. Give the routing table of R2.
- **Hint:** Routing table will have only one information in it which is first network address, its mask and interface. You can name interface as per your wish.

Example 4.16:- Consider a regional ISP is granted 16,384 addresses, starting from 120.14.64.0/18. The regional ISP has decided to divide these addresses into 4 subblocks, each with 4096 addresses. All these subblocks are assigned to Local ISP namely, *Local ISP1*, *Local ISP2*, *Local ISP3* and *Local ISP4*. The *Local ISP1* has divided its assigned subblock into 8 smaller sub blocks and assigned each to 8 smaller ISP, namely *Small ISP1 to Small ISP8.* Each Small ISP provides services to 128 households, namely *H001 to H128*, each using 4 addresses. The *Local ISP3* has divided its block into 4 blocks and has assigned addresses to 4 large organizations, namely LOrg1 to LOrg4, with 1024 addresses in each. The *Local ISP4* has divided its block into 16 blocks and has assigned each block to 16 small organizations, namely SOrg1 to SOrg16, with 256 addresses in each. Design the hierarchy of addressing using the concept of VLSM. Clearly state the assumptions, if any.

Solution:- refer next slide



H 001
H 128
120.14.64.0/30
Small ISP1
120.14.64.0/23
Total 512
H 001
H 128
120.14.78.0/30
Small ISP8
120.14.78.0/23
Total 512
Local ISP 1
120.14.64.0/20
Total 4096
Unused
120.14.80.0/20
Total 4096
Regional ISP
120.14.64.0/18
Total 16,384
To the rest of Internet
LOrg 01
LOrg 04
120.14.96.0/22
Local ISP 2
120.14.96.0/20
Total 4096
SOrg 01
SOrg 16
120.14.112.0/24
Local ISP 3
120.14.112.0/20
Total 4096