Network Layer & IP Protocol

VSNL'S INTERNET RATE CHART

Price structure of Videsh Sanchar Nigam Ltd's Internet service: August 1995

USER CATEGORY	DIAL-UP	LEASED LINE		
	9.6 kbps	9.6 kbps	64 kbps	128 kbps
Professionals	Rs 5,000	--	--	--
Non-commercial	Rs 15,000	Rs 2,40,000	Rs 6,00,000	Rs 10,00,000
Commercial	Rs 25,000	Rs 6,00,000	Rs 15,00,000	Rs 25,00,000
Exporters	Rs 20,000	Rs 4,80,000	Rs 12,00,000	Rs 20,00,000
Service providers	--	Rs 7,20,000	Rs 18,00,000	Rs 30,00,000

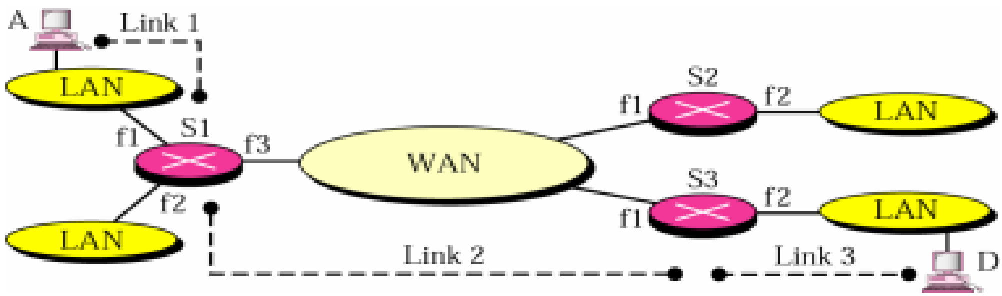
Network Layer

Network Layer – supervises host-to-host packet delivery – hosts could be separated by several physical networks

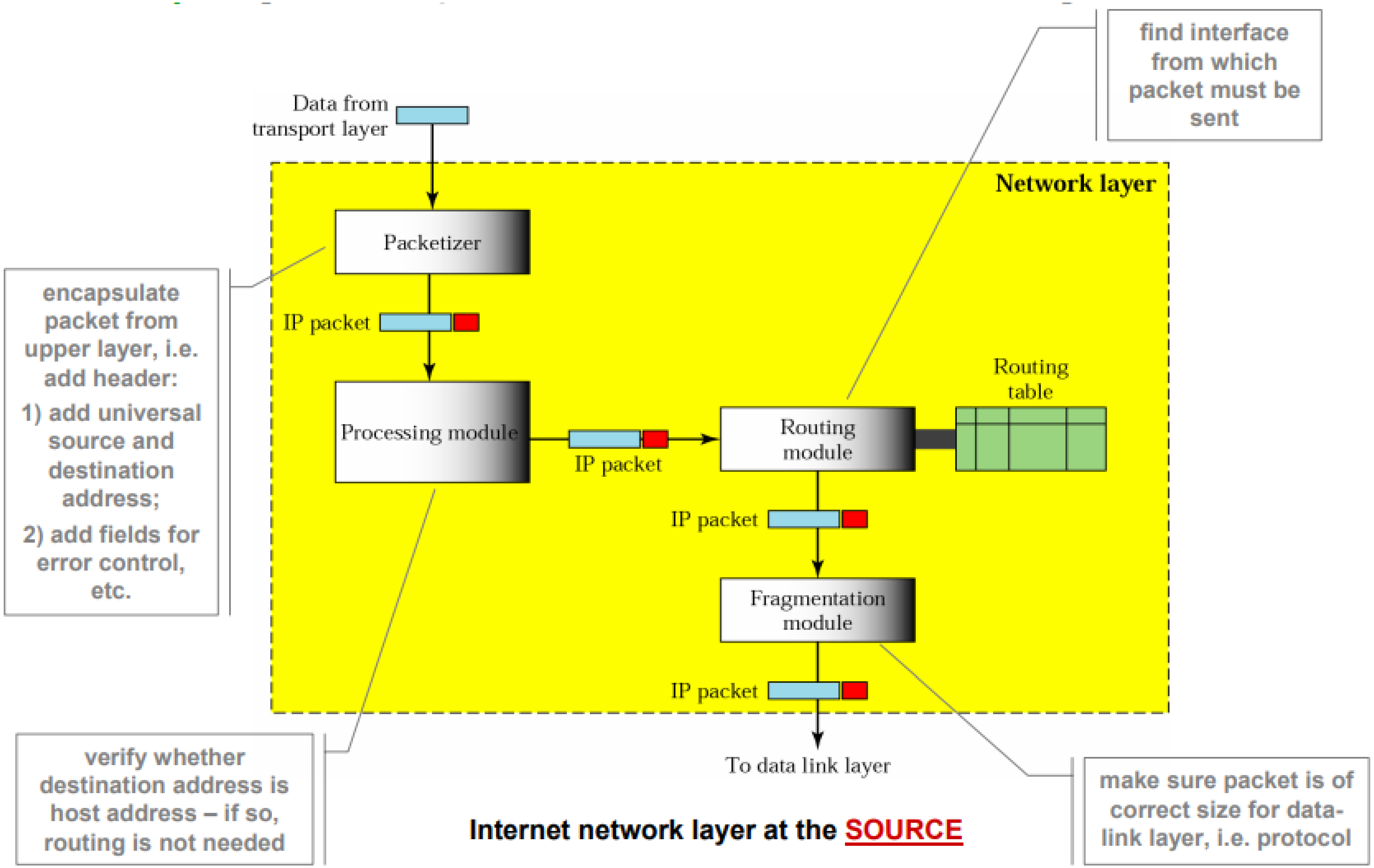
- data-link layer provides node-to-node delivery, transport layer provides process-to-process delivery

Major (Basic) Network Layer Duties

- **addressing**: identify each device uniquely to allow global communication
- **routing**: determine optimal route for sending a packet from one host to another
- **packetizing**: encapsulate packets received from upper-layer protocols
- **fragmenting**: decapsulate packets from one and encapsulate them for another network

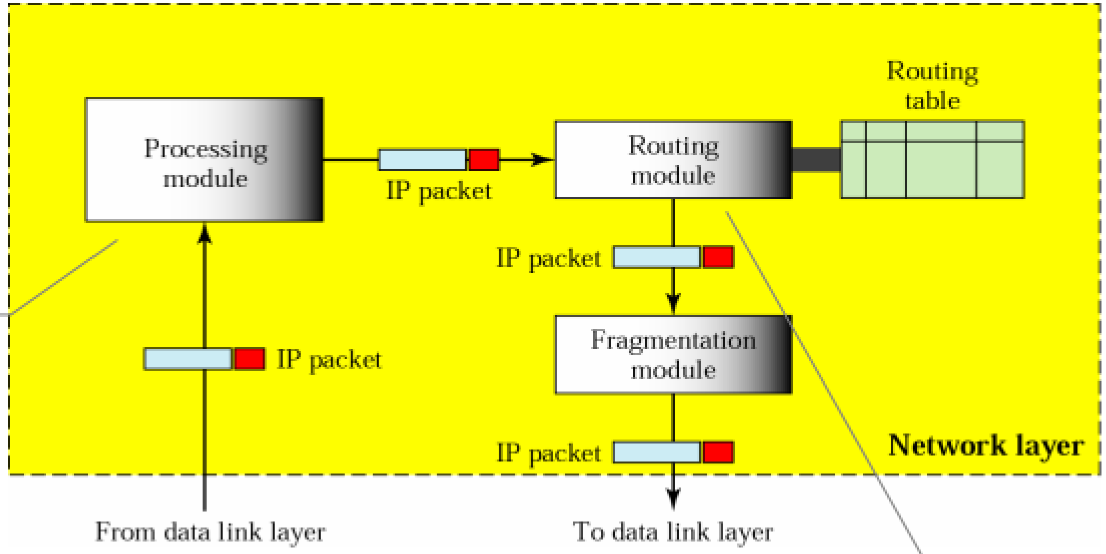


NWL Functionality at Source



Internet network layer at the SOURCE

NWL Functionality at Router



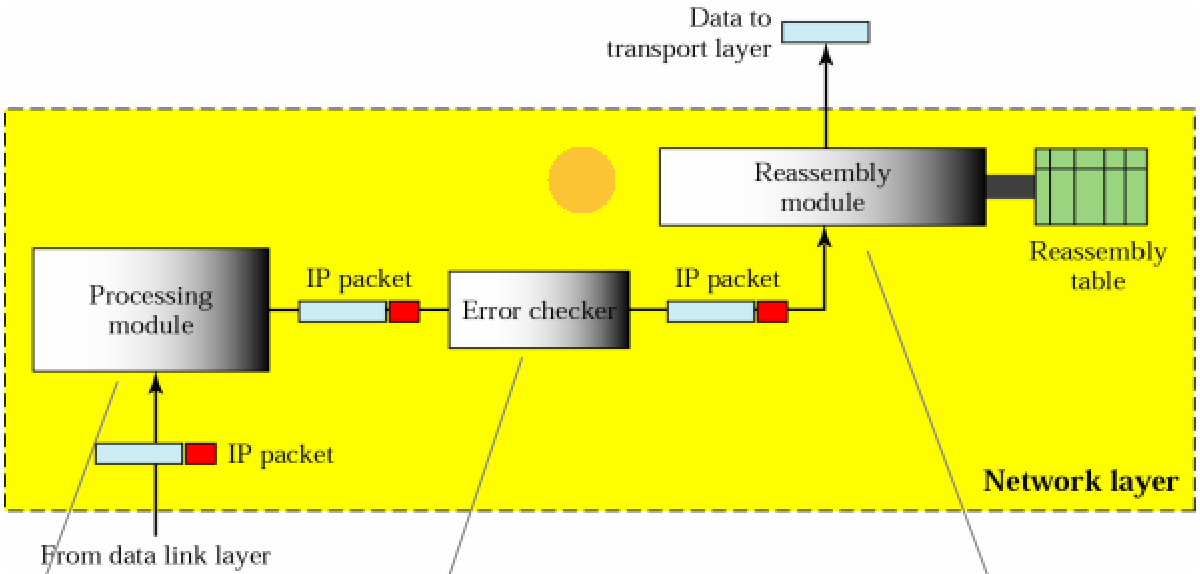
check if packet has reached its final destination or needs to be forwarded (TTL!)

+ header error checking !!!

find interface from which packet must be sent

Internet network layer at a <u>ROUTER</u>

NWL Functionality at Destination



Internet network layer at the DESTINATION

verify whether destination address is host address

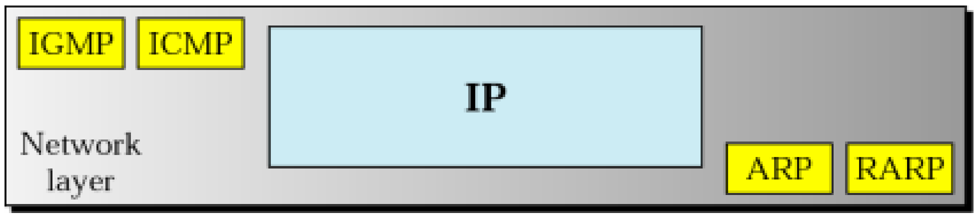
check if packet has been corrupted during transmission

if packet has been fragmented, wait until all fragments have arrived, reassemble them, and then deliver the reassembled packet to transport layer

Internet Network Layer Protocols

Network Layer Protocols in the Internet

- **IP** – main protocol, responsible for 'best effort' host-to-host delivery
- **ARP** – maps IP address of next hop to its MAC/physical address (used when passing packets to lower data-link layer)
- **RARP** – maps MAC/physical address to IP address (used at diskless machines for IP address recovery)
- **ICMP** – used by hosts and routers to handle unusual situations such as IP packet-header errors, unreachable hosts and networks, etc.
- **IGMP** – used by host and routers to achieve efficient network-layer multicasting
- **Routing Protocols** – responsible for routing table maintenance



IP ADDRESSING METHODS

What is an IP address?

- IP (Internet Protocol) address

➢ A way to identify machines on a network

➢ A unique identifier Used to connect to another computer

TYPES OF IP ADDRESSES

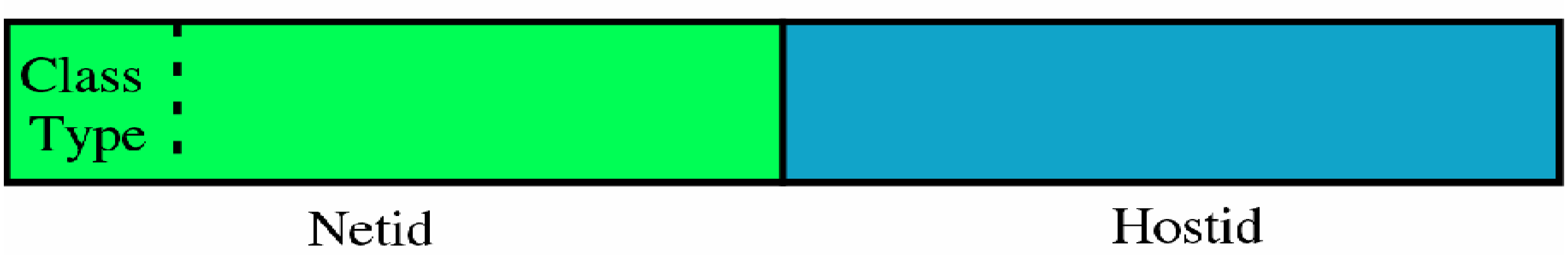
An IPv4 address is a 32-bit address that uniquely and universally defines the connection of a device (for example, a computer or a router) to the Internet.

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 IPv6.

An IPv6 address is 128 bits long.

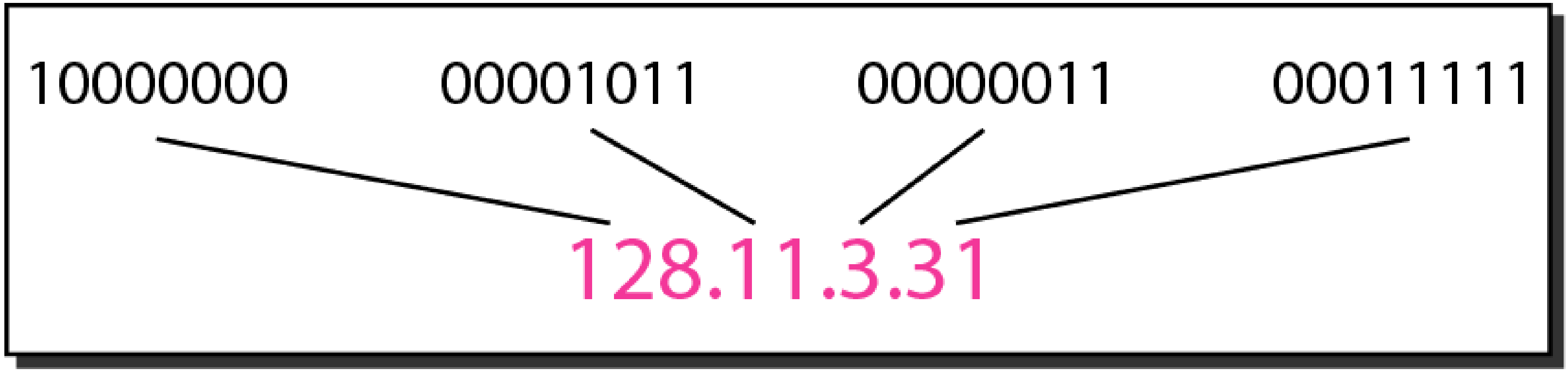
IP STRUCTURE

- IP addresses consist of four sections
- Each section is 8 bits long
- Each section can range from 0 to 255
- network layer address, consisting of NETWORK portion, and HOST portion



NOTATIONS

Dotted-decimal notation and binary notation for an IPv4 address



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

Classful addressing

- IPV4 addressing uses the concept of classes .
- This architecture is called as classful addressing
- Special case of classless addressing
- In CA the address space is divided into five classes :
  - **A,B,C,D,E**
  - Each class occupies some part of the address space

CLASSES

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

a. Binary 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			

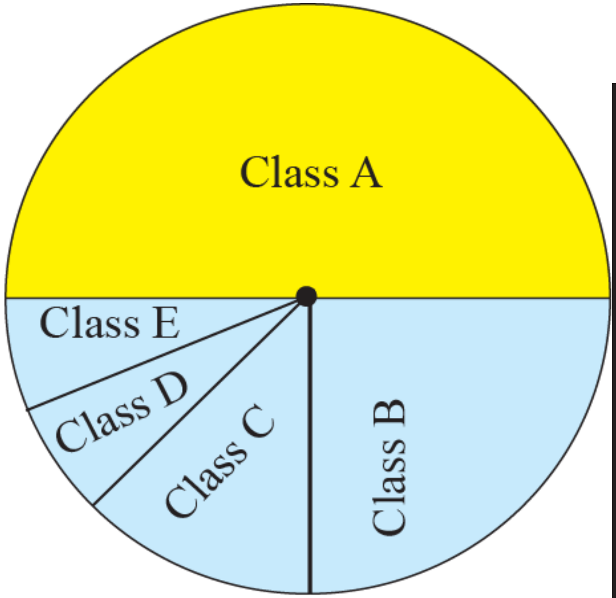
b. Dotted-decimal notation

ADDRESSES AND BLOCKS

Class	*Number of Blocks*	*Block Size*
A	2^{7} = 128	2^{24} = 16,777,216
B	2^{14} = 16,384	2^{16} = 65,536
C	2^{21} = 2,097,152	2^{8} = 256
D	1	2^{28} = 268,435,456
E	1	2^{28} = 268,435,456

The first address in a block is normally not assigned to any device; it is used as the network address that represents the organization to the rest of the world.

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



Class A: 2^{31} = 2,147,483,648 addresses, 50%

Class B: 2^{30} = 1,073,741,824 addresses, 25%

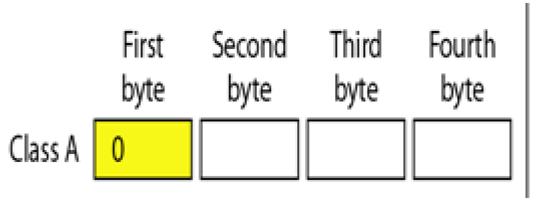
Class C: 2^{29} = 536,870,912 addresses, 12.5%

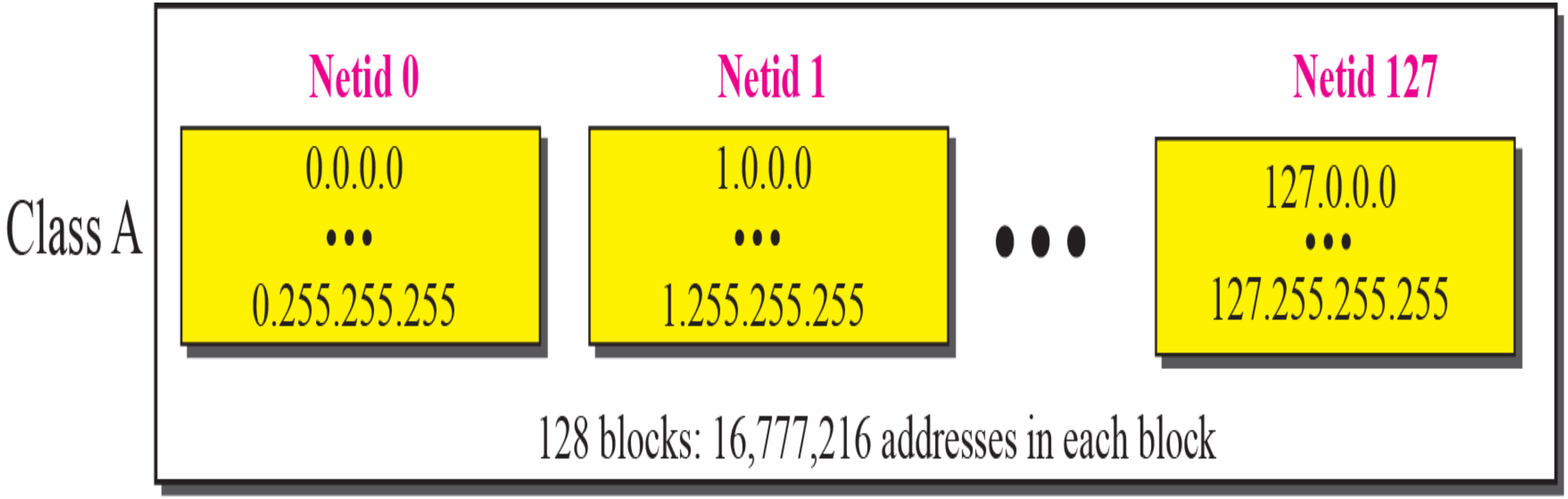
Class D: 2^{28} = 268,435,456 addresses, 6.25%

Class E: 2^{28} = 268,435,456 addresses, 6.25%

CLASS A

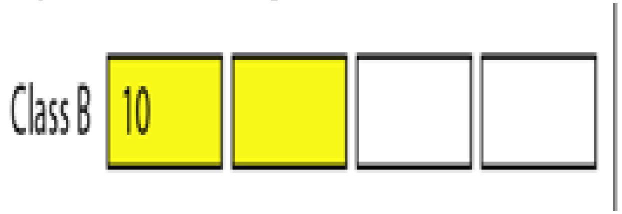
- This class is for very large networks, such as a major international company might have
  - 0000000-01111111
  - 0-127
  - 0 can not be used as Net ID
  - 127 is reserved for loop back functions
  - 126 Different Networks
  - 16,777,216 Hosts per Network

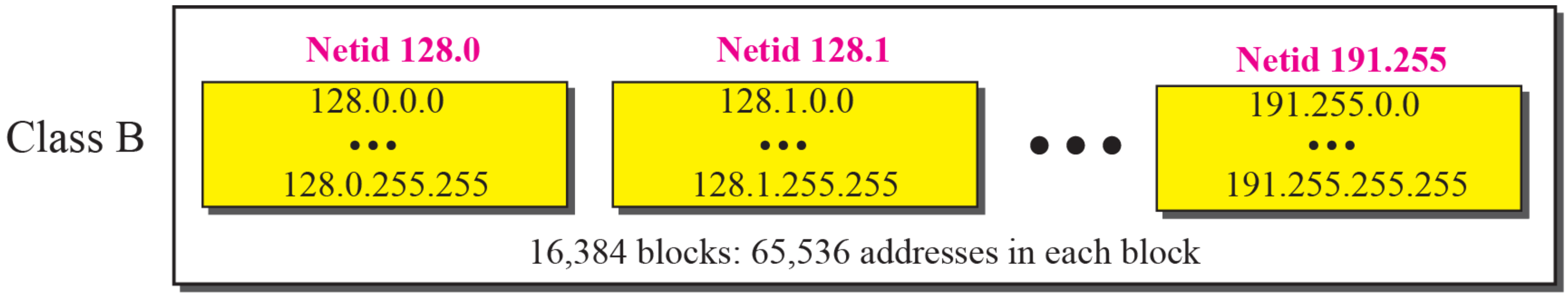




CLASS B

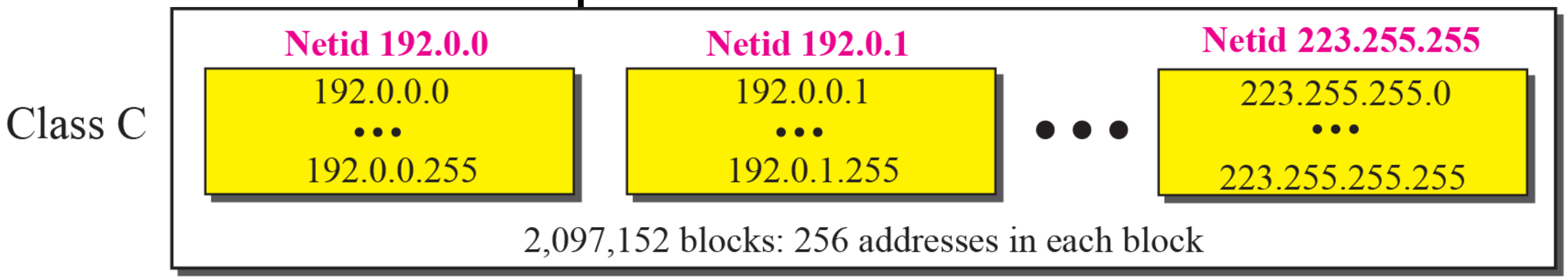
- This class is used for medium-sized networks.
- A good example is a large college campus.
  - 1000000-101111111
  - 128-191
  - The first IP Address is the NET ID
  - The last IP Address is the Broadcast Address
  - 16,384 Different Networks
  - 65,536 Hosts per Network





CLASS C

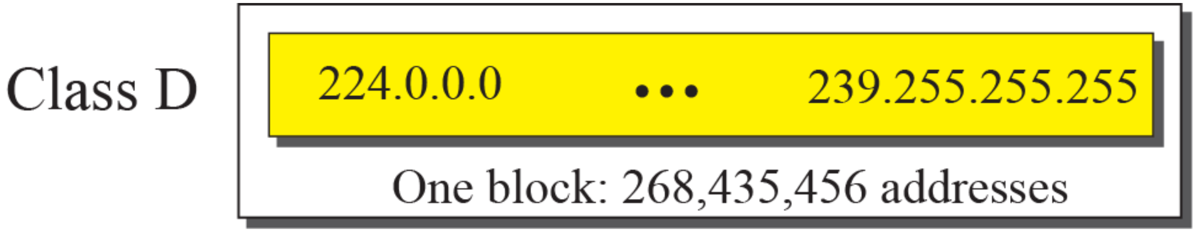
- Class C addresses are commonly used for small to mid-size businesses.
  11000000-11011111
  192-223
  - The first IP Address is the NET ID
  - The last IP Address is the Broadcast Address
  - 2,097,152 Different Networks
  - 256 Hosts per Network



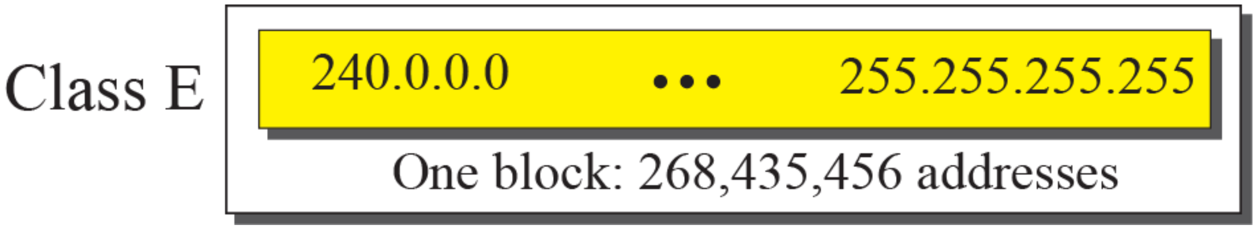
CLASS D &E

CLASS D – Used for multicast broadcasts

- Single Block of Class D address
- Each address in this class is used to define one group of hosts on the Internet.
- When a group is assigned an address in this class, every host will have unique IP in addition to common multicast address



CLASS E – Experimental addresses not available to the public



Example

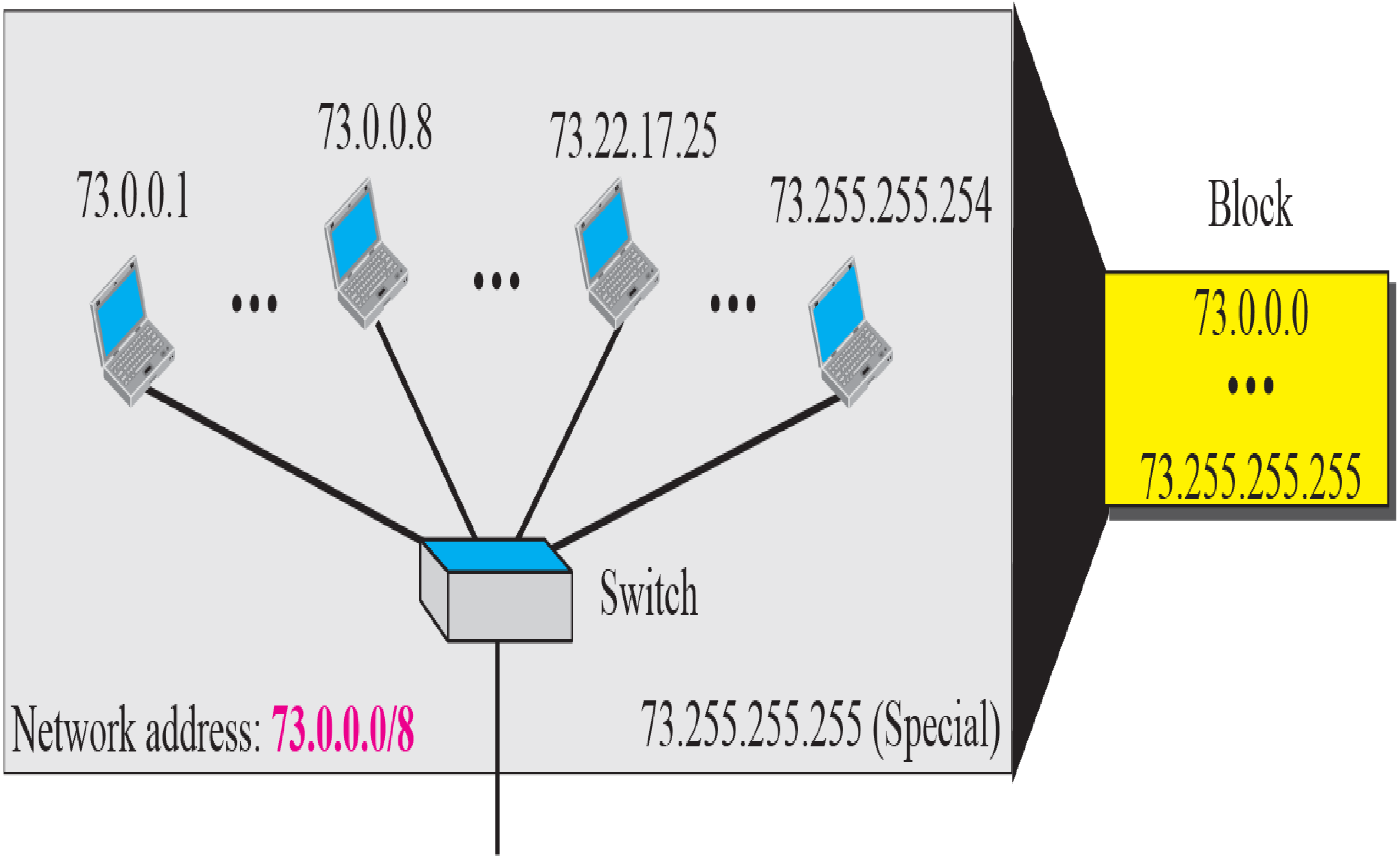
An Classful address in a block is given as 73.22.17.25. Find the number of addresses in the block, the first address, and the last address.

Solution

Figure 5.16 shows a possible configuration of the network that uses this block.

1. The number of addresses in this block is $N = 2^{32-n} =$ 16,777,216.
2. To find the first address, we keep the leftmost 8 bits and set the rightmost 24 bits all to 0s. The first address is 73.0.0.0/8, in which 8 is the value of *n*.
3. To find the last address, we keep the leftmost 8 bits and set the rightmost 24 bits all to 1s. The last address is 73.255.255.255.

Netid 73: common in all addresses



Example

An address in a block is given as 180.8.17.9. Find the number of addresses in the block, the first address, and the last address.

Solution

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1. The number of addresses in this block is $N = 2^{32-n} = 65{,}536$.
2. To find the first address, we keep the leftmost 16 bits and set the rightmost 16 bits all to 0s. The first address is 18.8.0.0/16, in which 16 is the value of *n*.
3. To find the last address, we keep the leftmost 16 bits and set the rightmost 16 bits all to 1s. The last address is 18.8.255.255.

Example

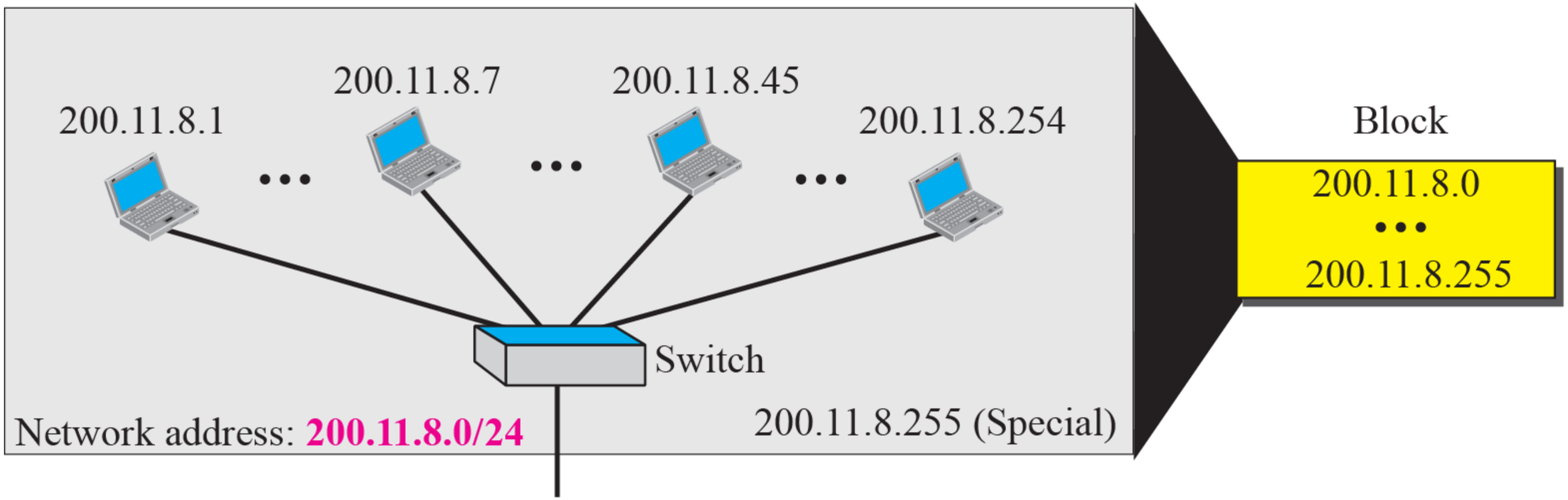
An address in a block is given as 200.11.8.45. Find the number of addresses in the block, the first address, and the last address.

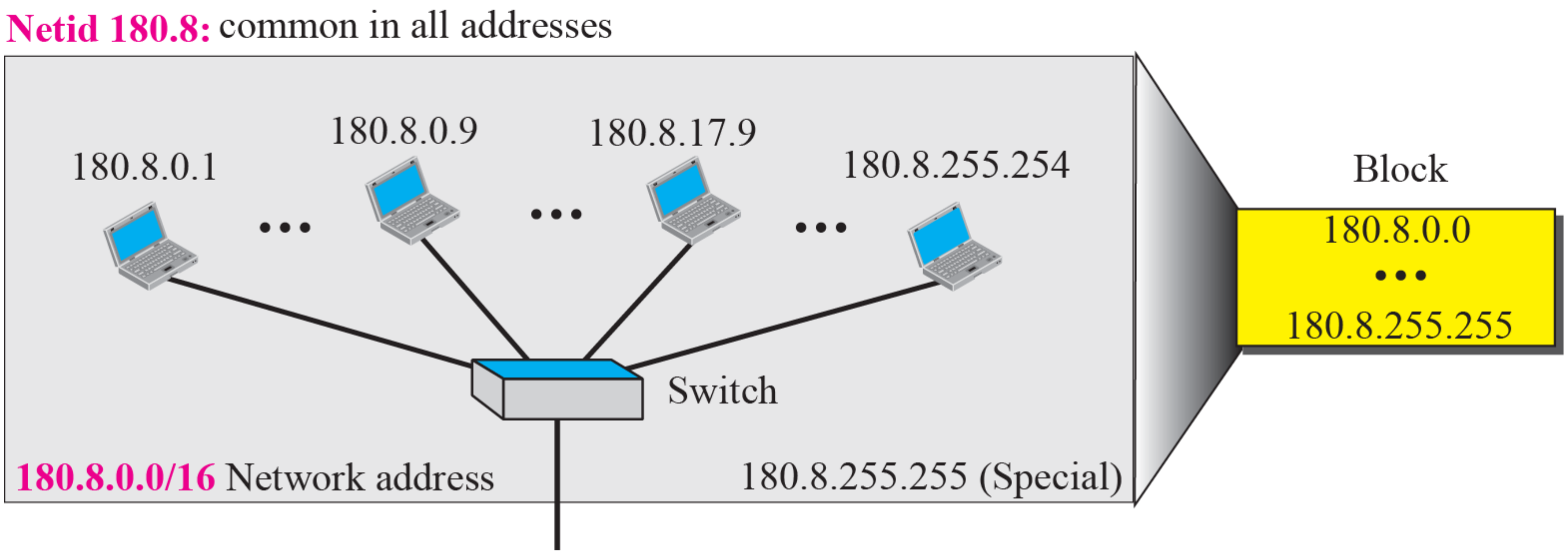
Solution

shows a possible configuration of the network that uses this block.

1. The number of addresses in this block is $N = 2^{32-n} = 256$.
2. To find the first address, we keep the leftmost 24 bits and set the rightmost 8 bits all to 0s. The first address is 200.11.8.0/16, in which 24 is the value of *n*.
3. To find the last address, we keep the leftmost 24 bits and set the rightmost 8 bits all to 1s. The last address is 200.11.8.255/16.

Netid 200.11.8: common in all addresses




Netid 180.8: common in all addresses
180.8.0.1
180.8.0.9
180.8.17.9
180.8.255.254
Switch
180.8.0.0/16 Network address
180.8.255.255 (Special)
Block
180.8.0.0
180.8.255.255

Special Unicast IPv4 Addresses

- Default Route
- Loopback Address
  - Special address that hosts use to direct traffic to themselves.
  - 127.0.0.0 to 127.255.255.255
- Link-Local Addresses
  - 169.254.0.0 to 169.254.255.255 (169.254.0.0 /16)
  - Can be automatically assigned to the local host by the operating system in environments where no IP configuration is available.
- TEST-NET Addresses
  - 192.0.2.0 to 192.0.2.255 (192.0.2.0 /24)
  - Set aside for teaching and learning purposes.
  - These addresses can be used in documentation and network examples.

Private Address

- RFC 1918
  - 10.0.0.0 to 10.255.255.255 (10.0.0.0 /8)
  - 172.16.0.0 to 172.31.255.255 (172.16.0.0 /12)
  - 192.168.0.0 to 192.168.255.255 (192.168.0.0 /16)
- The addresses will not be routed in the Internet
  - Need NAT/PAT (next)
- Should be blocked by your ISP
- Allows for any network to have up to 16,777,216 hosts (/8)

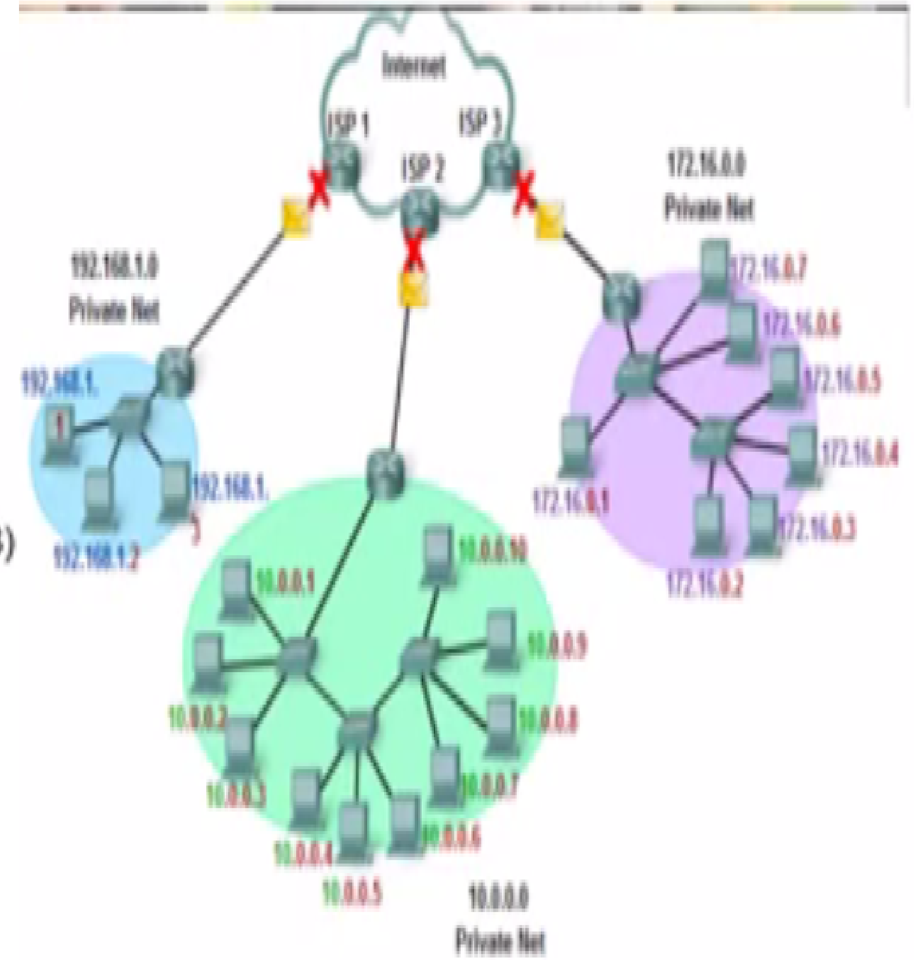
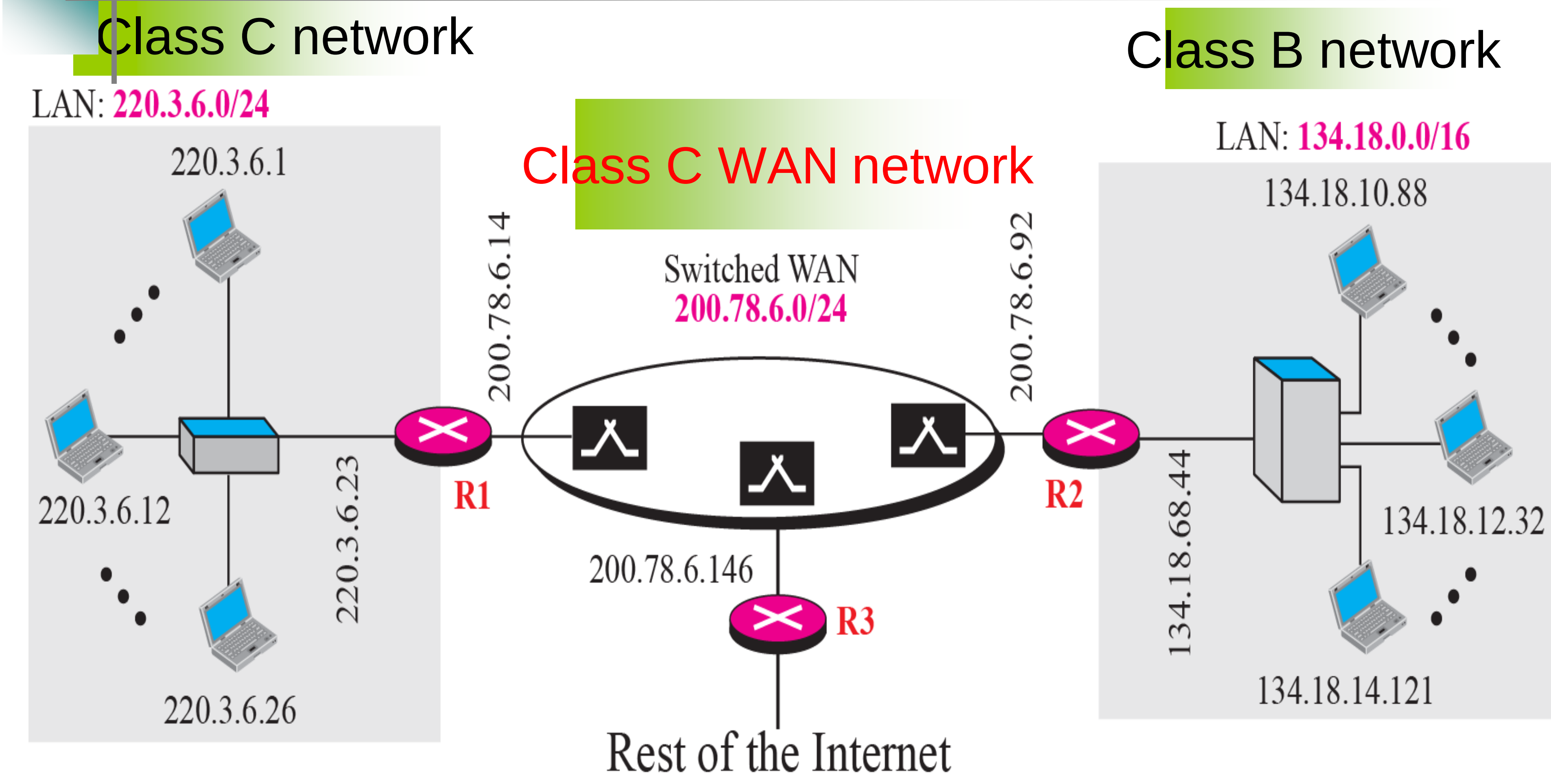


Figure 5.19 *Sample Internet*



Significance of network address

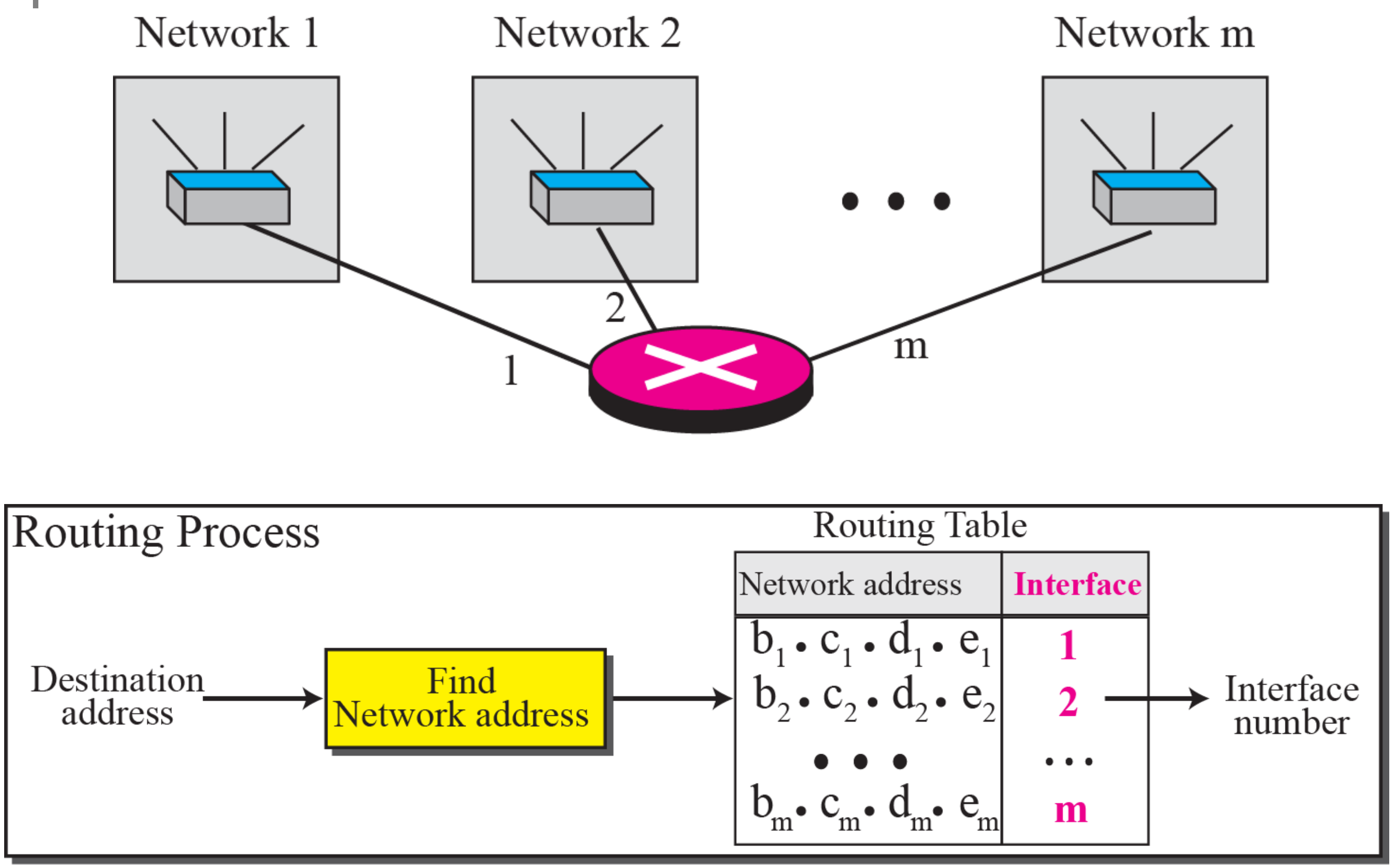
- Network address is the identifier of a network and not assigned/used for individual device.

- Refers to a whole network.
- It is used in routing a packet to its destination network.

- Assuming a router is connected to “m” network via its “m” interfaces, the router needs to know thru which network the packet needs to be sent out.

- **Router first finds Network address. Then it consults routing table to find the corresponding interface from which packet needs to be sent out.**

Figure 5.20 *Network addresses*



Network mask

- Routers in Internet uses an algorithm to **extract network address** from **destination address.**
- **For this, a network mask is used.**
- Network mask or default mask in classful addressing is a 32 bit number with:

“n” leftmost bits set to “1”

(32-n) rightmost bits set to “0”

Dose not apply to classes D and E.

CIDR(Classless Interdomain Routing): used to show the mask in the form /n (n=8,16,24)

There are three default masks for classful addressing.

Figure 5.21 *Network mask*

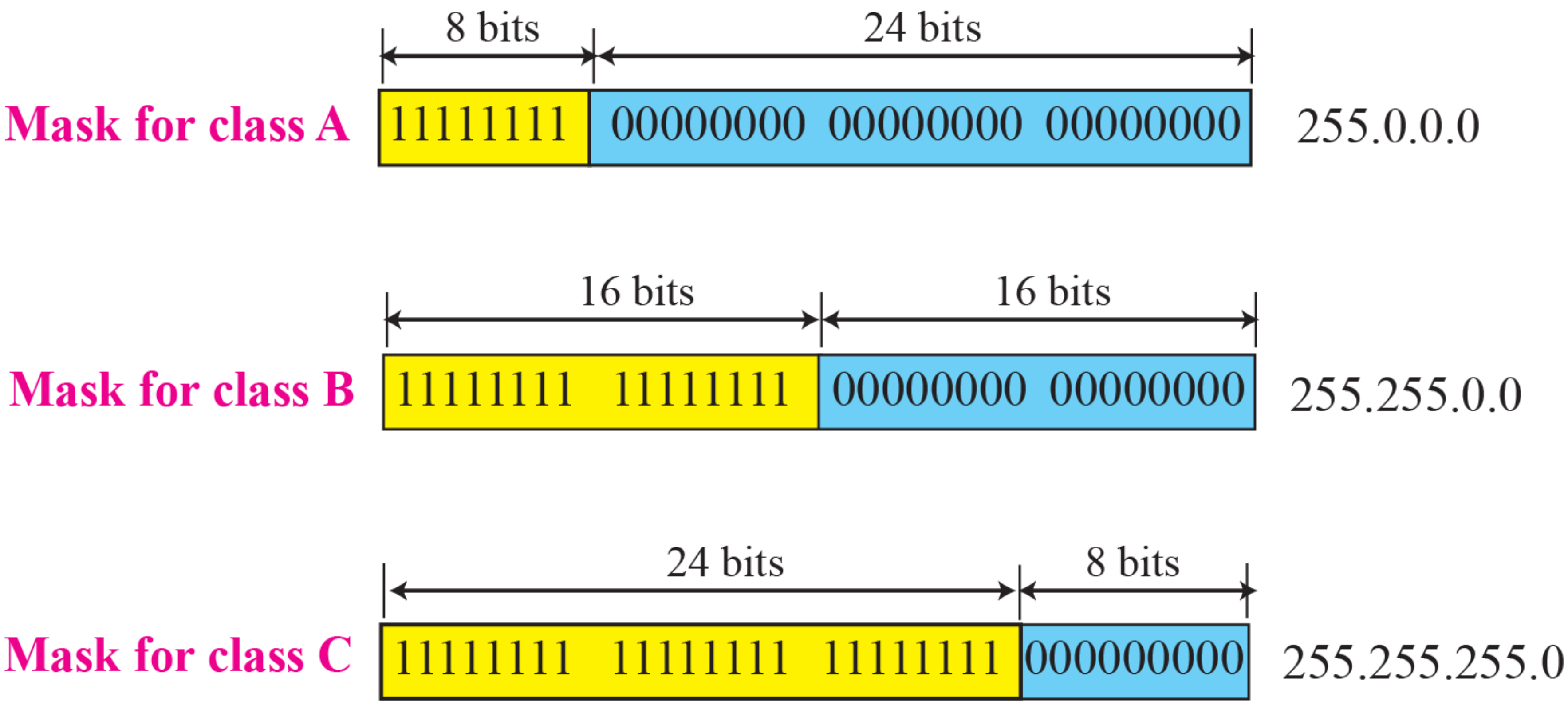
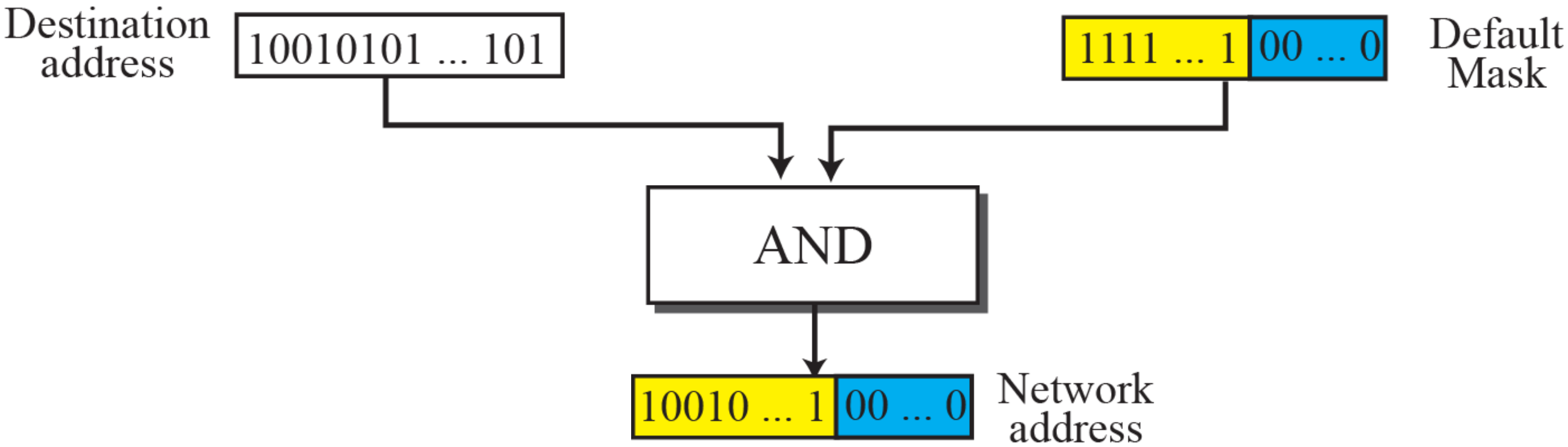


Figure 5.22 *Finding a network address using the default mask*



Example 5.16

A router receives a packet with the destination address 201.24.67.32. Show how the router finds the network address of the packet.

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A router receives a packet with the destination address 201.24.67.32. Show how the router finds the network address of the packet.

Solution

Since the class of the address is C, we assume that the router applies the default mask for class B, 255.255.255.0 to find the network address.

NA: 201.24.67.0

Problems in 2-level hierarchy of address

- **One problem is that each class is divided into fixed number of blocks with each block having a fixed size**
- Organization granted a **block from A or B** needed to divide its large network into several subnetworks – **for the purpose of security and management**
- **Blocks in Class A and B were also getting depleted, but addresses within them remain wasted**
- **Blocks in Class C are smaller than any organization needs**
- **Identified issue: Blocks of addresses within class A, B remains wasted whereas many other organizations need these addresses for their usage. For these orgs, Class C blocks are insufficient. Also, there is a need to divide networks for better management.**

Three Level addressing

Subnetting

Original design in classful addressing – 2 Levels

- IP addresses were originally designed with <u>two levels of addressing</u>

- **Idea:** To reach a host on a network, first reach a **network** and then the **host**

- **So two address components were required**

  [Network address part + Host address]

Problems in 2-level hierarchy of address

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What is Subnetting?

- Dividing a larger IP network into smaller IP networks that are logically separate networks

Why Subnetting?

- Subnetting increases network performance, reduces congestion and improves security

- Subnetting concept leads to classless addressing that is associated with CIDR notation

Three level hierarchy - Subnetting

- Class A and B addresses belonging to org1 can be divided into smaller subblocks and share them with other organizations – Org2

- **Idea of splitting a block to smaller blocks is referred to as <u>subnetting.</u>**

- In subnetting, **a network is divided into several smaller subnetworks** (subnets)

- Each **subnetwork** has its own **subnetwork address**

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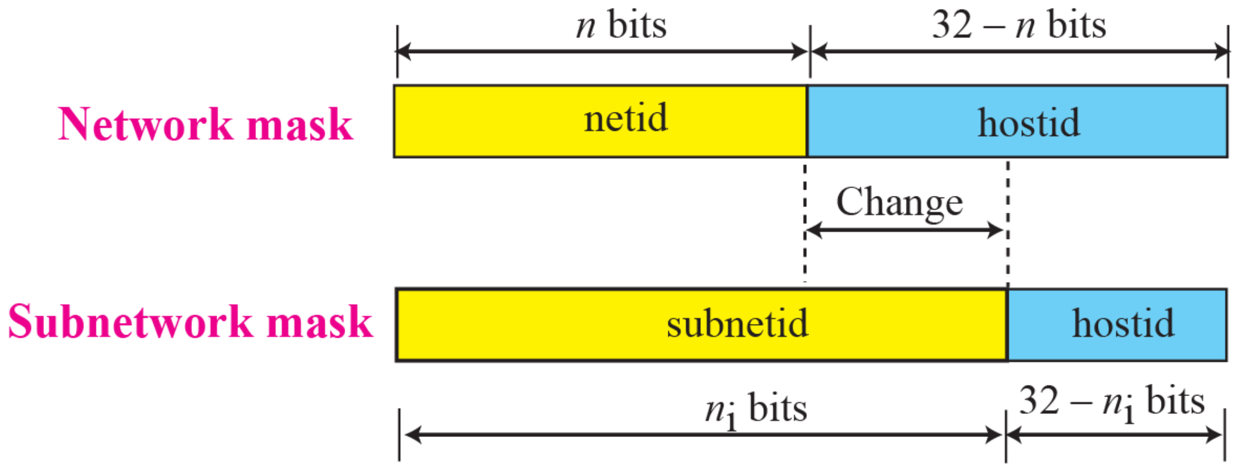


Differences between FLSM Subnetting and VLSM Subnetting

FLSM (Fixed Length Subnet Masks) Subnetting	VLSM (Variable Length Subnet Masks) Subnetting
All subnets are equal in size.	Subnets are variable in size.
All subnets have equal number of hosts.	Subnets have variable number of hosts.
All subnets use same subnet mask.	Subnets use different subnet masks.
It is easy in configuration and administration.	It is complex in configuration and administration.
It wastes a lot of IP addresses.	It wastes minimum IP addresses.

Subnet Mask

- Network mask is used **when network is not subnetted**

- When a network is divided into several subnetworks, **we need to create a subnetwork mask or subnet mask**

- Subnetwork has **subnetid and hostid**

- **Subnetting increases length of netid**

- **Decreases length of hostid**

Subnet Mask

- Say a network is divided into “s” subnetworks, each of equal number of hosts, “n” length of netid

- Subnetid for each subnetwork is

  $n_{sub} = n + \log_2 s$

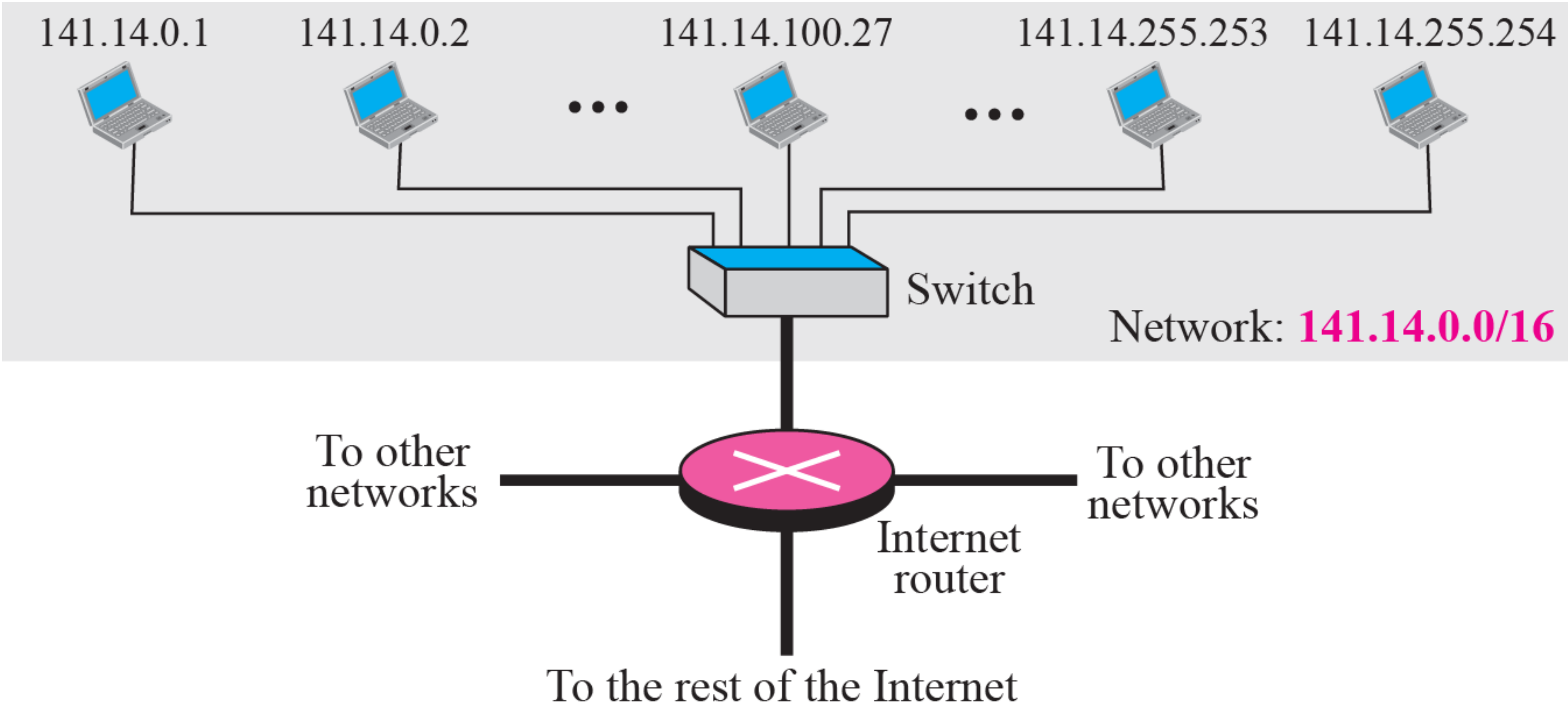
Fixed length-Class C Subnetting

200.1.2.0/24

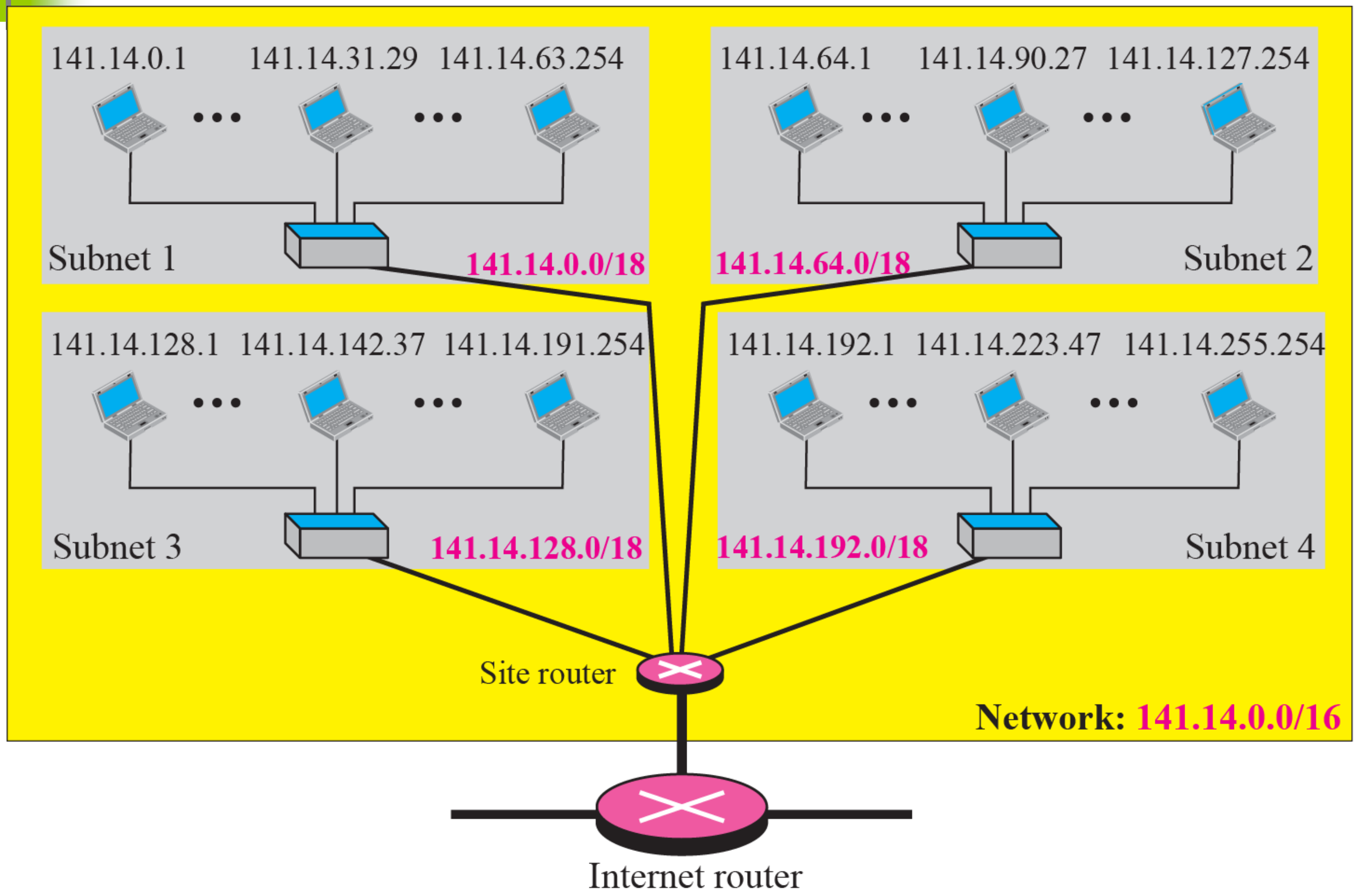
a) Two subets

b) Four subnets

– **Class B addresses before subnetting** - ***One network with almost 2^{16} hosts***



Subnetting


141.14.0.1
141.14.31.29
141.14.63.254
Subnet 1
141.14.0.0/18
141.14.64.1
141.14.90.27
141.14.127.254
141.14.64.0/18
Subnet 2
141.14.128.1
141.14.142.37
141.14.191.254
Subnet 3
141.14.128.0/18
141.14.192.1
141.14.223.47
141.14.255.254
141.14.192.0/18
Subnet 4
Site router
Network: 141.14.0.0/16
Internet router

VLSM-Class C

200.1.2.0/24

SN1-128

SN2-64

SN3-64

A block of addresses is granted to a small organization. We know that one of the addresses is 205.16.37.39/28. What is the first address in the block?

Solution

The binary representation of the given address is

11001101 00010000 00100101 00100111

If we set 32−28 rightmost bits to 0, we get

11001101 00010000 00100101 0010000

or

205.16.37.32.

Find the last address for the block

Solution

The binary representation of the given address is

11001101 00010000 00100101 00100111

If we set 32 − 28 rightmost bits to 1, we get

11001101 00010000 00100101 00101111

or

205.16.37.47

Find the number of addresses in the above Example

Solution

The value of n is 28, which means that number of addresses is 2 $^{32-28}$ or 16 continous address in that block.

205.16.37.32/28

205.16.37.33/28

205.16.37.34/28

205.16.37.35/28

….

205.16.37.47/28

Another way to find the first address, the last address, and the number of addresses is to represent the mask as a 32-bit binary (or 8-digit hexadecimal) number. This is particularly useful when we are writing a program to find these pieces of information. In the Example the /28 can be represented as

11111111 11111111 11111111 11110000

(twenty-eight 1s and four 0s).

Find

a. The first address

b. The last address

c. The number of addresses.

Solution

a. The first address can be found by ANDing the given addresses with the mask. ANDing here is done bit by bit. The result of ANDing 2 bits is 1 if both bits are 1s; the result is 0 otherwise.

Address:	11001101	00010000	00100101	00100111
Mask:	**11111111**	**11111111**	**11111111**	**11110000**
First address:	11001101	00010000	00100101	00100000

b. ***The last address can be found by ORing the given addresses with the complement of the mask. ORing here is done bit by bit. The result of ORing 2 bits is 0 if both bits are 0s; the result is 1 otherwise. The complement of a number is found by changing each 1 to 0 and each 0 to 1.***

Address:	11001101	00010000	00100101	00100111
Mask complement:	**00000000**	**00000000**	**00000000**	**00001111**
Last address:	11001101	00010000	00100101	00101111

c. ***The number of addresses can be found by complementing the mask, interpreting it as a decimal number, and adding 1 to it.***

Mask complement:	**000000000 00000000 00000000 00001111**
Number of addresses:	15 + 1 = 16

CLASSLESS ADDRESSING

Subnetting and supernetting in classful addressing did not really solve the address depletion problem.

With the growth of the Internet, it was clear that a larger address space was needed as a long-term solution.

Although the long-range solution has already been devised and is called IPv6, a short-term solution was also devised to use the same address space but to change the distribution of addresses to provide a fair share to each organization.

The short-term solution still uses IPv4 addresses, but it is called *classless addressing*.

Representation CIDR a.b.c.d/n

CIDR and Address assignments

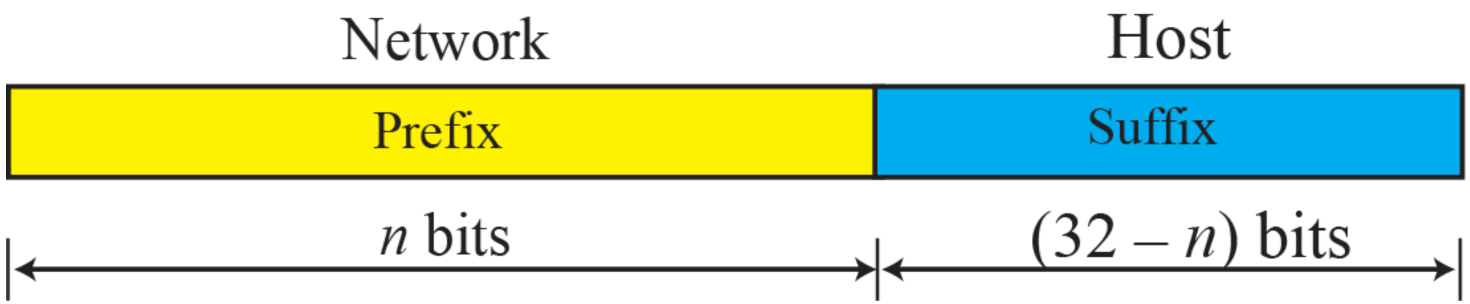
- Backbone ISPs obtain large block of IP addresses space and then reallocate portions of their address blocks to their customers.
- *In classless addressing, we need to* ***know one of the addresses in the block and the prefix length to define the block.***

Example:

- Assume that an ISP owns the address block 206.0.64.0/18, which represents 16,384 (2^{14}) IP addresses
- Suppose a client requires 800 host addresses
- With classful addresses: need to assign a class B address (and waste ~64,700 addresses) or four individual Class Cs (and introducing 4 new routes into the global Internet routing tables)
- With CIDR: Assign a /22 block, e.g., 206.0.68.0/22, and allocated a block of 1,024 (2^{10}) IP addresses.

Variable length blocks

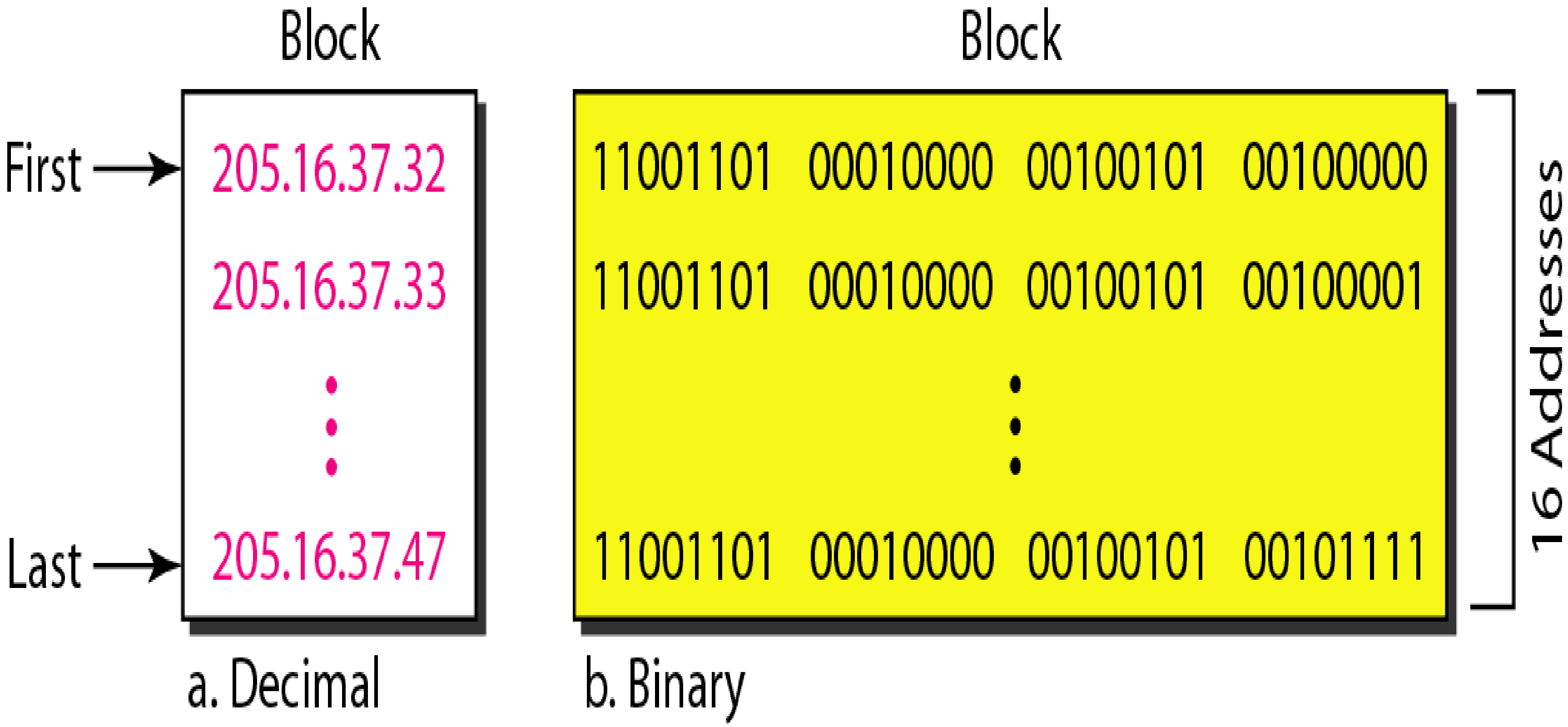
- In classless addressing, **the whole address space is divided into variable length blocks**
- We can have a block of 2^{0}, 2^1, 2^2,…..2^{32} addresses
- The only restriction is that the **number of addresses in a block needs to be a power of 2**



Rules for forming CIDR Blocks

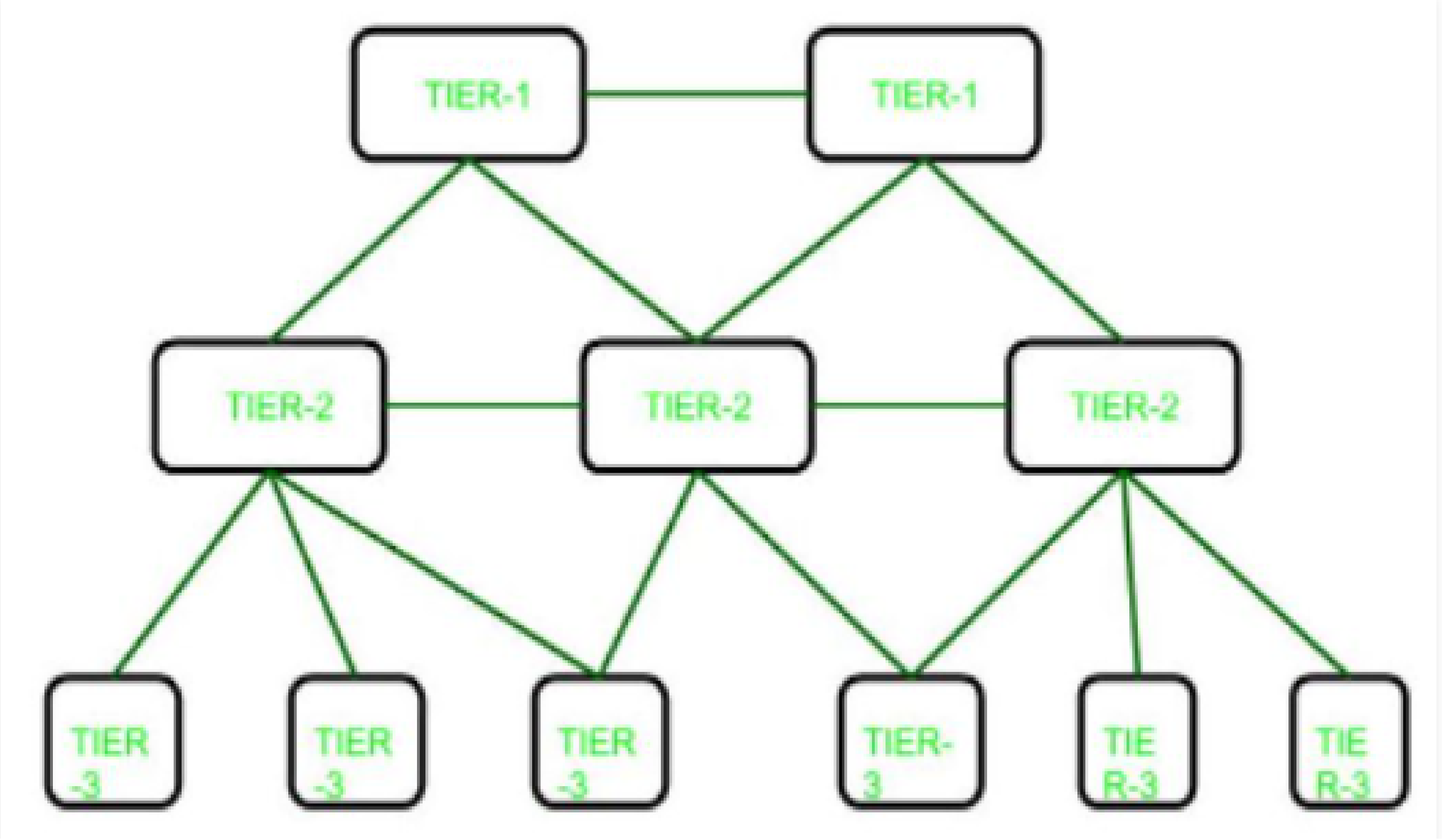
- All IP addresses must be contiguous.
- Block size must be the power of 2 (2^n). If the size of the block is the power of 2, then it will be easy to divide the Network. ...
- First IP address of the Block must be evenly divisible by the size of the block.
- Check whether 100.1.2.32 to 100.1.2.47 is a valid IP address block or not?
- Given the CIDR representation 20.10.30.35 / 27. Find the range of IP Addresses in the CIDR block.

A block of 16 addresses granted to a small organization



https://myip.ms/view/ip_addresses/763325440/45.127.108.0_45.127.108.255/45.127.108.0_45.127.108.255

ISP



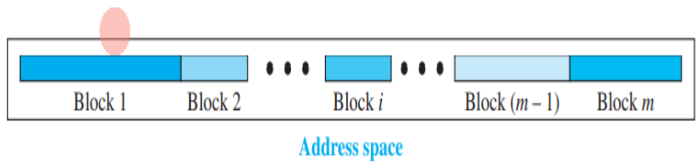
https://en.wikipedia.org/wiki/Tier_1_network#List_of_Tier_1_networks

CIDR: Prefix Size vs. Network Size

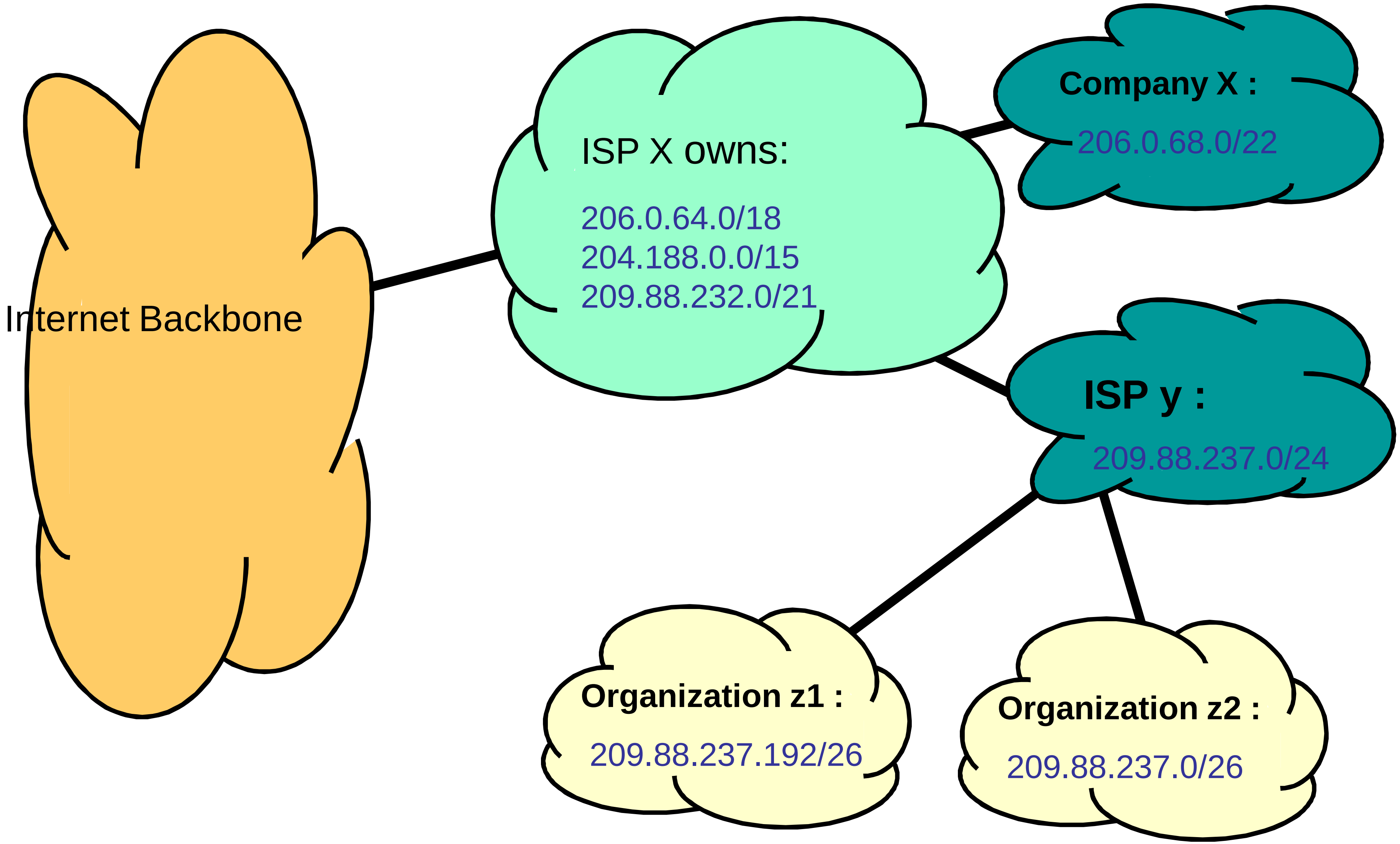
CIDR Block Prefix	# of Host Addresses
/27	32 hosts
/26	64 hosts
/25	128 hosts
/24	256 hosts
/23	512 hosts
/22	1,024 hosts
/21	2,048 hosts
/20	4,096 hosts
/19	8,192 hosts
/18	16,384 hosts
/17	32,768 hosts
/16	65,536 hosts
/15	131,072 hosts
/14	262,144 hosts
/13	524,288 hosts

1. How many subnets does this mask provide? Does it meet my business requirements?
2. How many hosts per subnet? Does it meet my business requirements?

Figure 18.19 *Variable-length blocks in classless addressing*



CIDR and Routing Information



Example

- An organization is granted a block of addresses 17.12.14.0/26.The org has 3 offices and needs to divide the addresses into three sub-blocks of 32,16 and 16 addresses . Design the sub-blocks and find the new masks.
- Total no of addresses is 64.
- $2^{(32-26)}=2^6=64$
- 64 should be splitted into 32,16,16.

Find the new masks

Subnet1:

Mask n1: $2^{32-n1} = 32$; n1=27

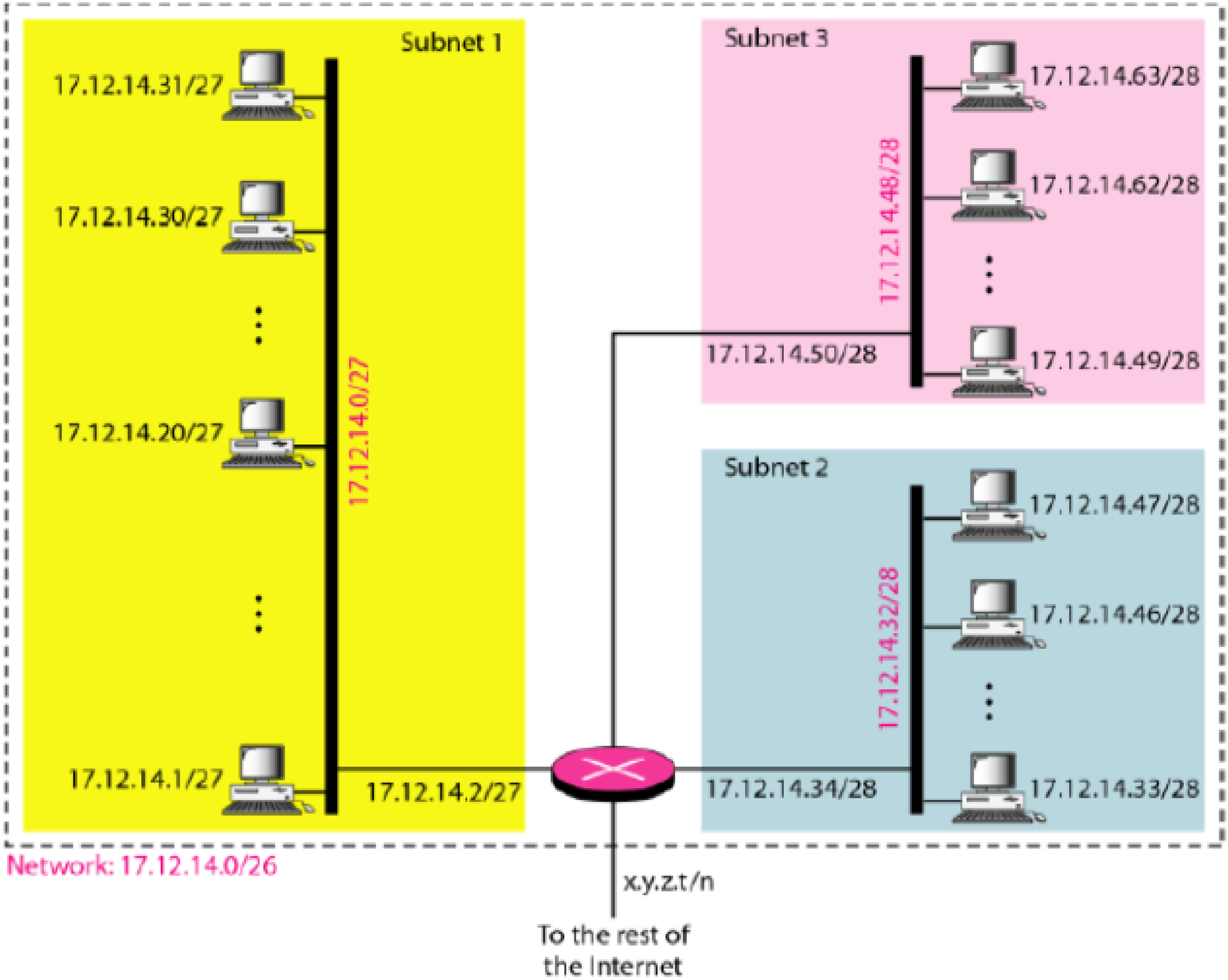
Subnet2

Mask n2: $2^{32-n2} =16$; n2=28

Subnet3

Mask n3: $2^{32-n2} = 16$; n3= 28

Organization mask -26
Subnet mask -27,28,28



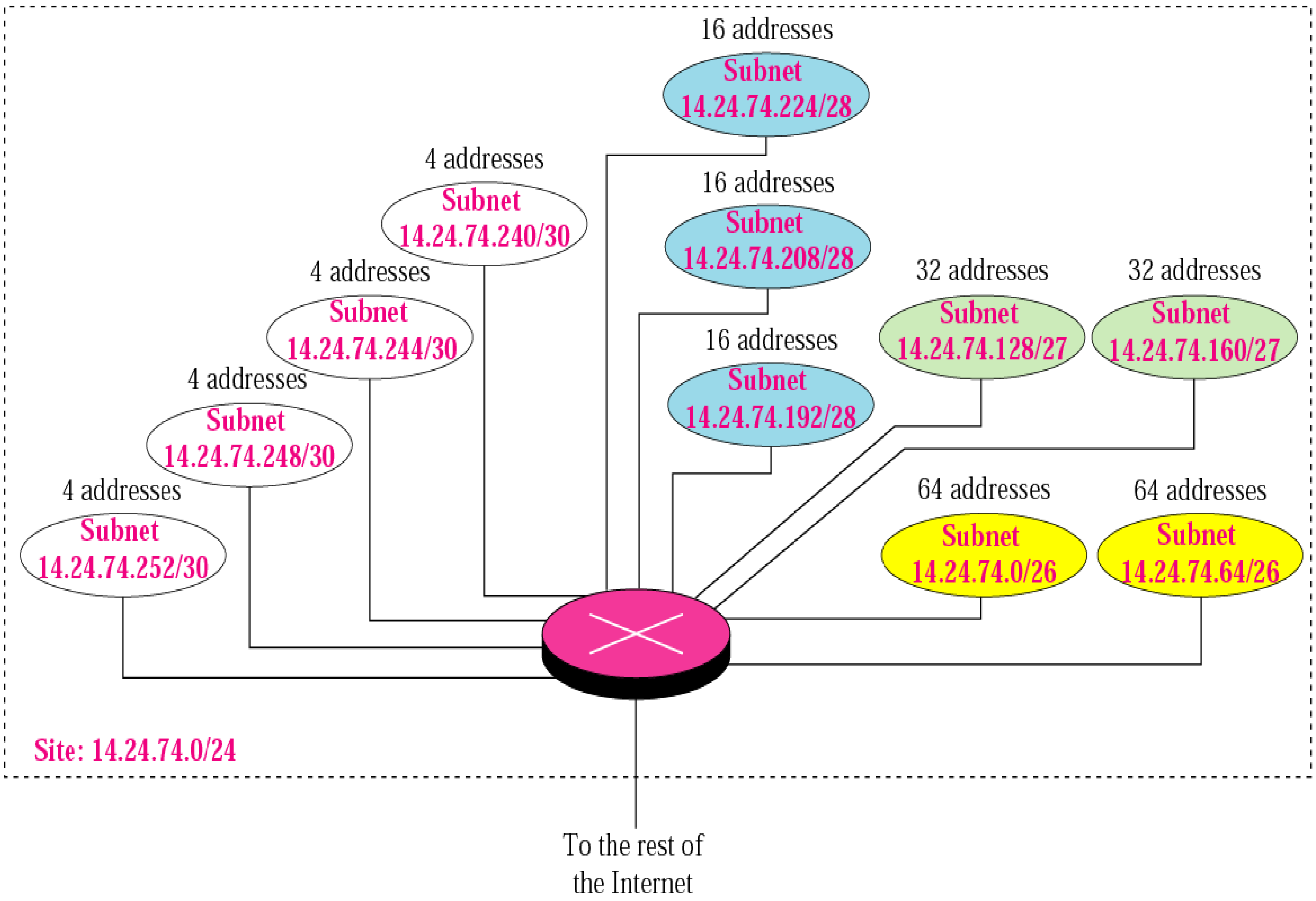
Subnet 1
17.12.14.31/27
17.12.14.30/27
17.12.14.20/27
17.12.14.1/27
17.12.14.0/27
17.12.14.2/27
Subnet 3
17.12.14.63/28
17.12.14.62/28
17.12.14.49/28
17.12.14.48/28
17.12.14.50/28
Subnet 2
17.12.14.47/28
17.12.14.46/28
17.12.14.33/28
17.12.14.32/28
17.12.14.34/28
Network: 17.12.14.0/26
x.y.z.t/n
To the rest of the Internet

ExamplE

An organization is granted a block of addresses with the beginning address 14.24.74.0/24. There are 2^{32-24}= 256 addresses in this block. The organization needs to have 11 subnets as shown below:

- ***a. two subnets, each with 64 addresses.***
- ***b. two subnets, each with 32 addresses.***
- ***c. three subnets, each with 16 addresses.***
- ***d. four subnets, each with 4 addresses.***

Design the subnets.


16 addresses
Subnet
14.24.74.224/28
4 addresses
Subnet
14.24.74.240/30
16 addresses
Subnet
14.24.74.208/28
4 addresses
Subnet
14.24.74.244/30
32 addresses
Subnet
14.24.74.128/27
32 addresses
Subnet
14.24.74.160/27
16 addresses
Subnet
14.24.74.192/28
4 addresses
Subnet
14.24.74.248/30
4 addresses
Subnet
14.24.74.252/30
64 addresses
Subnet
14.24.74.0/26
64 addresses
Subnet
14.24.74.64/26
Site: 14.24.74.0/24
To the rest of
the Internet

ADDRESS ALLOCATION

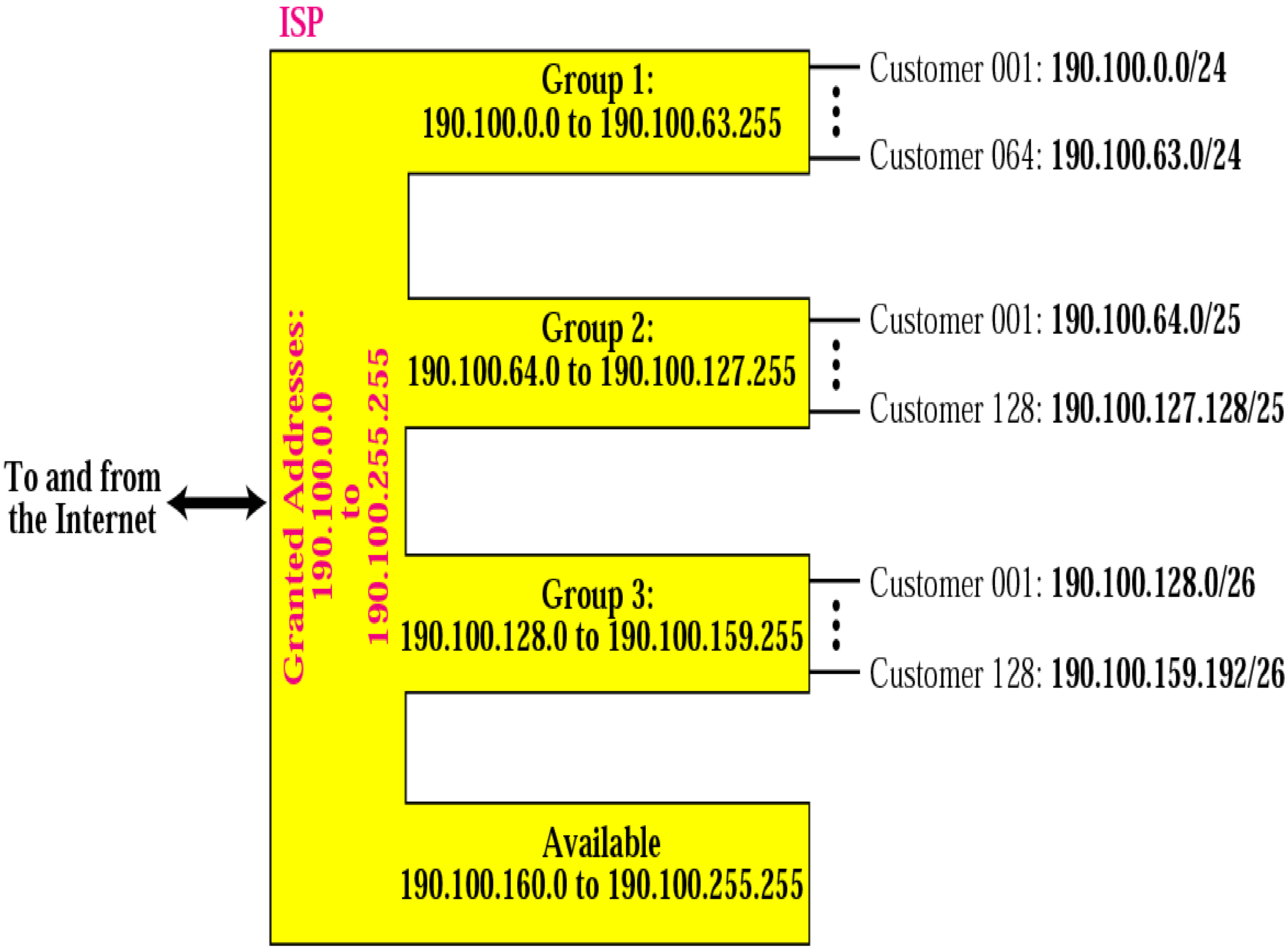
Address allocation is the responsibility of a global authority called the Internet Corporation for Assigned Names and Addresses (ICANN).

It usually assigns a large block of addresses to an ISP to be distributed to its Internet users.

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.


ISP
Group 1:
190.100.0.0 to 190.100.63.255
Group 2:
190.100.64.0 to 190.100.127.255
Group 3:
190.100.128.0 to 190.100.159.255
Available
190.100.160.0 to 190.100.255.255
Granted Addresses:
190.100.0.0
to
190.100.255.255
To and from
the Internet
Customer 001: 190.100.0.0/24
Customer 064: 190.100.63.0/24
Customer 001: 190.100.64.0/25
Customer 128: 190.100.127.128/25
Customer 001: 190.100.128.0/26
Customer 128: 190.100.159.192/26

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		

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:

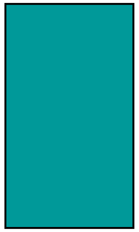
1st Customer	**190.100.64.0/25**	**190.100.64.127/25**
2nd Customer	**190.100.64.128/25**	**190.100.64.255/25**
. . .		
128th Customer	**190.100.127.128/25**	**190.100.127.255/25**

Total = 128 × 128 = 16,384

Group 3

For this group, each customer needs 64 addresses. This means the suffix length is 6 (26 = 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		



Number of granted addresses to the ISP: 65,536

Number of allocated addresses by the ISP: 40,960

Number of available addresses: 24,576

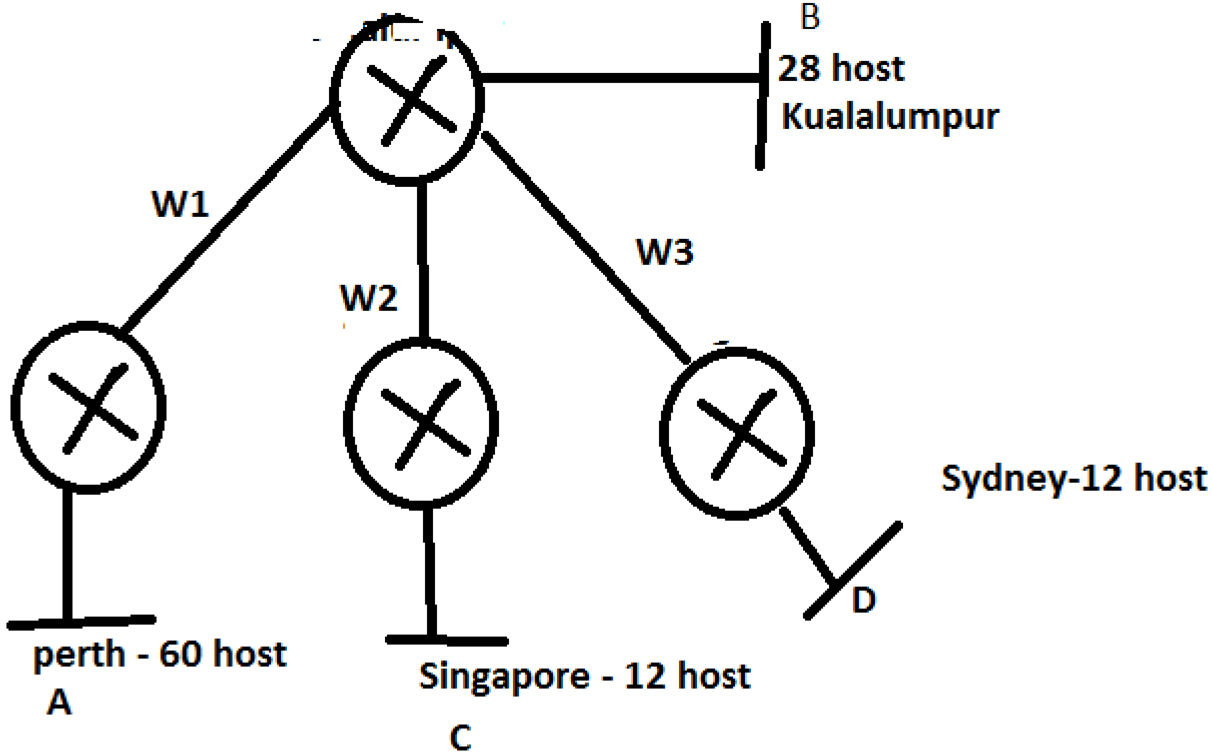
Calculating VLSM Subnets

Use variable-length subnet mask (VLSM) to support more efficient use of the assigned IP addresses

Objective

- Use variable-length subnet mask (VLSM) to support more efficient use of the assigned IP addresses and to reduce the amount of routing information at the top level

Given a network of 192.168.10.0/24, perform classless subnetting and create networks as per the below requirements:



- 192.168.10.0/24

- 256 hosts possible

- **No of hosts at each site:**

Perth – 60 [➔64 “A”]

Kualalumpur – 28 [➔32 “B”]

Singapore – 12 [➔16 “C”]

Sydney - 12 [➔16 “D”]

WAN Link 1 – 2 [➔4 “E”]

WAN Link 2 – 2 [➔4 “F”]

WAN Link 3 – 2 [➔4 “G”]

- 192.168.10.0/24
  - 256 hosts possible
- Subnetworks:
- S1: 192.168.10.0/26 – 64 host
- S2: 192.168.10.64/26 – 64 host
- S3: 192.168.10.128/26 - 64 host
- S4: 192.168.10.192/26 - 64 host

- S1 – 64 host - A
  - **First Address: 192.168.10.0/26 (Network address)**
  - **Last Address: 192.168.10.63/26 (Broadcast address)**
  - Hosts: 192.168.10.1/26 to 192.168.10.62/26

- S2 – 64 host
  - 32 – S2-1 - B
    - **First Address: 192.168.10. 64/27**
    - **Last Address: 192.168.10.95/27**
    - Hosts: 192.168.10. 65/27 to 192.168.10.94/27

  - 32 - S2-2 [S22-1, S22-2]

- S2-2 32 hosts total - used for C, D
  - 32 - S2-2 [S22-1, S22-2]
  - For C (16 hosts), S22-1:
    - **First Address: 192.168.10.96/28**
    - **Last Address: 192.168.10.111/28**
    - Hosts: 192.168.10. 97/28 to 192.168.110./28
  - For D (16 hosts): S22-2:
    - **First Address: 192.168.10.112/28**
    - **Last Address: 192.168.10. 127/28**
    - Hosts: 192.168.10. 113/28 to 192.168.10.126/28

- S3 : 64 host:
  - Used for addressing three WAN links each having four IP addressses (Total 12)
  - Remaining addresses unused

S4: Unused: 64 host

S3 – WAN links

- WAN link 1: Need 4 addresses
  - Prefix: 30
  - First address:192.168.10.128/30
  - Last Address: 192.168.10.131/30

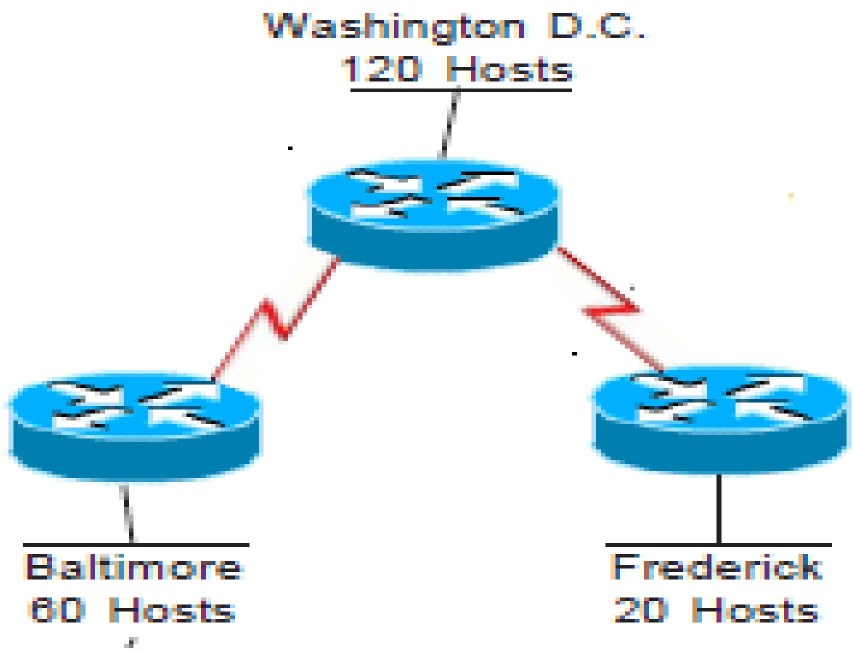
- WAN link 2: Need 4 addresses
  - Prefix: 30
  - First address:192.168.10.132/30
  - Last Address: 192.168.10.135/30

S3 – WAN links

- WAN link 3: Need 4 addresses
  - Prefix: 30
  - First address:192.168.10.136/30
  - Last Address: 192.168.10.139/30

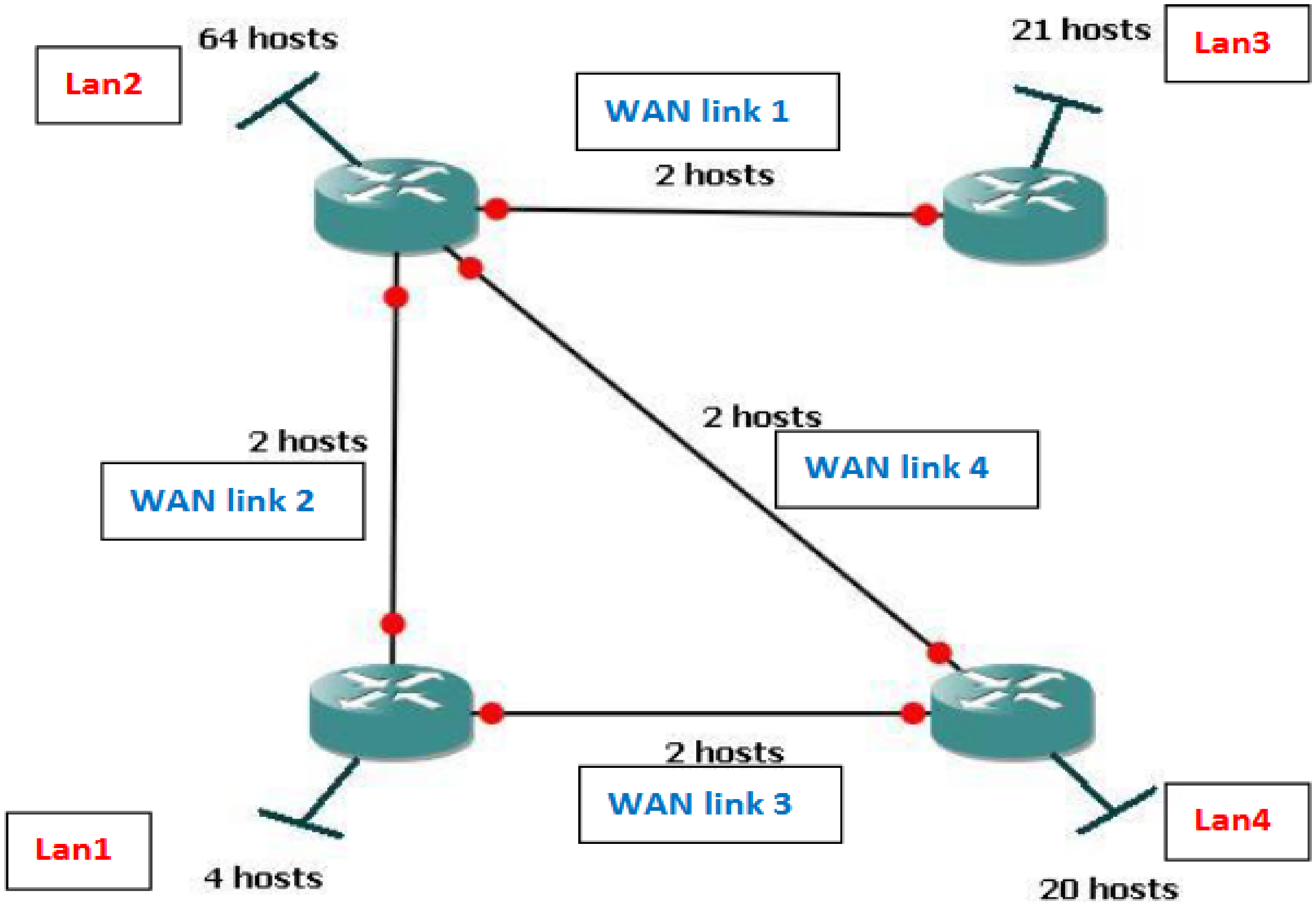
Homework -1

Using the network diagram and information given create an addressing scheme which utilizes variable-length subnet masks. Show the subnet addresses, First address and last address. This company will be using the class C address 192.168.16.0. Remember to start with your largest groups first. There are two WAN links between routers. Provide addresssing for the WAN links as well.



Homework -2

Perform classless subnetting using VLSM for the following network 10.23.22.0/24



Supernetting

- A company can combine several class C blocks to create a larger range of addresses
- Several networks are combined and a supernetwork is created

Why Supernetting?

- To address, IP address depletion problem
- Most orgs did not want to share their addresses with others
- Since class C blocks were available, but size was small
- New organizations can combine several class C addresses and create a supernetworks
- (ie.,) combine 4 class C blocks to get 1000 plus addresses

Supernet Mask

- Reverse of subnet mask

- "n" - length of bits in netid
- "n_{super}" – length of bits in supernetid

- $n_{super} = n - \log_2 c$

Figure 5.26 Comparison of subnet, default, and supernet mask for CLASS C

In Subnetting: A Class C network divided into 8 subnets

In Supernetting: 8 Class C blocks are combined into a supernet

Divide 1 class C block into 8 subblocks

Subnet mask	11111111 11111111 11111111 111	00000	$n_{sub} = 24 + 3 = 27$
Default mask	11111111 11111111 11111111	000 00000	$n = 24$
Supernet mask	11111111 11111111 11111	000 000 00000	$n_{super} = 24 - 3 = 21$

Combine 8 class C blocks into 1 superblock

Classful Routing Overview

Classful routing protocols do not include the subnet mask with the route advertisement.

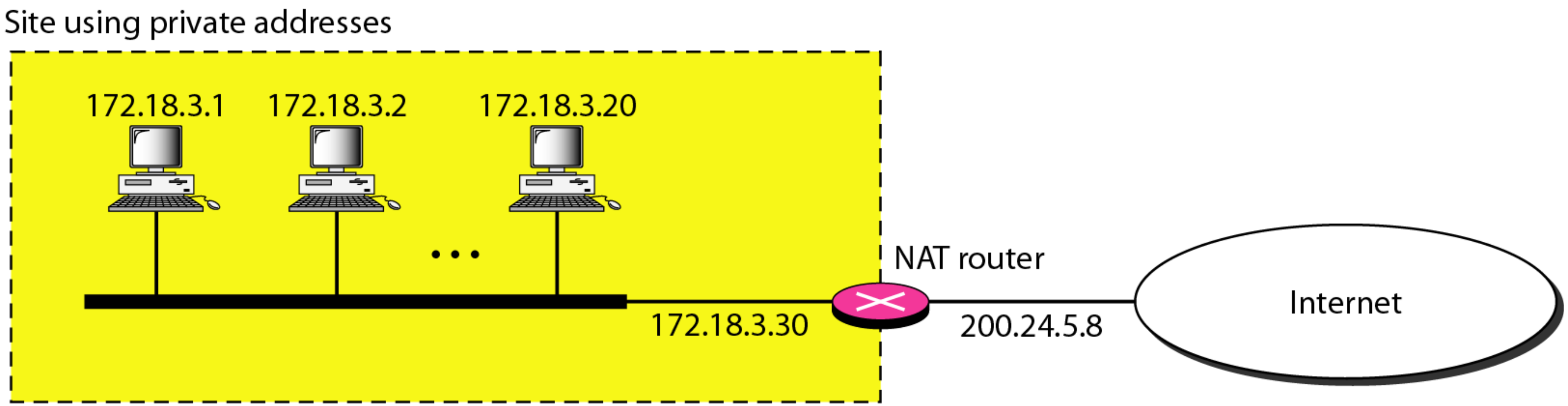
- Within the same network, consistency of the subnet masks is assumed.
- Summary routes are exchanged between foreign networks.
- Examples of classful routing protocols:
  - RIP Version 1 (RIPv1)
  - IGRP

Classless Routing Overview

Classless routing protocols include the subnet mask with the route advertisement.

- Classless routing protocols support variable-length subnet masking (VLSM).
- Advantages of classless routing:
  - Fewer IP addresses are wasted
  - Summarization can be manually controlled within the routing protocol
- Examples of classless routing protocols:
  - RIP Version 2 (RIPv2)
  - EIGRP
  - OSPF
  - IS-IS

A NAT implementation



- There are 126 class A addresses.
  - 0 and 127 have special meaning and are not used.
- 16,777,214 host addresses, one for network address and one for broadcast address.
- Only large organizations such as the military, government agencies, universities, and large corporations have class A addresses.
- For example ISPs have 24.0.0.0 and 63.0.0.0
- Class A addresses account for 2,147,483,648 of the possible IPv4 addresses.
- That's 50 % of the total unicast address space. *If* classful was still used in the Internet!

- There are 16,384 (2^{14}) class B networks.
- 65,534 host addresses, one for network address and one for broadcast address.
- Class B addresses represent 25% of the total IPv4 unicast address space.
- Class B addresses are assigned to large organizations including corporations

- IPv6, or IPng (IP – the Next Generation) uses a 128-bit address space, yielding

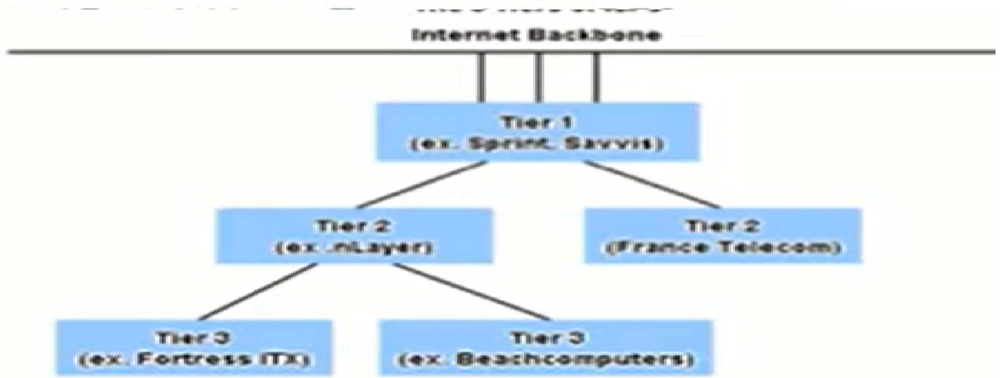
  340,282,366,920,938,463,463,374,607,431,768,211,456

  possible addresses.
- IPv6 has been slow to arrive
- IPv6 requires new software; IT staffs must be retrained
- IPv6 will most likely coexist with IPv4 for years to come.
- Some experts believe IPv4 will remain for more than 10 years.

- CIDR (Classless Inter-Domain Routing) – RFCs 1517, 1518, 1519, 1520
- VLSM (Variable Length Subnet Mask) – RFC 1009
- Private Addressing - RFC 1918

ISP (Internet Service Providers)

Most companies or organizations obtain their IPv4 address blocks from an ISP.



- Tier 1 ISP:
  - Large national or international ISPs that are directly connected to the Internet backbone.
  - Customers of Tier 1 ISPs:
    - lower-tiered ISPs
    - large companies and organizations.
  - Offer reliability and speed
  - AOL, SPRINT, Global Crossing, AT&T, Level 3, Verizon, NTT, Quest, SAVVIS

Special Unicast IPv4 Addresses

- Default Route
- Loopback Address
  - Special address that hosts use to direct traffic to themselves.
  - 127.0.0.0 to 127.255.255.255
- Link-Local Addresses
  - 169.254.0.0 to 169.254.255.255 (169.254.0.0 /16)
  - Can be automatically assigned to the local host by the operating system in environments where no IP configuration is available.
- TEST-NET Addresses
  - 192.0.2.0 to 192.0.2.255 (192.0.2.0 /24)
  - Set aside for teaching and learning purposes.
  - These addresses can be used in documentation and network examples.

PREFIX	SUBNET MASK	BINARY	NO. OF SUBNETS	NO. OF HOSTS PER SUBNET
/24	255.255.255.0	11111111.11111111.11111111.00000000	2^0=1	2^8-2=>256-2=254
/25	255.255.255.128	11111111.11111111.11111111.10000000	2^1=2	2^7-2=>128-2=126
/26	255.255.255.192	11111111.11111111.11111111.11000000	2^2=4	2^6-2=>64-2=62
/27	255.255.255.224	11111111.11111111.11111111.11100000	2^3=8	2^5-2=>32-2=30
/28	255.255.255.240	11111111.11111111.11111111.11110000	2^4=16	2^4-2=>16-2=14
/29	255.255.255.248	11111111.11111111.11111111.11111000	2^5=32	2^3-2=>8-2=6
/30	255.255.255.252	11111111.11111111.11111111.11111100	2^6=64	2^2-2=>4-2=2

Subnet	1	2	4	8	16	32	64	128	256
Host	256	128	64	32	16	8	4	2	1
Subnet Mask	/24	/25	/26	/27	/28	/29	/30	/31	/32