National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 16

Chapter 4

20th March, 2025

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Office Hours: 11:30 am till 01:00 pm (Every Tuesday & Thursday)

Chapter 4
Network Layer: Data Plane

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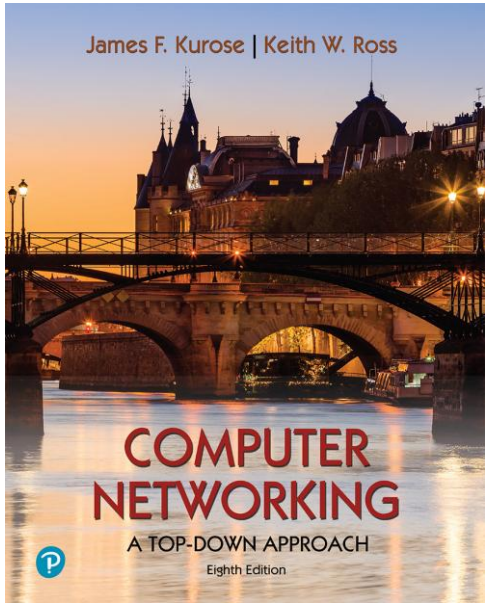
For a revision history, see the slide note for this page.

Thanks and enjoy! JFK/KWR



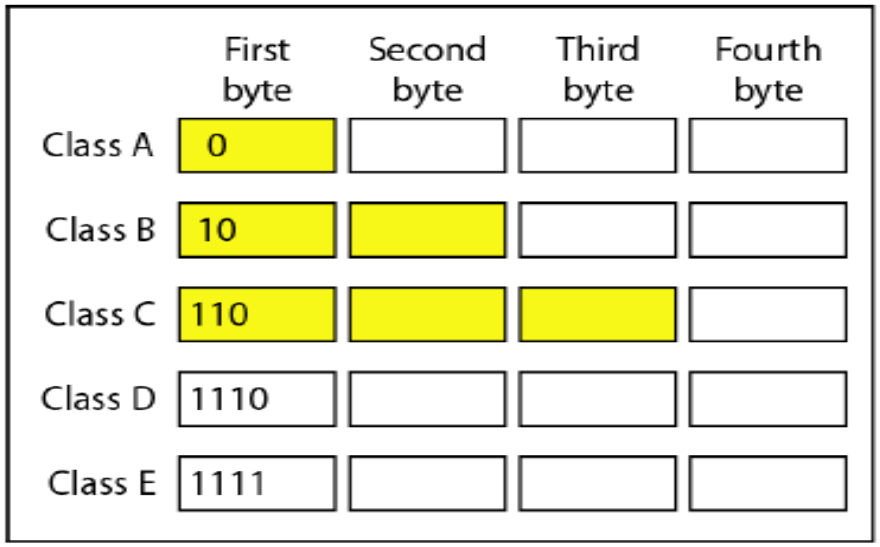
Computer Networking: A Top-Down Approach
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

IPv4 Addressing

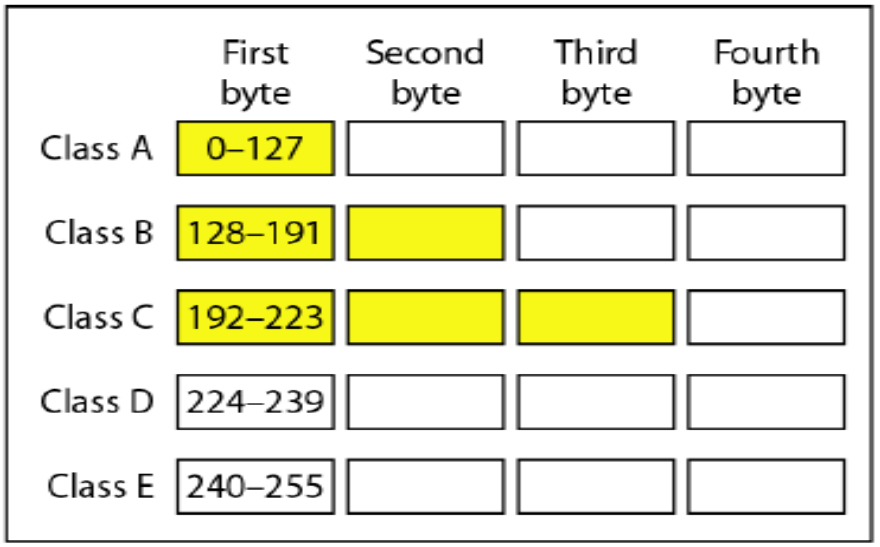
- IPv4 address is a 32-bit address, implemented in software, is used to uniquely and globally identify a host or a router on the Internet
- A device can have more than one IP address if it is connected to more than one network (multi-homed)
- An IP address have two parts, the netid and the hostid. They have variable lengths depending on the class of the address
- All devices on the same network have the same netid

- Two types of IPv4 addressing schemes, i.e.
  - Classful IP Addressing
  - Classless IP Addressing

Classful IPv4 Addressing



a. Binary notation

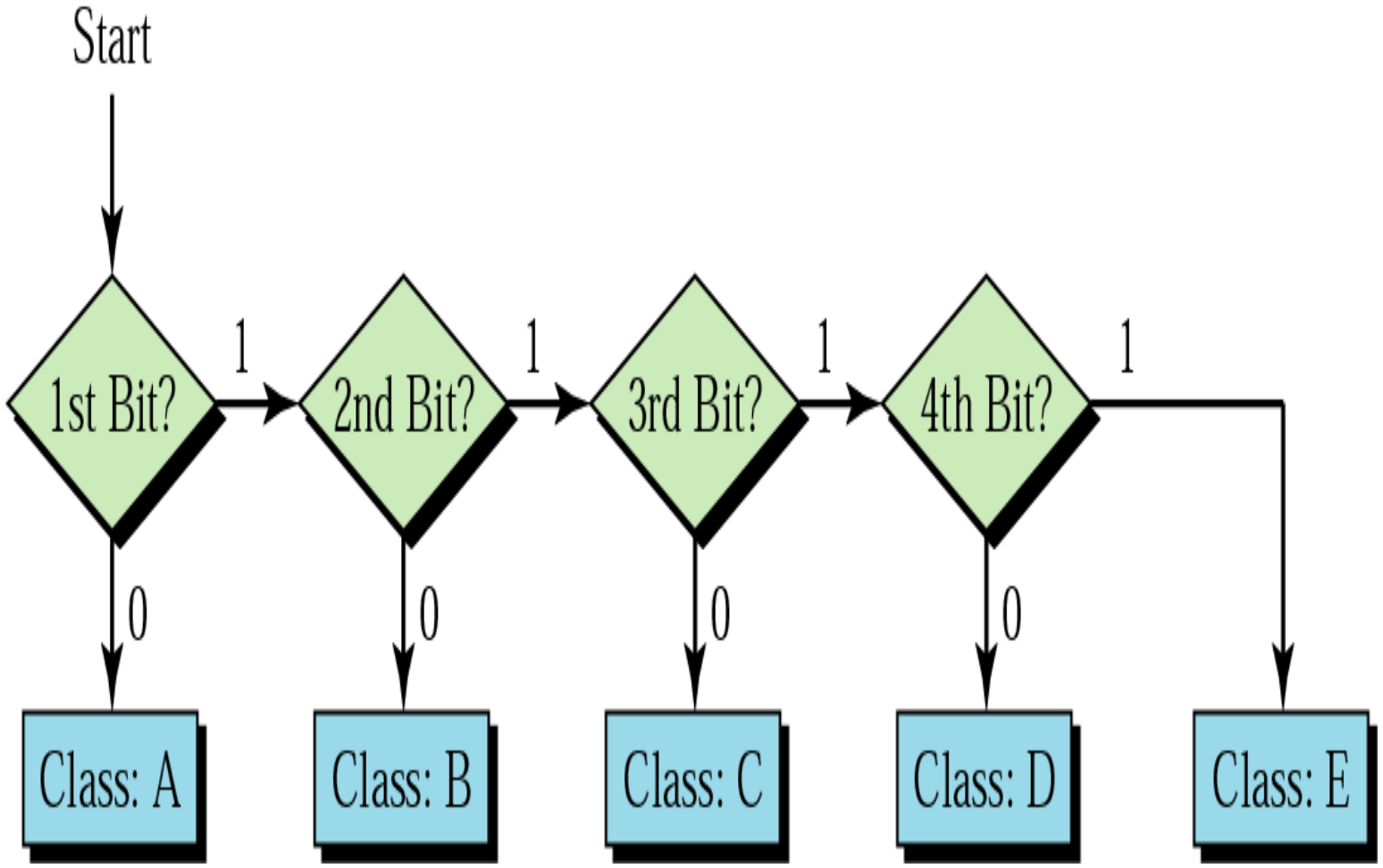


b. Dotted-decimal notation

⇒ Where ▭ = net ID & ▭ = host ID - ***Big Big Waste, thus being replaced by Classless IP Addressing***

Class	Max. Number of Networks (Blocks)	Max. # of nodes in the network (Block Size)	Application
A	$2^7 = 128$	$2^{24} = 16,777,216$	Unicast
B	$2^{14} = 16,384$	$2^{16} = 65,536$	Unicast
C	$2^{21} = 2,097,152$	$2^8 = 256$	Unicast
D	1	$2^{28} = 268,435,456$	Multicast
E	1	$2^{28} = 268,435,456$	Reserved

Finding the Class



Special IP addresses (Classful)

Special Address	Netid	Hostid	Source/Destination
▪ Network Address	Specific	All 0's	None Example: For IP Address 75.3.1.28, it will be 75.0.0.0
▪ Direct Broadcast Address	Specific	All 1's	Destination When source host in one network sends data to all hosts in another network (e.g. 75.255.255.255 for the above network.)
▪ Limited Broadcast Address	All 1's	All 1's	Destination Data reaches from source to all the hosts in the same network (i.e. 255.255.255.255)
▪ This host on this network	All 0's	All 0's	Source Reserved for this host when it boots up (temporary) (i.e. 0.0.0.0)
▪ Specific host on this network	All 0's	Specific	Destination Example: For IP Address 75.3.1.28, it will be 0.3.1.28
▪ Loopback address	127	Any	Destination Packets do not leave the node (NIC).

Private IP Addressing (Classful)

- One of the problems in IP network address allocation is that many hosts do not require access to hosts in other networks ⇒ Assigning Globally unique public IP addresses for such hosts may be wasteful
- IETF proposed the use of Private IP addresses that are not advertised outside the private network.

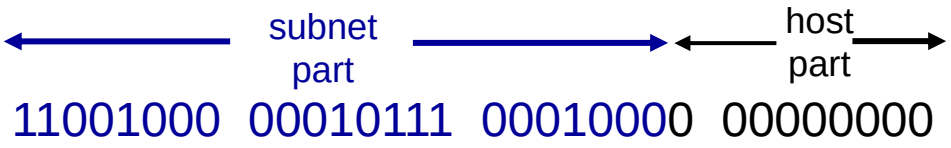
Range			*Total*
10.0.0.0	to	10.255.255.255	2^{24} Commercial use
172.16.0.0	to	172.31.255.255	2^{20} Mostly Commercial
192.168.0.0	to	192.168.255.255	2^{16} Residential use

Private IP Addresses are non-routable

IP addressing: CIDR

CIDR: Classless InterDomain Routing (pronounced “cider”)

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address

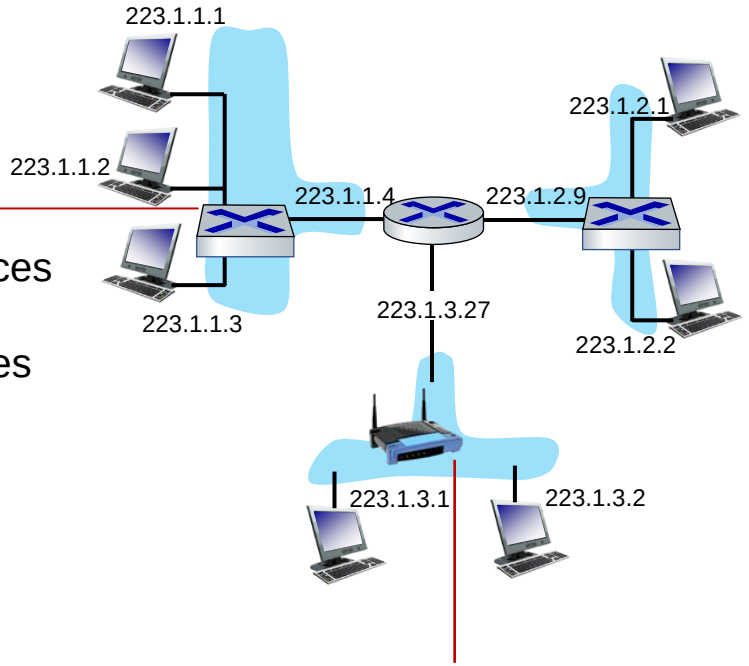


200.23.16.0/23

IP addressing: introduction

Q: how are interfaces actually connected?

A: we'll learn about that in chapters 6, 7



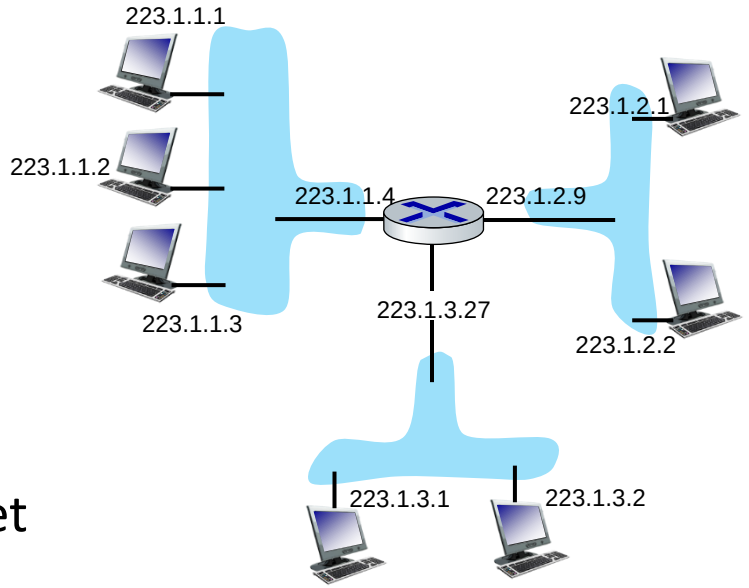
A: wired Ethernet interfaces connected by Ethernet switches

A: wireless WiFi interfaces connected by WiFi base station

For now: don't need to worry about how one interface is connected to another (with no intervening router)

Subnets

- *What's a subnet ?*
  - device interfaces that can physically reach each other without passing through an intervening router
- IP addresses have structure:
  - subnet part: devices in same subnet have common high order bits
  - host part: remaining low order bits

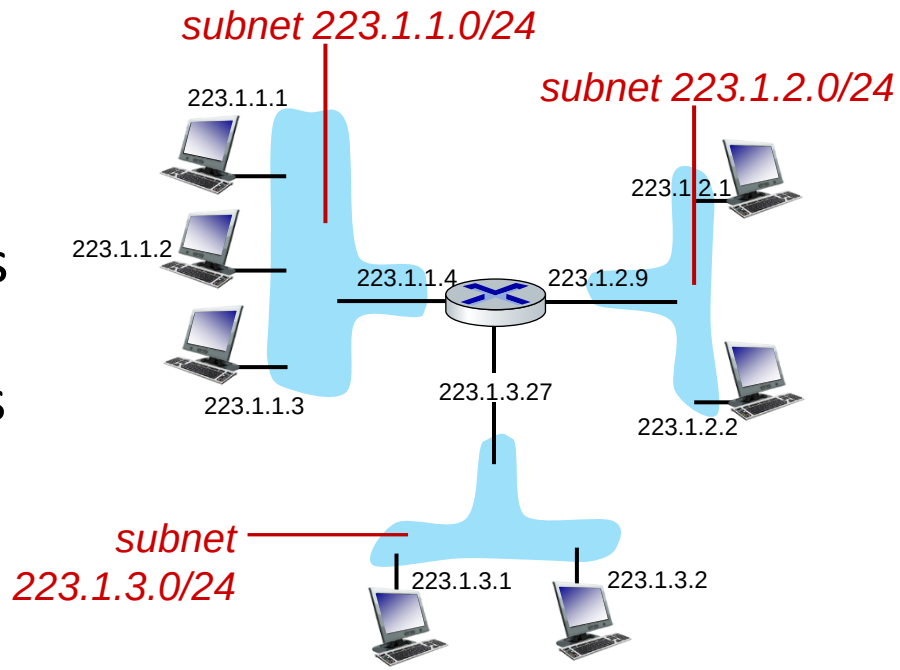


network consisting of 3 subnets

Subnets

Recipe for defining subnets:

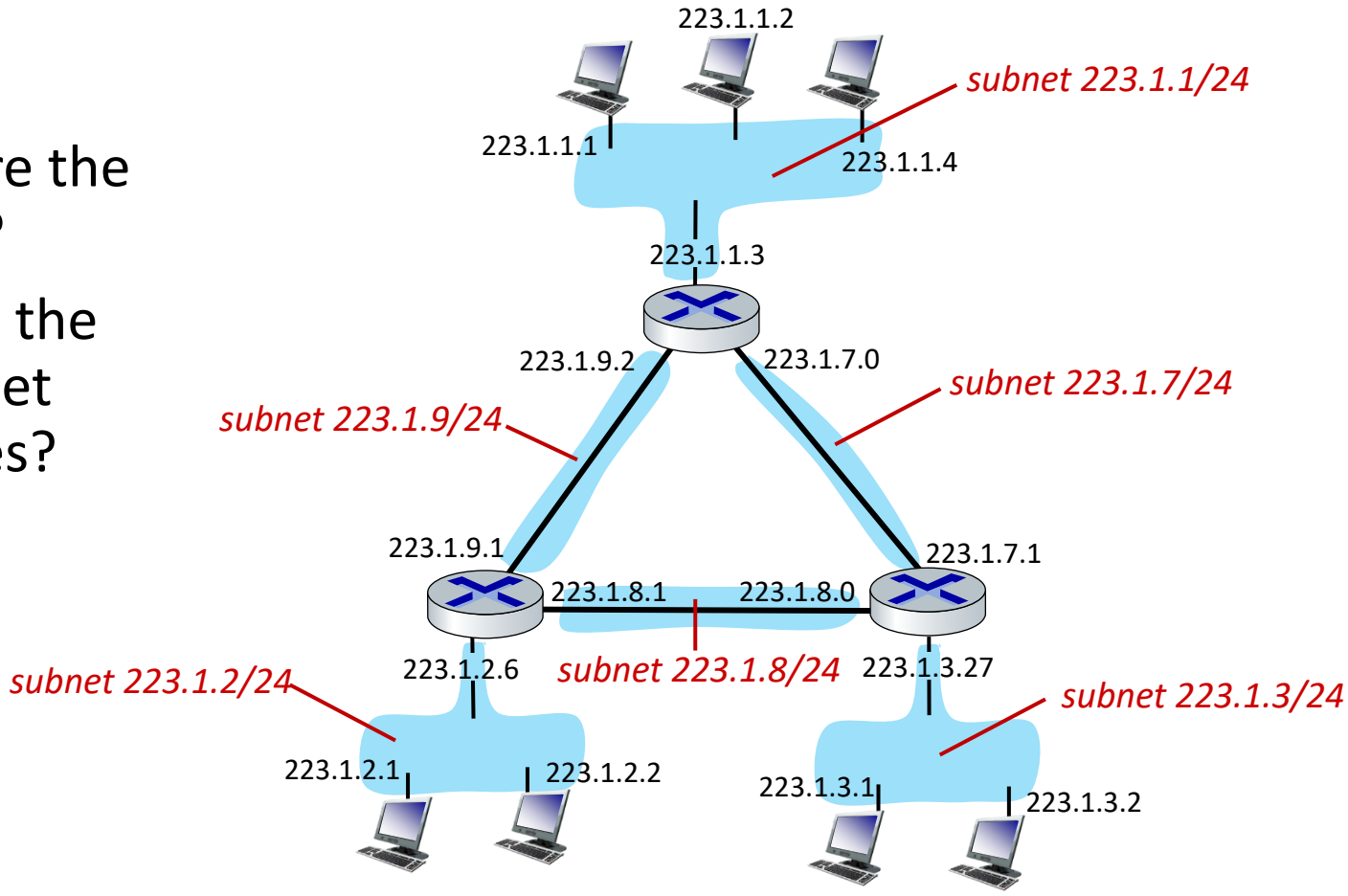
- detach each interface from its host or router, creating "islands" of isolated networks
- each isolated network is called a *subnet*



subnet mask: /24
(high-order 24 bits: subnet part of IP address)

Subnets

- where are the subnets?
- what are the /24 subnet addresses?



Subnetting

- Subnetting is the process of dividing a network (within a single IP network address space) into smaller sized networks called subnets

- It is transparent to the outside world, i.e. the outside world can only see one network and a single net ID, but internally, there can be multiple subnets, each having an ID similar to the parent network's net ID called subnet ID or network prefix or simply prefix

- Thus the tables in the routers of the internet are not affected, i.e. they don't need to have entries for any of the subnet, just the entry of the original (parent network) i.e., while only internal router of the corresponding network needs to have the subnet entries in it's tables

- IP addresses in Class A, B & C have two levels of hierarchy, i.e. *IP address = (net ID, host ID)* Subnetting creates another level of hierarchy, i.e. *IP address = (net ID, subnet ID, host ID)* Again, this subnet ID is transparent to the outside world, i.e. they will still see IP address = (net ID, host ID). Delivery of incoming IP packets from the internet to this network involves three steps now: *delivery to the site router*, *delivery to the subnet router*, *delivery to the end host*

Subnet Mask (SM)

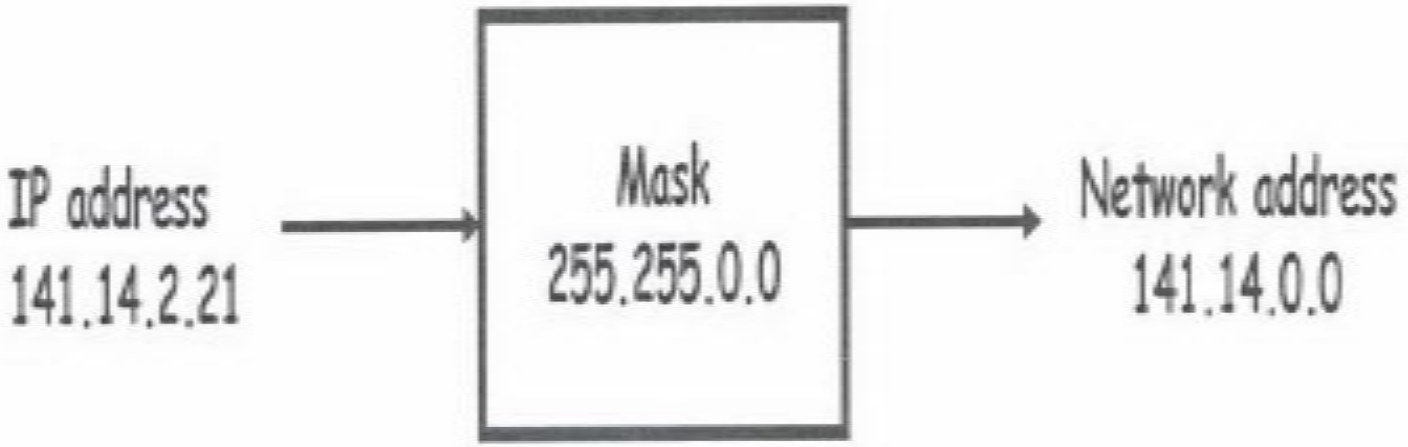
- Masking is the process of extracting the network address / net ID (if no subnetting is done) or subnet ID (if subnetting is done) from an IP address
- SM is a 32 bit **pattern / sequence** (not address) which has a **"1" in every network ID** & a **"1" in every subnet ID** (if any) bit **location** and a **"0" in every host ID bit location**.
- Subnet masking is performed (both at the host & the router) by applying "bit-wise-AND" operation between the IP Address & the subnet mask

- **Default masks (No subnetting)**: for Class A is 255.0.0.0, for Class B is 255.255.0.0, for Class C is 255.255.255.0, so from outer world (Global), subnet mask of unsubnetted network address 128.125.0.0 is 255.255.0.0 (since it is class B.)
- After subnetting network 128.125.0.0 network into 8 equal subnets, subnet mask will be 255.255.224.0 (visible only internally, invisible to the outside world.)
- All devices on the same subnet **must** have the same subnet mask. Furthermore, devices on different subnets **may** have the same subnet masks, but will have different subnet IDs
- When a host performs a **logical AND** between it's IP address & the subnet mask, it gets the net ID / subnet ID
- The network's internal router will have in it's **forwarding table 3 entry columns, i.e. i) subnet IDs of all the subnets, ii) their subnet masks & iii) their corresponding interfaces**
- **Question**: When a packet arrives at this router from the outside world for a host in one of the subnets, how does this router determine that the destination host resides on which subnet?
- **Answer**: The router performs a logical AND between the destination IP address it received and all the subnet masks in it's forwarding table. The result will be the subnet ID of one of the attached subnets. The router can now forward the incoming packet to this subnet.

Important Point: Net ID / Network Address of parent network (unsubnetted network) & first subnet may be the same, but their subnet masks will be different.

Subnet Mask (SM)

- Example 1: Class B network without subnetting
  - 141.14.2.21 10001101.00001110.00000010.00010101
  - 255.255.0.0 11111111.11111111.00000000.00000000
  - "Bit-wise and" 10001101.00001110.00000000.00000000



Examples of Classless IP Addressing

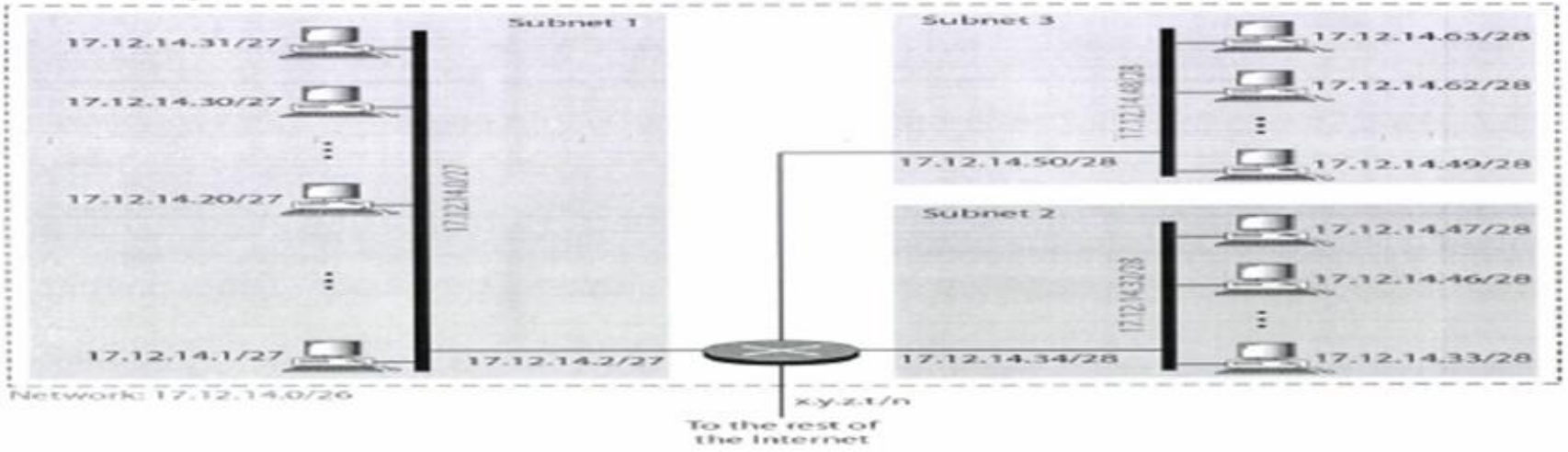
Example of Classless IP Addressing

- An ISP gets a block of IP addresses. The Block is 200.23.16.0/20 . The size of the block is 2^{12} = 4096. The ISP has 8 customers (organizations), each requiring a "block" of size 512

ISP's block	11001000	00010111	00010000	00000000	200.23.16.0/20
Organization 0	11001000	00010111	00010000	00000000	200.23.16.0/23
Organization 1	11001000	00010111	00010010	00000000	200.23.18.0/23
Organization 2	11001000	00010111	00010100	00000000	200.23.20.0/23
...	.....			....	....
Organization 7	11001000	00010111	00011110	00000000	200.23.30.0/23

Example of Classless IP Addressing

- Organization was assigned a block 17.12. 14 .0/26 (Size of block is 64).Organization has three departments. Three subnets of sizes 32, 16 and 16



Difference between Classful, CIDR, FLSM & VLSM in IP Addressing

These four terms can be categorized into two categories:

- ***Classful and CIDR*** — these have to do with the size of networks as they are assigned from IANA (a sub function of ICANN).
- ***FLSM and VLSM*** — (i.e. Fixed Length Subnet mask & Variable Length Subnet Mask.) These have to do with how the administrator allocate your IP space within your networks (assignment by the local network administrator.)

"FLSM & VLSM refer to how IP address space is assigned within each organization (by their **local network administrator**.) Classful and CIDR refer to how IP address space is allocated (**by ICANN - IANA**.)"

Summary

- Classful addressing is ICANN assigning IP space from Class A, B, or C blocks (legacy) & local administrator can then apply FLSM (if required)
- Classless is ICANN assigning IP space in any size block, as required (modern standard) and local administrator can then apply FLSM or VLSM (if required)
- CIDR is simply classless, but VLSM already applied by ICANN and then assigned to an organization.
- FLSM mandates that every IP subnet within your deployment be the same size (legacy).
- VLSM allows IP subnets within your deployment to be of different sizes (modern standard.)

Fixed Length Subnet Mask (FLSM) – Example Video (Watch First)

- For revision of FLSM discussed in the Class, please watch and review my video shared via Google Classroom. (Please watch the complete video, where I explain & solve an example of FLSM in detail.)

Variable Length Subnet Mask (VLSM) – Example Video (Watch Second)

- For revision of VLSM discussed in the Class, please watch and review my video shared via Google Classroom. (Please watch the complete video, where I explain & solve an example of VLSM in detail.)

Very Important topic of Computer Networks !!!!!!!

Assignment # 3 (Chapter – 3) (Already announced)

- *3rd Assignment will be uploaded on Google Classroom on Thursday, 13th March, 2025, in the Stream - Announcement Section*

- *Due Date: ~~Thursday, 20th March~~ Tuesday, 25th March, 2025 (Handwritten solutions to be submitted during the lecture; deadline extended due to LAB midterms next week)*

- *Please read all the instructions carefully in the uploaded Assignment document, follow & submit accordingly*

Quiz # 3 (Chapter – 3) (Already announced)

- *On: ~~Thursday, 20th March, 2025~~ , Tuesday, 25th March, 2025(During the lecture; deadline extended due to LAB midterms next week)*

- *Quiz to be taken during own section class only*