National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 16

Chapter 4

17th October, 2023

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Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

Chapter 4
Network Layer: Data Plane

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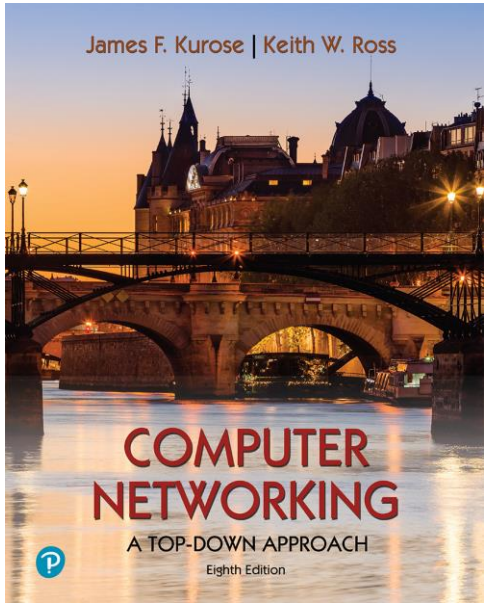


Computer Networking: A Top-Down Approach
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

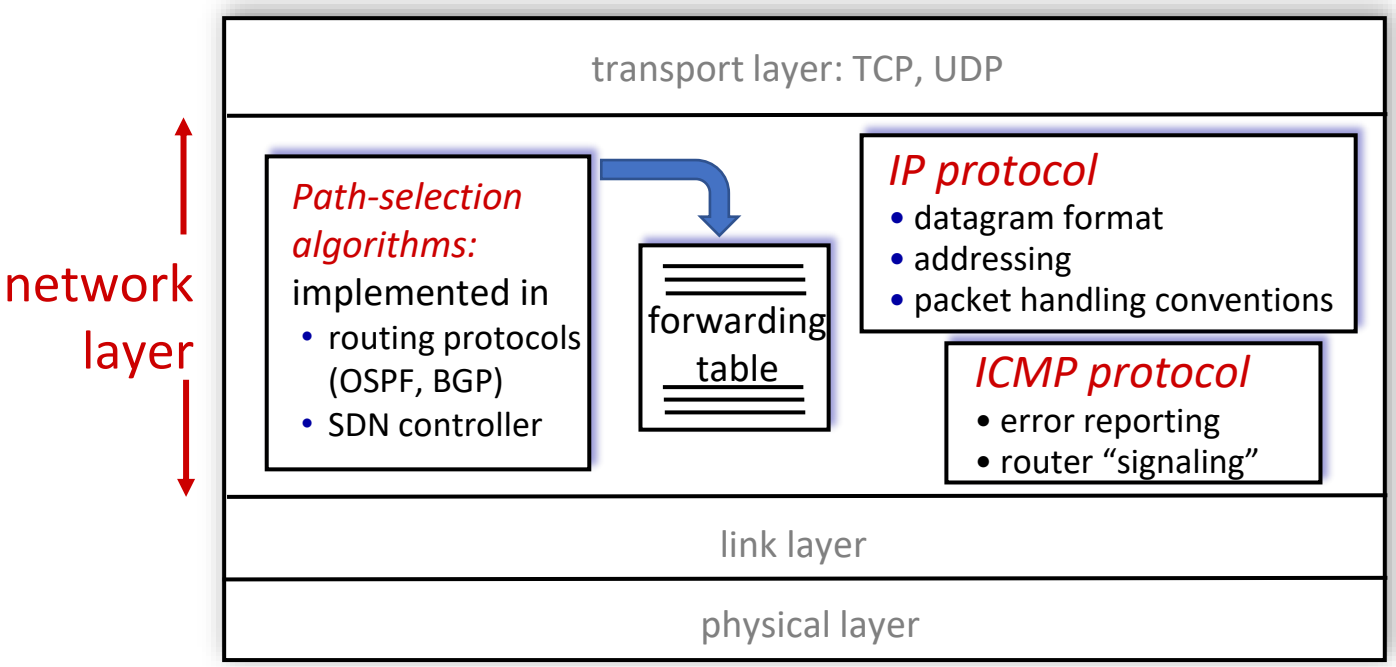
Network layer: "data plane" roadmap

- Network layer: overview
  - data plane
  - control plane
- What's inside a router
  - input ports, switching, output ports
  - buffer management, scheduling
- IP: the Internet Protocol
  - datagram format
  - addressing
  - network address translation
  - IPv6

- Generalized Forwarding, SDN
  - match+action
  - OpenFlow: match+action in action
- Middleboxes

Network Layer: Internet

host, router network layer functions:



The Internet Network's Layer 3 major components are

1. IP Protocol
2. Routing Component
3. Reporting Errors / Responding to Requests (ICMP, IGMP etc.)

The Internet Protocol (IP)

- *Connectionless* (no call set up at the network layer), *Unreliable designed to be used in a packet switched network like the Internet*

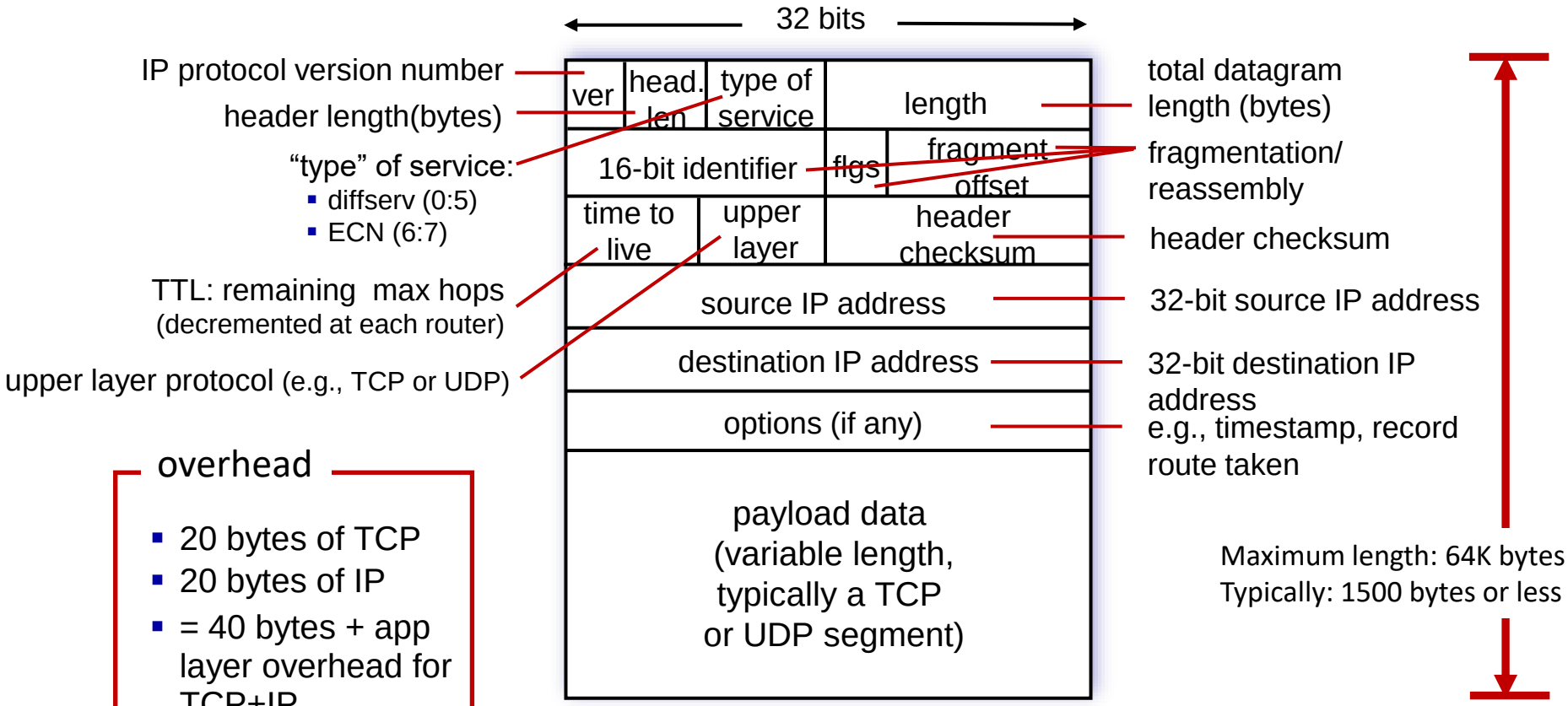
- No *state* about end-to-end connections

- *Best Effort Services* (no bandwidth, loss, error, in order, timing guarantees)

- No *Congestion* indicators

IP relies on TCP for these services

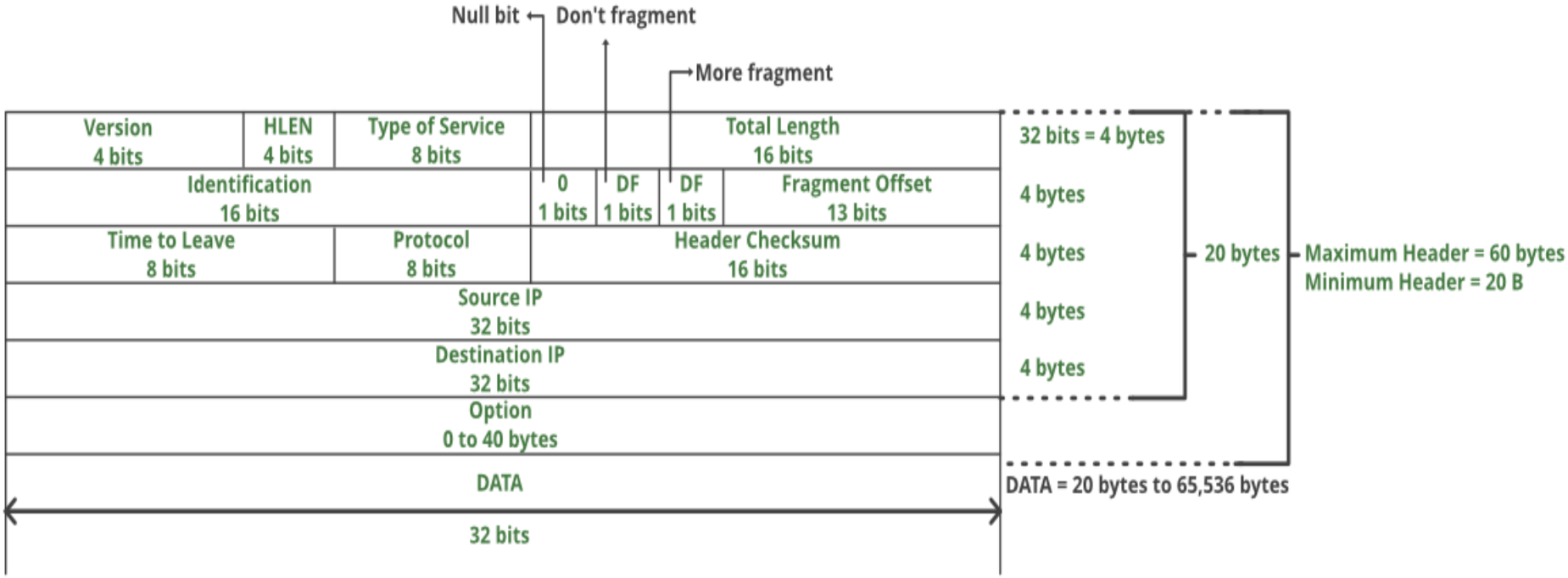
IPv4 Datagram format



overhead

- 20 bytes of TCP
- 20 bytes of IP
- = 40 bytes + app layer overhead for TCP+IP
- Typical IP datagram header is 20 bytes (if options not used)

IPv4 Header



- Ver field for IPv4 will always contain the decimal value 4 (i.e. 0100 in binary)

- Header length field is a 4 bit field that contains the length of the IP header in bytes, which always lies in the range of 20 bytes (min) to 60 bytes (max), but the range of these 4 bits can only be from 0000 (i.e. 0 in decimal) to 1111 (i.e. 15 in decimal), so to represent the header length, we use a scaling factor of 4. Thus

Actual Header length = (Header length field value x 4) bytes

IPv4 Header

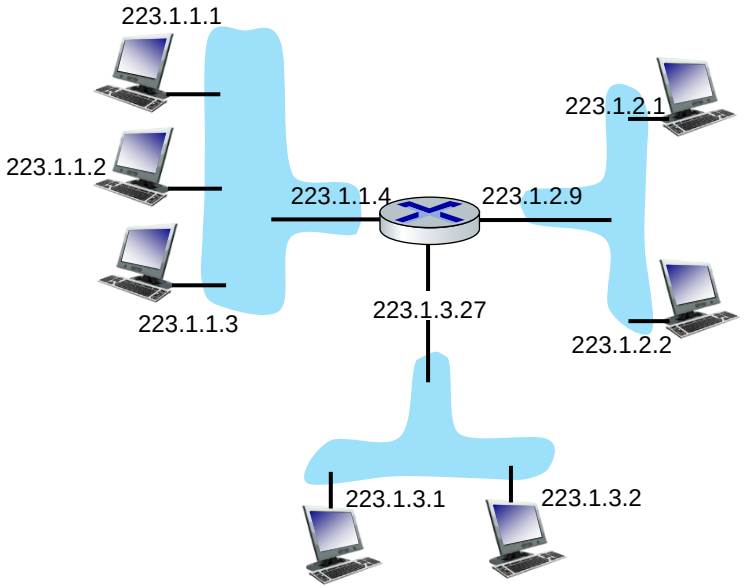
Examples:

- If the header length field contains the value 0101 (i.e. 5 in decimal), then the Actual Header length = 5 x 4 = 20 bytes

- Similarly, if the header length field contains the value 1010 (i.e. 10 in decimal), then the Actual Header length = 10 x 4 = 40 bytes

IPv4 addressing: introduction

- **IP address:** 32-bit identifier associated with each host or router *interface* (thus 2^{32} i.e. approx. 4 billion globally unique IPv4 addresses possible)
- **interface:** connection between host/router and physical link
  - router's typically have multiple interfaces
  - host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
  - IP addresses associated with each interface (& not with host or router)



dotted-decimal IP address notation:

223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

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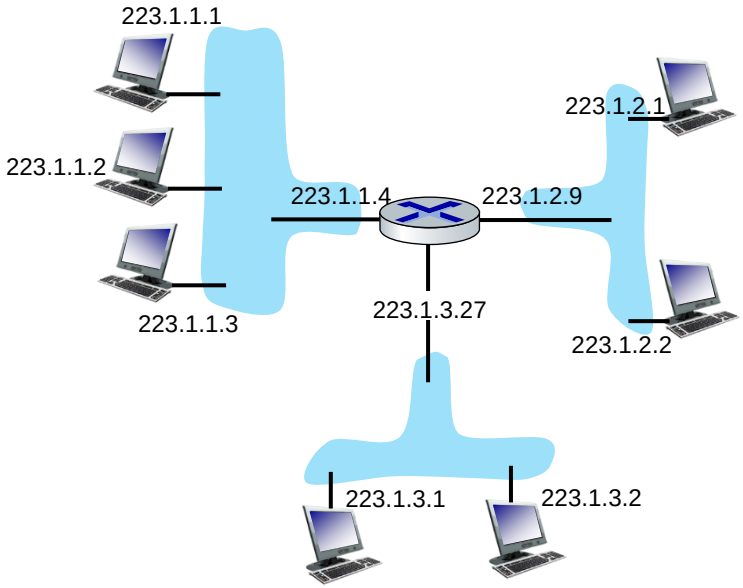


dotted-decimal IP address notation:

223.1.1.1 = 11011111 00000001 00000001 00000001

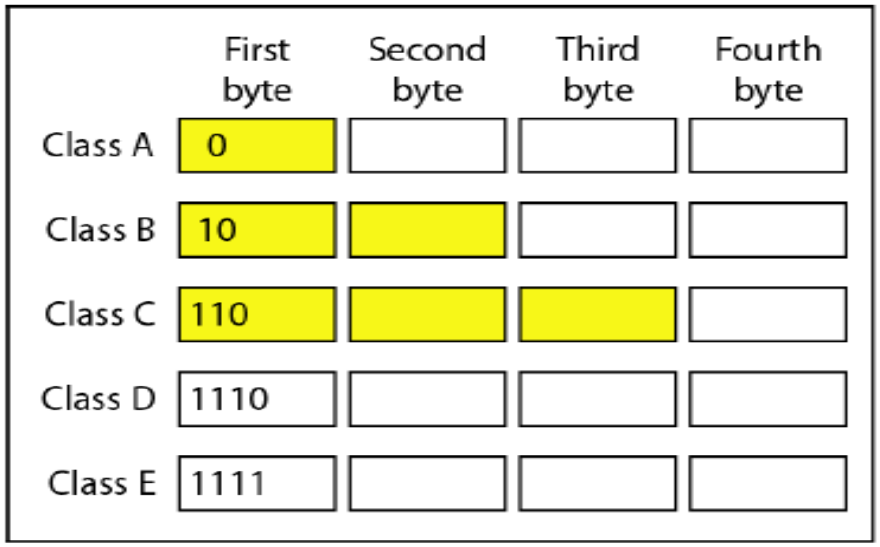
223 1 1 1

IPv4 Addressing

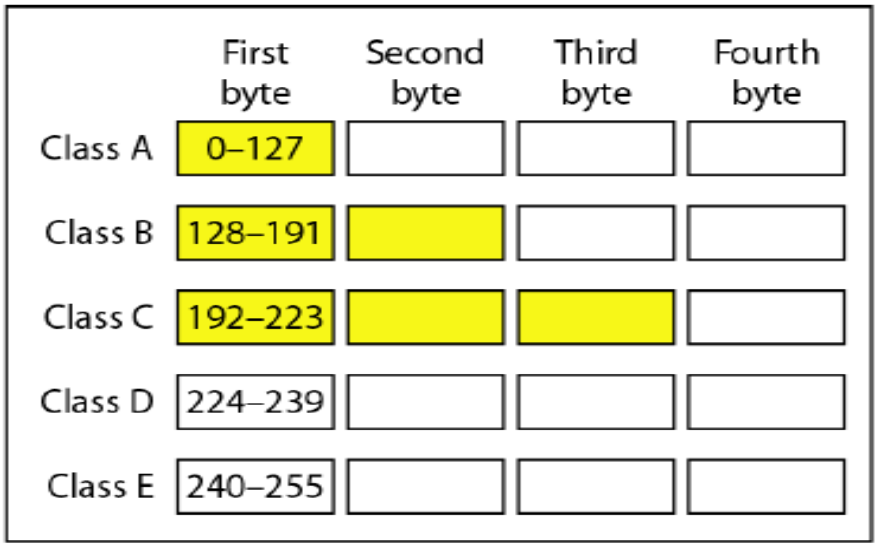
- IPv4 address is a 32-bit address, implemented in software, is used to uniquely and globally identify a host or a router on the Internet
- A device can have more than one IP address if it is connected to more than one network (multi-homed)
- An IP address have two parts, the netid and the hostid. They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

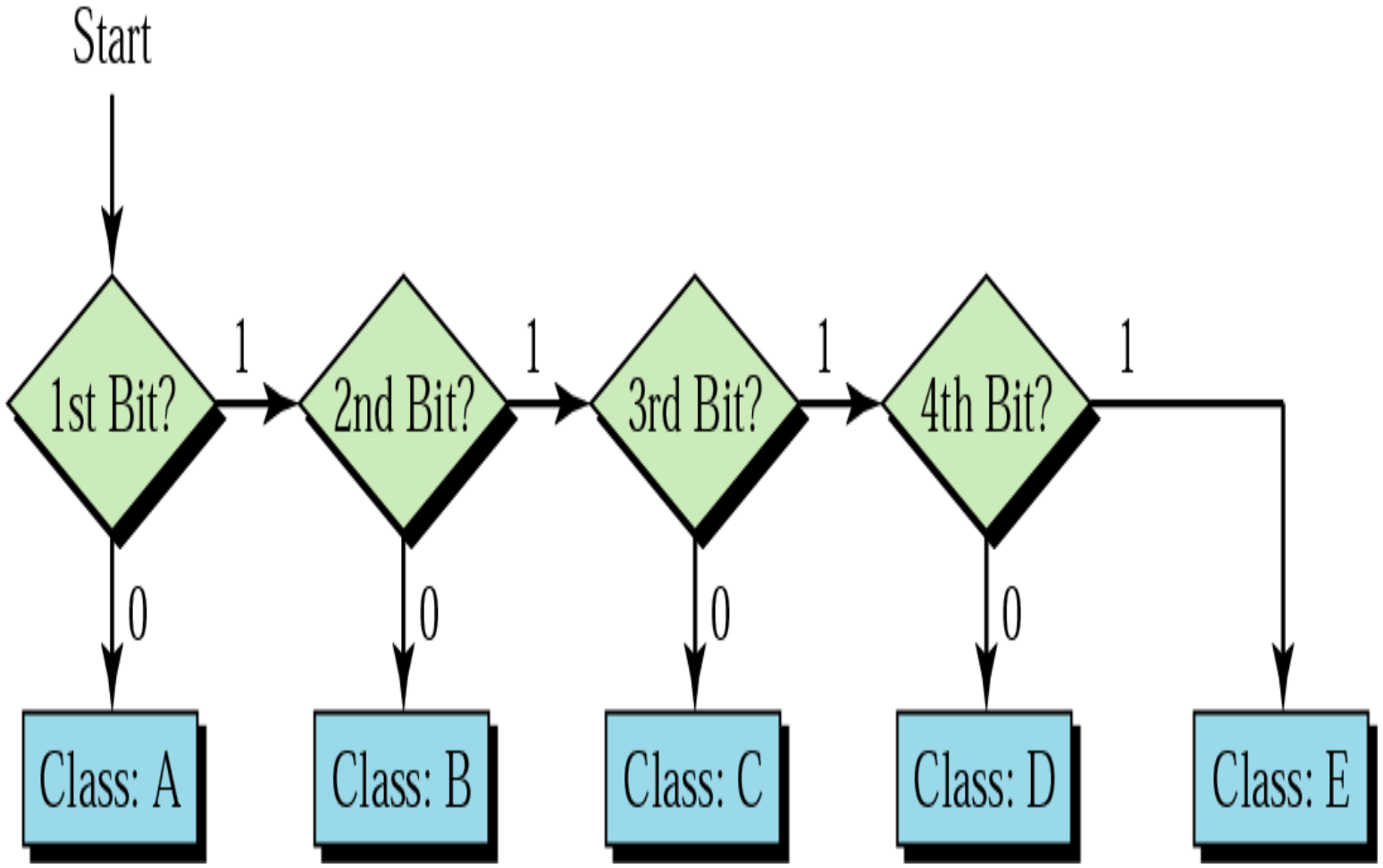


b. Dotted-decimal notation

⇒ 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.

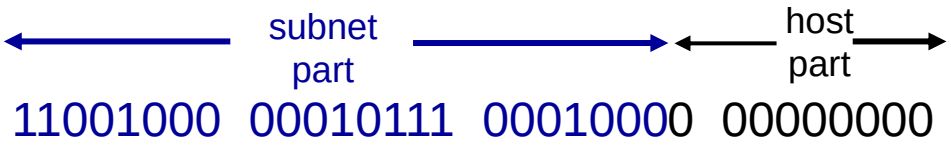
Range			*Total*
10.0.0.0	to	10.255.255.255	2^{24} Commercial use
172.16.0.0	to	172.31.255.255	2^{20} Mostly Commercial
192.168.0.0	to	192.168.255.255	2^{16} Residential use

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