Outline for Review

Chapter 1: introduction

Overview:

- Terminology and Concepts related to

  " Computer Network"

  - ✓ use Internet as example
- What's a protocol?
- Protocol layers and their service models
- Internet history

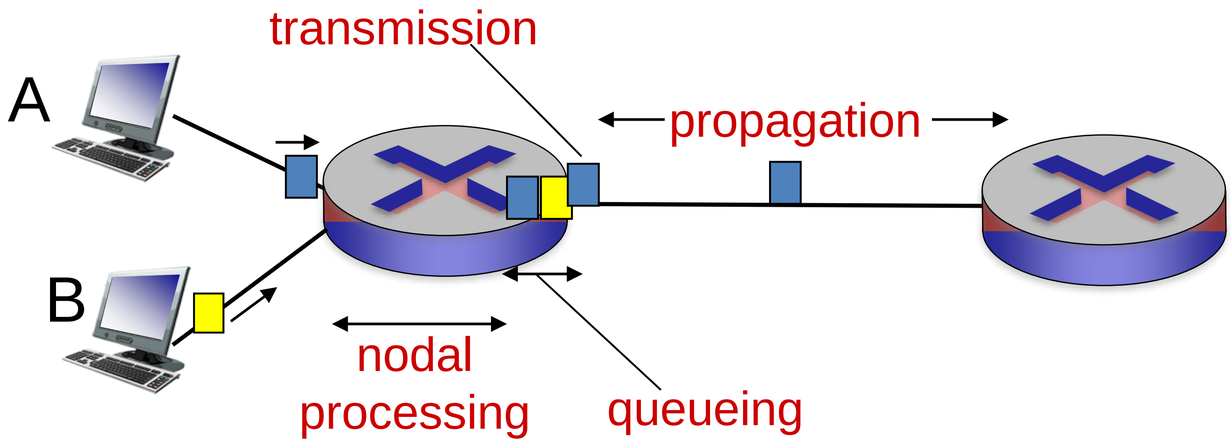
Keypoints:

- Protocol and three essential factors
- Protocol layers and layered architecture

Difficulties:

- Connection-oriented and connectionless
- Circuit switching and packet switching
- Delay and how to calculate the delay

Four sources of packet delay



$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

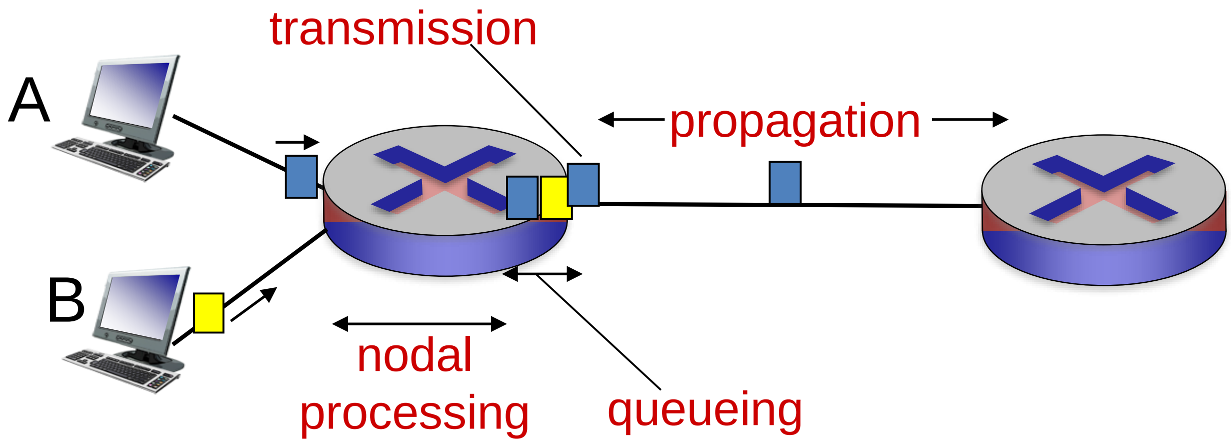
d_{proc}: nodal processing

- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

Four sources of packet delay



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{trans}: transmission delay:

- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{trans} and d_{prop} *very* different

d_{prop}: propagation delay:

- d: length of physical link
- s: propagation speed (~2×10^8 m/sec)
- $d_{prop} = d/s$

Exercise-1 (nodal delay)

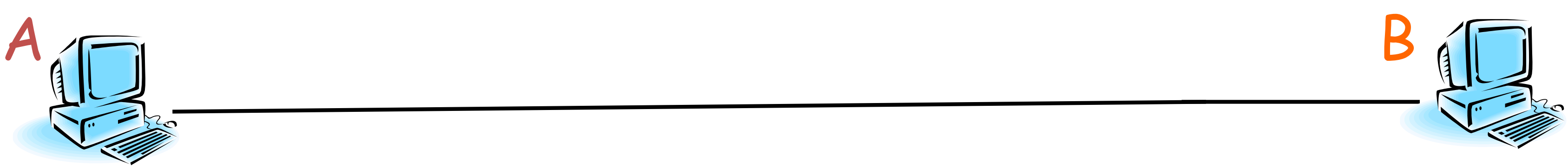
Assuming that the link length *d* between two hosts is 60m, the link bandwidth **R** is 10Mbps, and the signal propagation rate *s* is 2×10^8 m / s. Now host A sends 1-bit packet to host B.

1) How long does it take for host B to receive this packet? If host A starts transmitting the packet at time $t = 0$, how far does the front end of the signal of the packet spread at time $t = d_{trans}$?

2) What if the link length *d* is 20 meters?

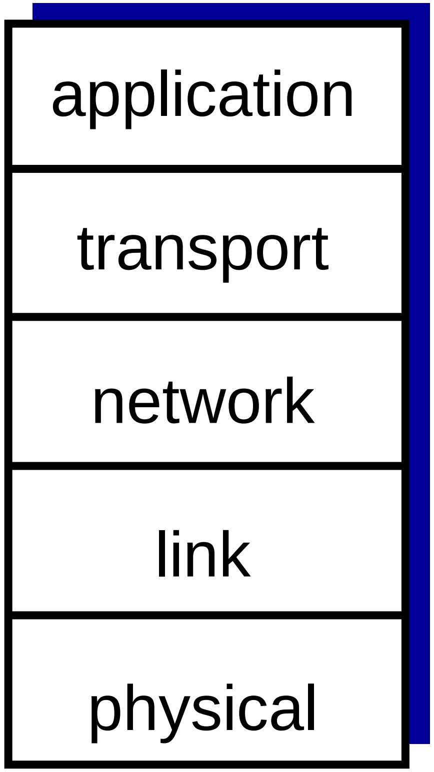
3) If the link length *d* is 10 meters, what is the specific transmission situation?

4) If host A sends n-bit packet to host B, how long does it take for host B to receive the packet?



Internet protocol stack

- *application:* supporting network applications
  – FTP, SMTP, HTTP
- *transport:* process-process data transfer
  – TCP, UDP
- *network:* routing of datagrams from source to destination
  – IP, routing protocols
- *link:* data transfer between neighboring network elements
  – Ethernet, 802.111 (WiFi), PPP
- *physical:* bits "on the wire"



Chapter 2: The Physical Layer

Overview:

1 What is the basic goal of the physical layer?

2 How to define the physical layer protocols?

3 What is the theoretical basis for the physical layer?

Keypoints:

- Nyquist's Law and Shannon-Hartley theorem
- Symbol code types: NRZ, Manchester encoding, Differential Manchester encoding

Difficulties:

- Channel transmission rate calculation

Shannon formula

- limit information transmission rate C of channel can be expressed as:

$$C = H\log_2(1+S/N)$$

H-channel frequency bandwidth, in Hz

S-The average power of the signals transmitted in the channel

N-The Gaussian noise power in the channel

S/N-signal to noise ratio, in db (decibels)

$$10\log_{10} S/N$$

Notes to unit db: When S / N = 10, the signal to noise ratio is 10db

When S / N = 1000, the signal to noise ratio is 30db

- Example:
  - For the standard telephone channel with frequency bandwidth of 3.1 kHz, if the signal-to-noise ratio S/N = 2500, then can the information transmission rate be 50kb/s?
- Solution:
  - Put W = 3.1kHz, S / N = 2500 into Shannon’s Formula
  - The limit information transmission rate is 35kb/s, so it is impossible to reach 50kb/s
- In order to achieve 50kb/s, you can
  - improve the signal-to-noise ratio in the channel
  - or increase the frequency bandwidth

Digital signal coding technology

- Non-Return-to-Zero (NRZ)
- Manchester encoding
- Differential Manchester encoding

Exercise:

Draw the waveform of "001101" with NRZ, Manchester encoding, differential Manchester encoding.

Exercise-2

1.In the physical layer interface characteristics, the time sequence used to describe the completion of each function is

A. Mechanical Characteristics

B. Electrical Characteristics

C. Functional Characteristics

D. Procedural Characteristics

2. Among the following options, that do not belong to the definition scope of physical layer interface specification is

A. interface shape   B. pin function

C. physical address   D. signal level

Exercise-3

1.Under the condition of no noise, if the frequency bandwidth of a communication link is 3kHz and QAM modulation technology with four phases and four amplitudes in each phase is adopted, the maximum data transmission rate of the communication link is

A. 12kbps B. 24kbps C. 48kbps D. 96kbps

2. If the data transmission rate of a communication link is 2400bps and 4-phase modulation is adopted, the baud rate of the link is

A. 600 baud B. 1200 baud

C. 4800 baud D. 9600 baud

Exercise-4

3. If the frequency bandwidth connecting R2 and R3 link is 8kHz and the signal-to-noise ratio is 30dB, and the actual data transmission rate of the link is about 50% of the maximum data transmission rate, the actual data transmission rate of the link is about

A. 8kbps B. 20kbps C. 40kbps D. 80kbps

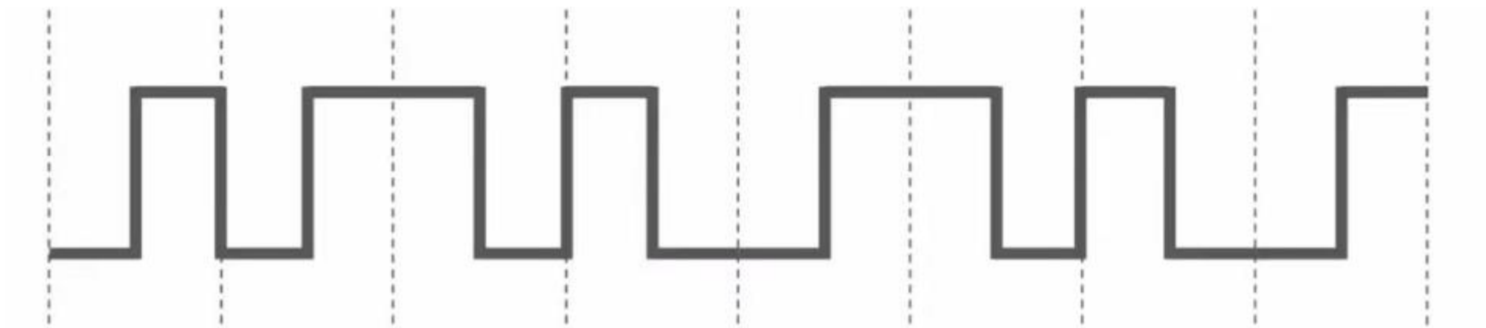
2. Among the following factors, which will not affect the channel data transmission rate is

A. signal to noise ratio B. frequency bandwidth

C. symbol speed D. signal propagation speed

Exercise-5

1.If the following figure shows the signal waveform received by the 10Base-T network interface card, the bit string received by the network interface card is



A. 00110110 B. 10101101 C. 01010010 D. 11000101

Chapter 3: The Link Layer

Overview:

- link layer services
- framing
- error detection, correction
- multiple access protocols and LANs
- link layer addressing

Keypoints:

- Four framing methods
- CRC
- multiple access protocols
- link layer addressing

Difficulties:

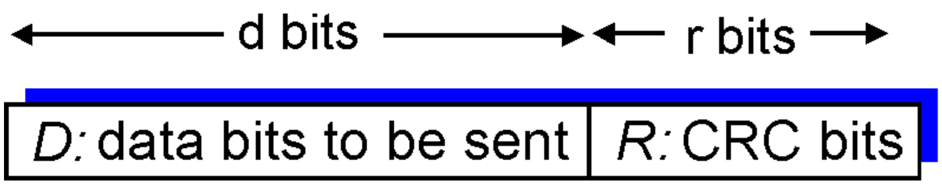
- CRC
- CSMA/CD

Framing

- Character count method :
  - encapsulate datagram into frame, adding header (character number)
- First and tail bound method based on character:
  - encapsulate datagram into frame, adding header, trailer (character)
- First and tail bound method based on bit:
  - encapsulate datagram into frame, adding header, trailer (bit sequence, e.g. 7EH)
- Physical layer coding violation method:
  - encapsulate datagram into frame without stuffing
  - Only be used in the networks with redundancy coding technology in the physical layer

Cyclic Redundancy Check

- view data bits, D, as a binary number
- choose r+1 bit pattern (generator), G
- goal: choose r CRC bits, R, such that
  - <D,R> exactly divisible by G (modulo 2)
  - receiver knows G, divides <D,R> by G. If non-zero remainder: error detected!
  - can detect all burst errors less than r+1 bits
- widely used in practice (ATM, HDLC, Ethernet)



bit pattern

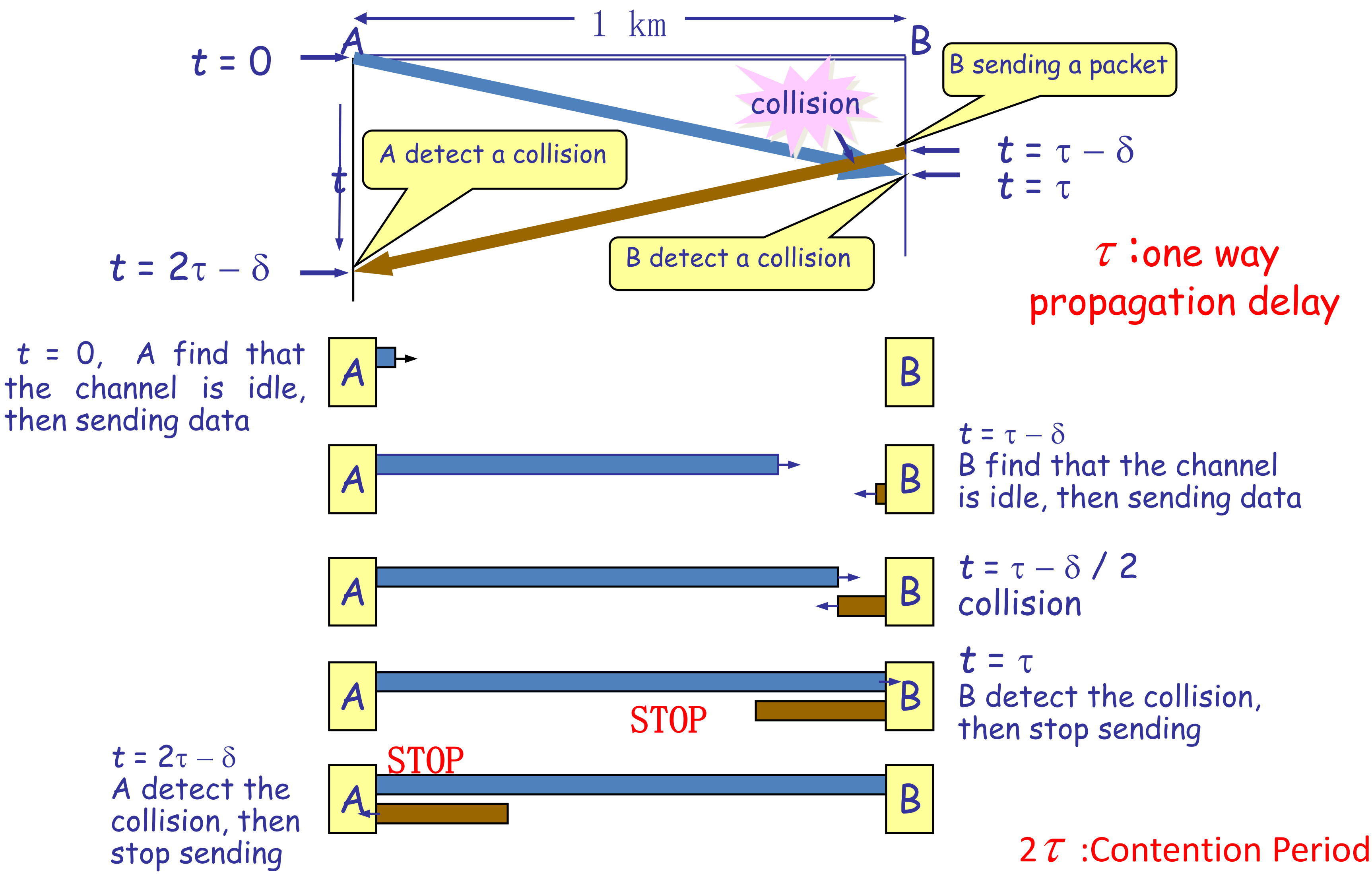
$$D * 2^r \quad \text{XOR} \quad R$$

mathematical formula

Summary of MAC protocols

- What do you do with a shared media?
  - Channel Partitioning, by time, frequency or code
    - Time Division,Code Division, Frequency Division
  - Random partitioning (dynamic),
    - ALOHA, S-ALOHA, CSMA, CSMA/CD
    - carrier sensing: easy in some technoligies (wire), hard in others (wireless)
    - CSMA/CD used in Ethernet
  - Taking Turns
    - polling from a central cite, token passing

CSMA/CD (Collision Detection)



Exercise-6

- A LAN adopts CSMA/CD protocol to realize the media access control. The data transmission rate is 10Mbps, the distance between host A and host B is 2km, and the signal propagation speed is 200000km/s. If there is a conflict when two hosts send data, how long will it take from the time when they start sending data to the time when both hosts detect the conflict? (What is the minimum and maximum duration?)

- In a LAN using CSMA / CD protocol, the transmission medium is a complete cable, the transmission rate is 1Gbps, and the signal propagation rate in the cable is 200000 km / s. if the minimum data frame length is reduced by 800 bits, the distance between the farthest two stations needs to be at least

(1) increased by 160m (2) increased by 80m (3) reduced by 160m (4) reduced by 80m

Chapter 4: Local Area network

Overview:

- LAN model
- addressing
- Ethernet
- hubs, switches
- 802.11

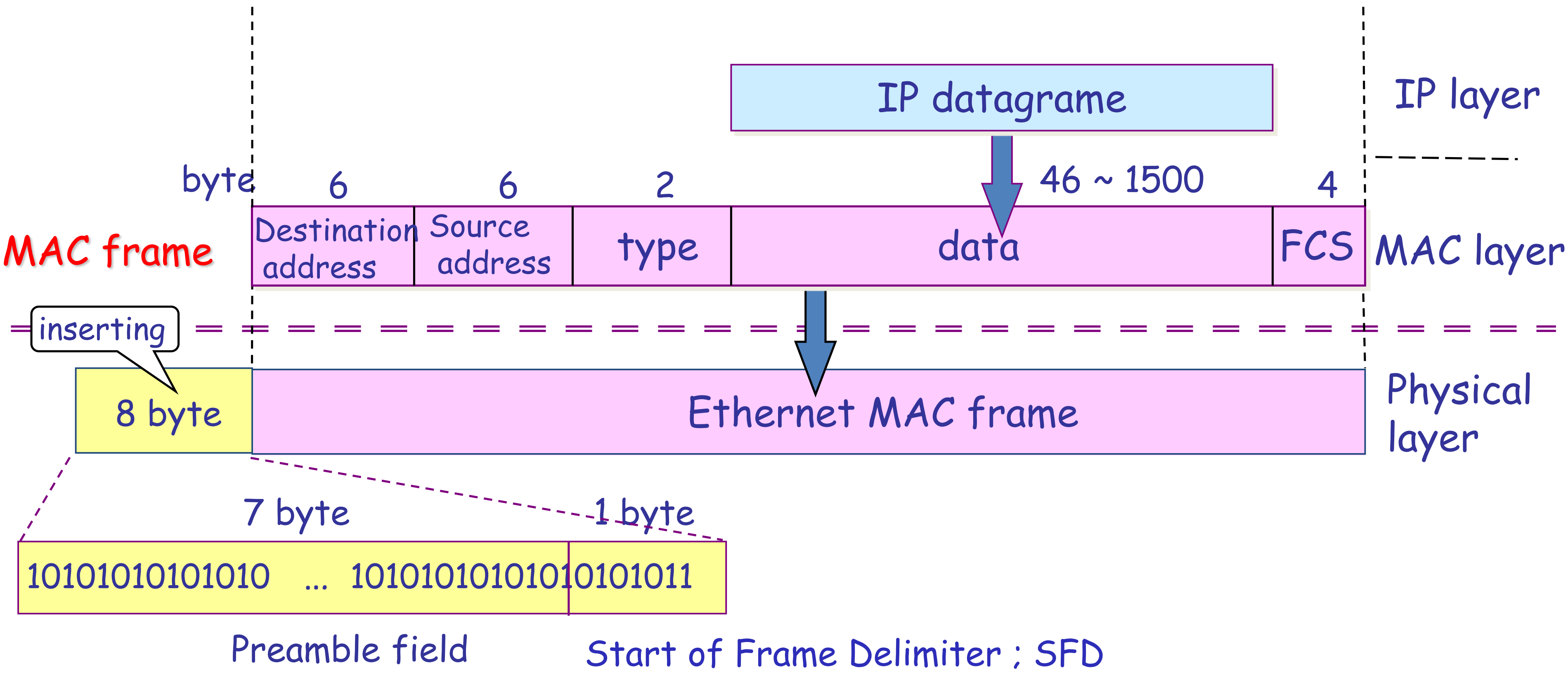
Keypoints:

- LAN model
- Ethernet
- Hubs, switches
- Wireless LAN-IEEE 802.11

Difficulties:

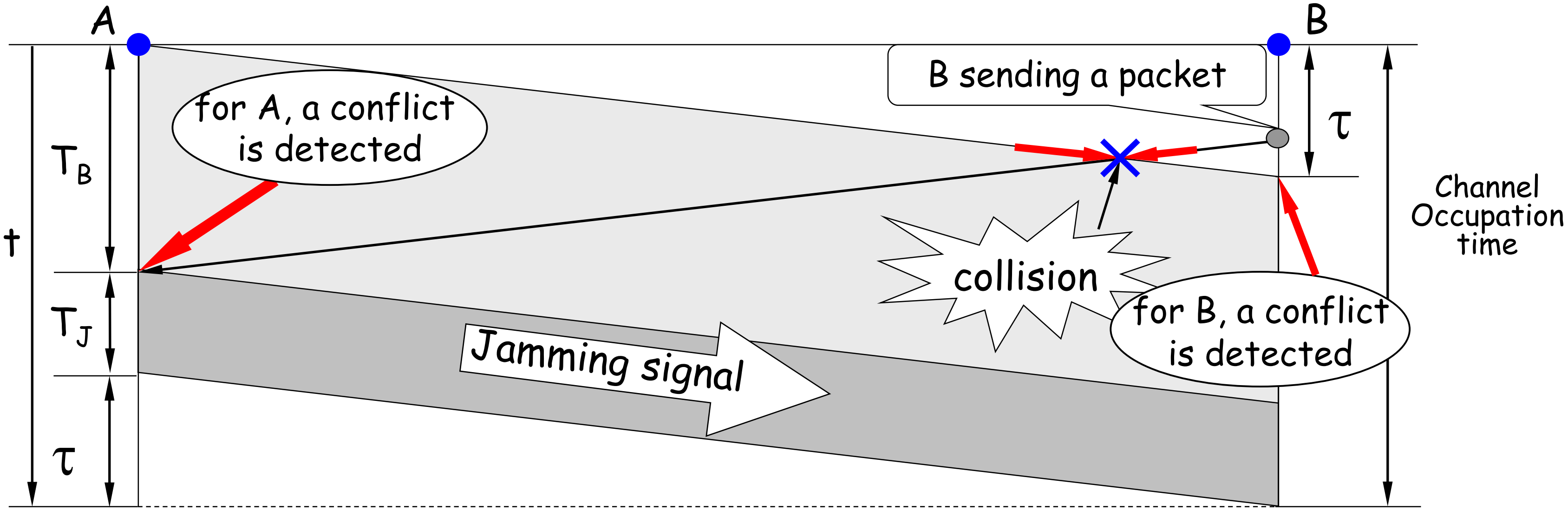
- The minimum frame length
- The exponential Backoff algorithm
- CSMA/CA

Ethernet Frame Structure



Ethernet's CSMA/CD (more)

Jam Signal: make sure all other transmitters are aware of collision; 48 bits;



Ethernet's CSMA/CD (more)

Exponential Backoff:

- *Goal*: adapt retransmission attemtps to estimated current load
  - heavy load: random wait will be longer
- delay is K x 512 bit transmission times (contention period: 2τ)
- first collision: choose K from {0,1};
- after second collision: choose K from {0,1,2,3}…
- after ten or more collisions, choose K from {0,1,2,3,4,…,1023}
- K=min(n,i),n: # collisions,n≤j(attempt limit);i:back off limit
- For Ethernet, i=10,j=16

Challenges of Wireless communications

- fading: path loss, multipath effect, shadow effect, Doppler effect
- interference: from other wireless communications
- hidden terminal problem
-
- Solution: CSMA/CA

Chapter 5: Network Layer

Overview:

- Virtual circuit and datagram networks
- What's inside a router?
- Routing algorithms
- Routing in the Internet
- IP: Internet protocol

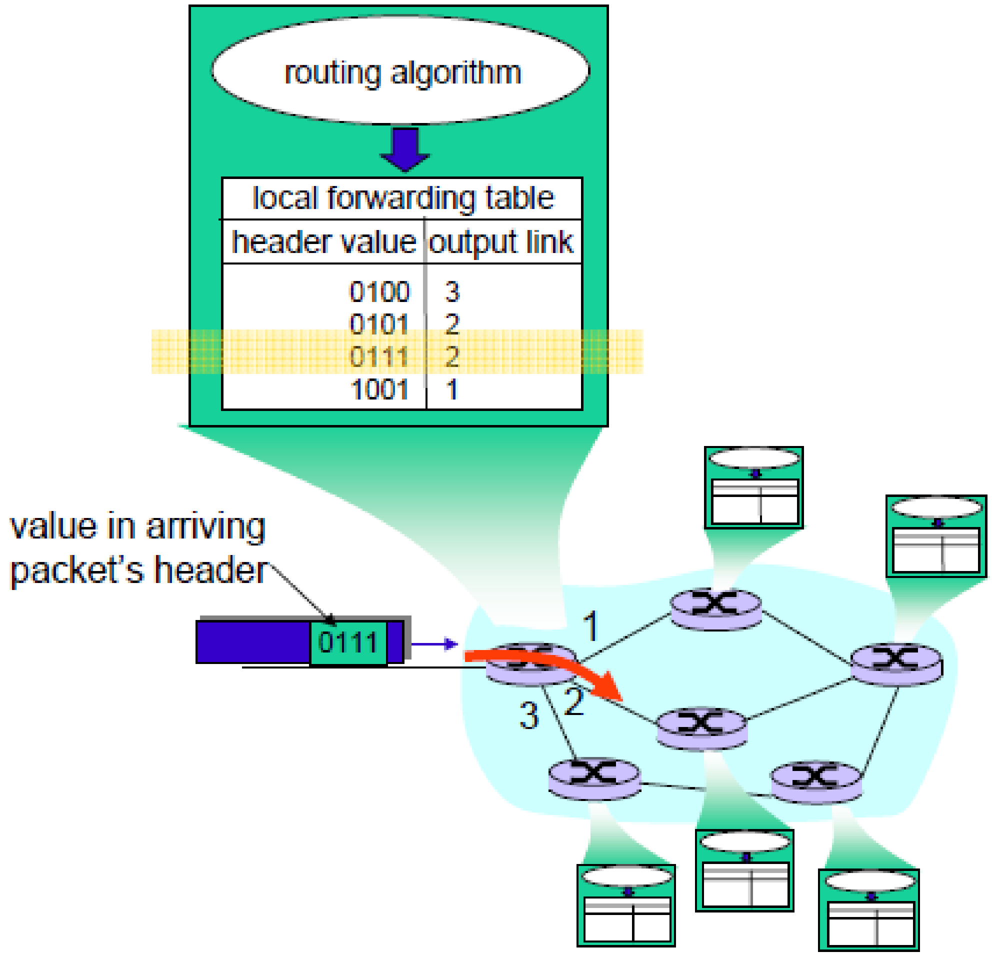
Keypoints:

- Link state routing algorithm
- Distance vector routing algorithm
- IPv4
- IPv6

Difficulties:

- Virtual circuit and datagram networks
- Subnet and Subnet Division
- IP fragment

Interplay between routing and forwarding



Longest prefix matching

- when looking for forwarding table entry for given destination address, use *longest* address prefix that matches destination address

Destination Address Range	Link interface
11001000 00010111 00010*** *********	0
11001000 00010111 00011000 *********	1
11001000 00010111 00011*** *********	2
otherwise	3

examples:

DA: 11001000 00010111 00010110 10100001 which interface?

DA: 11001000 00010111 00011000 10101010 which interface?

Link state algorithm

Broadcast routing + Dijkstra's algorithm

- Having each node broadcast link-state packets to all other nodes → all nodes have an identical and complete view of the network.
- Using Dijkstra's algorithm compute the least-cost path from one node to all other nodes in the network
- If a link cost changes, re-broadcast and re-compute

Dijkstra's algorithm

```
Initialization:
  N' = {u}
  for all nodes v
    if v adjacent to u
      then D(v) = c(u,v)
    else D(v) = ∞

Loop
  find w not in N' such that D(w) is a minimum
  add w to N'
  update D(v) for all v adjacent to w and not in N' :
     D(v) = min( D(v), D(w) + c(w,v) )
  /* new cost to v is either old cost to v or known
   shortest path cost to w plus cost from w to v */
until all nodes in N'
```

Distance vector algorithm

Iterative, asynchronous:

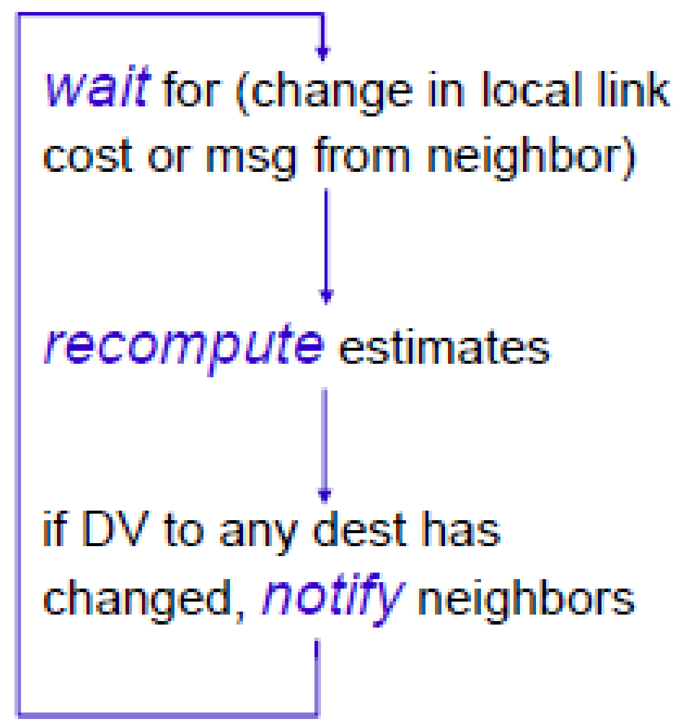
Each local iteration caused by:

- Local link cost change
- DV update message from neighbor

Distributed:

- Each node notifies neighbors only when its DV change
- Neighbors then notify their neighbors if necessary

Each node:



Count to infinity problem

Link cost changes:

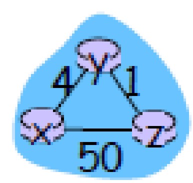
- good news travels fast
- Bad news travels slow – "count to infinity" problem!

How to solve the count to infinity problem:

- Poisoned reverse

"bad news travels slow"

"count to infinity" problem



node x table

from \ cost to	x	y	z
x	0	4	5
y	4	0	1
z	5	1	0

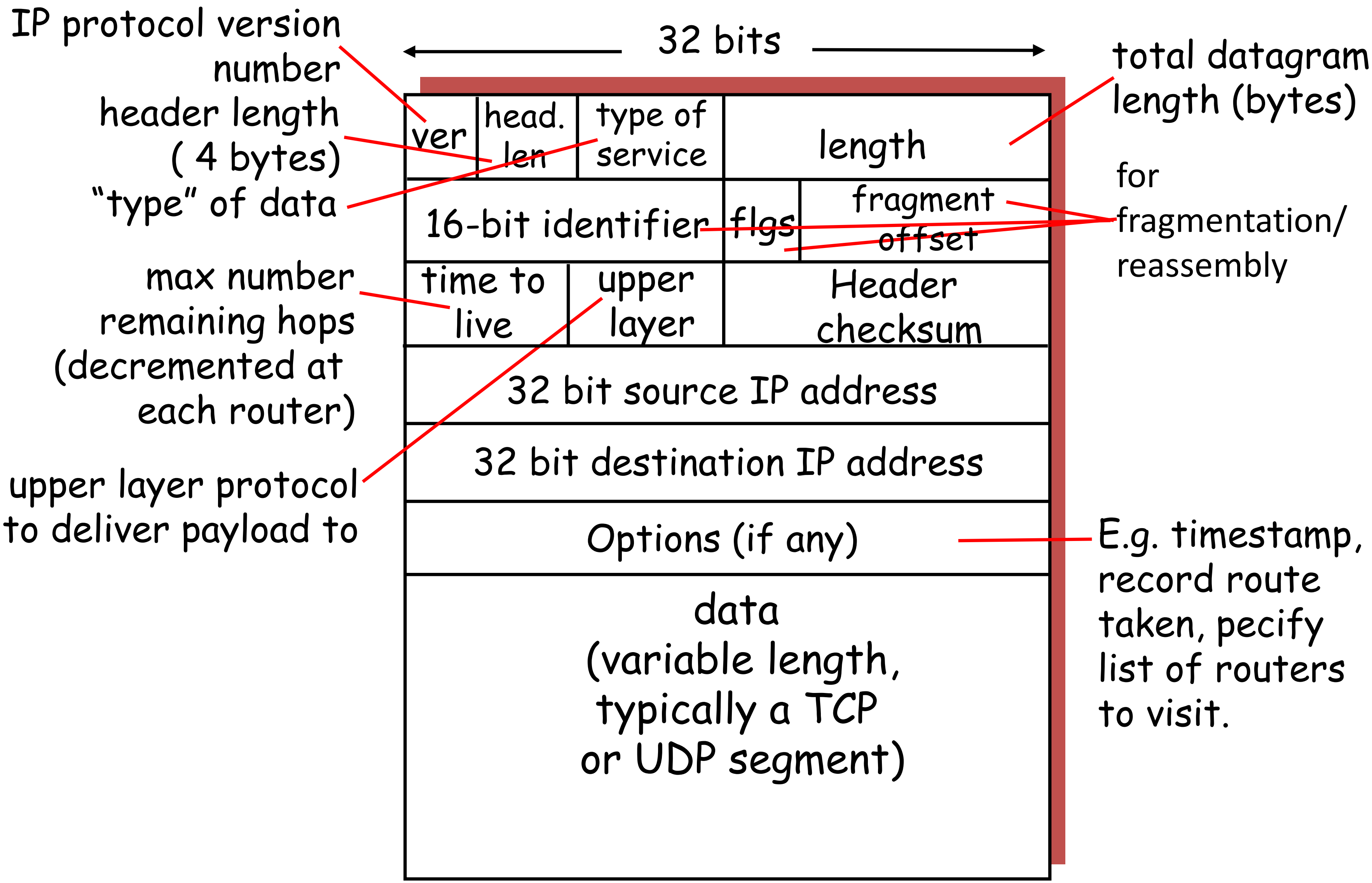
node y table

from \ cost to	x	y	z
x	0	4	5
y	4	0	1
z	5	1	0

node z table

from \ cost to	x	y	z
x	0	4	5
y	4	0	1
z	5	1	0

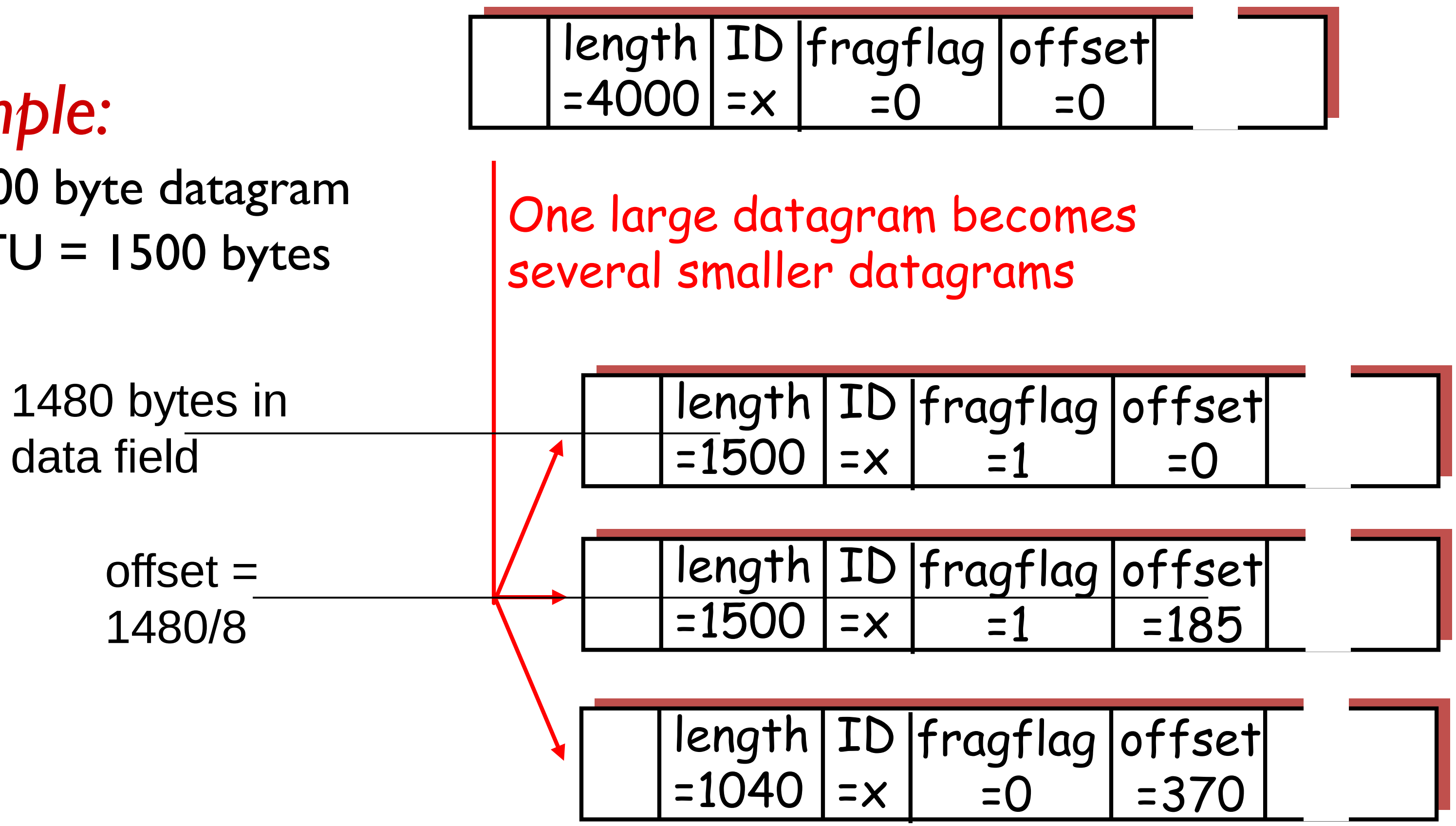
IP datagram format



IP Fragmentation and Reassembly

example:

- 4000 byte datagram
- MTU = 1500 bytes



IPv4 addressing

- Dotted-decimal notation:193.32.216.9
- classful addressing:
- Subnetting and subnet mask
- CIDR: Classless InterDomain Routing
  - network portion of address of arbitrary length
  - address format: a.b.c.d/x

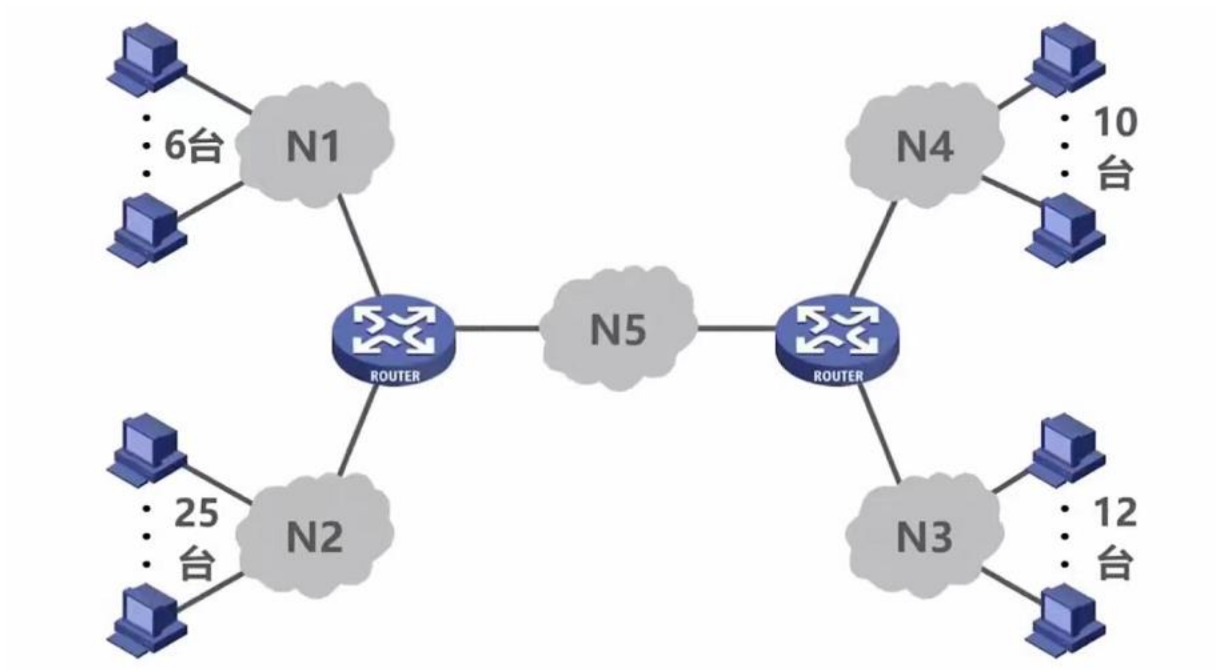
network part | host part

11001000 00010111 00010000 00000000

200.23.16.0/23

Exercise-7

Assuming that the applied IP address block is 218.75.230.0/24, please assign IP addresses to the devices in the figure below using fixed length and variable length subnet masks respectively.



Exercise-7

Assuming that the applied IP address block is 218.75.230.0/24, please assign IP addresses to the devices in the figure below using fixed length and variable length subnet masks respectively.

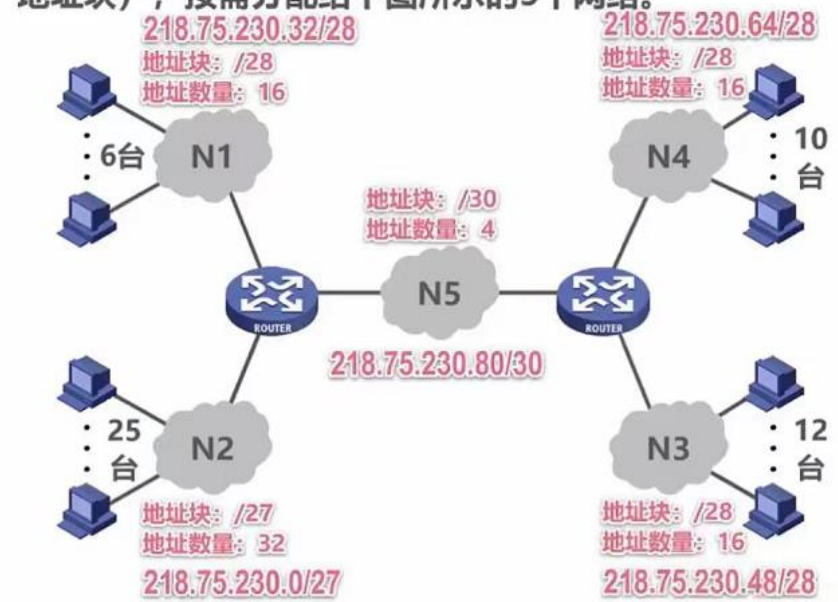
使用子网掩码255.255.255.224 对C类网络218.75.230.0进行子网划分的细节			
子网	网络地址	广播地址	该子网可分配的地址
1	218.75.230.0	218.75.230.31	218.75.230.1 ~ 218.75.230.30
2	218.75.230.32	218.75.230.63	218.75.230.33 ~ 218.75.230.62
3	218.75.230.64	218.75.230.95	218.75.230.65 ~ 218.75.230.94
4	218.75.230.96	218.75.230.127	218.75.230.97 ~ 218.75.230.126
5	218.75.230.128	218.75.230.159	218.75.230.129 ~ 218.75.230.158
6	218.75.230.160	218.75.230.191	218.75.230.161 ~ 218.75.230.190
7	218.75.230.192	218.75.230.223	218.75.230.193 ~ 218.75.230.222
8	218.75.230.224	218.75.230.255	218.75.230.225 ~ 218.75.230.254

从子网1~8中任选5个分配给左图中的N1~N5。

Exercise-7

Assuming that the applied IP address block is 218.75.230.0/24, please assign IP addresses to the devices in the figure below using fixed length and variable length subnet masks respectively.

应用需求：从地址块218.75.230.0/24中取出5个地址块（1个“/27”地址块，3个“/28”地址块，1个“/30”地址块），按需分配给下图所示的5个网络。



218.75.230.0/24地址块所包含的全部地址如下所示：

218.75.230.0	网络N2的网络地址
⋮	网络N2可分配地址
218.75.230.31	网络N2的广播地址
218.75.230.32	网络N1的网络地址
⋮	网络N1可分配地址
218.75.230.47	网络N1的广播地址
218.75.230.48	网络N3的网络地址
⋮	网络N3可分配地址
218.75.230.63	网络N3的广播地址
218.75.230.64	网络N4的网络地址
⋮	网络N4可分配地址
218.75.230.79	网络N4的广播地址
218.75.230.80	网络N5的网络地址
⋮	网络N5可分配地址
218.75.230.83	网络N5的广播地址
218.75.230.84	
⋮	剩余待分配
218.75.230.255	

Exercise-8

Figure 1 shows the network topology, and Figure 2 shows the hex-content of the first 80 bytes of an Ethernet frame of the host for a Web request.

(1) What is the IP address of the Web server? What is the MAC address of the default gateway of this host?

(2) When the IP packet encapsulated in this frame is forwarded through router R, which fields in the IP packet need to be modified？

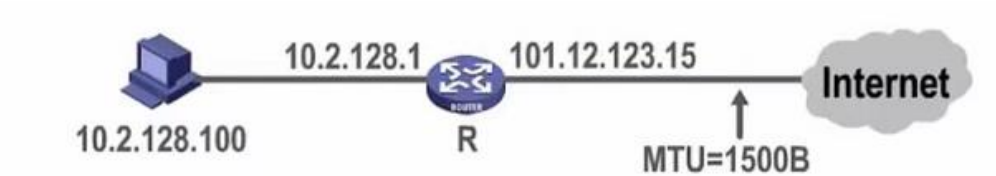


Fig. 1

00	21	27	21	51	ee	00	15	c5	c1	5e	28	08	00	45	00
01	ef	11	3b	40	00	80	06	ba	9d	0a	02	80	64	40	aa
62	20	04	ff	00	50	e0	e2	00	fa	7b	f9	f8	05	50	18
fa	f0	1a	c4	00	00	47	45	54	20	2f	72	66	63	2e	68
74	6d	6c	20	48	54	54	50	2f	31	2e	31	0d	0a	41	63

Fig. 2

IPv6 address

- Three types: unicast, multicast, anycast
- Colon hexadecimal notation:

68E6:8C64:FFFF:FFFF:0:1180:960A:FFFF

- Zero compression:

FF05:0:0:0:0:0:0:B3 == FF05::B3 ;

0:0:0:0:0:0:128.10.2.1 == ::128.10.2.1

Chapter 6: Transport Layer

Overview:

- Principles behind transport layer services:
  - Multiplexing, demultiplexing: port numbers and sockets
  - Reliable data transfer
  - Flow control
  - Congestion control: causes/costs of congestion
- Two transport layer protocols in the Internet
  - TCP, UDP
  - How to choose?

Keypoints:

- Port numbers
- TCP

Difficulties:

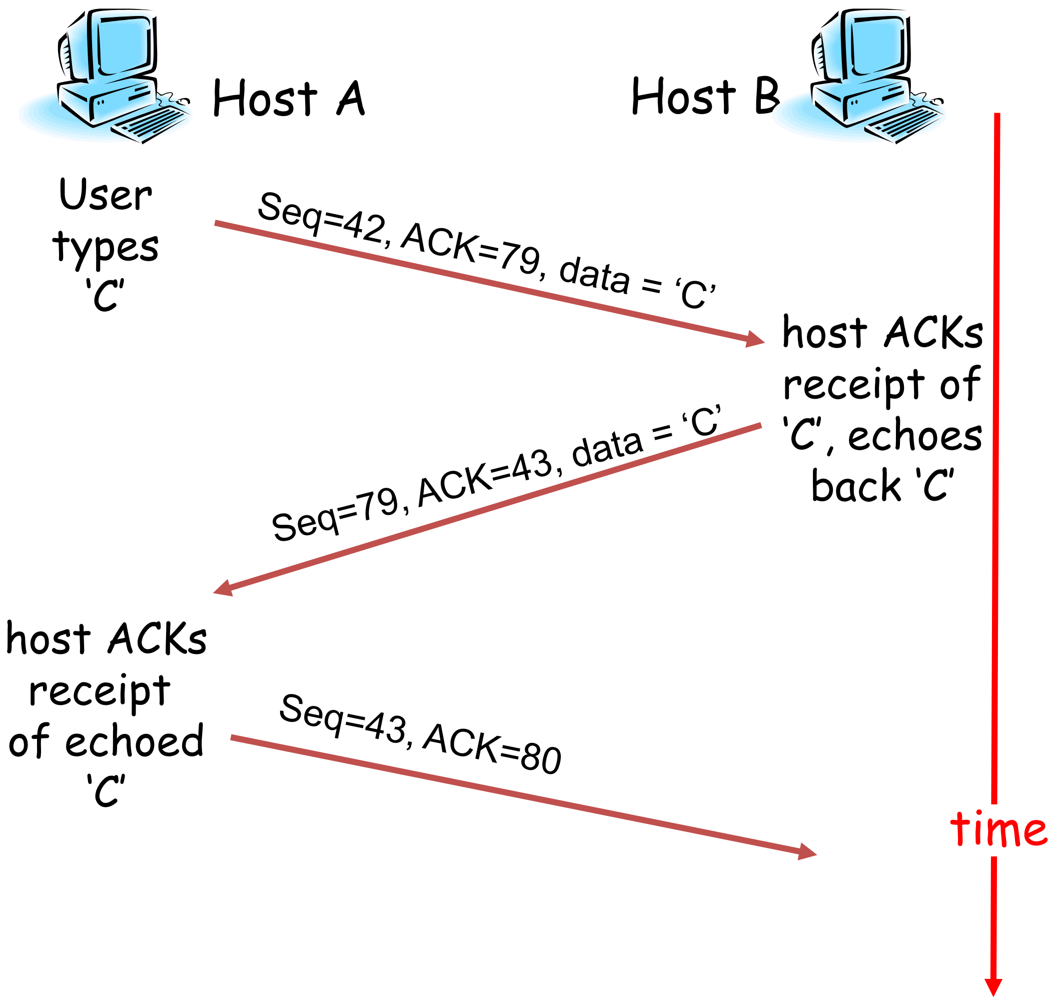
- Virtual circuit and datagram networks
- Subnet and Subnet Division
- IP fragment
- Flow control vs congestion control?

Principles of reliable data transfer

- From rdt 1.0 to rdt 3.0: Assumptions and mechanisms
  - rdt 1.0: over a perfectly reliable channel
  - rdt2.x (rdt2.0, 2.1, 2,2): channel with bit errors
  - rdt3.0: channels with errors and loss
- Pipelined protocols
  - Go-back-N
  - Selective Repeat

TCP Seq. #'s and ACKs

Simple telnet scenario



Exercise-9

1. The data link layer uses the GBN protocol, and the sender has sent frames numbered 0 ~ 7. When the timer expires, if the sender only receives the acknowledgement of frames 0, 2 and 3, the number of frames to be retransmitted by the sender is ( )

   A. 2 B. 3 C. 4 D.5

2. Considering GBN protocol and SR protocol, assuming that the length of sequence number space is *n*, what is the maximum allowed sender window?

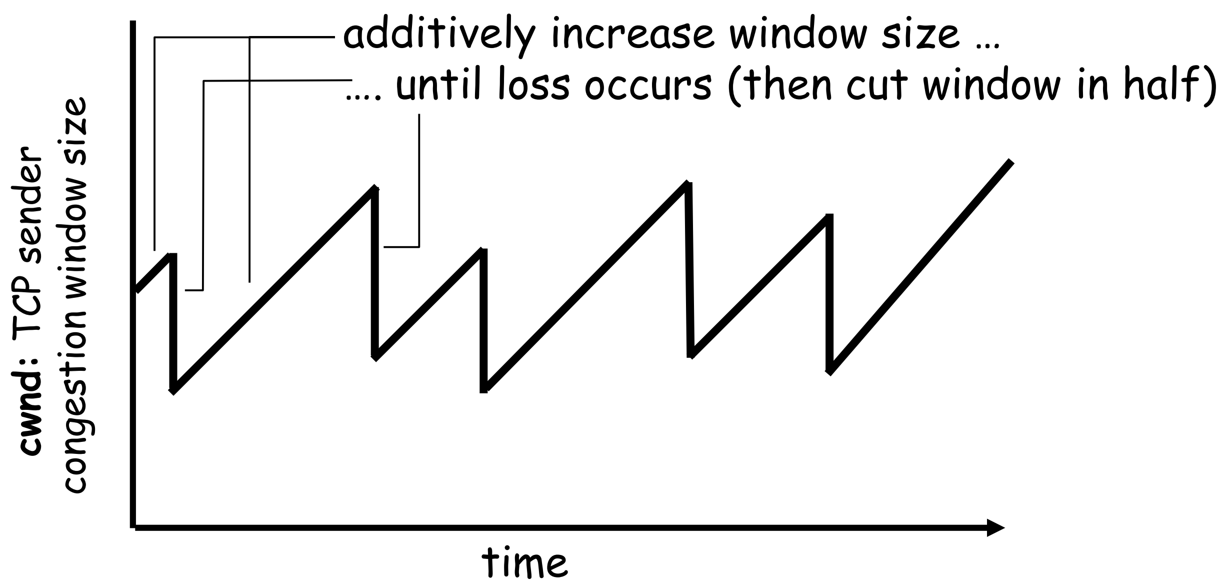
TCP: Overview

- point-to-point:
  - one sender, one receiver
- reliable, in-order *byte stream:*
  - no "message boundaries"
- pipelined:
  - TCP congestion and flow control set window size
- full duplex data:
  - bi-directional data flow in same connection
  - MSS: maximum segment size
- connection-oriented:
  - handshaking (exchange of control msgs) inits sender, receiver state before data exchange
- flow controlled:
  - sender will not overwhelm receiver
- Congestion controlled

TCP congestion control:
additive increase multiplicative decrease

- *approach:* sender increases transmission rate (window size), probing for usable bandwidth, until loss occurs
  - *additive increase:* increase **cwnd** by 1 MSS every RTT until loss detected
  - *multiplicative decrease*: cut **cwnd** in half after loss

AIMD saw tooth behavior: probing for bandwidth



The Big Picture