LAN Systems

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Overview

❑ IEEE 802.3: Ethernet and fast Ethernet

❑ IEEE 802.5: Token ring

❑ Fiber Distributed Data Interface (FDDI)

LAN Topologies

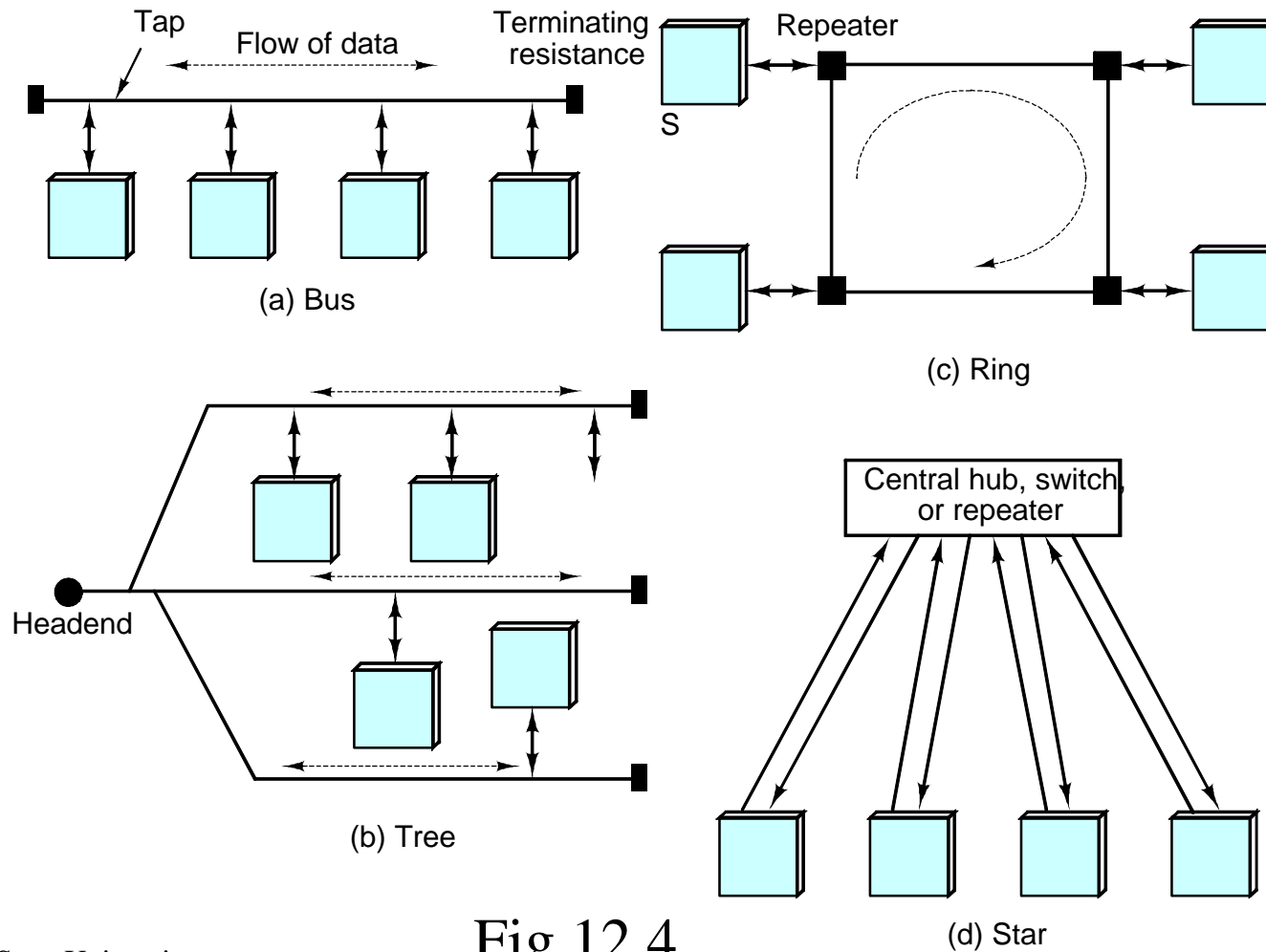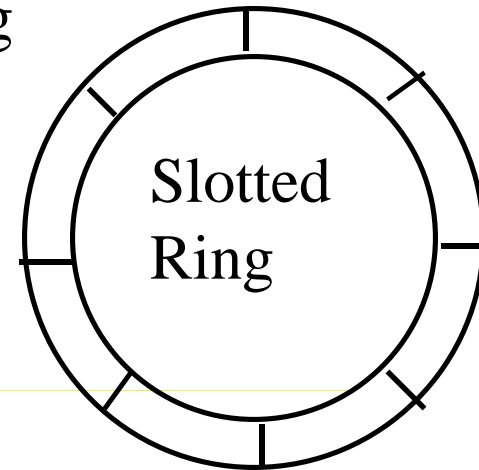Tap Flow of data Terminating resistance Repeater

(a) Bus

(b) Tree

Headend

(c) Ring

S

Central hub, switch, or repeater

(d) Star

Media Access Control (MAC)

	Bus Topology	Ring Topology
Token Passing	IEEE 802.4 Token bus	IEEE 802.5 Token Ring
Slotted Access	IEEE 802.6 DQDB	Cambridge Ring
Contention	IEEE 802.3 CSMACD	

Slotted Ring

(a) Multiple Access

(b) Carrier-Sense Multiple Access with Collision Detection

CSMA/CD

- Aloha at Univ of Hawaii:
  Transmit whenever you like
  Worst case utilization = $1/(2e)$ = 18%
- Slotted Aloha: Fixed size transmission slots
  Worst case utilization = $1/e$ = 37%
- CSMA: Carrier Sense Multiple Access
  Listen before you transmit
- p-Persistent CSMA: If idle, transmit with probability p. Delay by one time unit with probability 1-p
- CSMA/CD: CSMA with Collision Detection
  Listen while transmitting. Stop if you hear someone else

IEEE 802.3 CSMA/CD

❑ If the medium is idle, transmit (1-persistent).

❑ If the medium is busy, wait until idle and then transmit immediately.

❑ If a collision is detected while transmitting,

　❍ Transmit a jam signal for one slot
　　$(= 51.2 \ \mu s = 64$ byte times$)$

　❍ Wait for a random time and reattempt (up to 16 times)

　❍ Random time $=$ Uniform$[0,2^{\min(k,10)}-1]$ slots

❑ Collision detected by monitoring the voltage
　High voltage $\Rightarrow$two or more transmitters $\Rightarrow$Collision
　$\Rightarrow$Length of the cable is limited to 2 km

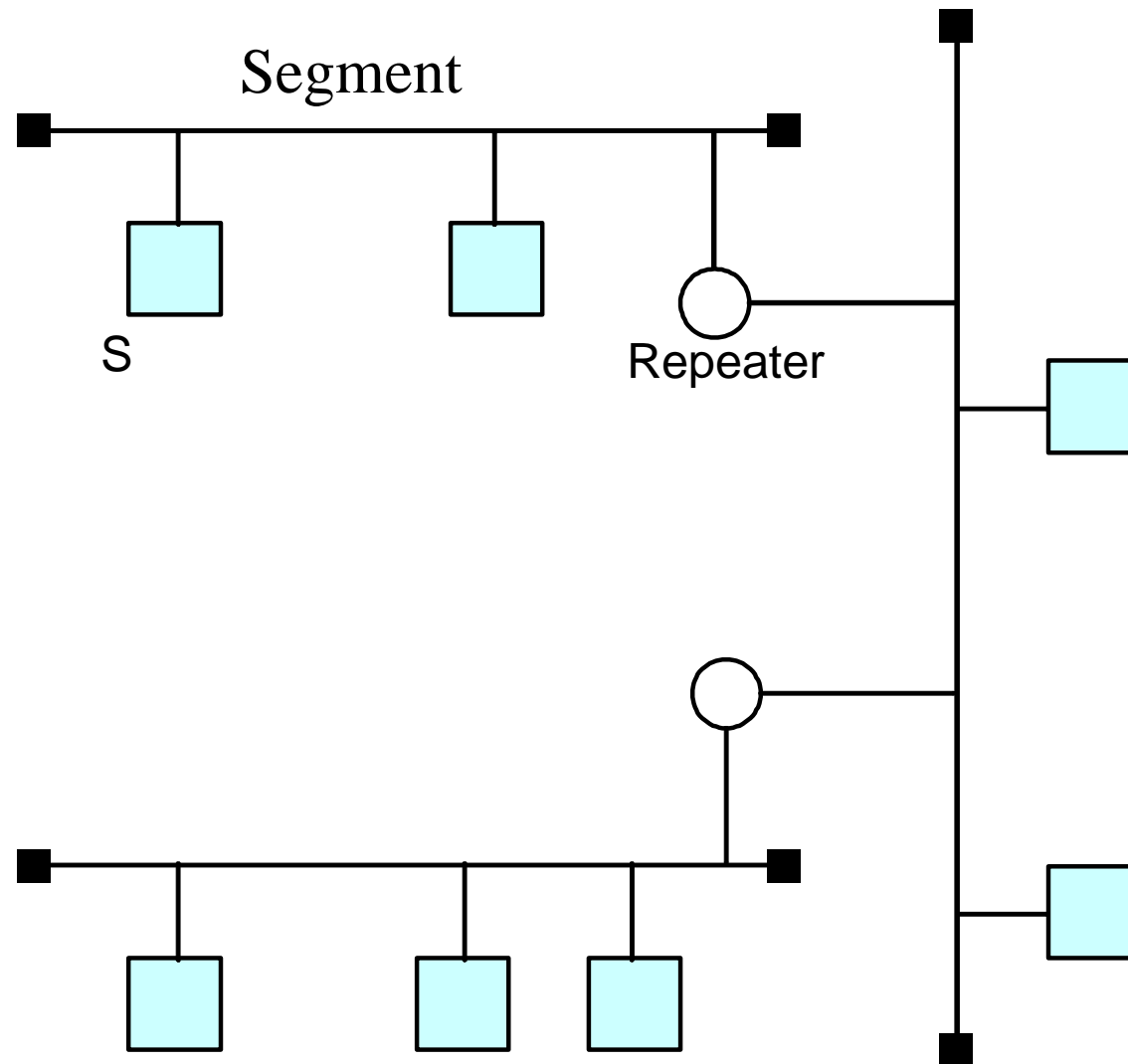Raj Jain

CSMA/CD Operation

□ Collision window = 2 X One-way Propagation delay = 51.2 μs
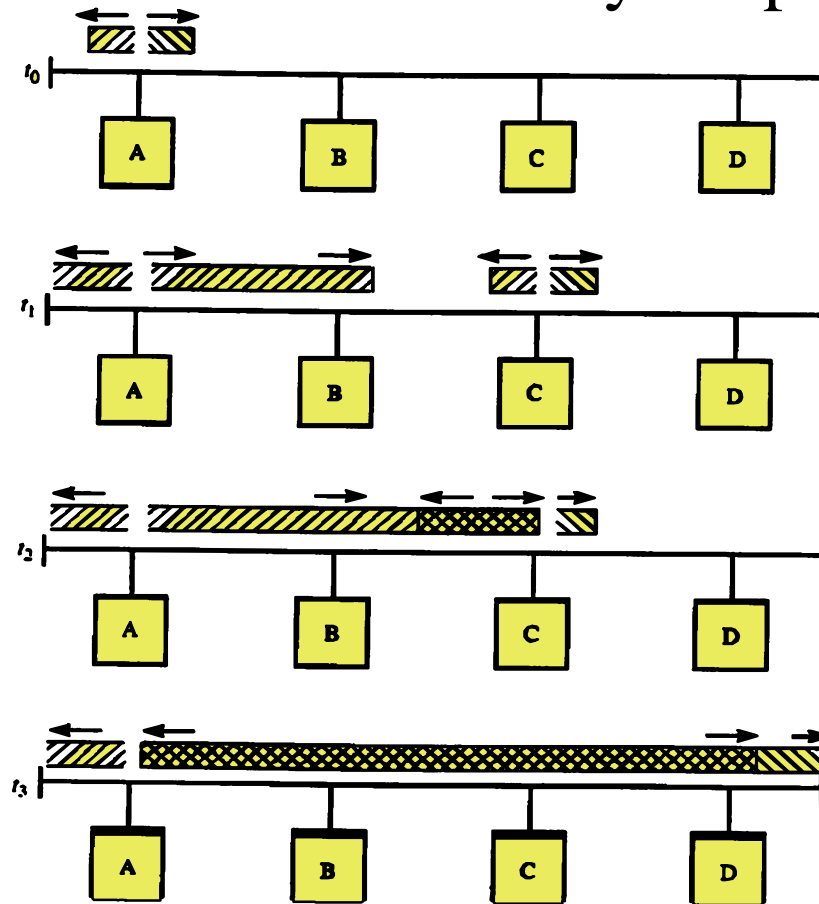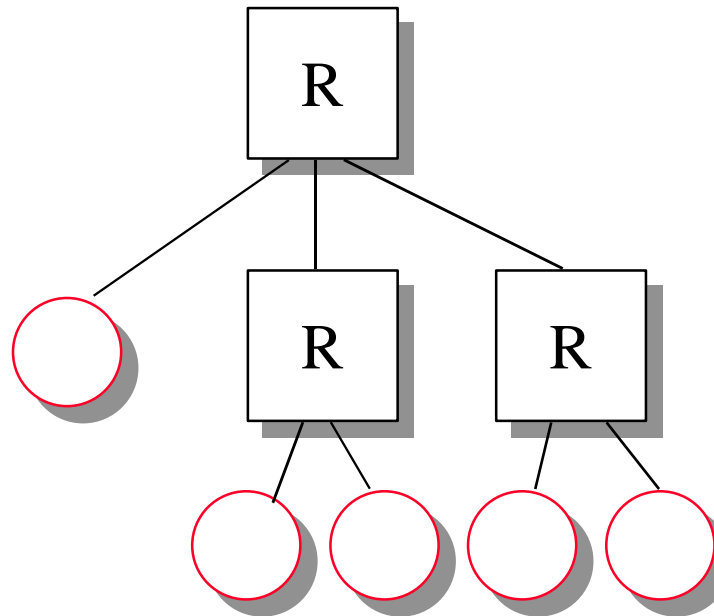
One way delay = 25.6 μs

Max Distance <2.5 km

Fig 13.1

Original Ethernet Configuration

Segment

S

Repeater

10BASE-T

❑ Collision detected by the hub.

❑ Activity on two or more channels $\Rightarrow$ Collision
Collision presence (CP) transmitted by hub to all
stations
Collision window $= 2\times$ One-way delay between
farthest stations
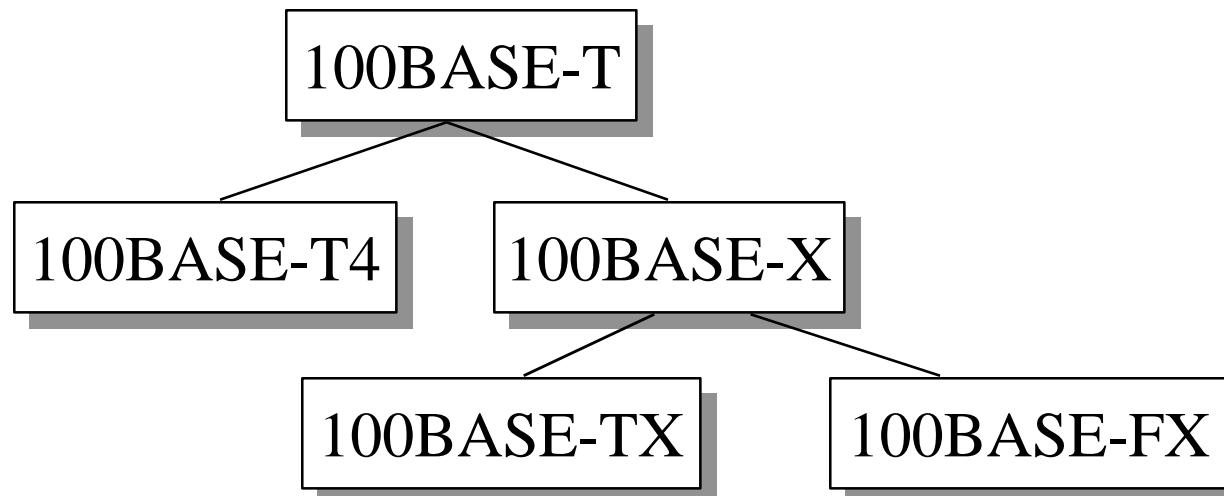
Ethernet Standards

- ❑ 10BASE5: 10 Mb/s over coaxial cable (ThickWire)
- ❑ 10BROAD36: 10 Mb/s over broadband cable, 3600 m max segments
- ❑ 1BASE5: 1 Mb/s over 2 pairs of UTP
- ❑ 10BASE2: 10 Mb/s over thin RG58 coaxial cable (ThinWire), 185 m max segments
- ❑ 10BASE-T: 10 Mb/s over 2 pairs of UTP
- ❑ 10BASE-FL: 10 Mb/s fiber optic point-to-point link
- ❑ 10BASE-FB: 10 Mb/s fiber optic backbone (between repeaters). Also, known as synchronous Ethernet.

Ethernet Standards (Cont)

❑ 10BASE-FP: 10 Mb/s fiber optic passive star + segments

❑ 10BASE-F: 10BASE-FL, 10BASE-FB, or 10BASE-FP

❑ 100BASE-T4: 100 Mb/s over 4 pairs of CAT-3, 4, 5 UTP

❑ 100BASE-TX: 100 Mb/s over 2 pairs of CAT-5 UTP or STP

❑ 100BASE-FX: 100 Mbps CSMA/CD over 2 optical fiber

Ethernet Standards (Cont)

❑ 100BASE-X: 100BASE-TX or 100BASE-FX

❑ 100BASE-T: 100BASE-T4, 100BASE-TX, or 100BASE-FX

❑ 1000BASE-T: 1 Gbps (Gigabit Ethernet)

```
                    ┌──────────────┐
                    │  100BASE-T   │
                    └──────────────┘
                     /            \
        ┌──────────────┐      ┌──────────────┐
        │ 100BASE-T4   │      │  100BASE-X   │
        └──────────────┘      └──────────────┘
                               /            \
                    ┌──────────────┐   ┌──────────────┐
                    │ 100BASE-TX   │   │ 100BASE-FX   │
                    └──────────────┘   └──────────────┘
```

CSMA/CD Performance

❑ a = Propagation delay/Frame time

❑ U = Frame Time/(Propagation delay+Frame Time) = $1/(1+a)$

t=0

t=0

Start of transmission

Start of transmission

t=a

$t_0 + a$

t=a

$t_0 + 1$

Start of reception

End of transmission

t=a

$t_0 + 1$

t=a

$t_0 + a$

End of transmission

Start of reception

t=1+a $t_0 + 1 + a$

$t_0 + 1 + a$ t=1+a

End of reception

End of reception

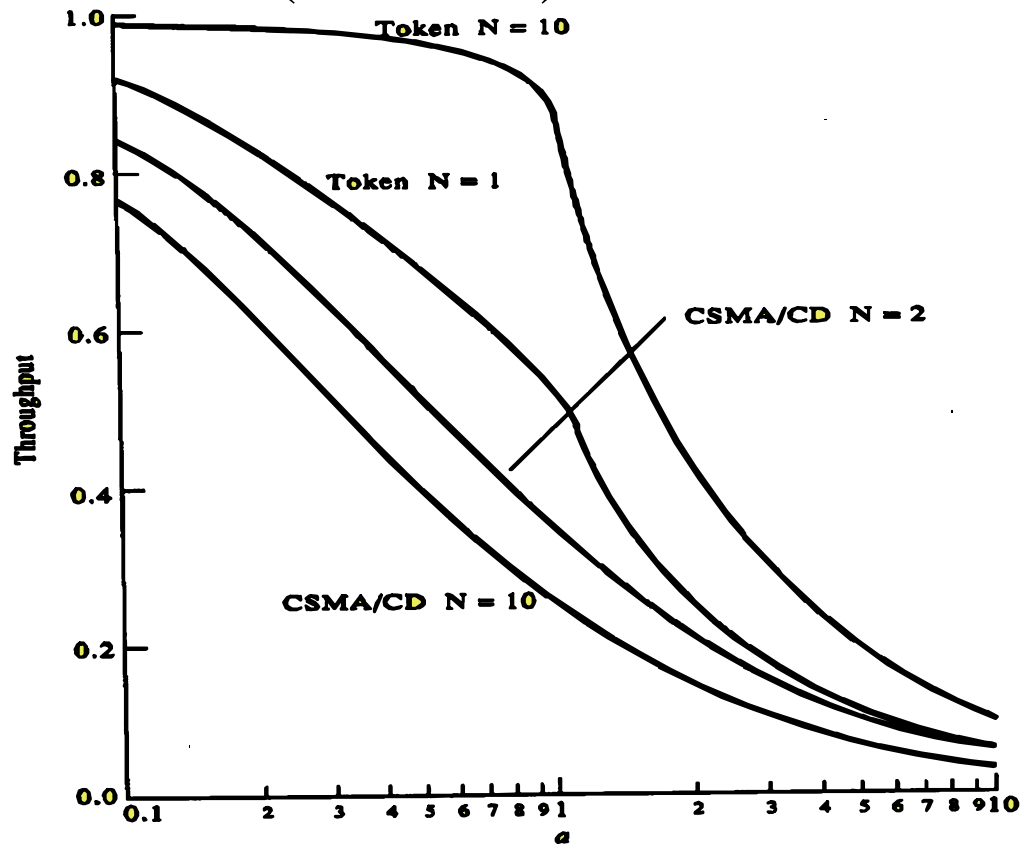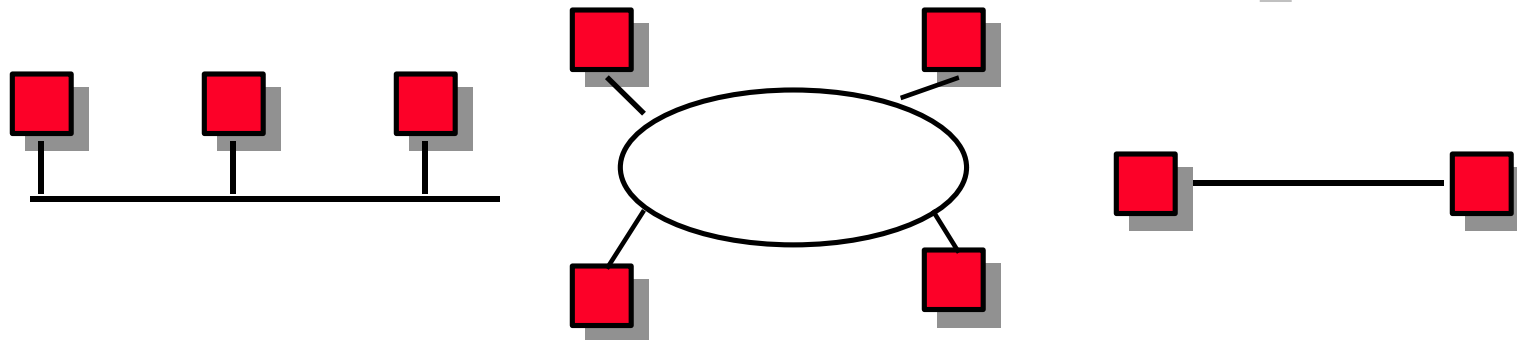(a) Transmission time = 1; propagation time = $a < 1$ (b) Transmission time = 1; propagation time = $a > 1$
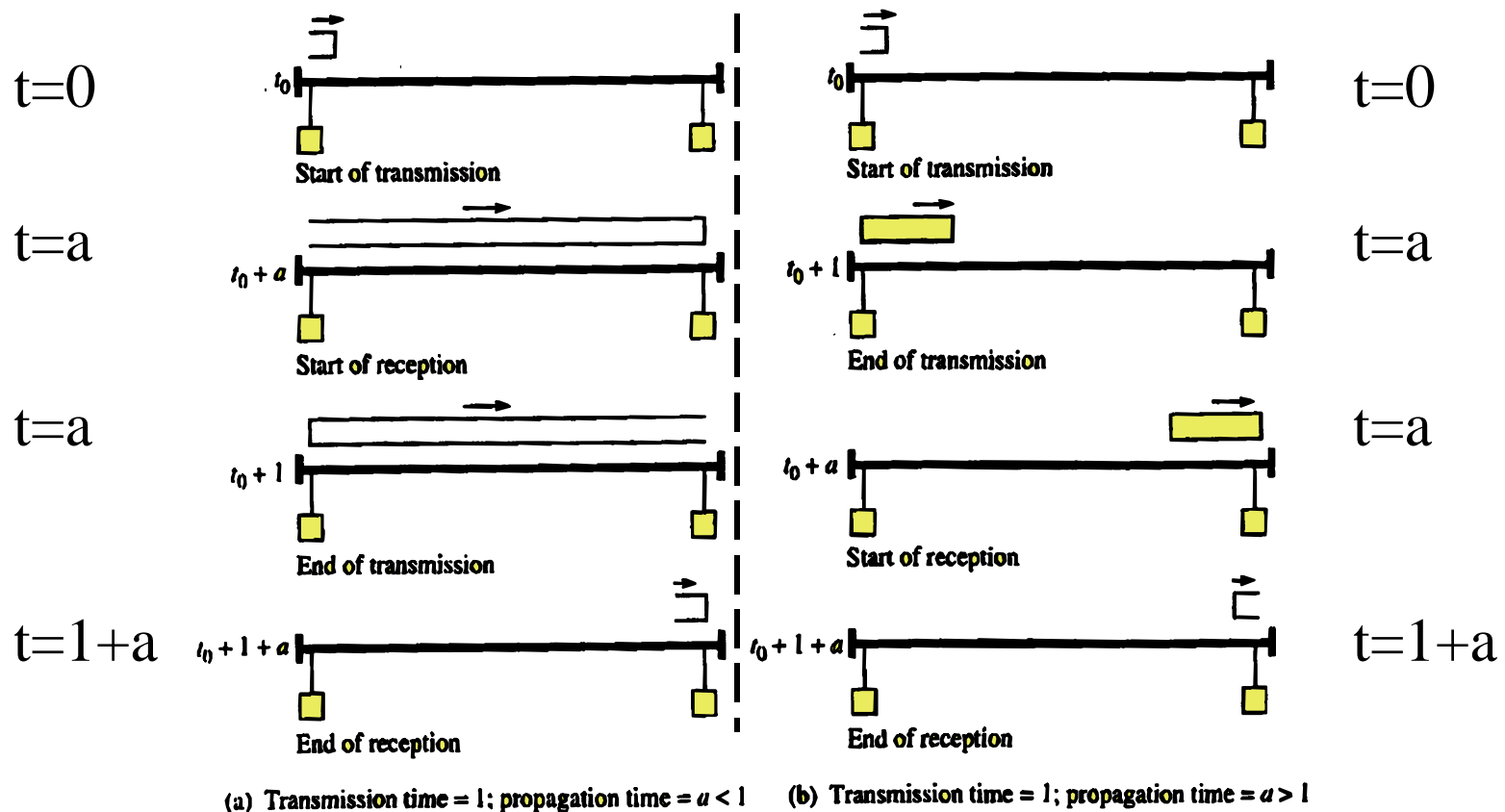
Fig 13.26

CSMA/CD Performance (Cont)

- ❑ $U = 1/[1+2a(1-A)/A]$, where $A = (1-1/N)^{N-1} \to e^{-1}$
- ❑ Worst case $U = 1/(1+3.44a)$ with $N = \infty$


Fig 13.28

Distance-B/W Principle

❑ Efficiency = Max throughput/Media bandwidth

❑ Efficiency is a decreasing function of α
α = Propagation delay /Transmission time
= (Distance/Speed of light)/(Transmission size/Bits/sec)
= Distance$\times$Bits/sec/(Speed of light)(Transmission size)

❑ Bit rate-distance-transmission size tradeoff.

❑ 100 Mb/s $\Rightarrow$ Change distance or frame size

Ethernet vs Fast Ethernet

	Ethernet	Fast Ethernet
Speed	10 Mbps	100 Mbps
MAC	CSMA/CD	CSMA/CD
Network diameter	2.5 km	205 m
Topology	Bus, star	Star
Cable	Coax, UTP, Fiber	UTP, Fiber
Standard	802.3	802.3u
Cost	X	2X
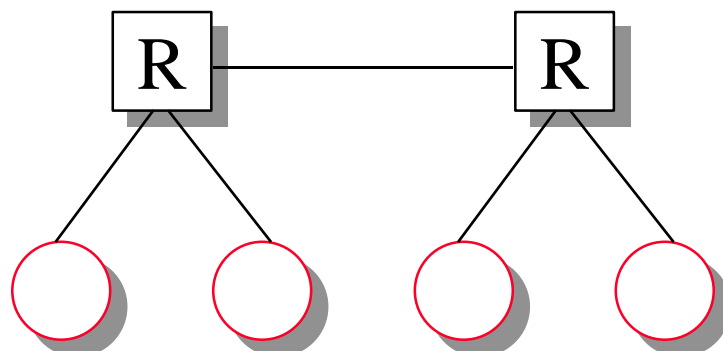
Full-Duplex Ethernet
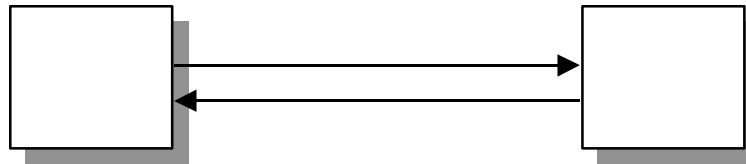
❏ Uses point-to-point links between TWO nodes

❏ Full-duplex bi-directional transmission

❏ Transmit any time

❏ Not yet standardized in IEEE 802

❏ Many vendors are shipping switch/bridge/NICs with full duplex

❏ No collisions $\Rightarrow$ 50+ Km on fiber.

❏ Between servers and switches or between switches

IEEE 802 Address Format

q 48-bit:1000 0000 : 0000 0001 : 0100 0011
   : 0000 0000 : 1000 0000 : 0000 1100
   = 80:01:43:00:80:0C

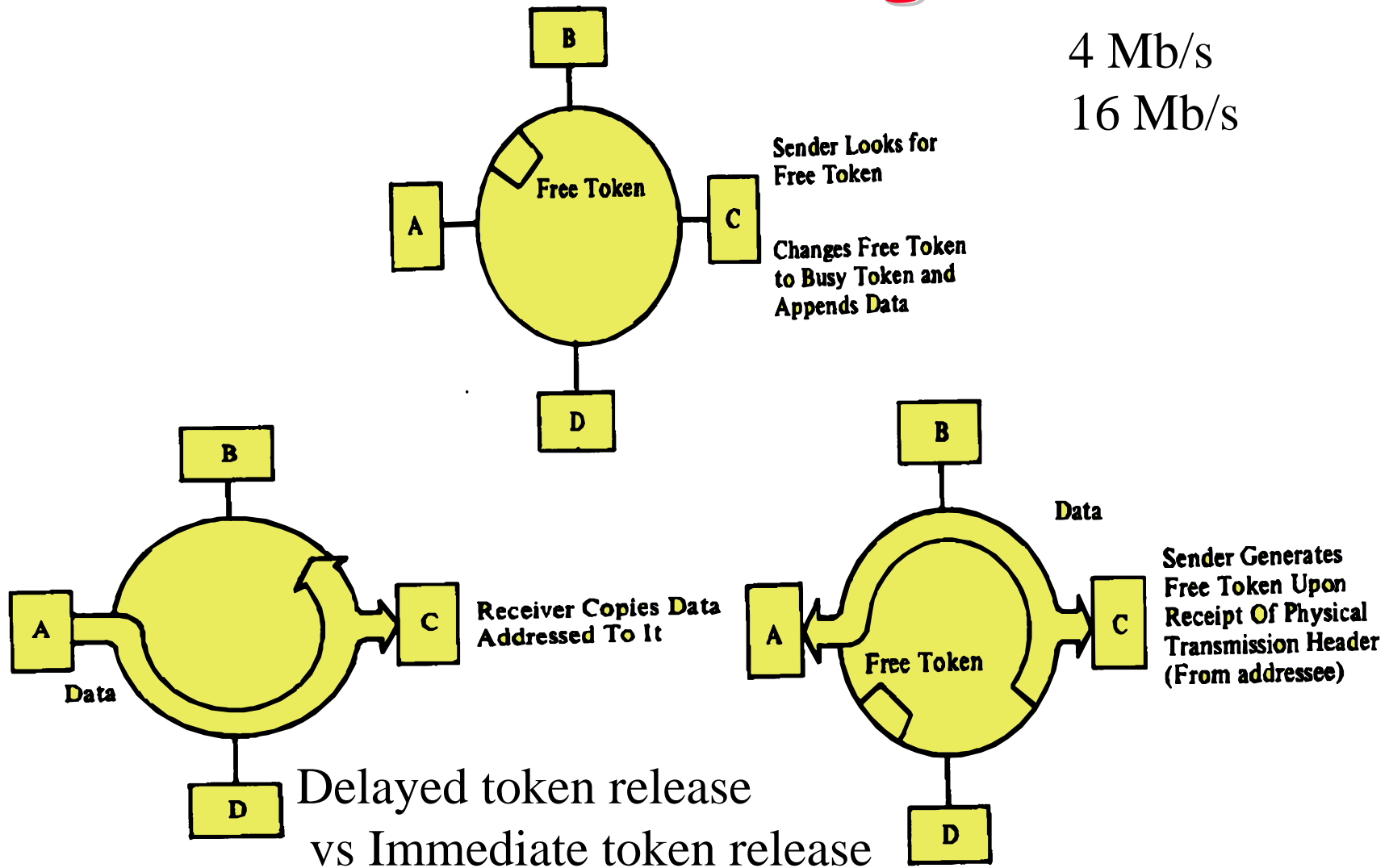| Organizationally Unique Identifier (OUI)			24 bits assigned by OUI Owner
Individual/ Group	Universal/ Local		
1	1	22	24

❑ Multicast = "To all bridges on this LAN"

❑ Broadcast = "To all stations"
   = 111111....111 = FF:FF:FF:FF:FF:FF

Token Ring

4 Mb/s
16 Mb/s

B

Free Token

A   **C**

D

Sender Looks for
Free Token

Changes Free Token
to Busy Token and
Appends Data

B

A   **C**

Data

D

Receiver Copies Data
Addressed To It

B

Data

A   **C**

Free Token

D

Sender Generates
Free Token Upon
Receipt Of Physical
Transmission Header
(From addressee)

Delayed token release
vs Immediate token release

Token Ring Priority Rules

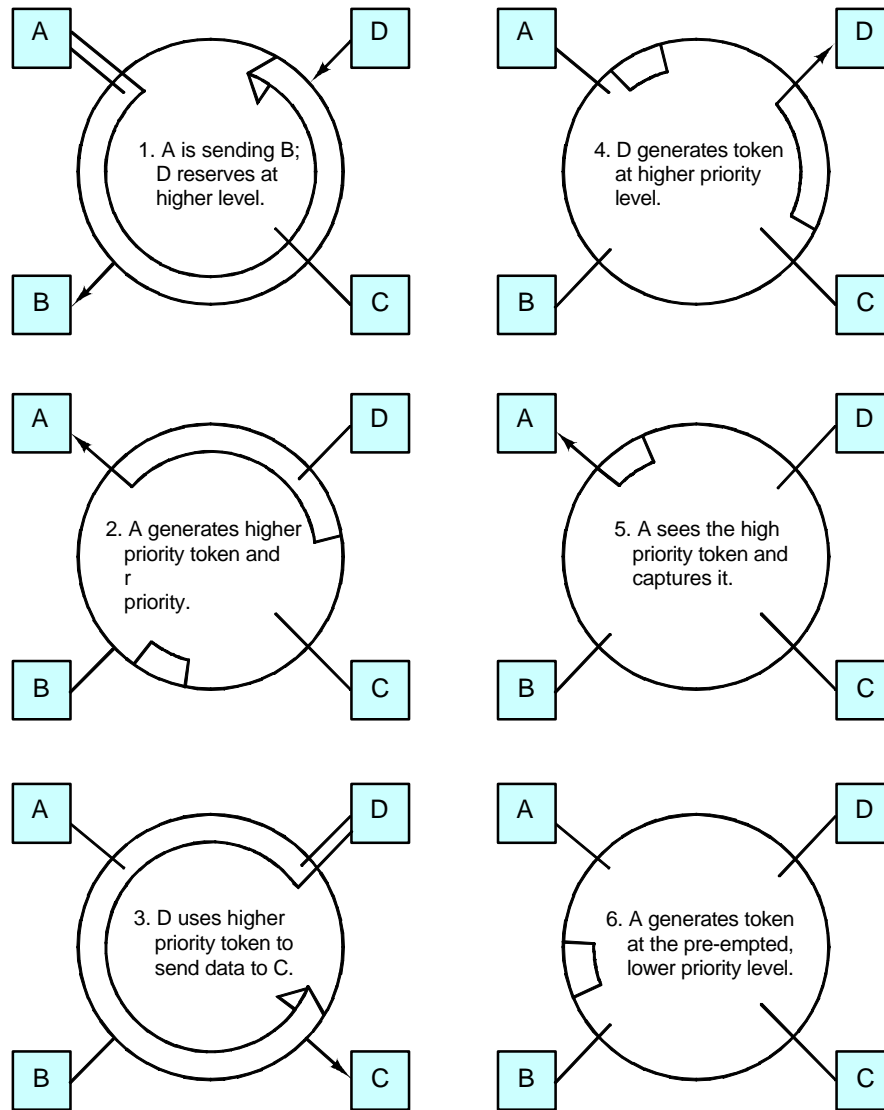| Received Priority	Busy	Monitor	Received Reservation
3b	1b	1b	3b

- Received Priority = Pr $\Rightarrow$ This token/frame's priority
- Received reservation = Rr $\Rightarrow$ Someone on the ring wants to transmit at Rr
- To transmit a message of priority Pm, you should get a free token with Pr $\leq$ Pm
- If free but Pr>Pm and Rr<Pm, reserve token by setting Rr=Pm
- If busy and Rr<Pm then reserve by seeing Rr $\leftarrow$ Pm
- If busy and Rr>Pm, wait
- When you transmit, set Rr=0, and busy=1. After transmission, issue a new token with Pr=Max{Pr,Pm,Rr}, Rr=Max{Rr,Pm}

Homework

Fill in the table with all 8 possible combinations

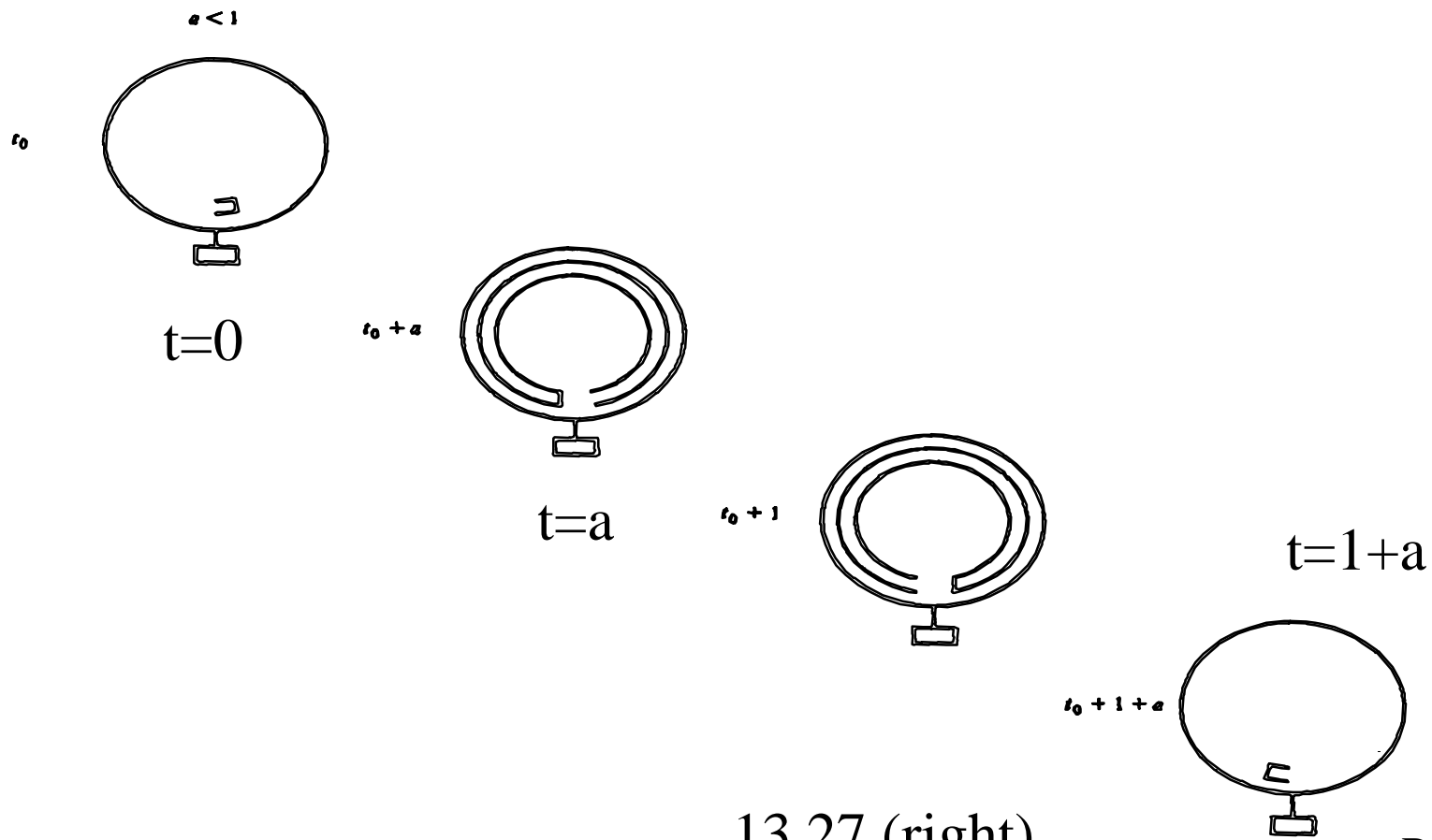| Busy	Pr$\leq$Pm	Rr$\leq$Pm	Action

Priority Stack

1. A is sending B; D reserves at higher level.

4. D generates token at higher priority level.

2. A generates higher priority token and r priority.

5. A sees the high priority token and captures it.

3. D uses higher priority token to send data to C.

6. A generates token at the pre-empted, lower priority level.

Token Ring Performance

❏ a>1, token is released at t_0+a, reaches next station at t_0+a+a/N, U=1/(a+a/N)

a > 1

t_0

$t_0 + 1$

$t_0 + a$

$t_0 + 1 + a$

t=1

t=1+a

Fig 13.27(left)
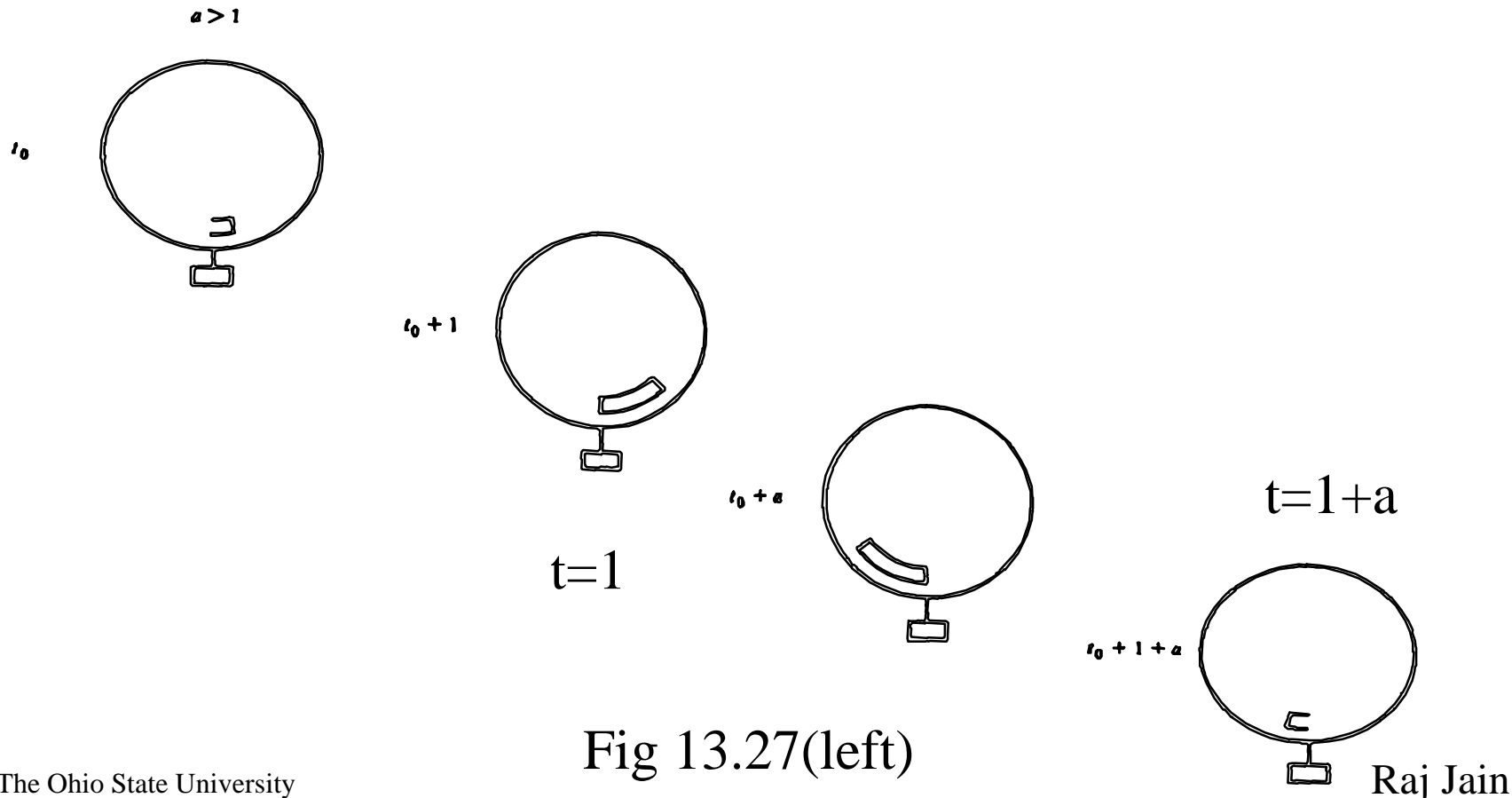
Performance (Continued)

❑ a<1, Token is released at t_0+a, $U=1/(1+a/N)$

a < 1

t_0

t=0

$t_0 + a$

t=a

$t_0 + 1$

t=1+a

$t_0 + 1 + a$

13.27 (right)

Performance (continued)

Fig 13.29
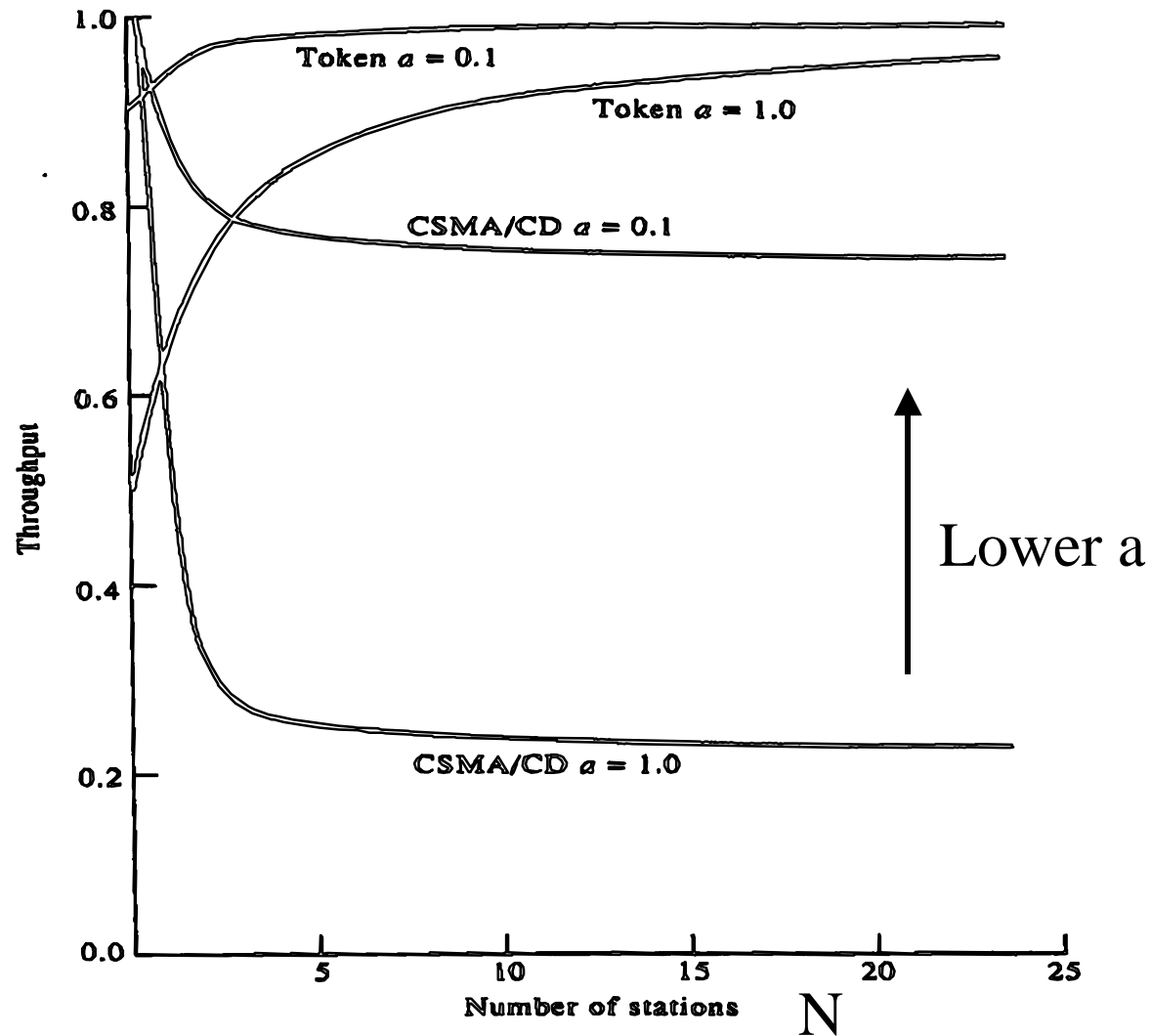
FDDI

- Fiber Distributed Data Interface
- ANSI Standard for 100 Mbps over Fiber and twisted pair
- Inter-node links of up to 2km on multimode fiber, 60+ km on single mode fiber, Longer SONET links, 100 m on UTP.
- Round-trip signal path limited to 200 km $\Rightarrow$ 100 km cable.
- Maximum frame size is 4500 bytes.
- Synchronous (guaranteed access delay) and asynchronous traffic
- Arranged as single- or dual-ring logical topology

Dual-Ring of Trees Topology
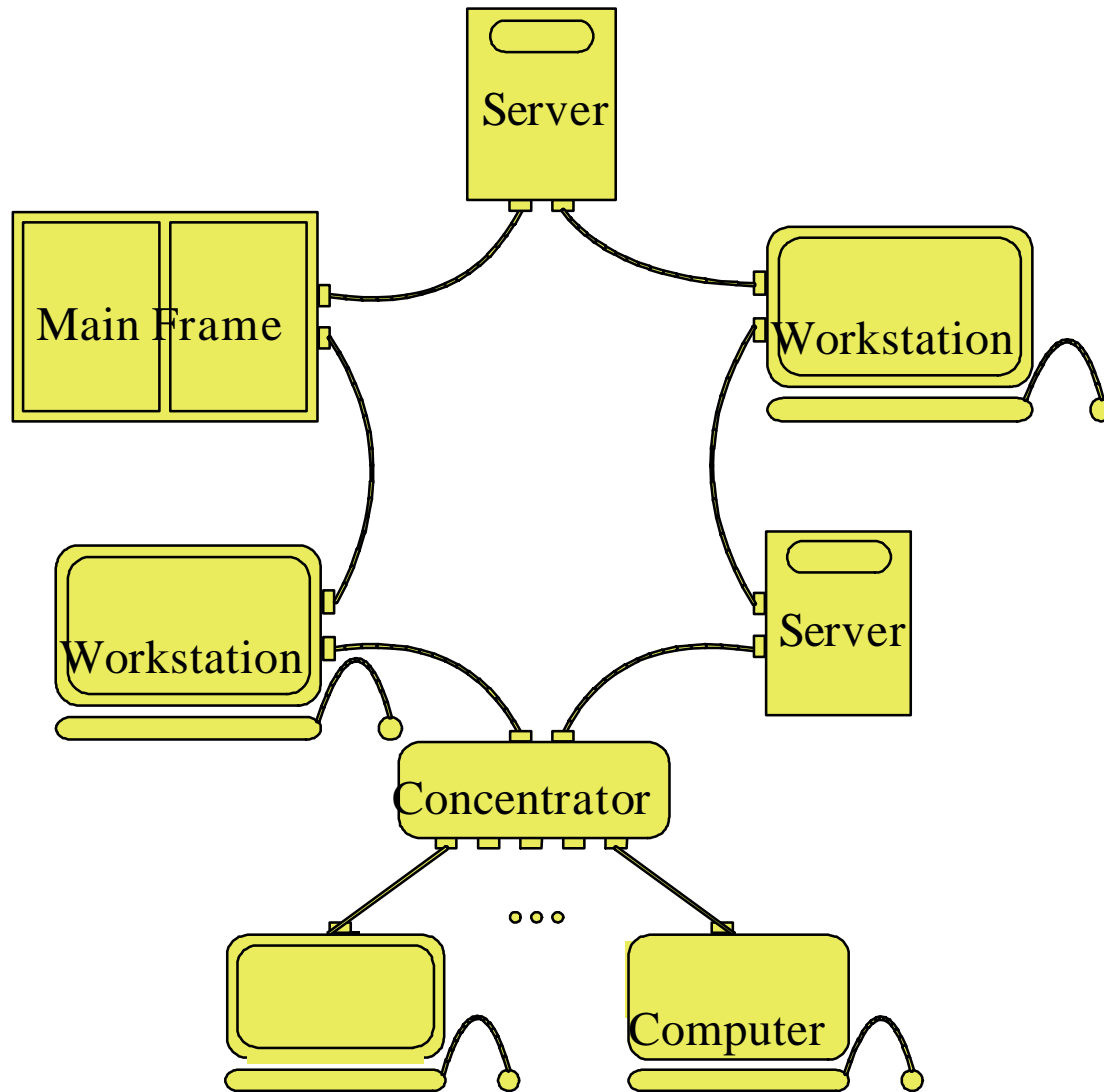
Timed Token Access

- Two classes of traffic: Synchronous, Asynchronous
- Asynchronous: Timed token access
- Stations agree on a target token rotation time (TTRT)
- Stations monitor token rotation time (TRT)
- A station can transmit TTRT-TRT
  =Token Holding Time (THT)
- Yellow Light Rule:
  Complete the frame if THT expires in the middle
- Immediate Release:
  Release the token at the end of frame transmission
- If TRT>TTRT, Increment late count (LC)
- Reinitialize the ring if LC = 2
- Synchronous: ith station can transmit SAi (pre-allocated)

Example

Ring Latency = D = 3

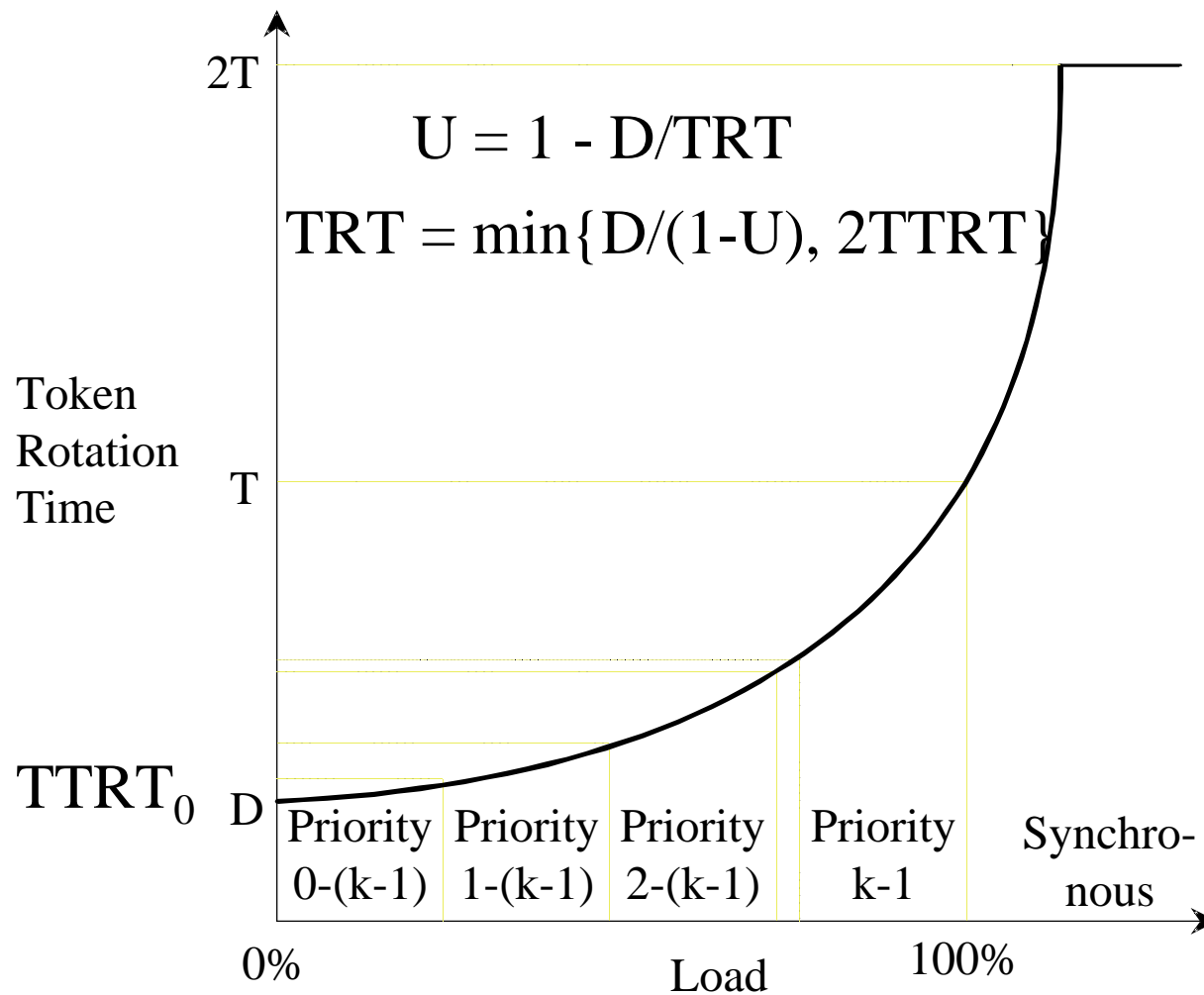TTRT = T = 15
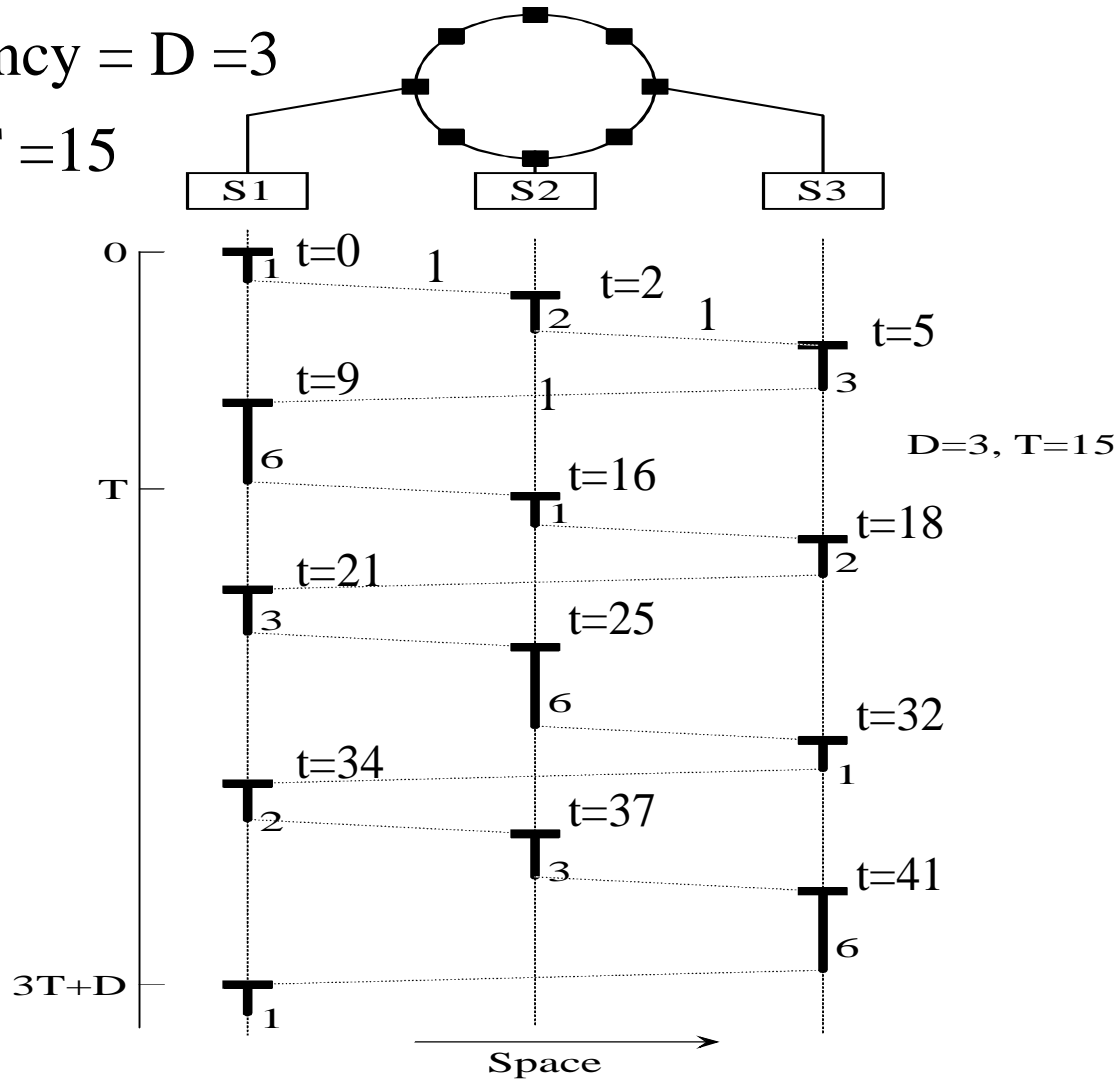
TRT

- Maximum TRT = TTRT+Max Frame time + Token Time + ΣSAi
- It is required that ΣSAi < TTRT-Max Frame time - Token Time
- Maximum TRT = 2 TTRT
- If D=Ring latency, then
  Utilization U=(TRT-D)/TRT = 1- D/TRT
- Max U = 1-D/TTRT
- High load $\Leftrightarrow$ High TRT
  Low load $\Leftrightarrow$ Low TRT
- Lower priority traffic allowed only if TRT is low
- Set $TTRT_0 < TTRT_1 < TTRT_2 < ... < TTRT_6 < TTRT$

Priorities

$$U = 1 - D/TRT$$

$$TRT = \min\{D/(1-U), 2TTRT\}$$

Token Rotation Time

2T

T

$TTRT_0$

D

| Priority 0-(k-1) | Priority 1-(k-1) | Priority 2-(k-1) | Priority k-1 | Synchro-nous |

0%   Load   100%

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TP-PMD

❑ Twisted-Pair Physical Media Dependent
  = Copper FDDI or CDDI
❑ Allows 100 m over Cat-5 unshielded twisted pair
  (UTP)
  ❍ **Cat-3**: 15 MHz Voice grade
  ❍ **Cat-4**: 20 MHz
  ❍ **Cat-5**: 100 MHz data grade
❑ Uses scrambling and 3-level encoding

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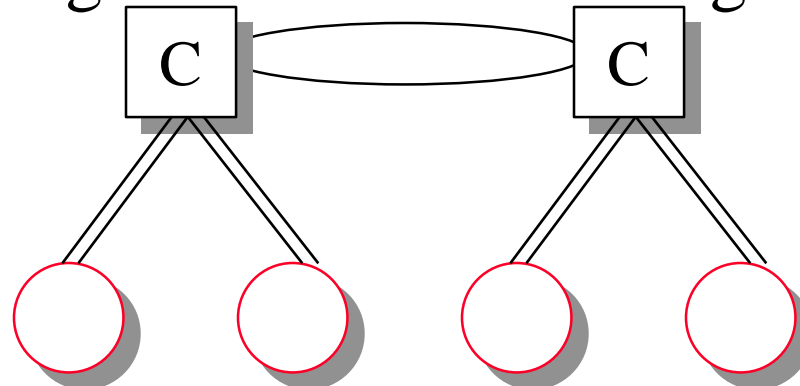
Summary

- Ring, Bus, Tree, Star topologies
- Ethernet/IEEE 802.3: CSMA/CD, Baseband, broadband
- Token ring/IEEE 802.5
- FDDI Timed token access

Homework

❑ Read chapter 13.2-13.5, 14.1-14.2, 14A, 14B of Stallings' sixth edition

❑ Submit answers to Exercises 13.4, 13.6