

# LAN Systems

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- ❑ IEEE 802.3: Ethernet and fast Ethernet
- ❑ IEEE 802.5: Token ring
- ❑ Fiber Distributed Data Interface (FDDI)

# LAN Topologies

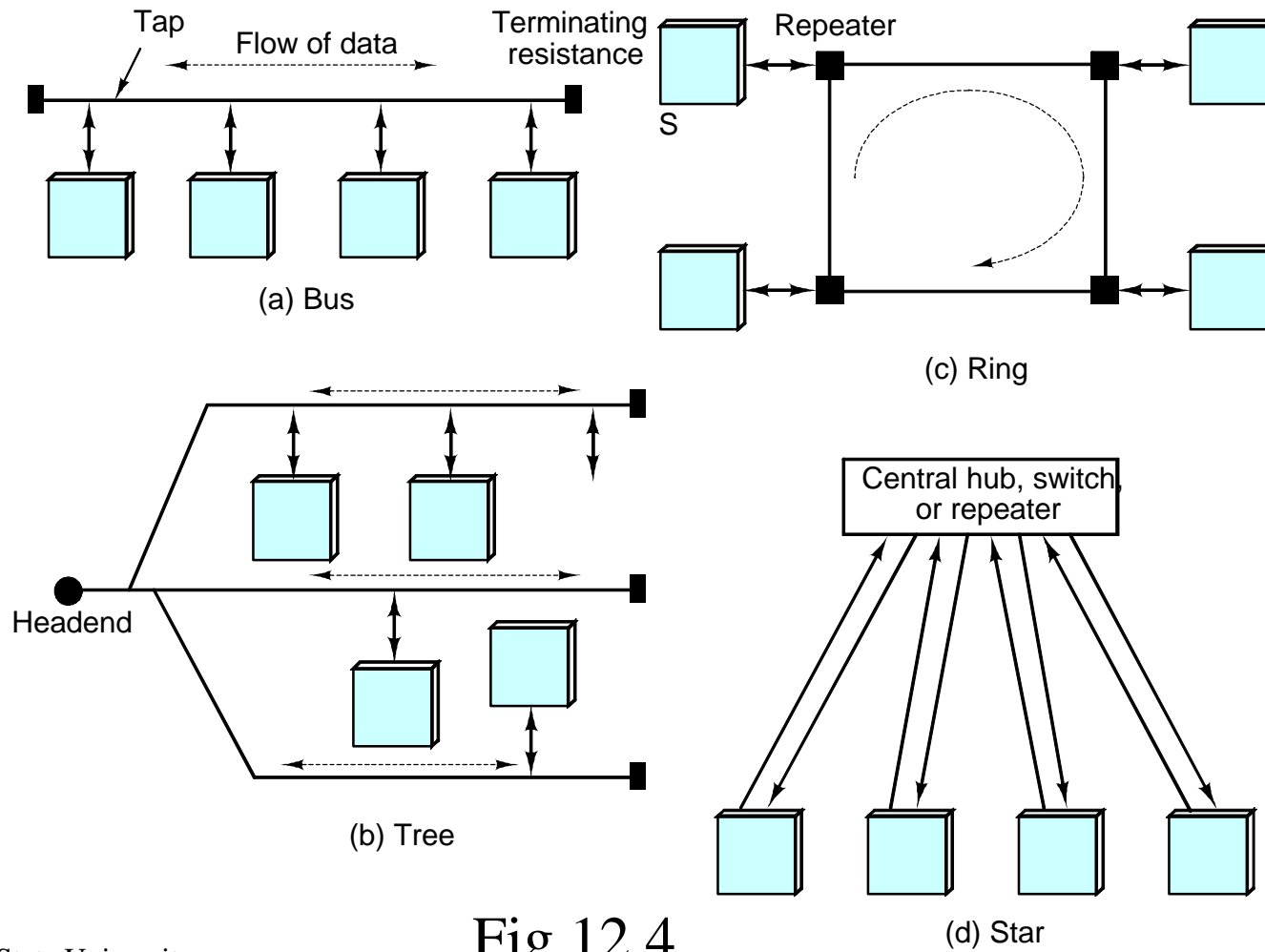
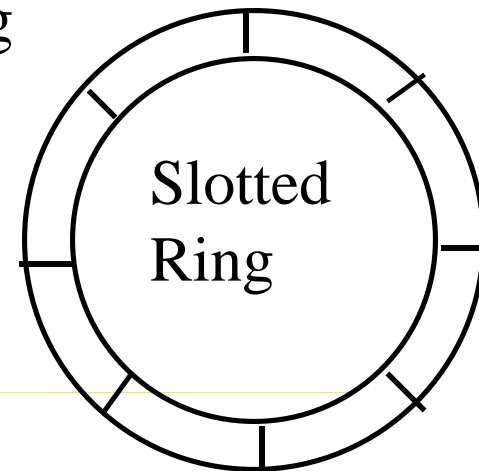


Fig 12.4

# 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	





(a) Multiple Access



(b) Carrier-Sense Multiple Access with Collision Detection

# CSMA/CD



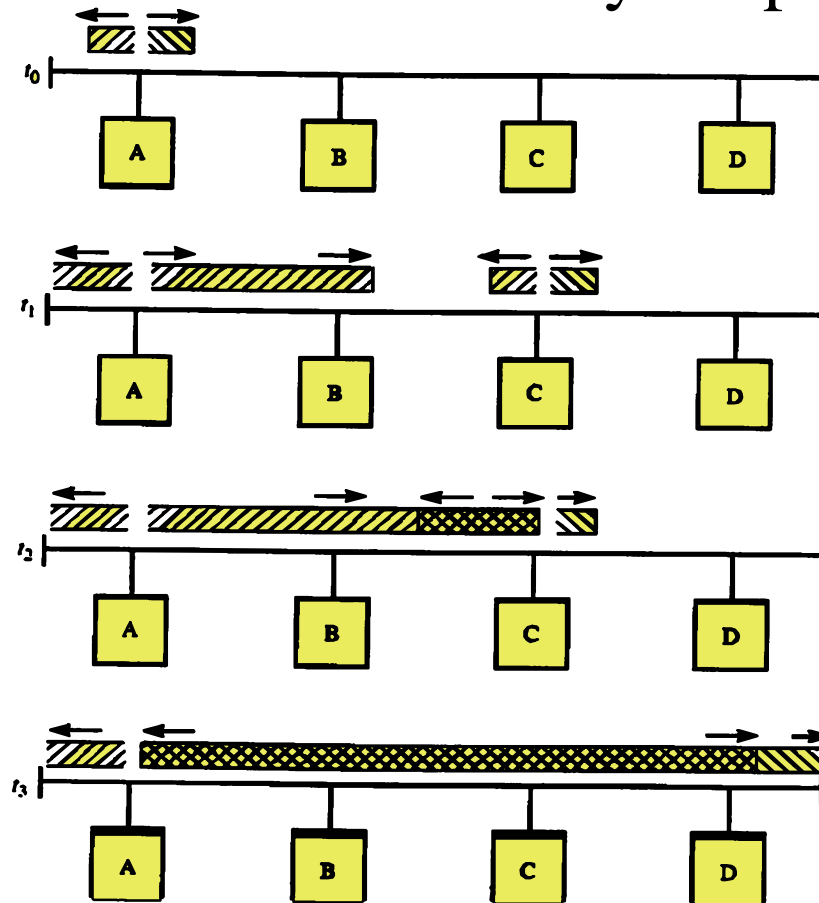
- ❑ Aloha at Univ of Hawaii:  
Transmit whenever you like  
Worst case utilization =  $1/(2e) = 18\%$
- ❑ Slotted Aloha: Fixed size transmission slots  
Worst case utilization =  $1/e = 37\%$
- ❑ CSMA: Carrier Sense Multiple Access  
Listen before you transmit
- ❑ p-Persistent CSMA: If idle, transmit 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 =  $\text{Uniform}[0, 2^{\min(k, 10)} - 1]$  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

# CSMA/CD Operation

- Collision window = 2 X One-way Propagation delay = 51.2  $\mu$ s

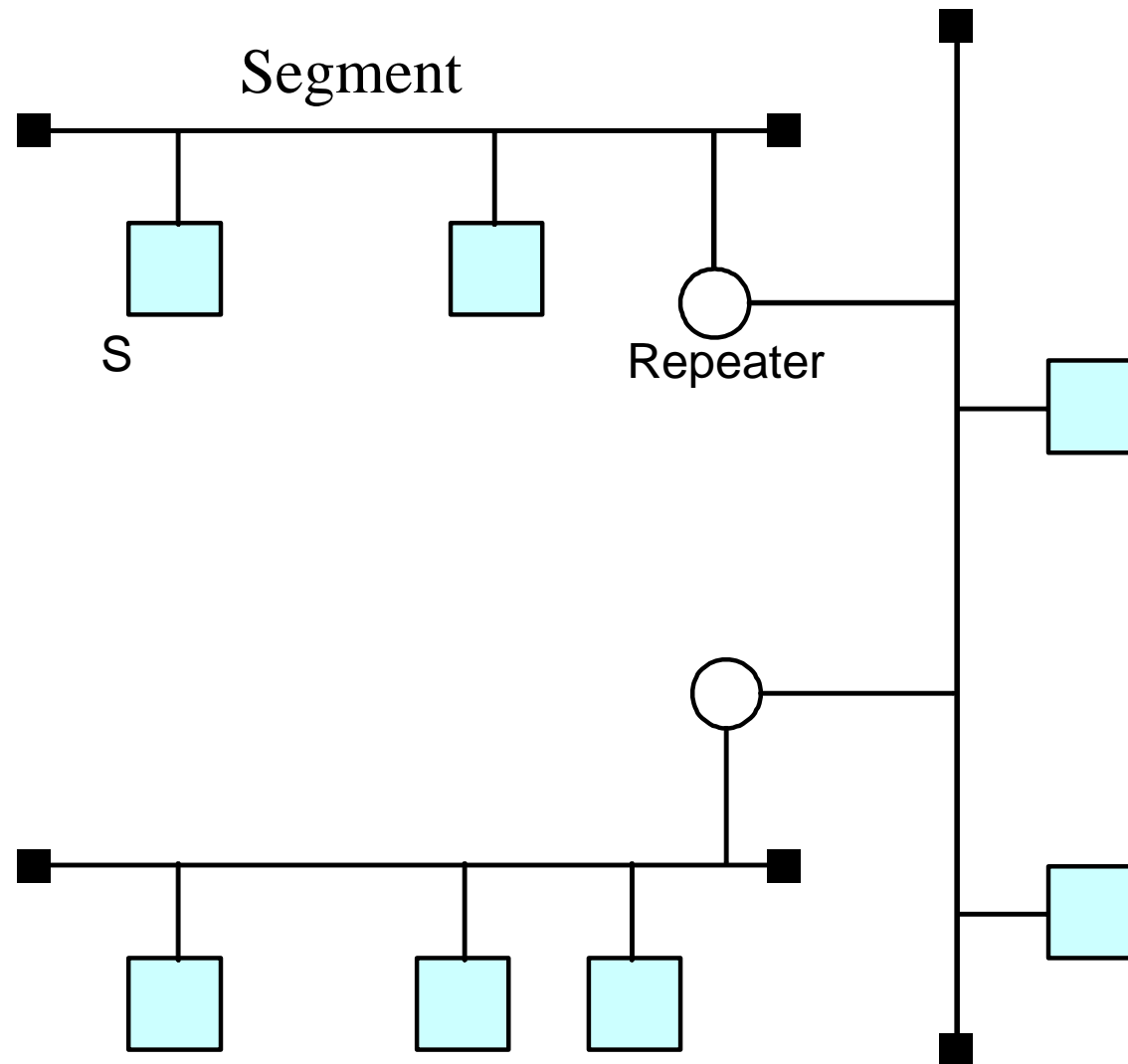


One way delay = 25.6  $\mu$ s  
Max Distance < 2.5 km

Fig 13.1

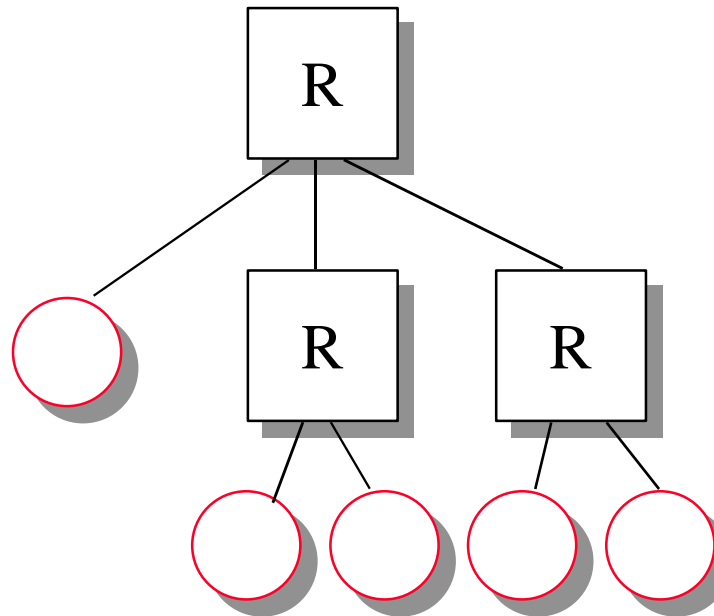


# Original Ethernet Configuration



# 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

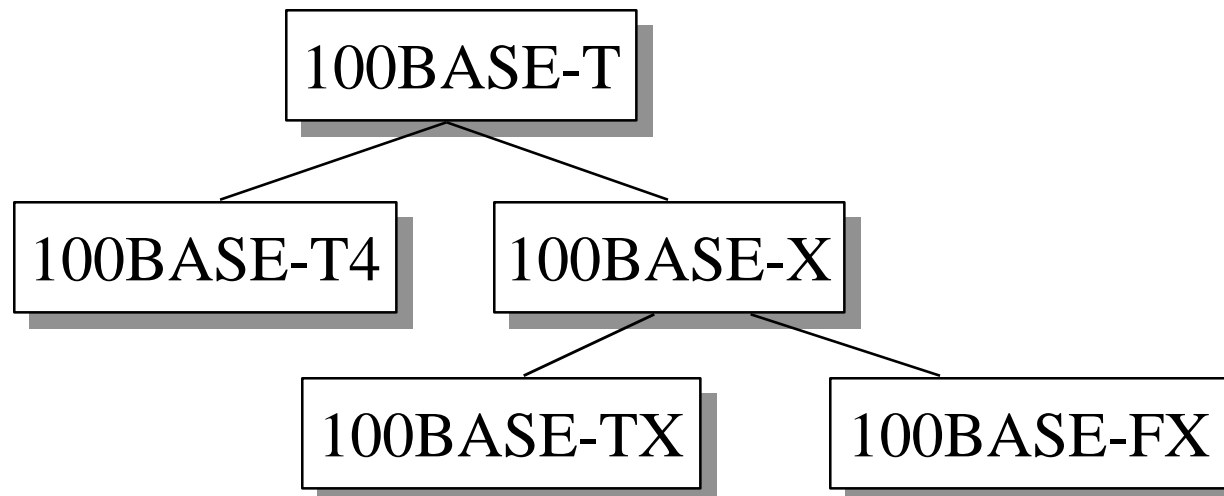
- ❑ 10BASE5: 10 Mb/s over coaxial cable (ThickWire)
- ❑ 10BROAD36: 10 Mb/s over broadband cable, 3600 m max segments
- ❑ 1BASE5: 1 Mb/s over 2 pairs of UTP
- ❑ 10BASE2: 10 Mb/s over thin RG58 coaxial cable (ThinWire), 185 m max segments
- ❑ 10BASE-T: 10 Mb/s over 2 pairs of UTP
- ❑ 10BASE-FL: 10 Mb/s 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)



# CSMA/CD Performance

- $a = \text{Propagation delay/Frame time}$
- $U = \text{Frame Time}/(\text{Propagation delay} + \text{Frame Time}) = 1/(1+a)$

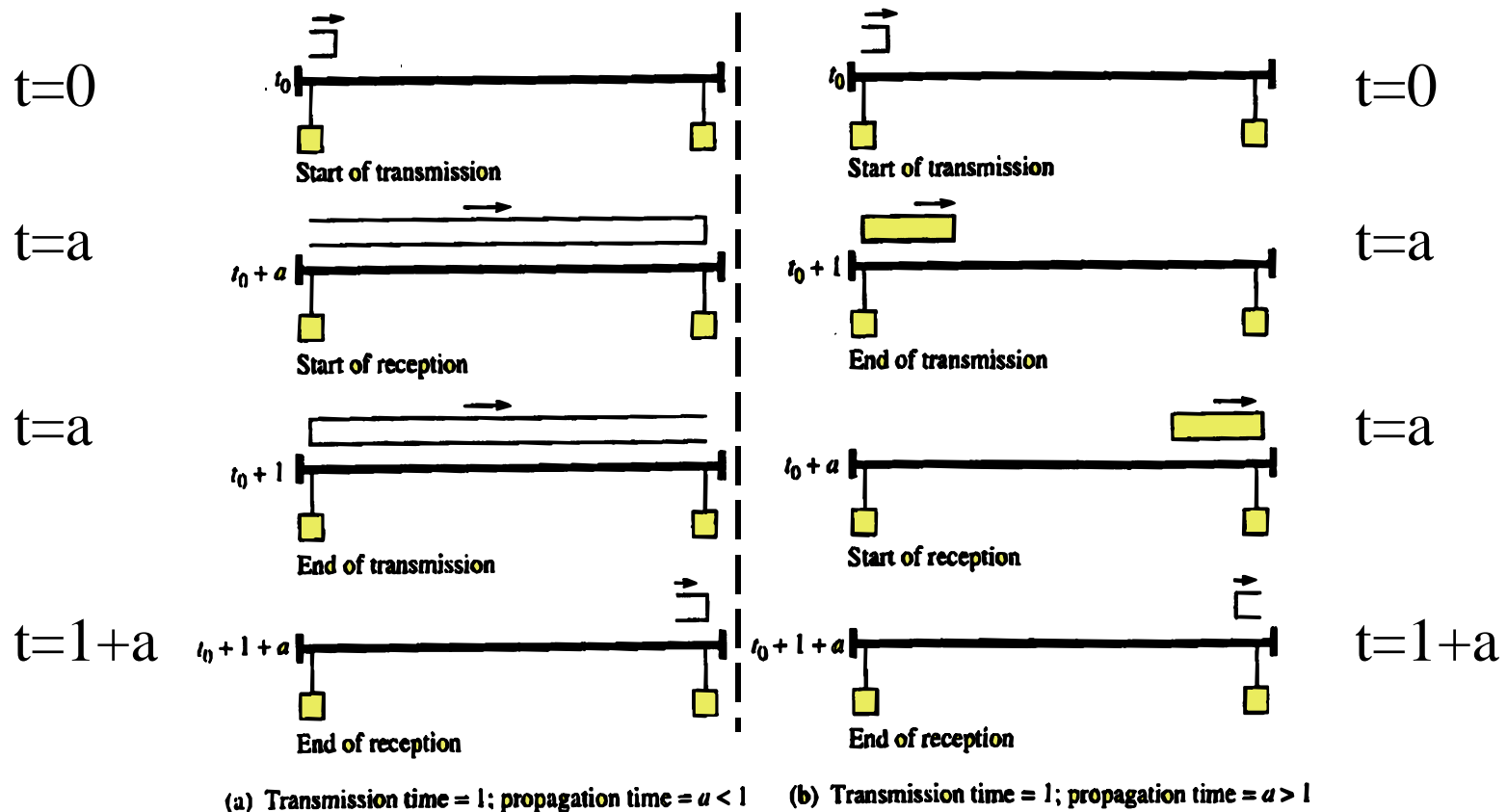
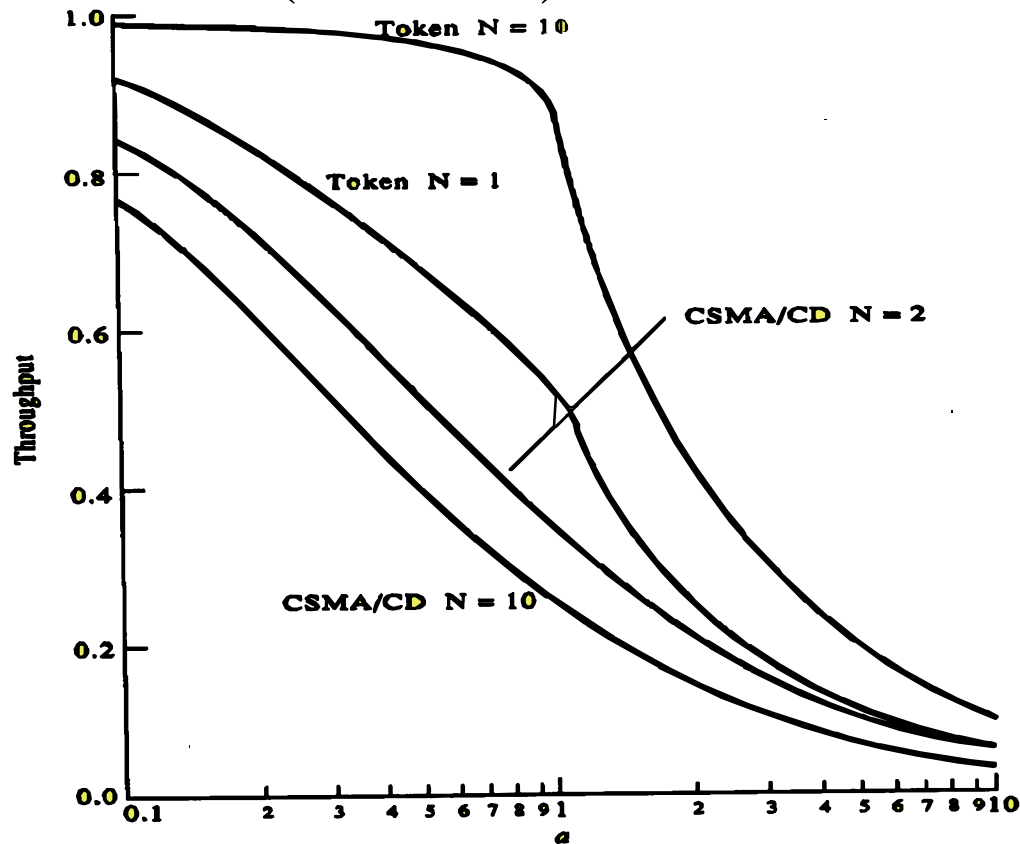


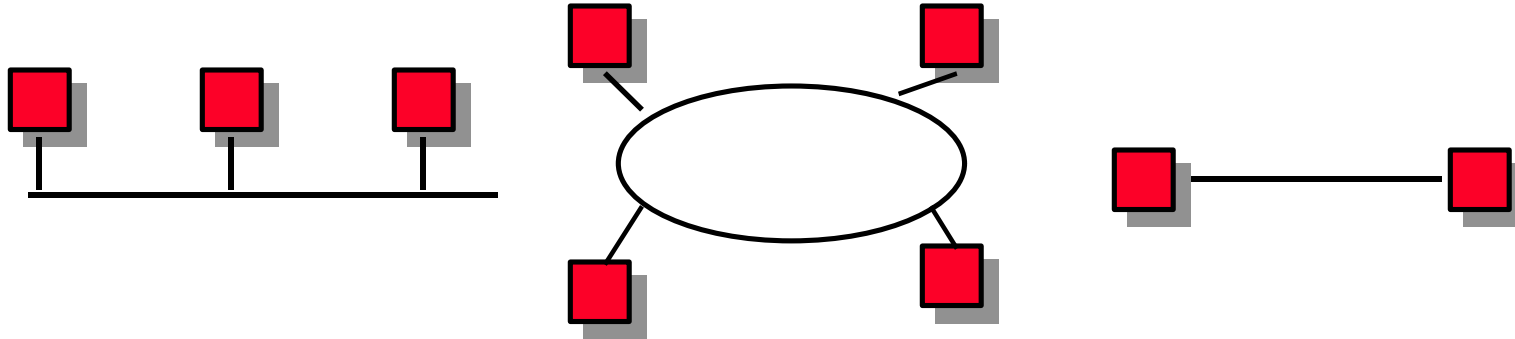
Fig 13.26

# CSMA/CD Performance (Cont)

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



# Distance-B/W Principle

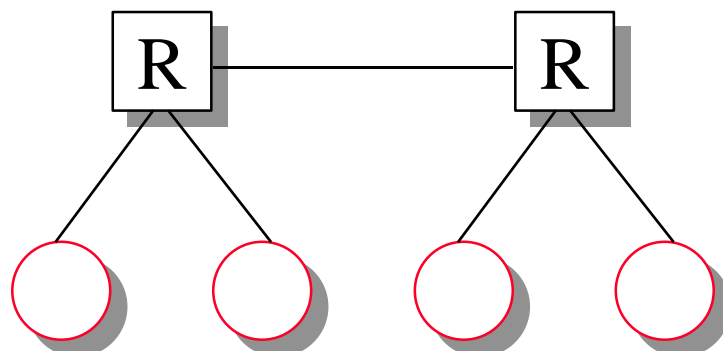


- Efficiency = Max throughput/Media bandwidth
- Efficiency is a decreasing function of  $\alpha$   
 $\alpha = \text{Propagation delay} / \text{Transmission time}$   
 $= (\text{Distance} / \text{Speed of light}) / (\text{Transmission size} / \text{Bits/sec})$   
 $= \text{Distance} \times \text{Bits/sec} / (\text{Speed of light})(\text{Transmission size})$
- Bit rate-distance-transmission size tradeoff.
- 100 Mb/s  $\Rightarrow$  Change distance or frame size

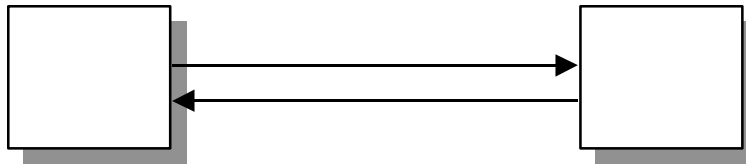


# Ethernet vs Fast Ethernet

	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

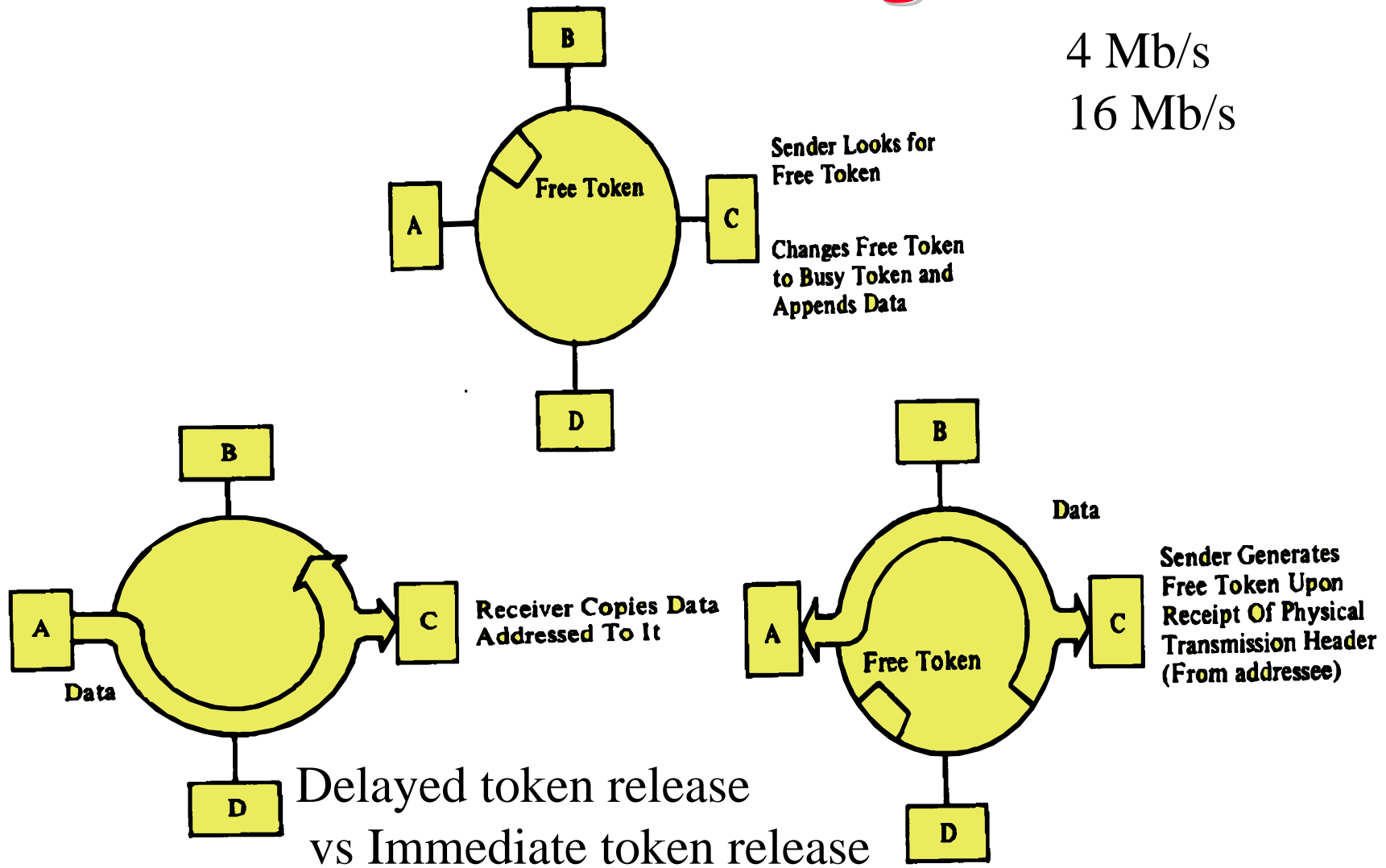
24

❑ Multicast = “To all bridges on this LAN”

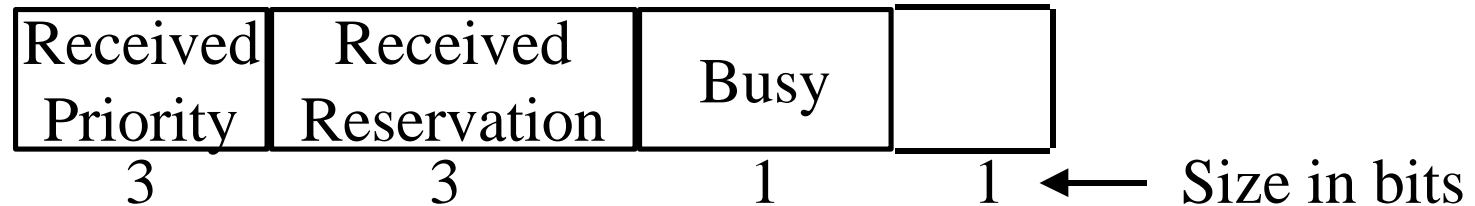
❑ Broadcast = “To all stations”

= 111111...111 = FF:FF:FF:FF:FF:FF

# Token Ring



# Token Ring Priority Rules



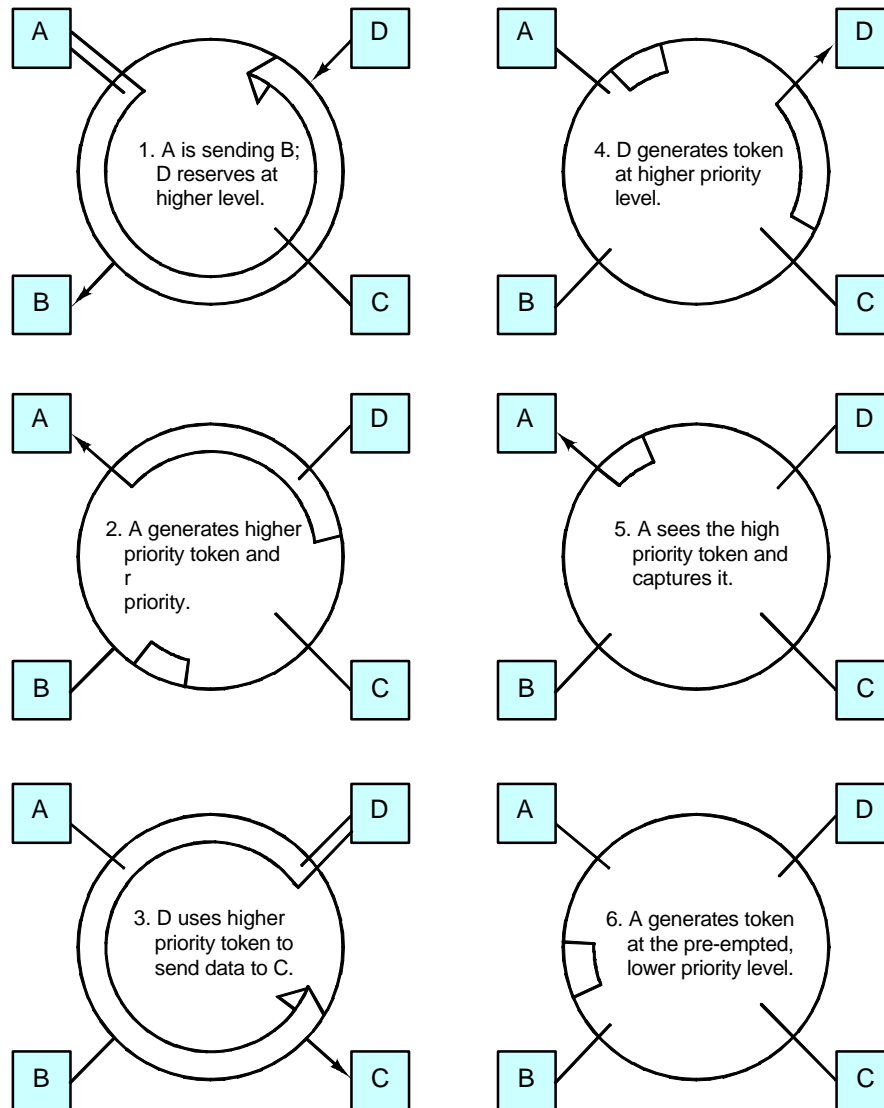
- Received Priority =  $P_r \Rightarrow$  This token/frame's priority
- Received reservation =  $R_r \Rightarrow$  Someone on the ring wants to transmit at  $R_r$
- To transmit a message of priority  $P_m$ , you should get a free token with  $P_r \leq P_m$
- If free but  $P_r > P_m$  and  $R_r < P_m$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

# Homework

Fill in the table with all 8 possible combinations

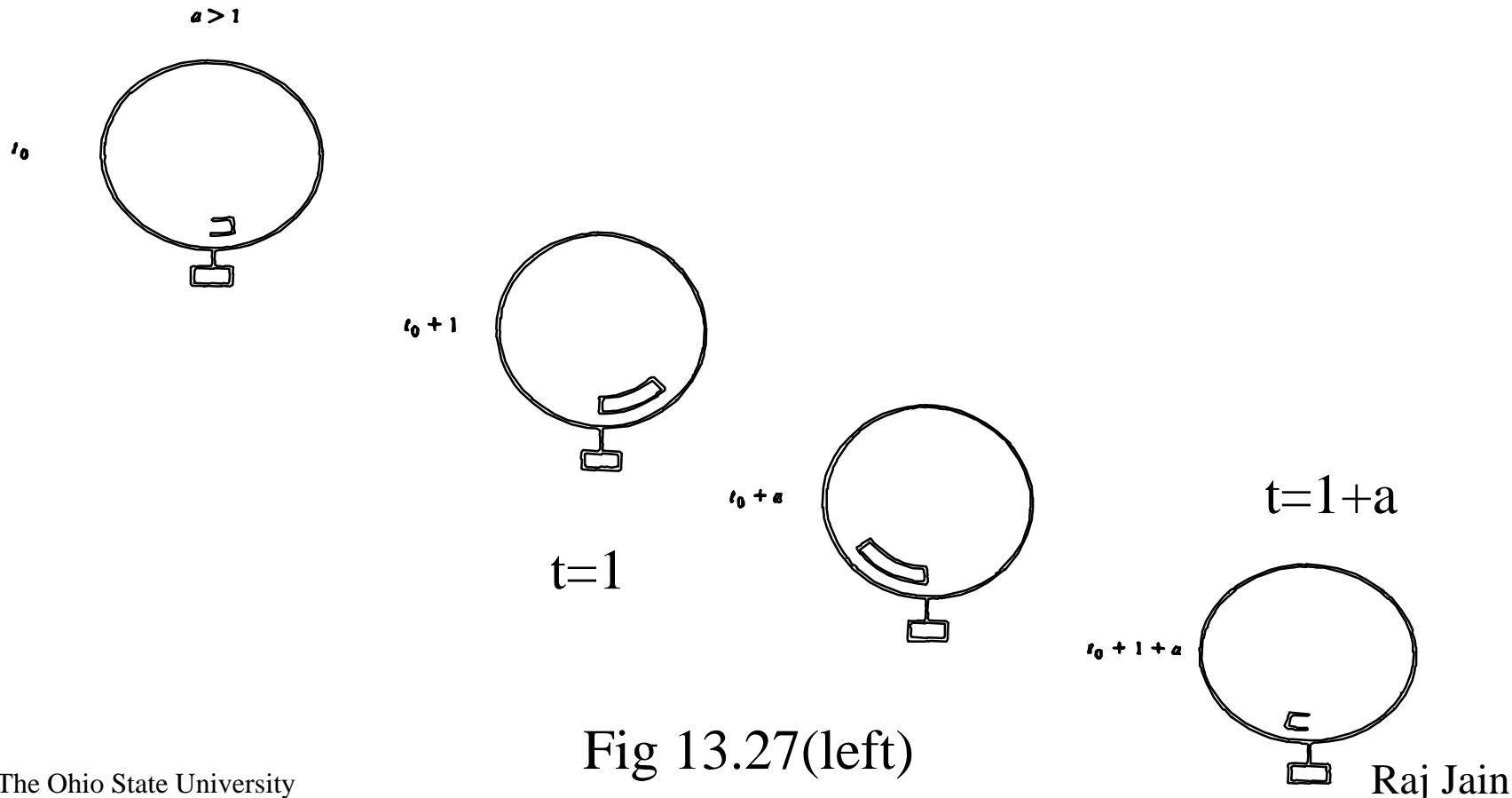
Busy	$Pr \leq Pm$	$Rr \leq Pm$	Action

# Priority Stack



# Token Ring Performance

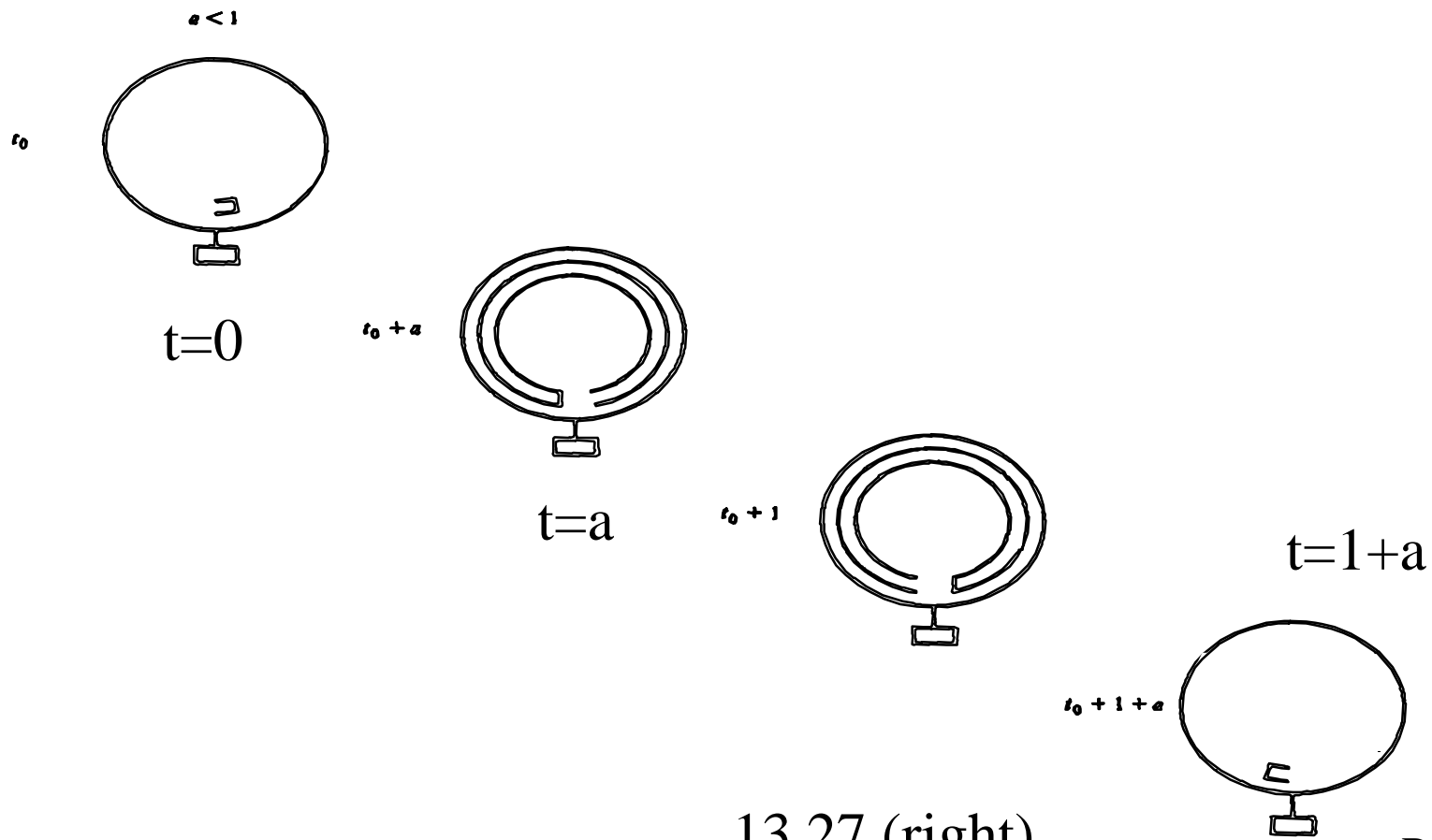
- $a > 1$ , token is released at  $t_0 + a$ , reaches next station at  $t_0 + a + a/N$ ,  $U = 1/(a + a/N)$



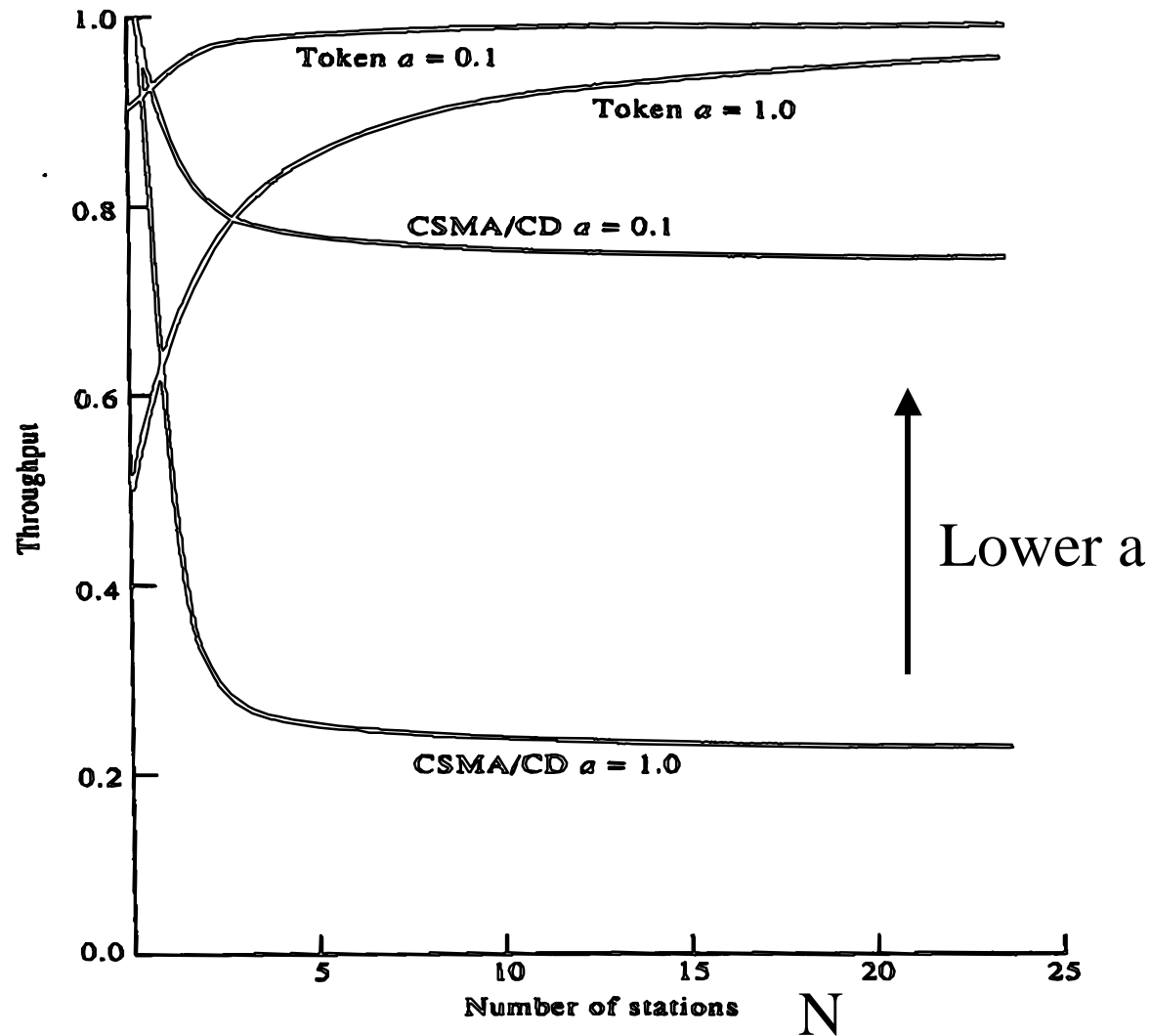


# Performance (Continued)

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



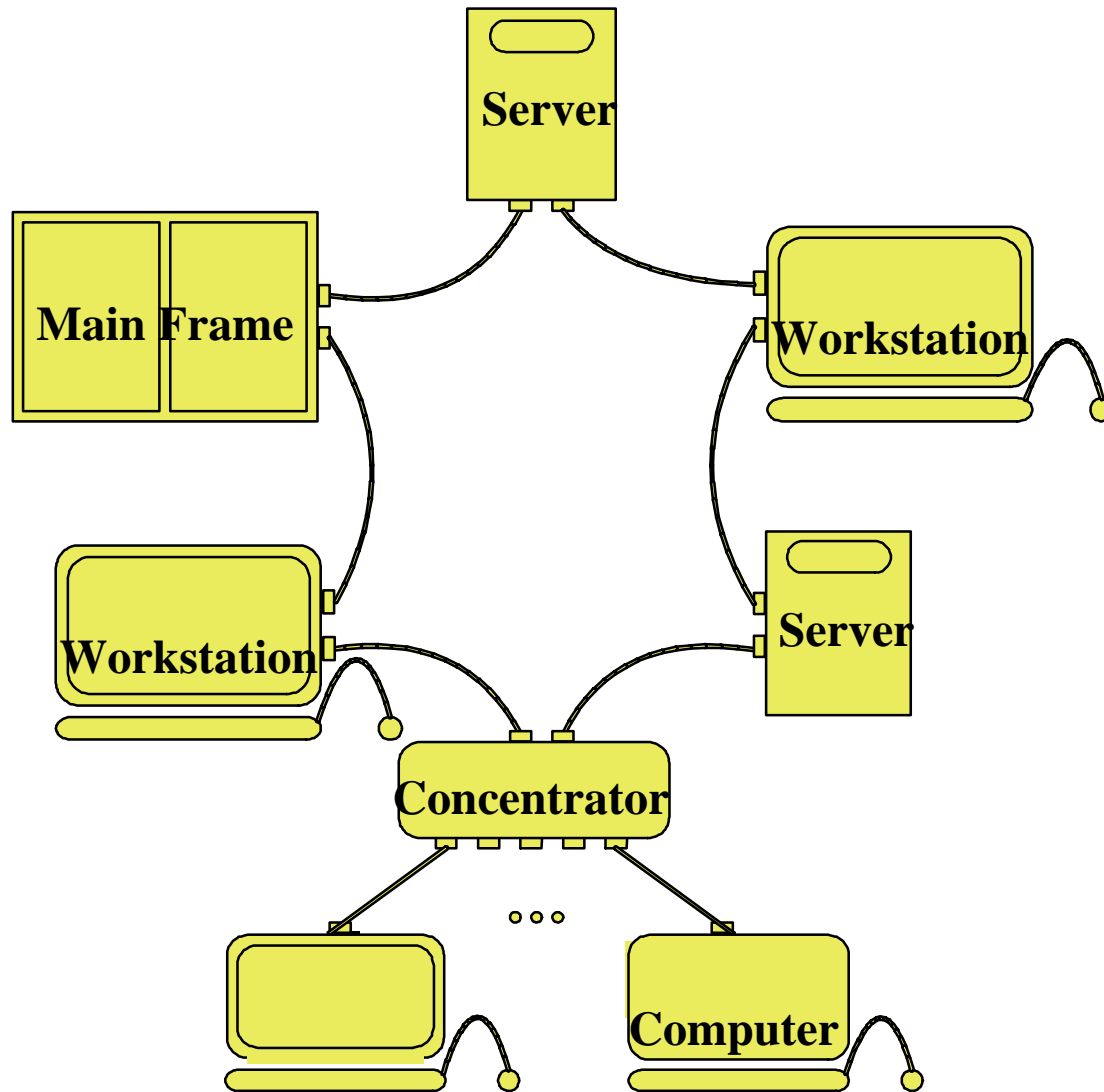
# Performance (continued)



# 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



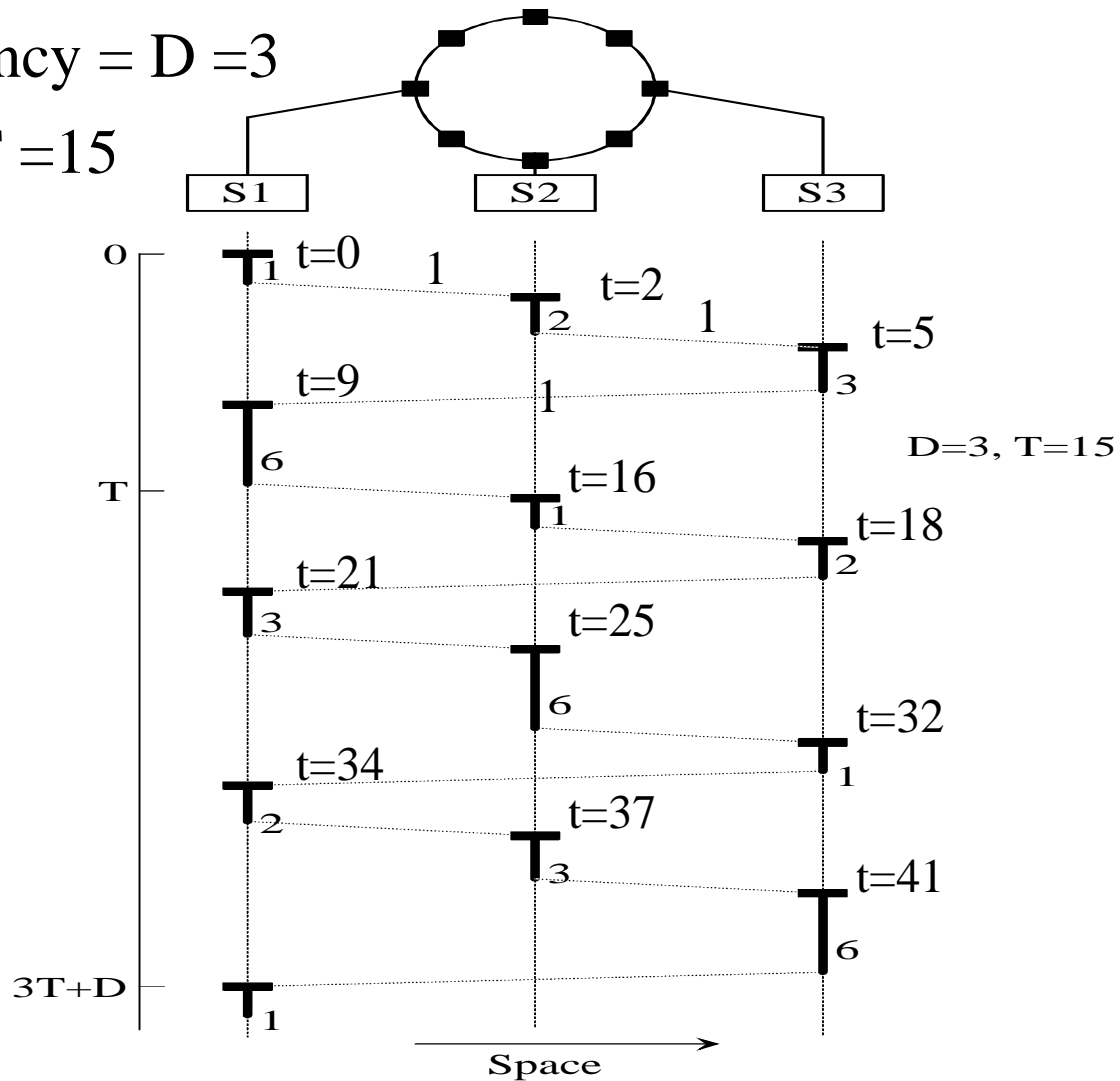
# Timed Token Access

- ❑ 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:  $i$ th station can transmit  $SA_i$  (pre-allocated)

# Example

Ring Latency =  $D = 3$

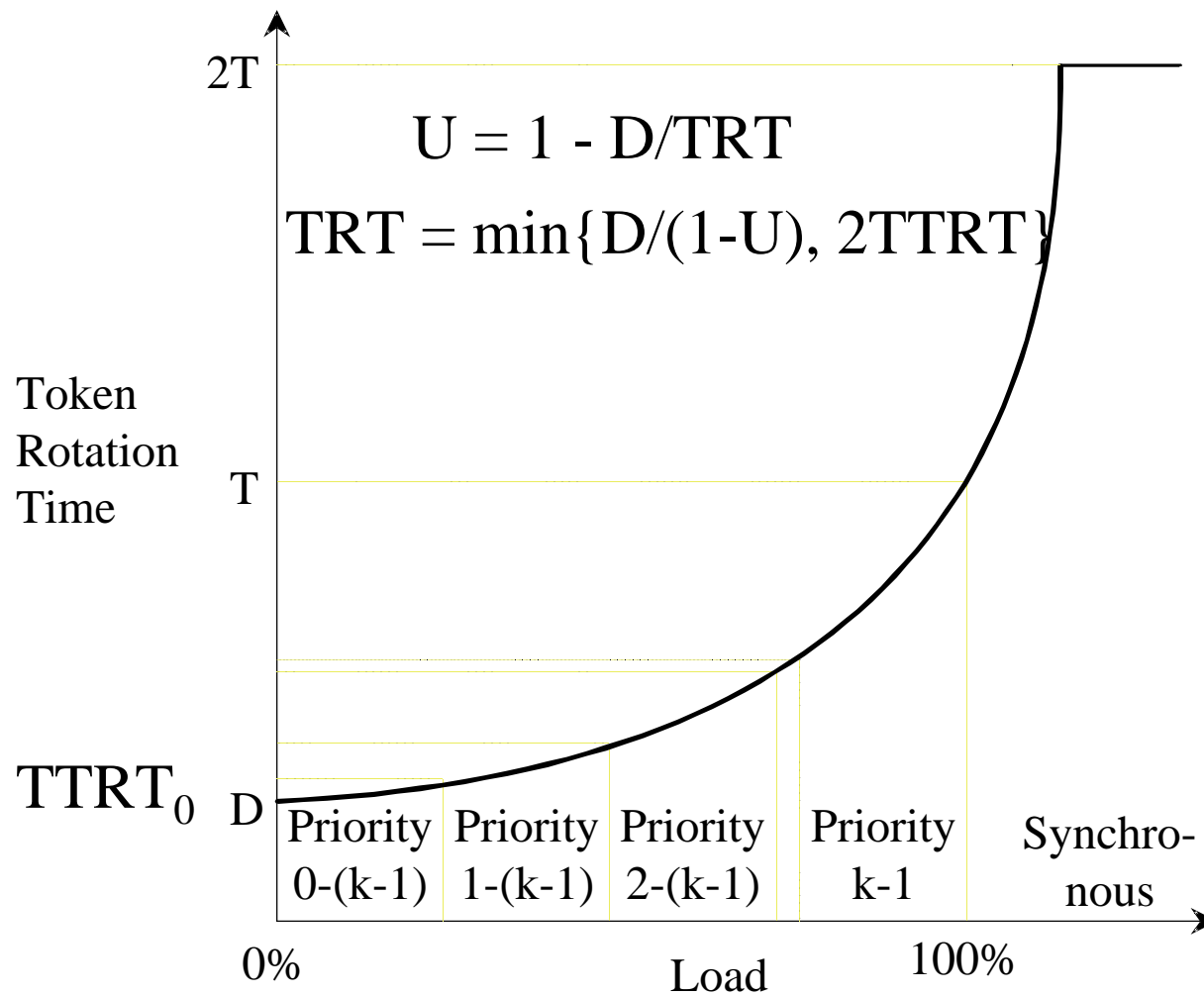
TTRT =  $T = 15$



# TRT

- ❑ Maximum TRT = TTRT + Max Frame time + Token Time +  $\sum SA_i$
- ❑ It is required that  $\sum SA_i < TTRT - \text{Max Frame time} - \text{Token Time}$
- ❑ Maximum TRT = 2 TTRT
- ❑ If  $D = \text{Ring latency}$ , 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  $TTRT_0 < TTRT_1 < TTRT_2 < \dots < TTRT_6 < TTRT$

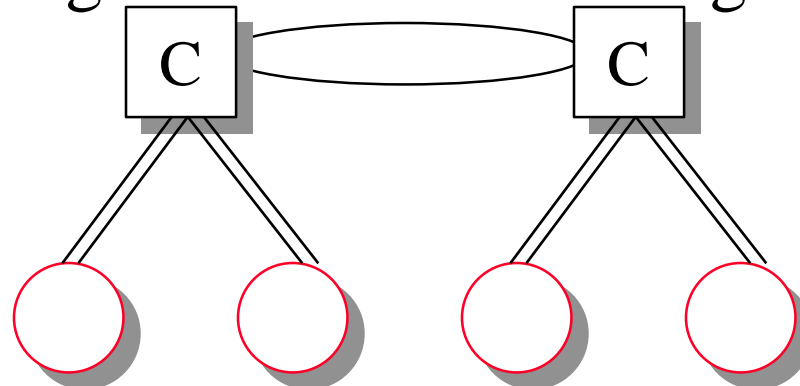
# Priorities



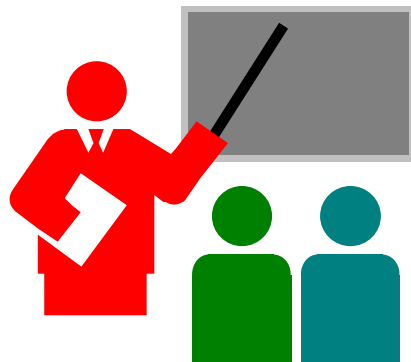


# TP-PMD

- ❑ 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



# 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 12.1-12.4, 13.1-13.2, 13A, 13B
- ❑ Submit answers to Exercises 12.4, 12.7