Chapter 9: Local and Metropolitan Area Networks

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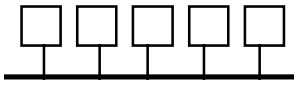
- LAN, MAN, WAN, GAN, DAN
- Topologies: Star, ring, tree, bus
- Baseband and broadband
- IEEE 802.3: Ethernet or
- IEEE 802.5: Token ring
- Fiber Distributed Data Interface (FDDI)
- IEEE 802.2: Logical Link Control

LAN vs WAN

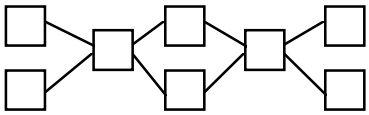
LAN

- Usually shared medium
- Broadcast
- No intermediate stations
- Access protocols
- Infrastructure owned by a private organization



WAN

- Point-to-point
- Unicast
- Intermediate Routers/switches
- Access protocols
- Infrastructure owned by a public telecommunication company



Classification of Networks

- WAN = Wide Area Network
- LAN = Local Area Network
- MAN = Metropolicatan Area Network
- CAN = Campus Area Network
- DAN = Desk Area Network
- GAN = Global Area Network

Topology

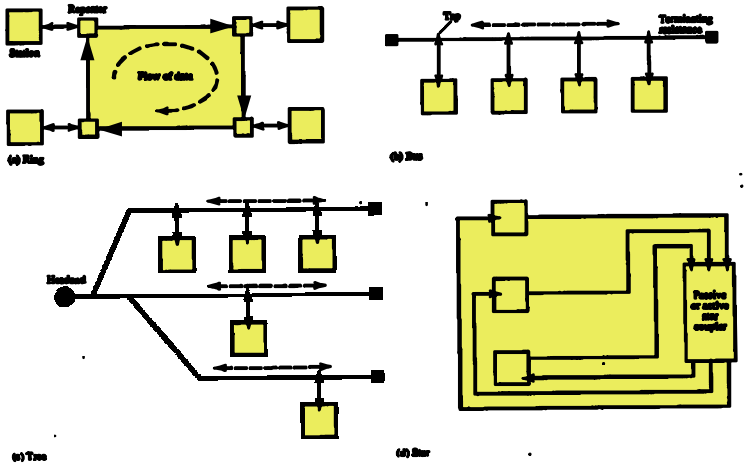
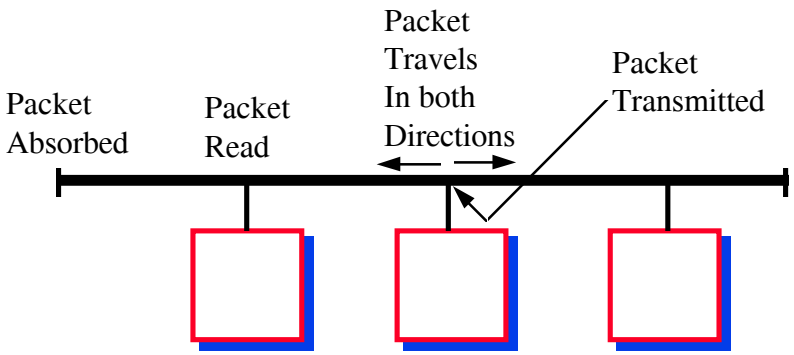


Fig 9.1

Transmission Media [Self-Reading]

- Unshielded Twisted Pair
- Shielded Twisted Pair
- Coaxial Cable
- Optical fiber

Baseband



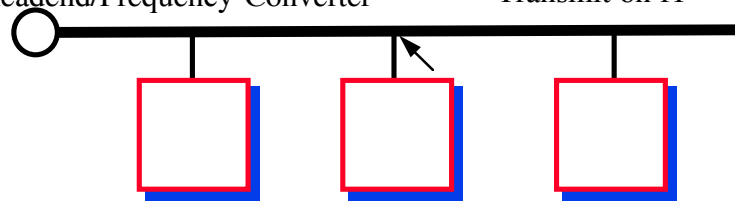
Broadband

- Broadband: Mid-split

Receive on f2

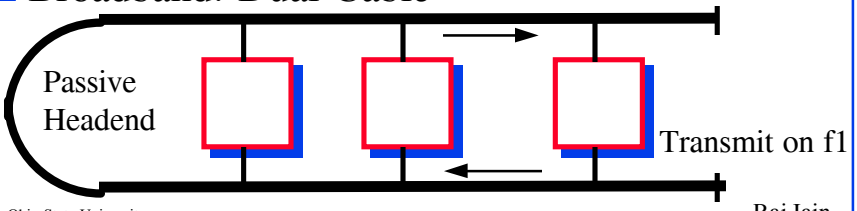
Headend/Frequency Converter

Transmit on f1



- Broadband: Dual Cable

Receive on f1



Baseband vs Broadband

- Baseband
- One frequency band
- Bidirectional repeaters
- Bidirectional signal flow
- No headend required
- Simple

- Broadband
- Multiple frequency band
- Unidirectional repeaters
- Unidirectional signal flow
- Headend required for return path
- Complex

Ethernet or IEEE 802.3

- 10 Mbps, 500 m segments, 2500 span, 100 nodes per segement, 2.5 m between stations, 0.4 in thick coaxial cable (10BASE5)
- 10 Mbps, 200 m segments, 1000 span, 30 nodes per segement, 0.5 m between stations, 0.25 in thin coaxial cable (10BASE2)

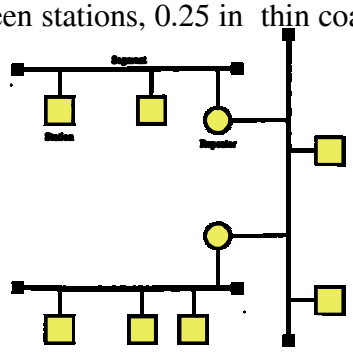
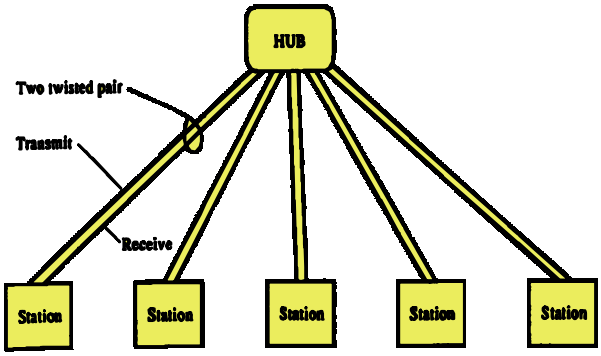


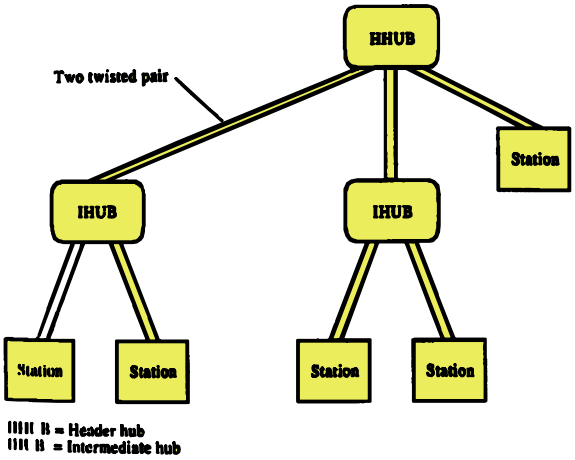
Fig 9.3

10BASE-T

- Unshielded twisted pair, hub (repeater), signal broadcast to all stations. Max 100 m to hub at 10 Mbps

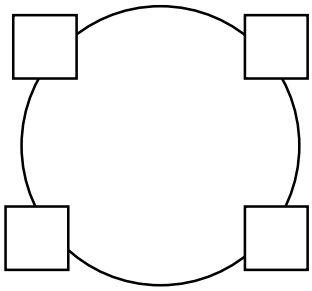


Multilevel Hierarchy



Ring Issues

- Per hop Clock Synch: Need synchronous transmission
- Around the ring clock synch: Need buffers
- Frame removal
- Reliability: N repeaters in a series



Bypass

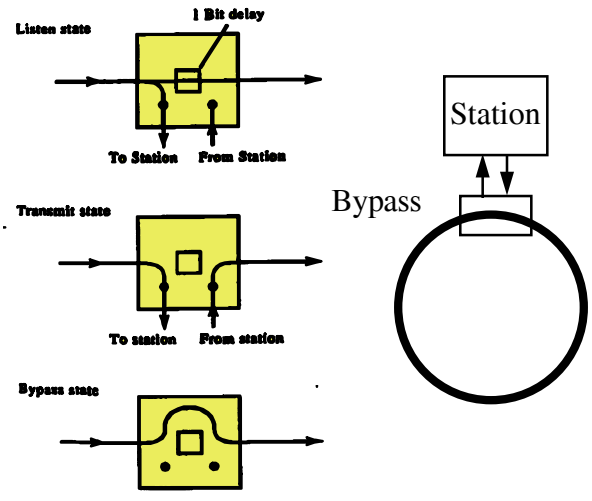
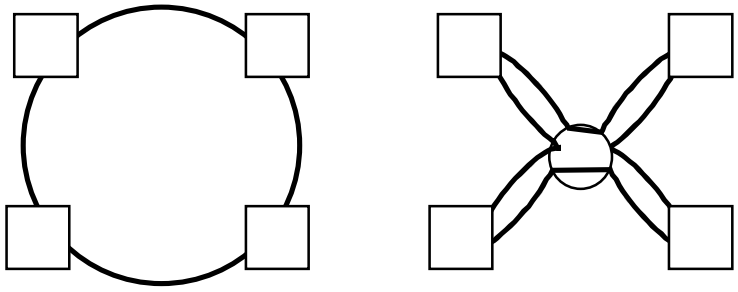


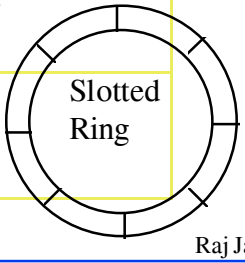
Fig 9.9

Star-Shaped Ring



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	



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%

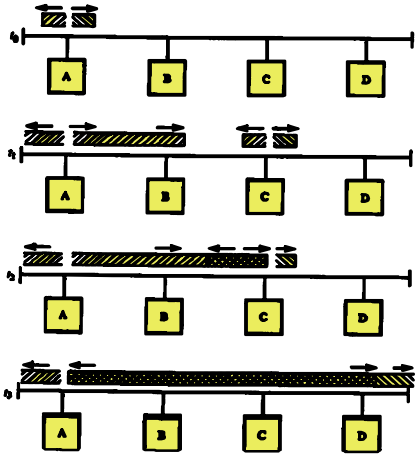
- CSMA: Carrier Sense Multiple Access
  Listen before you transmit
- p-Persistent CSMA: If idle, transmit with probability p
  Delay by one time unit with probability 1-p
- CSMA/CD: CSMA with Collision Detection
  Listen while transmitting. Stop if you hear someone else

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 μs = 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 ⇒ two or more transmitters ⇒ Collision
  ⇒ Length of the cable is limited to 2 km

CSMA/CD Operation

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



One way delay = 25.6 ms
Max Distance <2.5 km

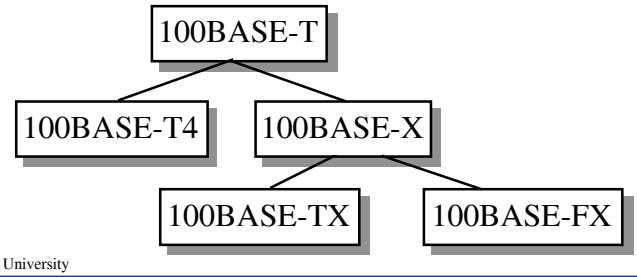
Fig 9.12

CSMA/CD PHY 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.
- **10BASE-FP:** 10 Mb/s fiber optic passive star + segments
- **10BASE-F:** 10BASE-FL, 10BASE-FB, or 10BASE-FP

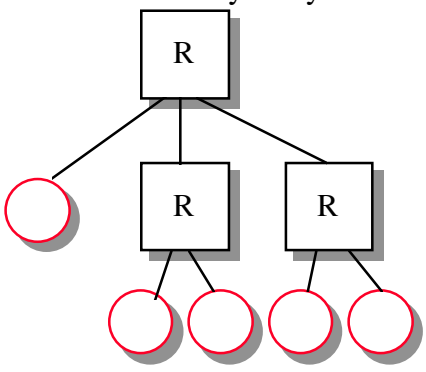
Fast Ethernet Standards

- **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
- **100BASE-X:** 100BASE-TX or 100BASE-FX
- **100BASE-T:** 100BASE-T4, 100BASE-TX, or 100BASE-FX



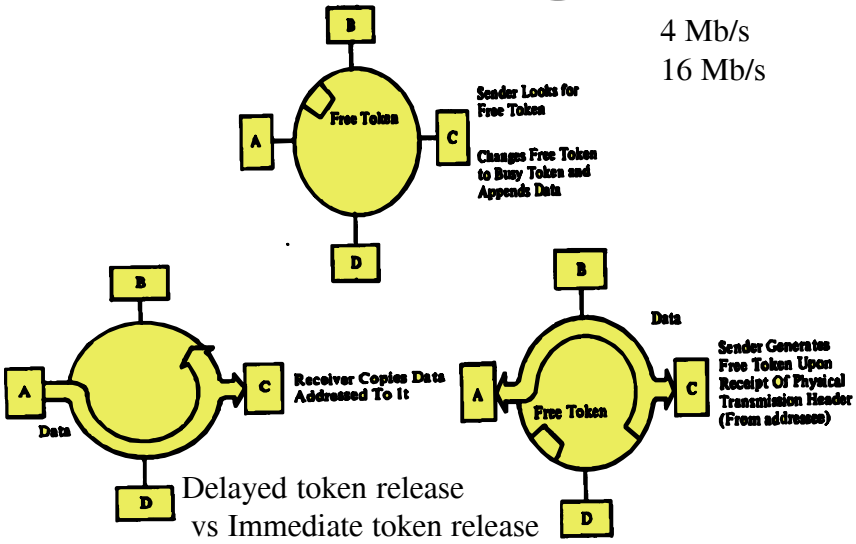
10BASE-T

- Collision detected by the hub.
- Activity on two or more channels ⇒ Collision
  Collision presence (CP) transmitted by hub to all stations
  Collision window = 2X One-way delay between farthest stations



Token Ring

4 Mb/s
16 Mb/s



Delayed token release
vs Immediate token release

Priorities

Received Priority	Received Reservation	Busy	
3	3	1	1

← Size in bits

- Received Priority = Pr ⇒ This token/frame's priority
- Received reservation = Rr ⇒ Someone on the ring wants to transmit at Rr
- To transmit a message of priority Pm, you should get a free token with Pr ≤ Pm
- If free but Pr>Pm and Rr<Pm, reserve token by setting Rr=Pm
- If busy and Rr<Pm then reserve by seeting Rr ← 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 9A

Fill in the table with all 8 possible combinations

Busy	Pr≤Pm	Rr≤Pm	Action

Priority Stack

- If you issue a higher priority token, remember the new and old priority. Next time grab the higher priority token and reset the priority to old value

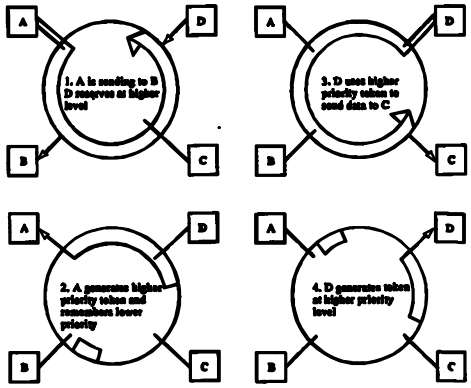


Fig 9.19(1-4)

Priority Stack (continued)

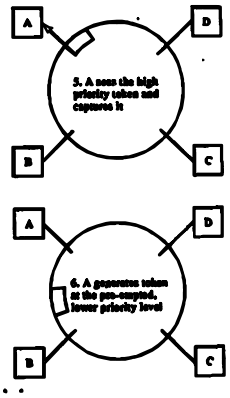
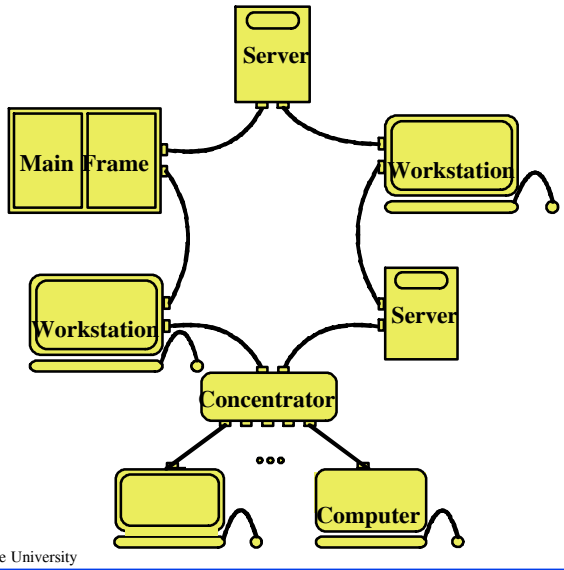


Fig 9.19(5-6)

FDDI

- Fiber Distributed Data Interface
- ANSI Standard for 100 Mbps over Fiber and twisted pair
- Timed token access
- Up to 500 stations on a single FDDI network
- 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.
- Eight priority levels
- Synchronous (guaranteed access delay) and asynchronous traffic
- Arranged as single- or dual-ring logical topology

Dual-Ring of Trees Topology



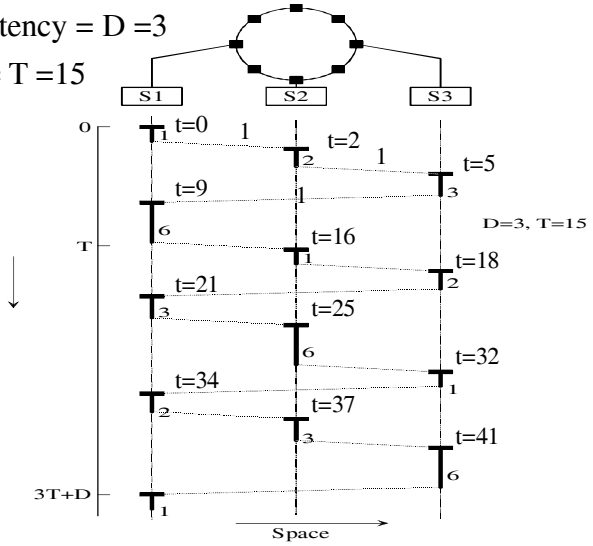
Timed Token Access

- 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 of a frame
- 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

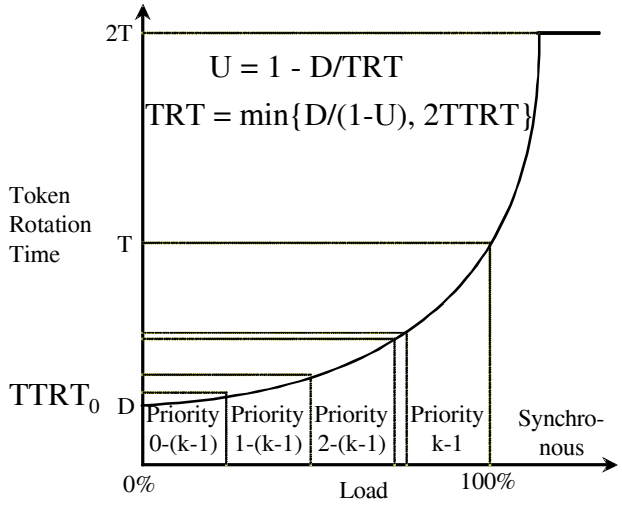
TTRT = T =15



TRT

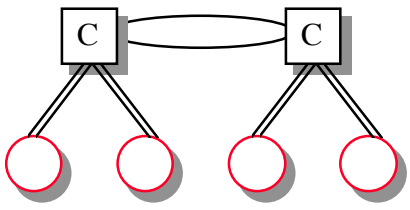
- Maximum TRT = TTRT+Max Frame time + Token Time + ΣSAi
- It is required that ΣSAi < TTRT-Max Frame time - Token Time
- Maximum TRT = 2 TTRT
- If D=Ring latency, then
  Utilization U=(TRT-D)/TRT = 1- D/TRT
- Max U = 1-D/TTRT
- High load ⇔ High TRT
  Low load ⇔ Low TRT
- Lower priority traffic allowed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

Priorities



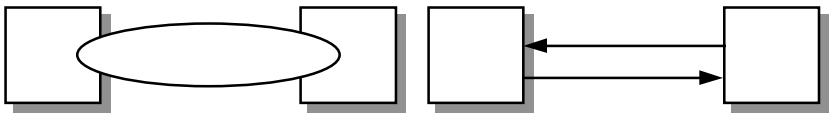
TP-PMD

- 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



Full Duplex FDDI

- The stations transmit and receive simultaneously.
- Works only on a 2-station ring.
- 200 Mbps.
- Network starts in ring mode.
- After detecting a two node ring using SMT frames, the stations negotiate and enter full duplex mode
- On error, stations enter the ring mode.
- Patented and licensed by Digital.



MAC Performance: Baseband Bus

- a = Propagation delay/Frame time
- U = Frame Time/(Propagation delay+Frame Time) = 1/(1+a)

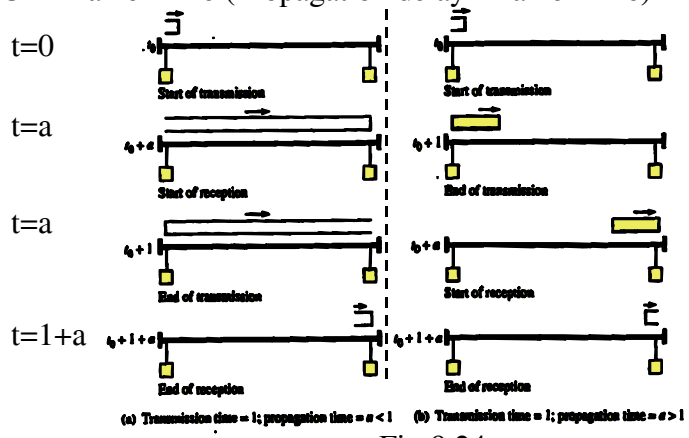


Fig 9.24

Token Ring

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

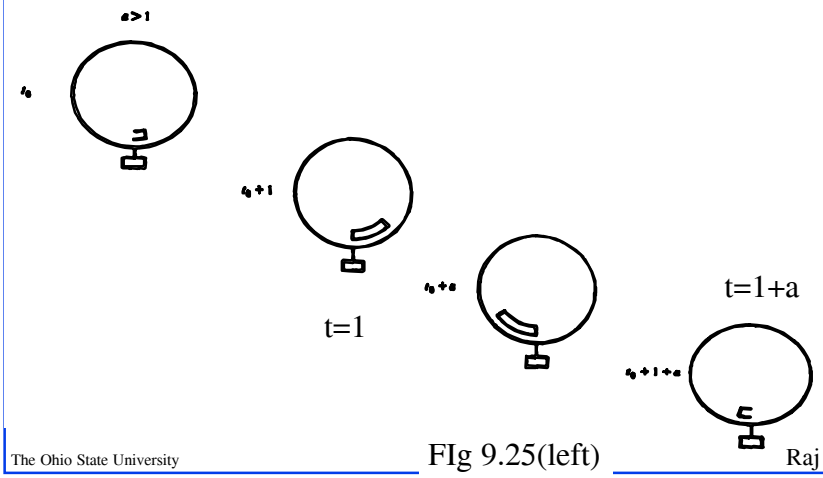


FIg 9.25(left)

Token Ring (Continued)

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

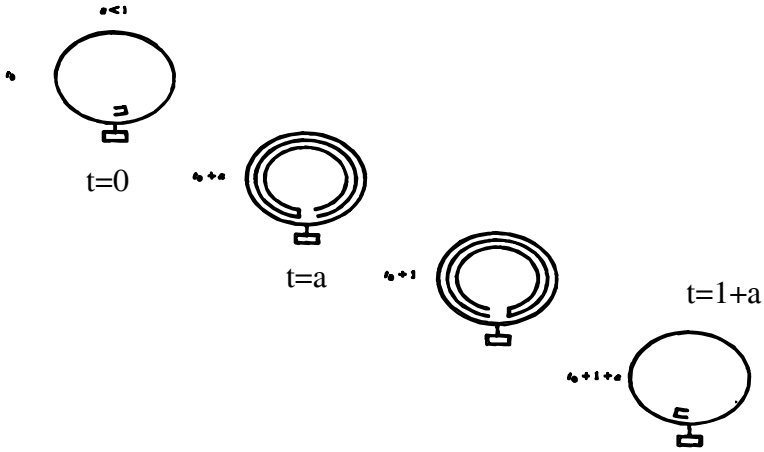
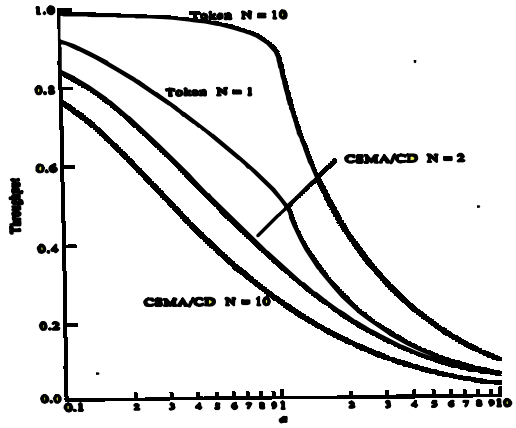


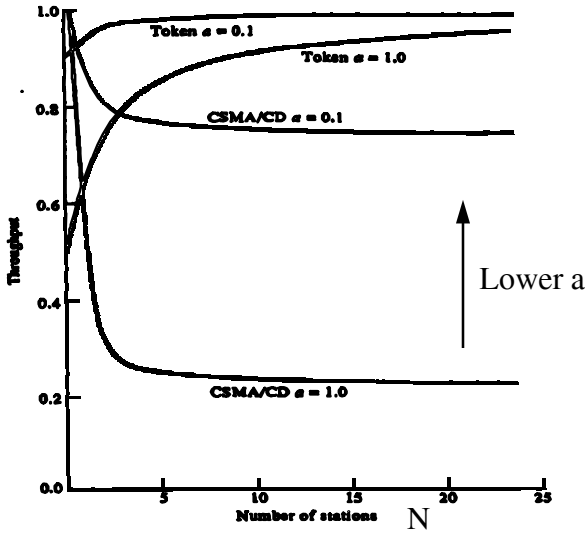
Fig9.25 (right)

CSMA/CD

- 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= ∞



CSMA/CD (continued)



Bridges

- Filtering, switching, buffering

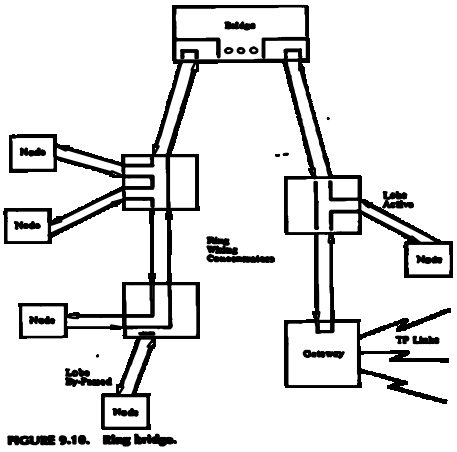


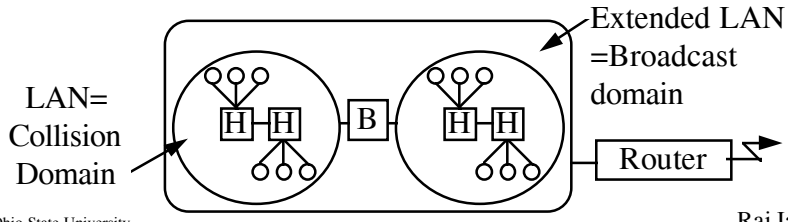
Fig 9.10

Hub Functions

- Signal Restoration (timing and amplitude)
- Data forwarding
- Collision detection (by monitoring receive ports)
- Jam signal propagation to all ports
- Fault detection and recover: autopartition and restore

Interconnection Devices

- **Repeater**: PHY device that restores data and collision signals
- **Hub:** Multiport repeater + collision detection, notification and signal broadcast
- **Bridge:** Datalink layer device connecting two or more collision domains
- **Router:** Network layer device (does propagate MAC multicasts)

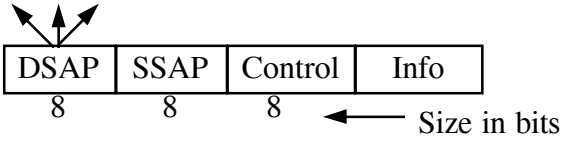


Logical Link Control (LLC)

- Type 1: Unacknowledged connectionless (Used on 802.3)
  No flow or error control. Provides protocol multiplexing.
  Uses 3 types of protocol data units (PDUs):
  UI = Unnumbered informaton
  XID = Exchange ID = Types of operation supported, window
  Test = Loop back test
- Type 2: Acknowledged connection oriented (Used on 802.5)
  Provides flow control, error control. Uses
  SABME (Set asynchronous balanced mode), UA (unnumbered ack), DM (disconneced mode), DISC (disconnect)
- Type 3: Acknowledged connectionless
  Uses one-bit sequence number
  AC command PDUs acked by AC response PDUs

LLC Multiplexing

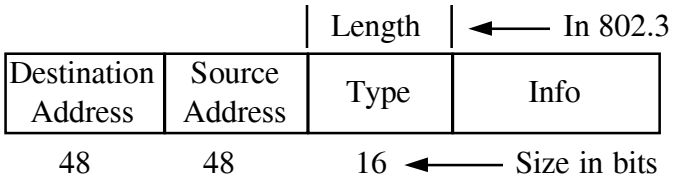
- Multiplexing allows multiple users (network layer protocols) to share a datalink
- Each user is identified by a "service access point (SAP)"



- Eight-bit SAP
  ⇒ Only 256 standard values possible
- Even IP couldn't get a standard SAP.
  Use Subnetwork Access Protocol SAP
  (SNAP SAP)

Multiplexing in Ethernet

- Original (not IEEE 802.3) Ethernet had protocol type field for multiplexing



- Internet Engineering Task Force (IETF) assigned protocol types (Ethernet Types) for most protocols including IP, IPX, Appletalk, etc. (RFC 1042).
- Length ≤1518, Protocol type > 1518

SNAP SAP

- SubNetwork Access Protocol Service Access Point
- When DSAP=AA, SSAP=AA, Control=UI, protocol ID field is used for multiplexing

DSAP	SSAP	Control		
AA	AA	03	Protocol ID	Info

40 bits

- Protocol ID is 40 bit long. The first 24 bits are Organizationally Unique Identifiers (OUI). OUI of 0 is used. The Ethernet type values are used in the last 16 bits. Protocol ID = 00-00-00-xx-xx

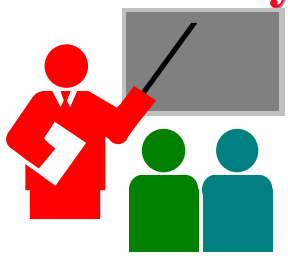
IEEE 802

- 802.1 Network management and bridging
- 802.2 Logical link control
- 802.3 Ethernet (CSMA/CD)
- 802.4 Token Bus
- 802.5 Token Ring
- 802.6 DQDB
- 802.7 Broadband technical advisory group
- 802.8 Fiber-optic technical advisory group
- 802.9 Integrated data and voice
- 802.10 Security and privacy

IEEE 802 (Cont)

- 802.11 Wireless LANs
- 802.12 100VG-AnyLAN
- 802.13 ?Bad Luck
- 802.14

Summary



- Ring, Bus, Tree, Star topologies
- Ethernet/IEEE 802.3: CSMA/CD, Baseband, broadband
- Token ring/IEEE 802.5
- FDDI Timed token access
- LLC type 1, 2, 3

Homework 9B

- 9.4, 9.19, 9.20, 9.21