

Chapter 9: Local and Metropolitan Area Networks

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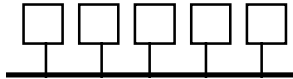


- LAN, MAN, WAN, GAN, DAN
- Topologies: Star, ring, tree, bus
- Baseband and broadband
- IEEE 802.3: Ethernet or
- IEEE 802.5: Token ring
- Fiber Distributed Data Interface (FDDI)
- IEEE 802.2: Logical Link Control

LAN vs WAN

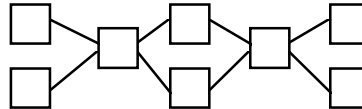
LAN

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



WAN

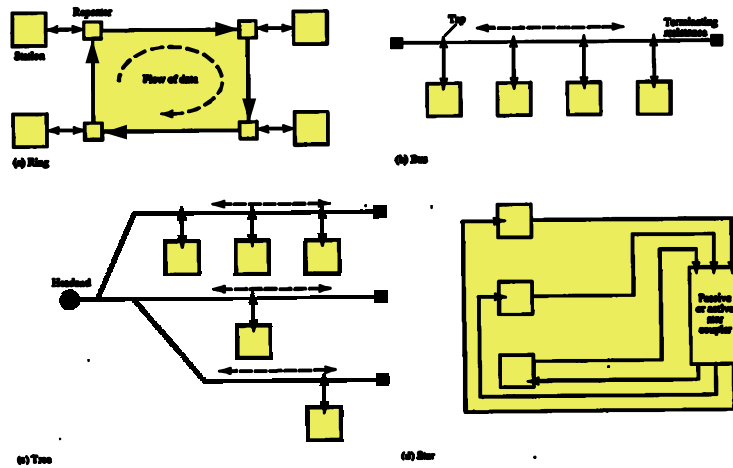
- Point-to-point
- Unicast
- Intermediate Routers/switches
- Access protocols
- Infrastructure owned by a public telecommunication company



Classification of Networks

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

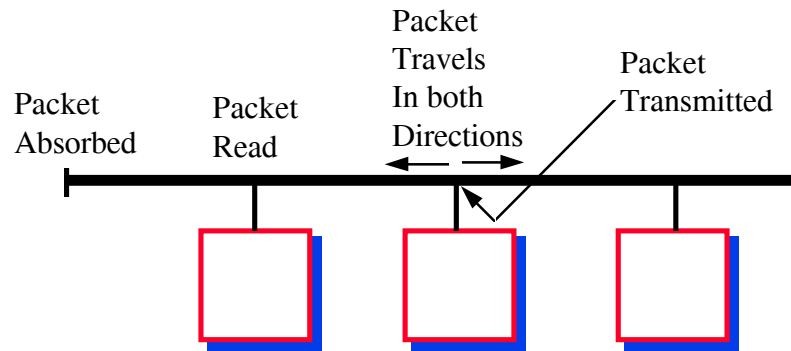
Topology



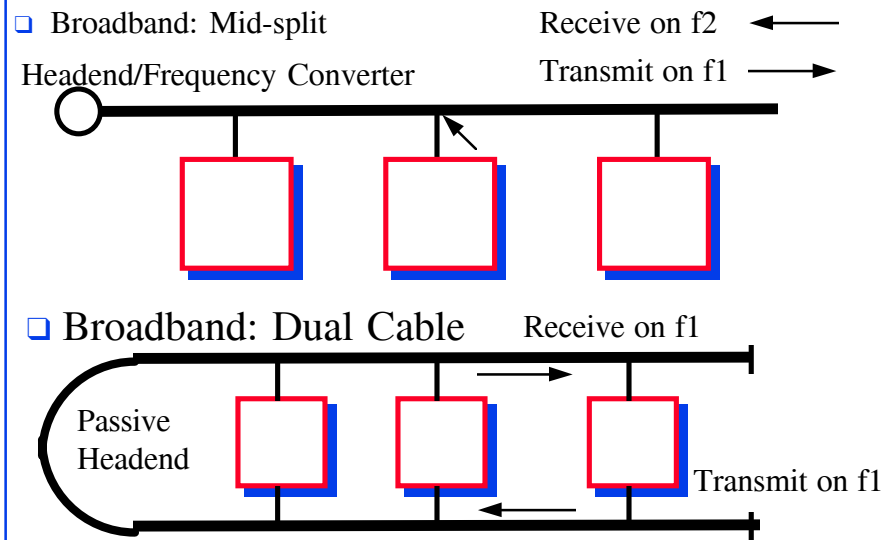
Transmission Media [Self-Reading]

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

Baseband



Broadband



Baseband vs Broadband

- | | |
|---|---|
| <ul style="list-style-type: none"><input type="checkbox"/> Baseband<input type="checkbox"/> One frequency band<input type="checkbox"/> Bidirectional repeaters<input type="checkbox"/> Bidirectional signal flow<input type="checkbox"/> No headend required
<input type="checkbox"/> Simple | <ul style="list-style-type: none"><input type="checkbox"/> Broadband<input type="checkbox"/> Multiple frequency band<input type="checkbox"/> Unidirectional repeaters<input type="checkbox"/> Unidirectional signal flow<input type="checkbox"/> Headend required for return path
<input type="checkbox"/> Complex |
|---|---|

Ethernet or IEEE 802.3

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

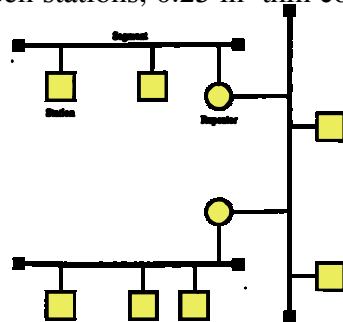


Fig 9.3

10BASE-T

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

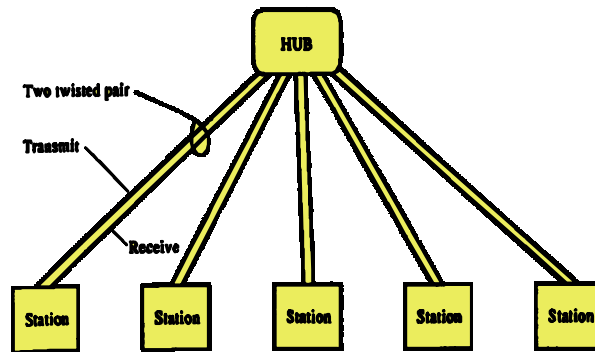


Fig 9.4
9-11

Multilevel Hierarchy

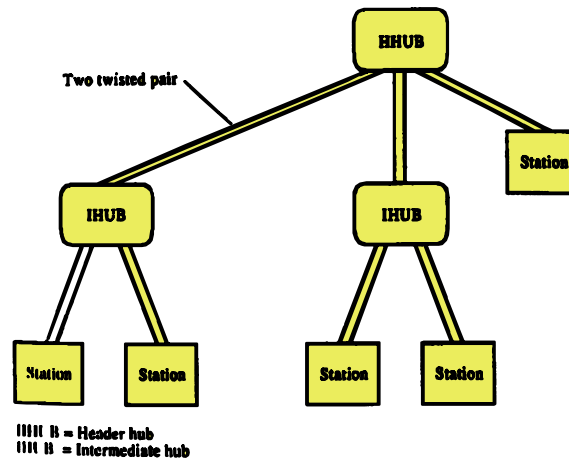
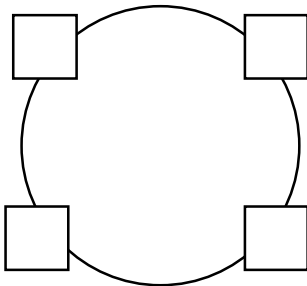


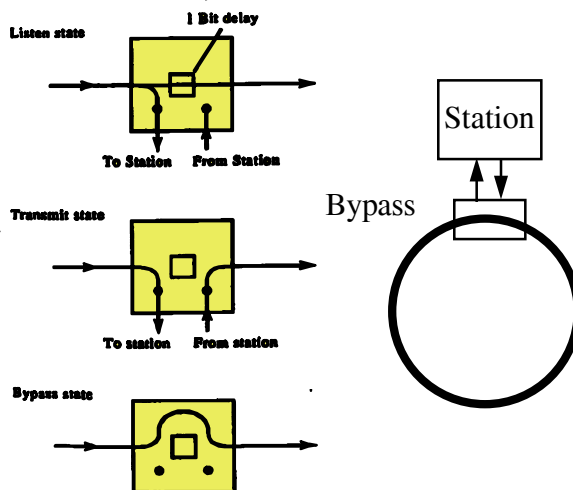
Fig 9.5
9-12

Ring Issues

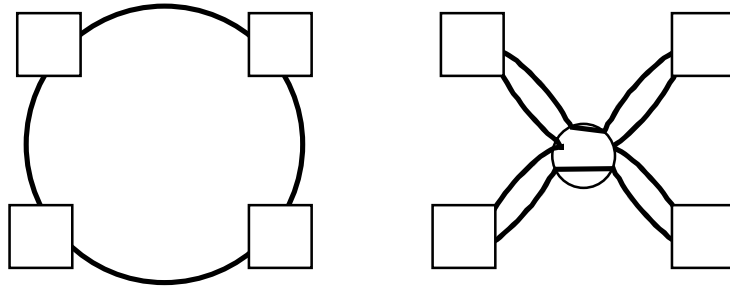
- ❑ Per hop Clock Synch: Need synchronous transmission
- ❑ Around the ring clock synch: Need buffers
- ❑ Frame removal
- ❑ Reliability: N repeaters in a series



Bypass

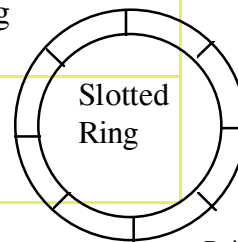


Star-Shaped Ring

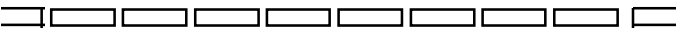


Media Access Control (MAC)

	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
(= $51.2 \mu\text{s} = 64$ 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 μ s

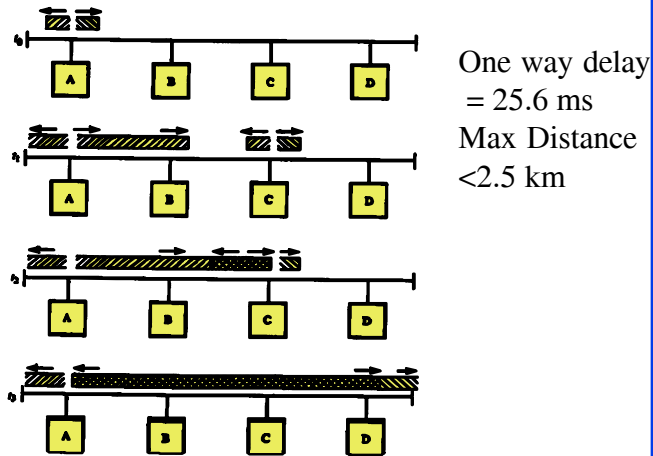


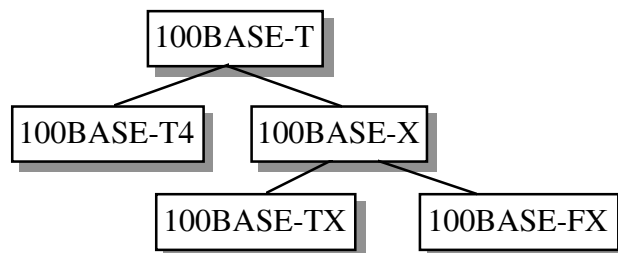
Fig 9.12

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

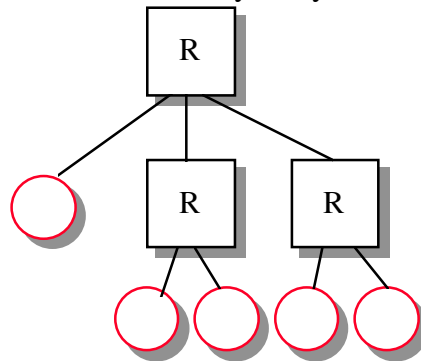
Fast Ethernet Standards

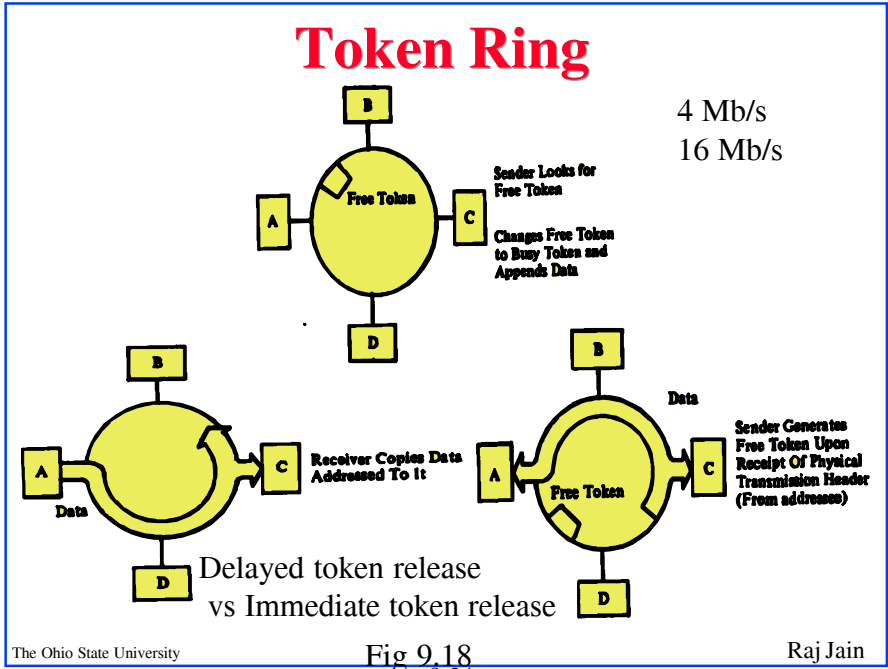
- ❑ **100BASE-T4:** 100 Mb/s over 4 pairs of CAT-3, 4, 5 UTP
- ❑ **100BASE-TX:** 100 Mb/s over 2 pairs of CAT-5 UTP or STP
- ❑ **100BASE-FX:** 100 Mbps CSMA/CD over 2 optical fiber
- ❑ **100BASE-X:** 100BASE-TX or 100BASE-FX
- ❑ **100BASE-T:** 100BASE-T4, 100BASE-TX, or 100BASE-FX



10BASE-T

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





Priorities

Received Priority	Received Reservation	Busy	
3	3	1	1

← Size in bits

- ❑ 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 setting $Rr \leftarrow Pm$
- ❑ If busy and $Rr > Pm$, wait
- ❑ When you transmit, set $Rr = 0$, and $busy = 1$. After transmission, issue a new token with $Pr = \text{Max}\{Pr, Pm, Rr\}$, $Rr = \text{Max}\{Rr, Pm\}$

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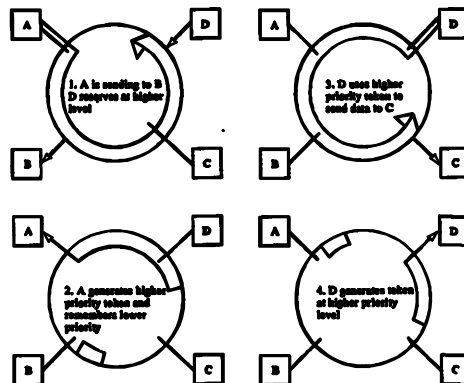
Homework 9A

Fill in the table with all 8 possible combinations

Busy	$Pr \leq P_m$	$Rr \leq P_m$	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



Priority Stack (continued)

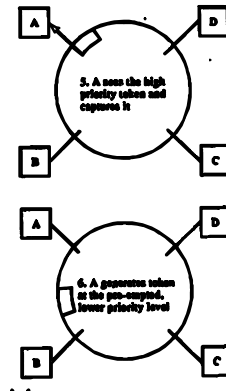
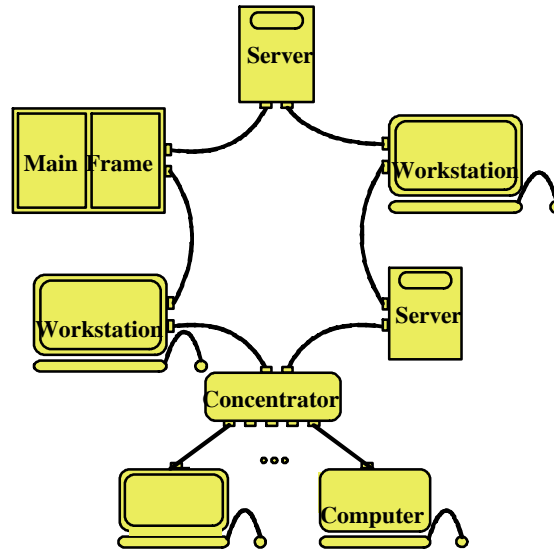


Fig 9.19(5-6)

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



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

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Example

Ring Latency = $D = 3$

TTRT = $T = 15$



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TRT

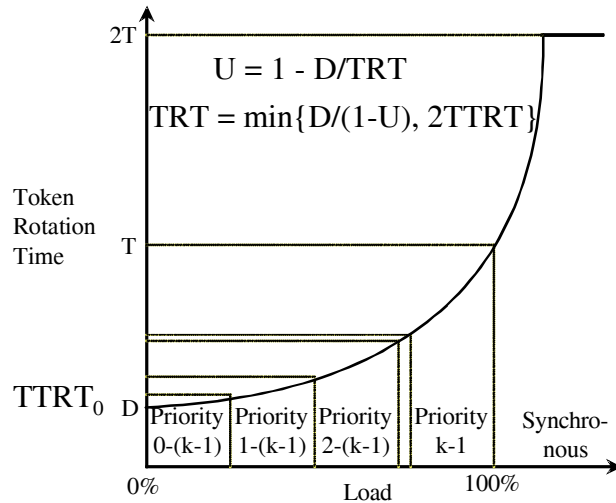
- ❑ Maximum TRT = TTRT + Max Frame time + Token Time + $\sum SA_i$
- ❑ It is required that $\sum SA_i < TTRT - \text{Max Frame time} - \text{Token Time}$
- ❑ Maximum TRT = 2 TTRT
- ❑ If $D = \text{Ring latency}$, then
Utilization $U = (TRT - D) / TRT = 1 - D / TRT$
- ❑ Max $U = 1 - D / TTRT$
- ❑ High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

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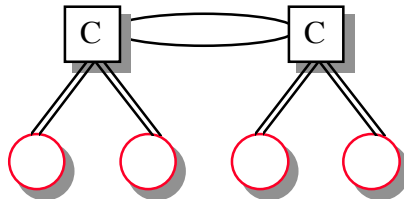
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Priorities



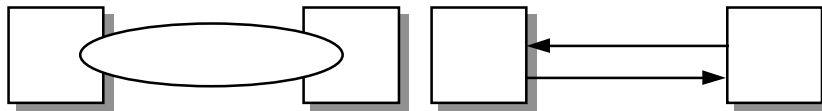
TP-PMD

- ❑ 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

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

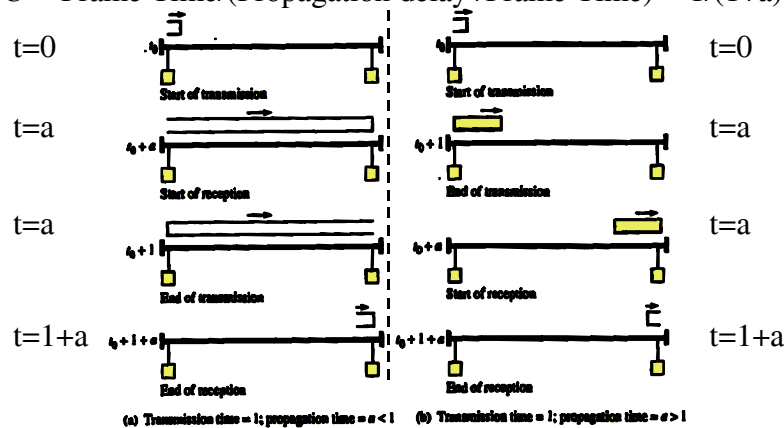
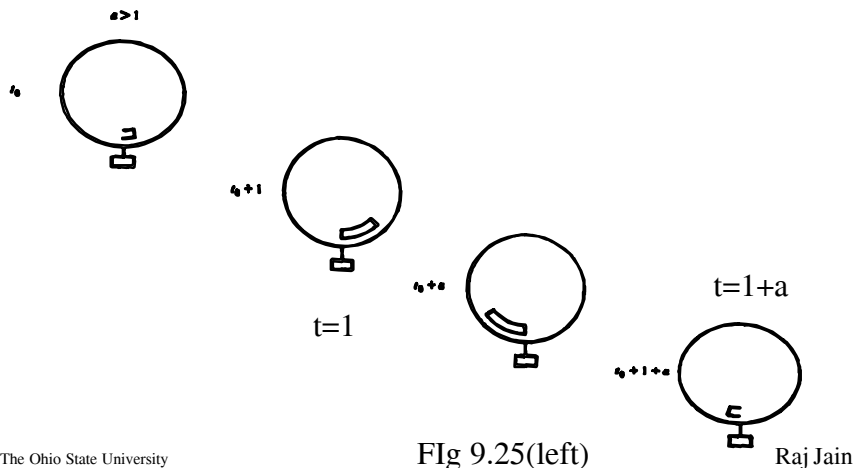


Fig 9.24

Token Ring

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



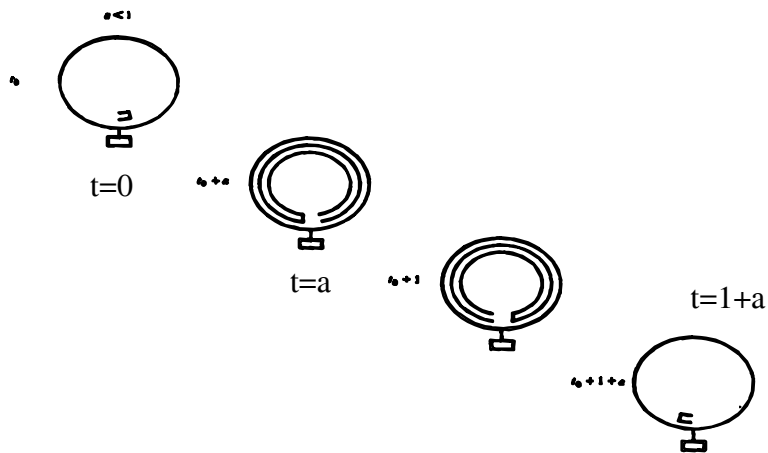
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Fig 9.25(left)
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Token Ring (Continued)

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



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Fig9.25 (right)
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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 $N = \infty$

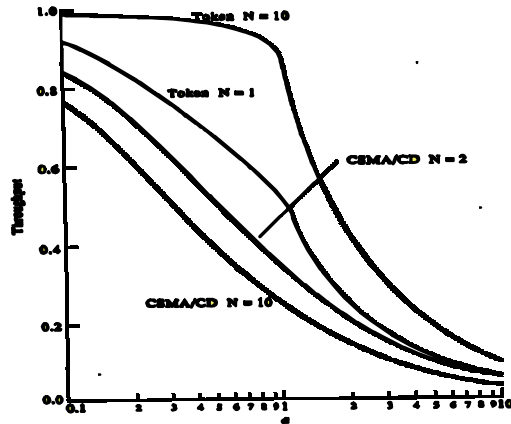


Fig 9.26
9-40

CSMA/CD (continued)

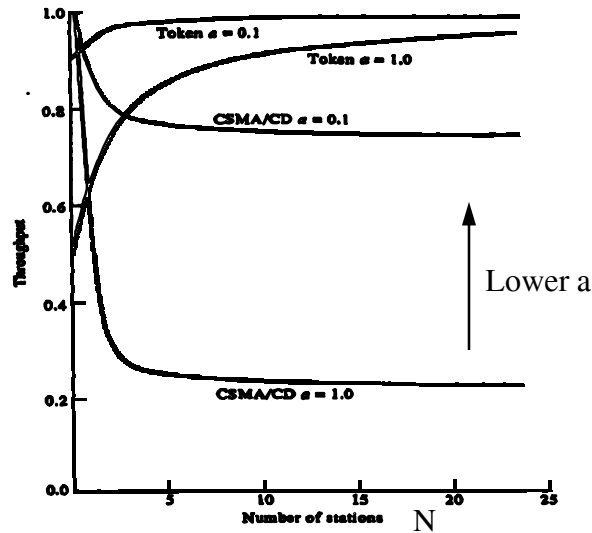
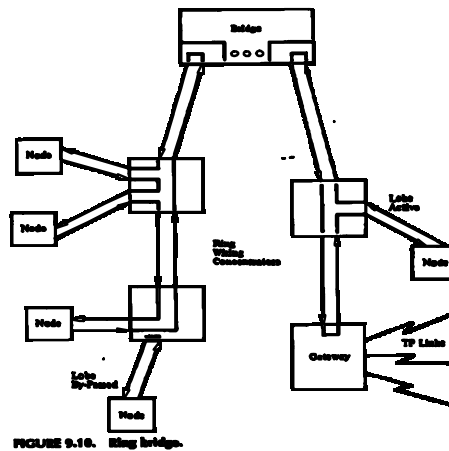


Fig 9.27
9-41

Bridges

- Filtering, switching, buffering

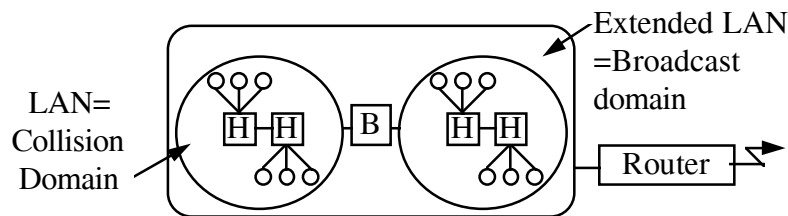


Hub Functions

- 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)



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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 (disconnected mode), DISC (disconnect)
- ❑ Type 3: Acknowledged connectionless
Uses one-bit sequence number
AC command PDUs acked by AC response PDUs

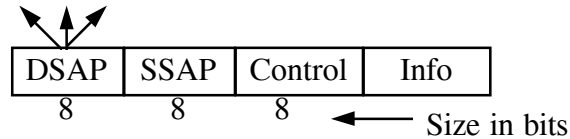
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LLC Multiplexing

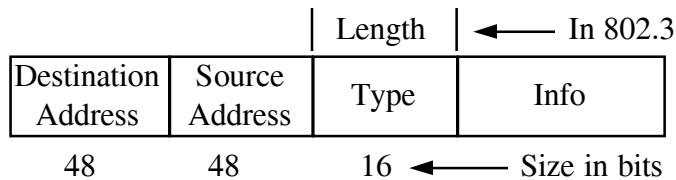
- ❑ Multiplexing allows multiple users (network layer protocols) to share a datalink
- ❑ Each user is identified by a “service access point (SAP)”



- ❑ 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

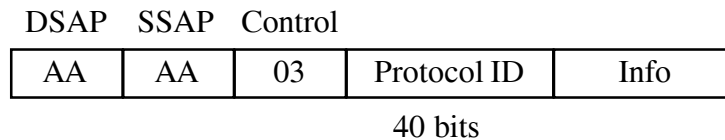
- ❑ Original (not IEEE 802.3) Ethernet had protocol type field for multiplexing



- ❑ 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



- ❑ 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

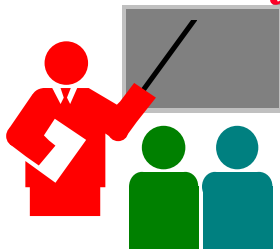
IEEE 802

- ❑ 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