Chapter 4: The Medium Access Sublayer

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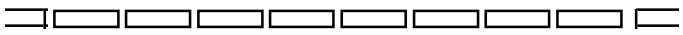
- 4.2 Mulitple Access: Aloha, Slotted Aloha, CSMA/CD
- 4.3 IEEE 802 LANs: Ethernet, Token Ring, LLC
- 4.4 Bridges: Transparent, Source Routing, Remote
- 4.5 High Speed LANs: FDDI, Fast Ethernet

Multiple Access Protocols

- 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%

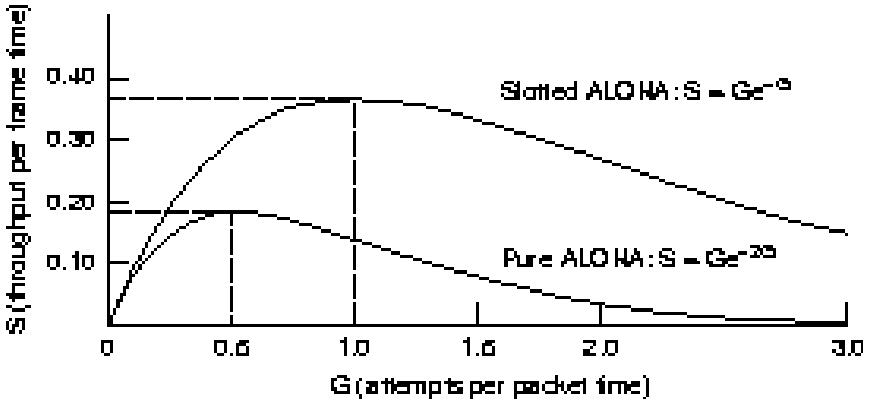


- CSMA: Carrier Sense Multiple Access
  Listen before you transmit
- CSMA/CD: CSMA with Collision Detection
  Listen while transmitting. Stop if you hear someone else

Aloha Performance

- Let frame time = 1
- S = New Traffic in Number of frames/unit time
- S = 1 $\Rightarrow$ Fully loaded system
- G = New frames + Retransmissions = Total load
- S = GP[0]
- P[k frames/unit time] = $G^k e^{-G}/k!$, k=1,2,3,...
- P[0] = e^{-2G}
- S = Ge^{-2G}
- Max S = 1/2e, at G=0.5
- For Slotted Aloha: S = Ge^{-G} $\Rightarrow$ Max S = 1/e at G=1

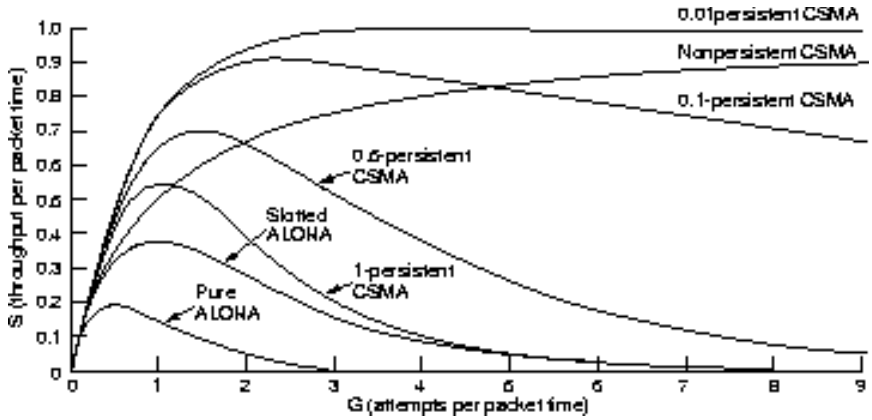
Aloha Performance (cont)



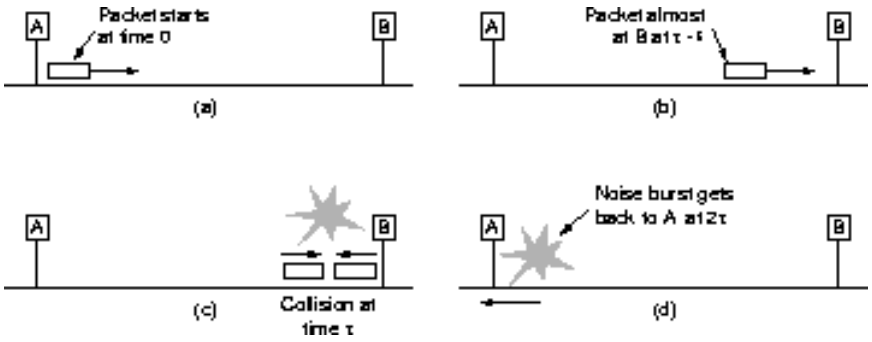
CSMA

- 1-persistent CSMA: If the channel is idle, transmit
  If the channel is busy, wait until idle and transmit
- Nonpersistent CSMA: If the channel is busy, go away for a random period of time
- p-persistent CSMA: Applies to slotted channels.
  If the channel is busy, wait until next slot.
  If the channel is idle, transmit with a probability p or wait until next slot with probability 1-p

CSMA Performance



CSMA/CD



- Collision detection can take as long as 2× One-way propagation delay
- Packet time $\geq 2\tau = 51.2\ \mu s = 64$ bytes at 10 Mbps

Fig 4-22

CSMA/CD Performance

- Efficiency= Max throughput/Line rate = $P/(P+2\tau/A)$
  Where, P = Frame time
  τ = one-way propagation delay
  A = P[only one station transmits during a slot]
  = fn{# of stations trying to transmit}
  = 1/e for infinite stations
- Efficiency = $1/(1+2\alpha/A)$
  Where α = Propagation delay/Frame time
  = (Distance/Speed of signal)/(Frame size/Data rate)
  = (Distance ×Data Rate)/(Frame Size × Signal Speed)
- Efficiency is a decreasing function of α

CSMA/CD Performance

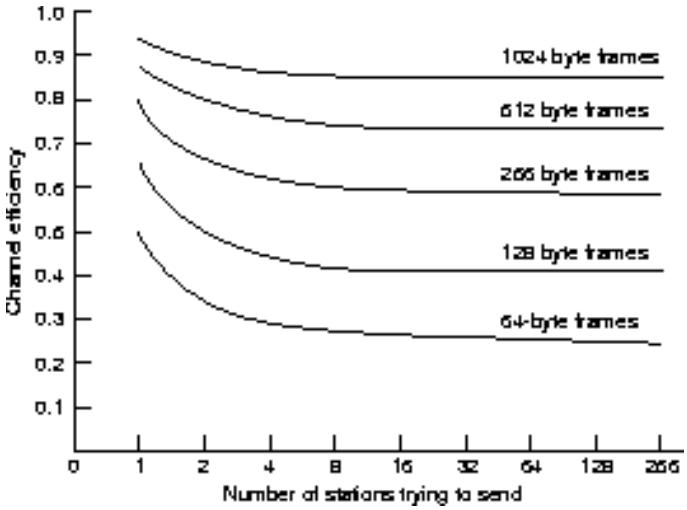


Fig 4-23

IEEE 802.3 CSMA/CD

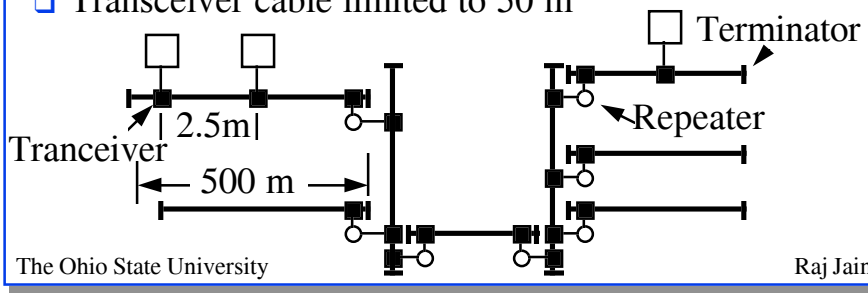
- If the medium is idle, transmit (1-persistent).
- If the medium is busy, wait until idle and then transmit immediately.
- If a collision is detected while transmitting,
  - Transmit a jam signal for one slot (= 51.2 μs = 64 byte times)
  - Wait for a random time and reattempt (up to 16 times)
  - Random time = Uniform[0,$2^{\min(k,10)}$-1] slots
    ⇒ truncated binary exponential backoff

IEEE 802.3 CSMA/CD

- Collision detected by monitoring the voltage
  High voltage ⇒ two or more transmitters
  ⇒ Collision
-

10Base5 Cabling Rules

- Thick coax
- Length of the cable is limited to 2.5 km, no more than 4 repeaters between stations
- No more than 500 m per segment ⇒ 10Base5
- No more than 2.5 m between stations
- Transceiver cable limited to 50 m

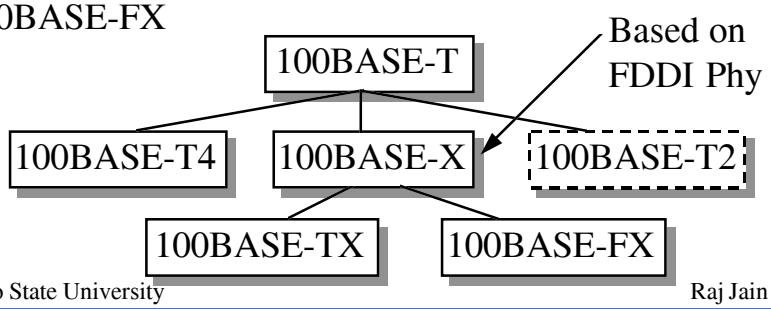


802.3 PHY Standards

- **10BASE5:** 10 Mb/s over coaxial cable (ThickWire)
- **10BROAD36:** 10 Mb/s over broadband cable, 3600 m max segments
- **10BASE2:** 10 Mb/s over thin RG58 coaxial cable (ThinWire), 185 m max segments
- **1BASE5:** 1 Mb/s over 2 pairs of UTP
- **10BASE-T:** 10 Mb/s over 2 pairs of UTP
- **10BASE-F:** Fiber Optic inter-repeater link (FOIRL), 10BASE-FL (link), 10BASE-FB (backbone), or 10BASE-FP (Passive)

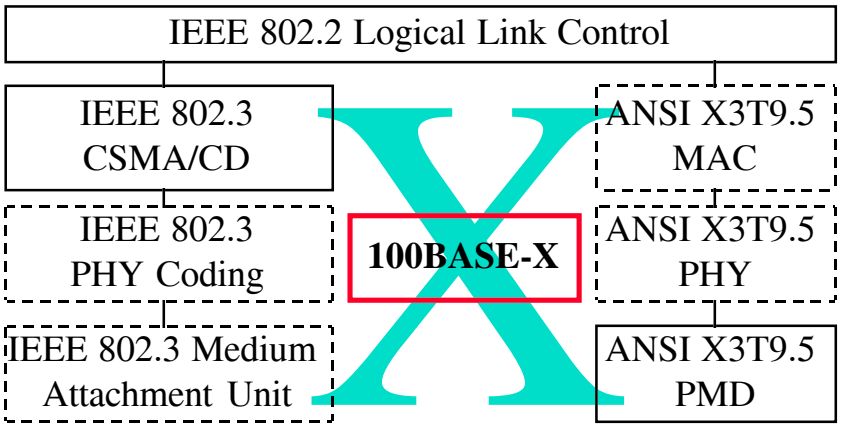
Fast Ethernet Standards

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

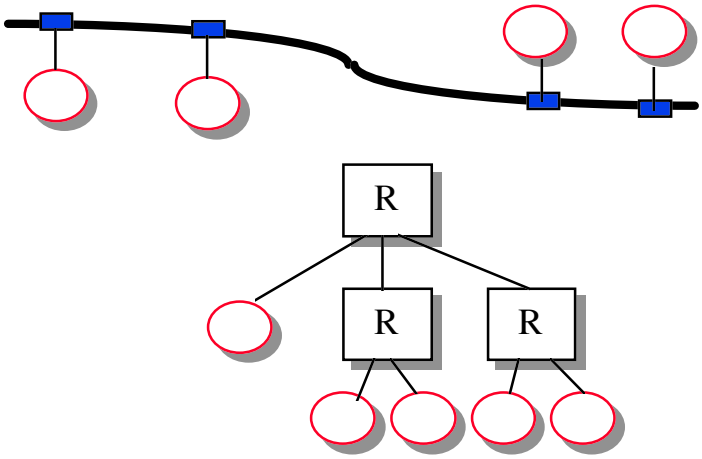


100 BASE-X

- X = Cross between IEEE 802.3 and ANSI X3T9.5



10BASE5 vs 10BASE-T

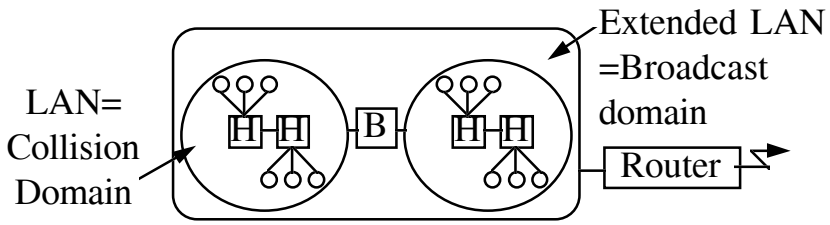


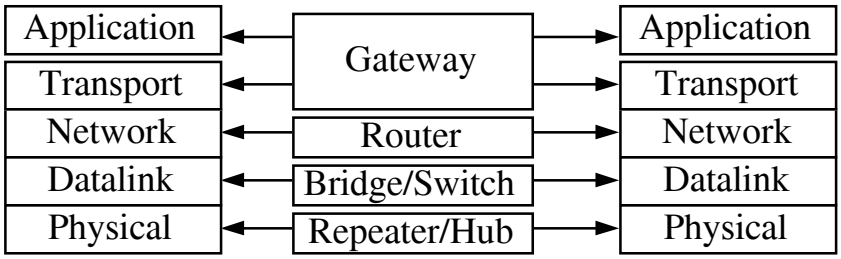
Interconnection Devices

- **Repeater**: PHY device that restores data and collision signals
- **Hub:** Multiport repeater + fault detection and recovery
- **Bridge:** Datalink layer device connecting two or more collision domains. MAC multicasts are propagated throughout "extended LAN."
- **Router:** Network layer device. IP, IPX, AppleTalk. Does not propagate MAC multicasts.
- **Switch**: Multiport bridge with parallel paths

These are functions. Packaging varies.

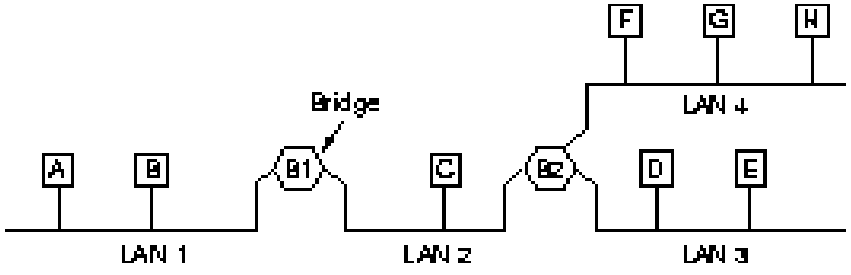
Interconnection Devices





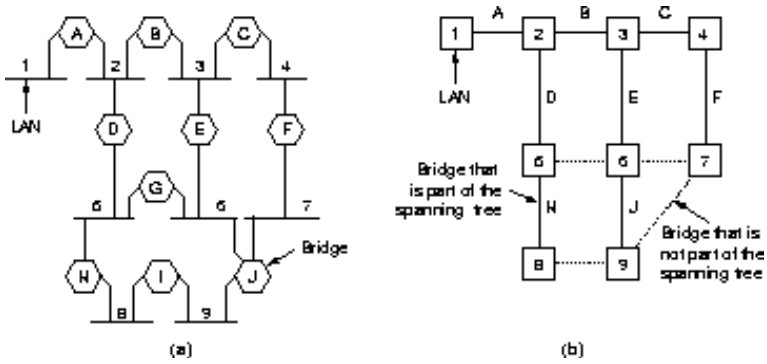
Transparent Bridges

- Bridges learn the location of stations by monitoring source addresses
- Stations do not realize that there is a bridge between them ⇒ Transparent



Transparent Bridges (cont)

- They avoid loops by forming a spanning tree
  ⇒ Spanning tree bridges

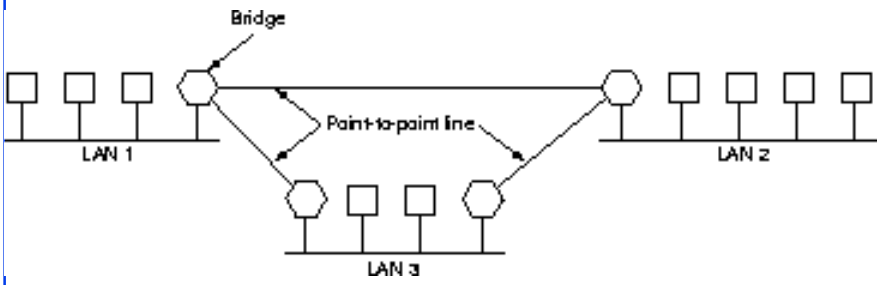


Source Routing Bridges

- Sources specify the route ⇒ list the bridges and the rings that the packet should go through
  L1-B1-L2-B2-L3
- Source find route by flooding the route-discovery packet. All bridges indicate the path in the packet.

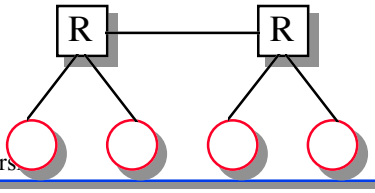
Remote Bridges

- Bridge distant LANs

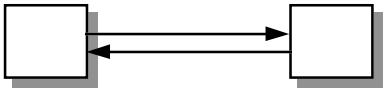


Ethernet vs Fast Ethernet

	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

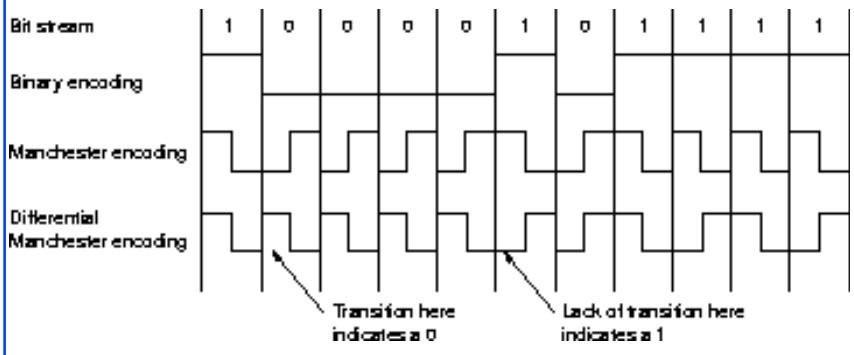


Full-Duplex Ethernet



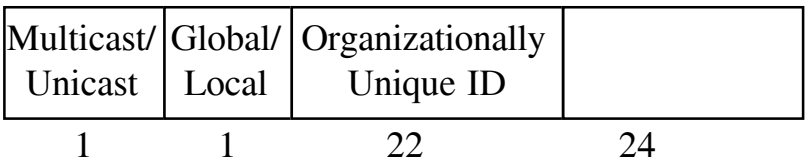
- Uses point-to-point links between TWO nodes
- Full-duplex bi-directional transmission
- Transmit any time
- Not yet standardized in IEEE 802
- Many vendors are shipping switch/bridge/NICs with full duplex
- No collisions ⇒ 50+ Km on fiber.
- Between servers and switches or between switches

Manchester Encoding



- Manchester: 1= down, 0 = up
- Differential Manchester: 0 = Transition, 1=No transition

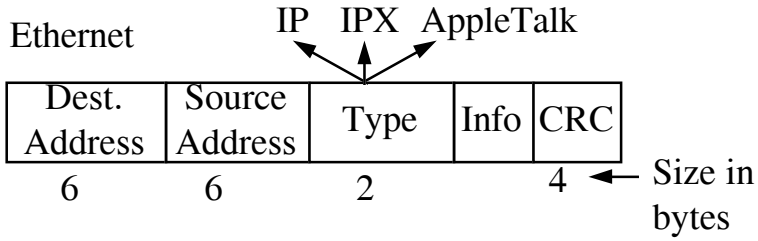
Ethernet Address Format



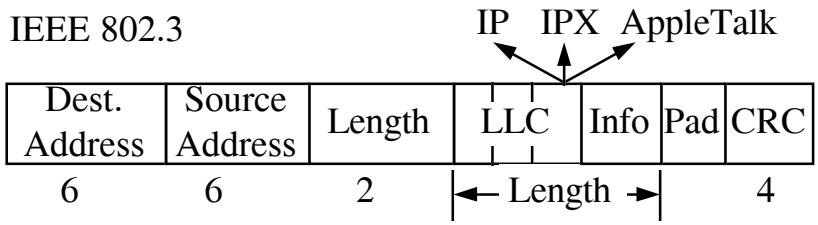
- Multicast = "To all bridges on this LAN"
- Broadcast = "To all stations"
  = 111111....111 = FF:FF:FF:FF:FF:FF

Frame Format

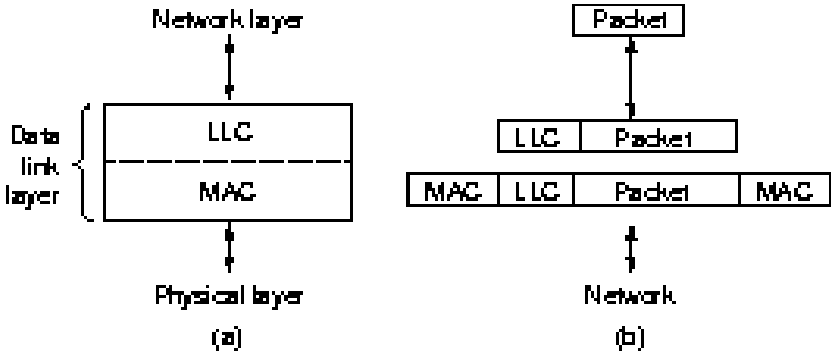
- Ethernet



- IEEE 802.3



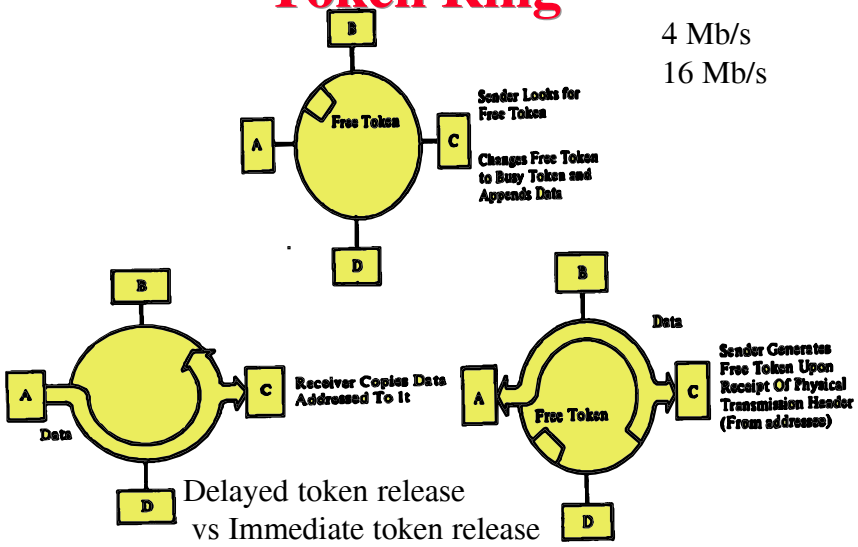
Logical Link Control



- LLC used for all IEEE 802 protocols
- LLC type 1, type 2, type 3, type 4, ...

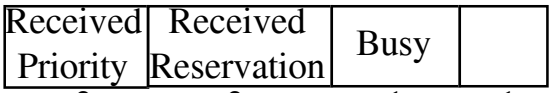
Token Ring

4 Mb/s
16 Mb/s



Delayed token release
vs Immediate token release

Priorities



- 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

Priorities (Cont)

- 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

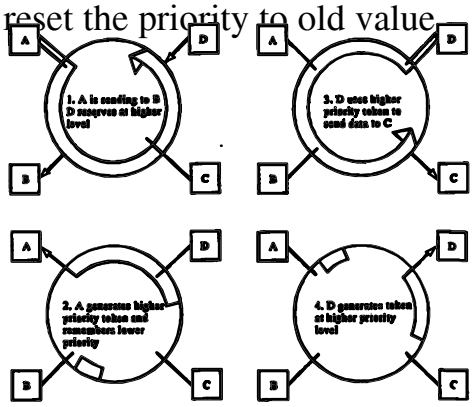


Fig 9.19(1-4)

Priority Stack (continued)

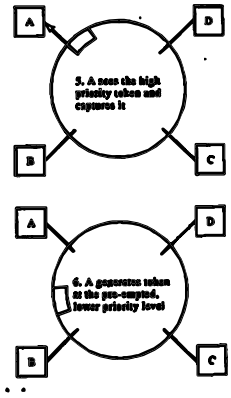


Fig 9.19(5-6)

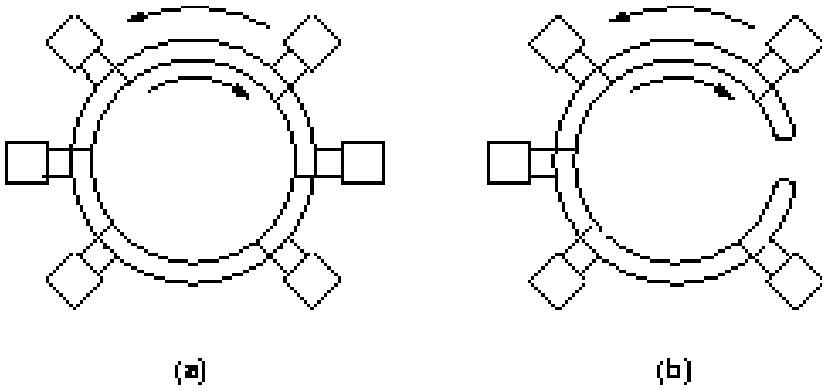
FDDI

- 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.

FDDI (cont)

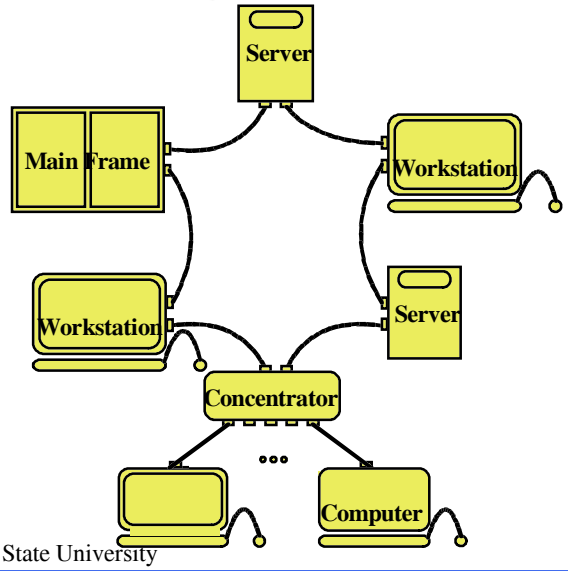
- Maximum frame size is 4500 bytes.
- Eight priority levels
- Synchronous (guaranteed access delay) and asynchronous traffic
- Arranged as single- or dual-ring logical topology

Dual Rings: Wrap



- Counterrotating rings

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

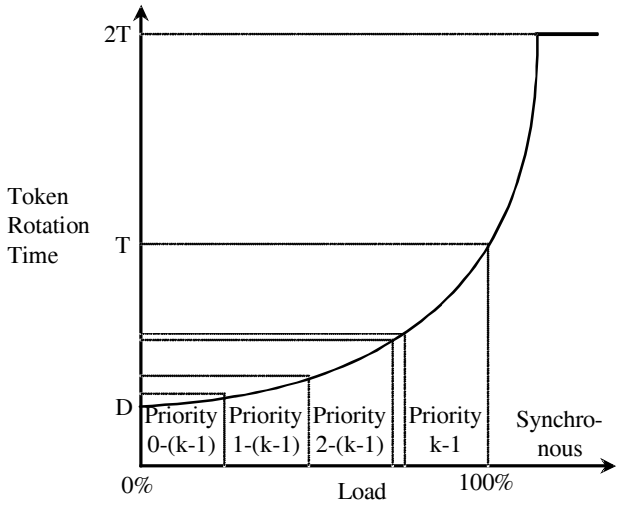
Timed Token Access (Cont)

- If TRT>TTRT, Increment late count (LC)
- Reinitialize the ring if LC = 2
- Synchronous: ith station can transmit SAi (pre-allocated)

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
- High load ⇒ High TRT
  Low load ⇒ Low TRT
- Lower priority traffic allowed only if TRT is low
- Set $TTRT_0 < TTRT_1 < TTRT_2 < ... < TTRT_6$

Priorities



Summary

- Ethernet/IEEE 802.3: CSMA/CD, Baseband, broadband
- Fast Ethernet
- Token ring/IEEE 802.5
- FDDI Timed token access
- LLC
- Transparent and source routing bridges

Homework

- Read sections 4.2.1, 4.2.2, 4.3.1, 4.3.3, 4.3.5, 4.3.6, 4.4, 4.5.1, 4.5.2
- Problems: 1, 3, 4, 5, 6, 18, 21, 22, 26, 28, 30, 32, 41