The Medium Access Sublayer

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Based in part upon the slides of Prof. Raj Jain (OSU), K. Vastola (RPI)

- Multiple Access:
  Aloha, Slotted Aloha, CSMA/CD
- IEEE 802 LANs: Ethernet, Token Ring, LLC
- Bridges: Transparent, Source Routing, Remote
- High Speed LANs: Fast Ethernet

The MAC Layer Problem

- Single communications channel shared by many spatially distributed users who can communicate only through this channel.
- A MAC protocol is a set of rules employed independently by each multi-access user to gain access to the channel (a distributed algorithm)
- Classification:
  - ***Fixed Assignment Protocols:*** TDMA, FDMA, CDMA
  - ***Random Access Protocols:*** Aloha, CSMA, CSMA/CD
  - ***Demand Assignment Protocols:*** Polling, Token Passing

Fixed Assignment Multiaccess Protocols

- Oldest and conceptually simplest approach
- Basic idea: assign each user a fixed portion of channel resources (“spatial multiplexing”)
- Ways to do it:
  - Time: ***Time Division Multiple Access (TDMA)***
    - Divide time into equal-length slots and allocate one slot per-user in turn (round-robin fashion).
    - A TDMA “frame”: set of N slots (one per user)
    - Note: TDMA is “distributed” TDM

Fixed Assignment Multiaccess Protocols

- Frequency/bandwidth: ***FDMA***
  - User gets frequency band and can transmit continuously in that band.
  - Matches need of continuous streams (eg analog video)
  - Bandwidth wasted due to guard bands
  - All-optical networks uses variant: "WDMA"
- Combination of time/frequency: ***CDMA***
  - Code Division Multiple Access
  - Divvy up both time and frequency into a 2-d grid of slots
  - Frequency Hopping CDMA: each user is assigned a different frequency in each time slot

Fixed Assignment: Performance

- Fixed assignment protocols ideal for continuous streams, but bad for data because it exploits only spatial multiplexing.
- With ideal statistical multiplexing ("using channel when packets are waiting"), M/M/1 queueing analysis says that the mean delay:
  - **$E(T) = 1/(\mu-\lambda)$,** where λ is the mean arrival rate and μ is the mean service rate
- With fixed assignment, each channel has service rate μ/N and assuming arrival rates of λ/N, and separate M/M/1 queues, we find:
  - **$E(T) = 1/(\mu/N - \lambda/N) = N/(\mu-\lambda)$**
  - So, use of fixed assignment protocols for packet switched data implies an ***increase in mean delay by a factor of N*** !!

Random Access Protocols

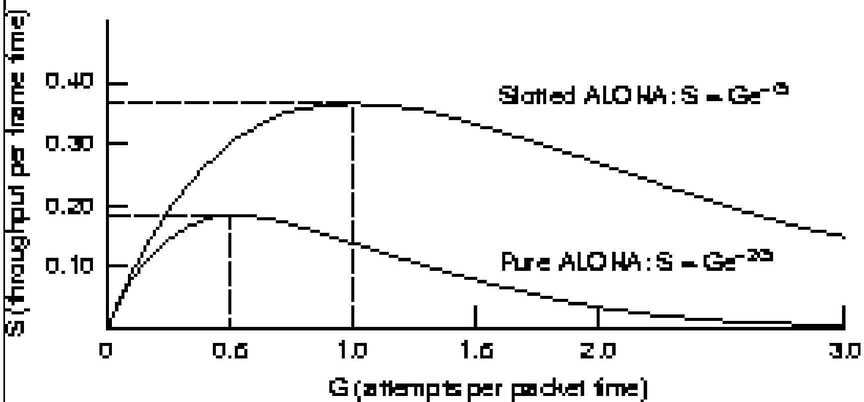
- Fundamentally different approach.
- <u>Aloha</u> at Univ of Hawaii:
  Transmit whenever you like. Random retransmission time.
  Worst case utilization = 1/(2e) =18%
- <u>Slotted Aloha</u>: Fixed size transmission slots
  Worst case utilization = 1/e = 37%

- <u>CSMA</u>: Carrier Sense Multiple Access
  Listen before you transmit
- <u>CSMA/CD:</u> 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}, assuming a *window of vulnerability* of normalized length 2 units = P[no attempts in 2 time units]
- P[0] = success rate/attempt rate = S/G.
- Equating the above two results, we get: **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***

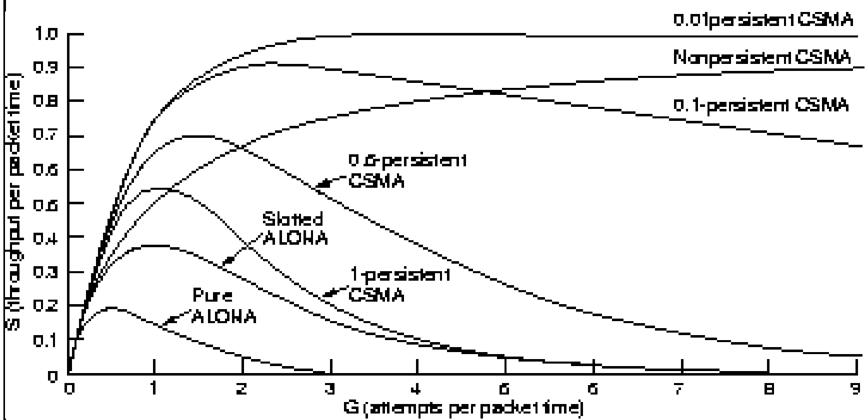
Aloha Performance (cont)



CSMA

- "Sense the carrier" (radio lingo) before transmitting
- <u>1-persistent CSMA:</u> If the channel is idle, transmit
  If the channel is busy, wait until idle and transmit
- <u>0-persistent CSMA</u>: If the channel is busy, go away for a random period of time
- <u>p-persistent CSMA:</u> 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
  - Slot length = propagation delay

CSMA Performance



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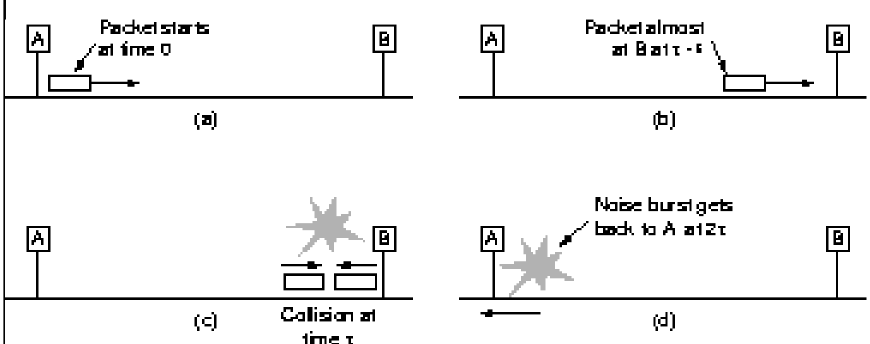
CSMA/CD



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

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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 = $\mathbf{1/(1+2\alpha/A)}$
  Where α = Propagation delay/Frame time
  = (Distance/Speed of signal)/(Frame size/Data rate)
  = (Distance $\times$Data Rate)/(Frame Size $\times$ Signal Speed)
- Efficiency is a decreasing function of α

CSMA/CD Performance

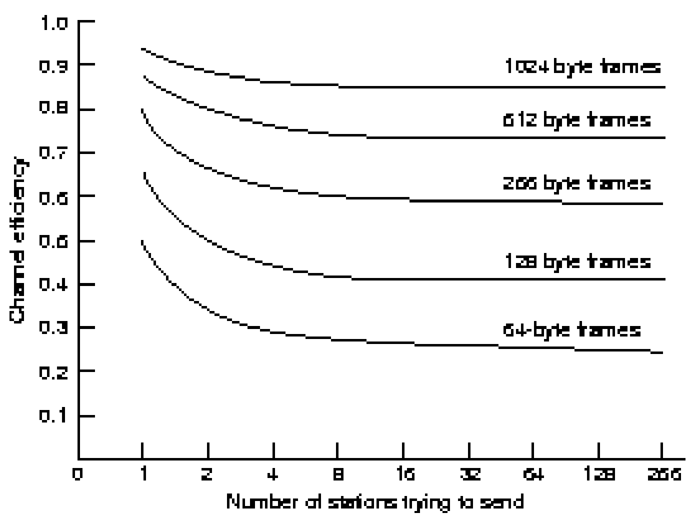


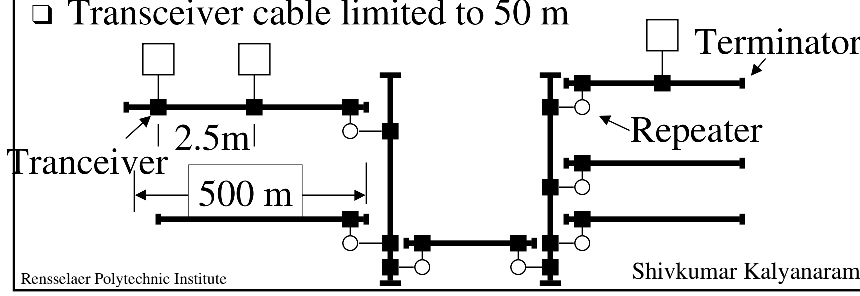
Fig 4-23

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

10Base5 Cabling Rules

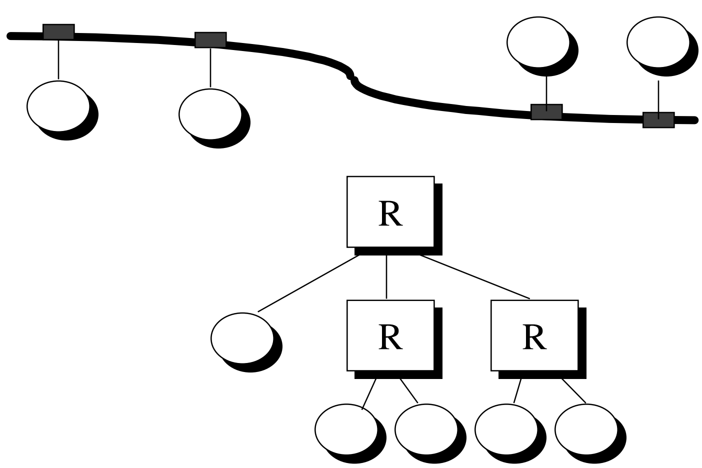
- ❑ Thick coax
- ❑ Length of the cable is limited to 2.5 km, no more than 4 repeaters between stations
- ❑ No more than 500 m per segment ⇒ 10Base5
- ❑ No more than 2.5 m between stations
- ❑ Transceiver cable limited to 50 m



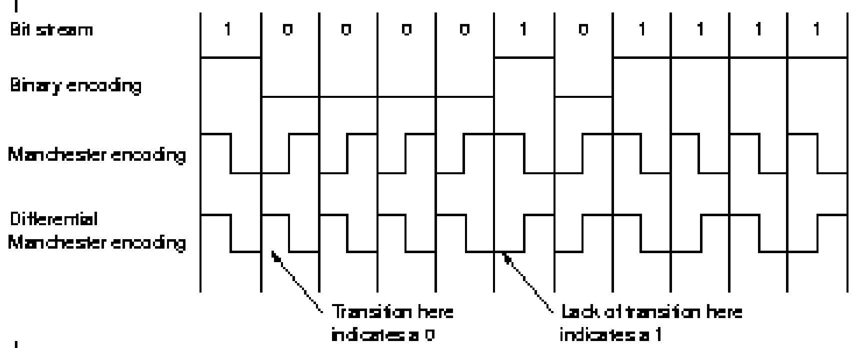
802.3 PHY Standards

- **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)

10BASE5 vs 10BASE-T



Manchester Encoding



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

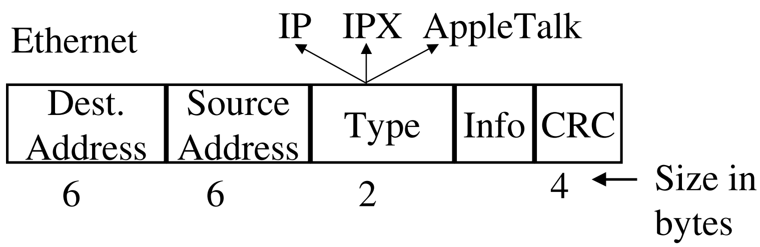
Ethernet Address Format

Multicast/ Unicast	Global/ Local	Organizationally Unique ID	
1	1	22	24

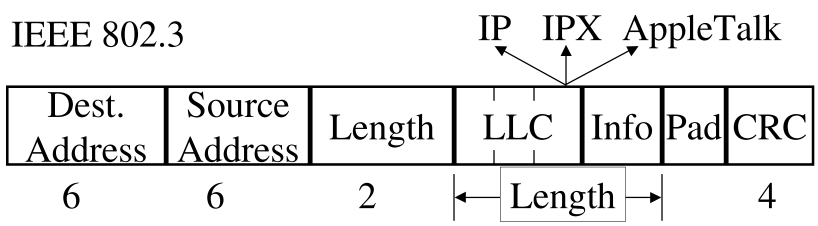
- Multicast = “To all bridges on this LAN”
- Broadcast = “To all stations”
  = 111111....111 = FF:FF:FF:FF:FF:FF

Frame Format

- Ethernet

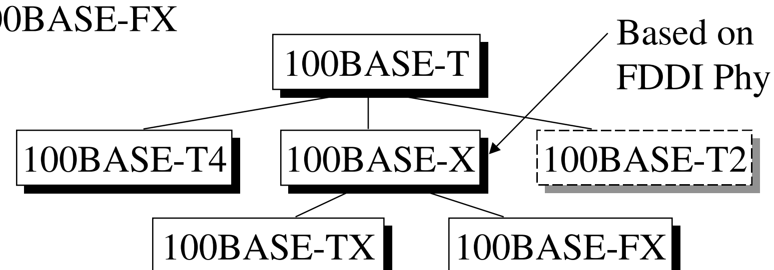


- IEEE 802.3



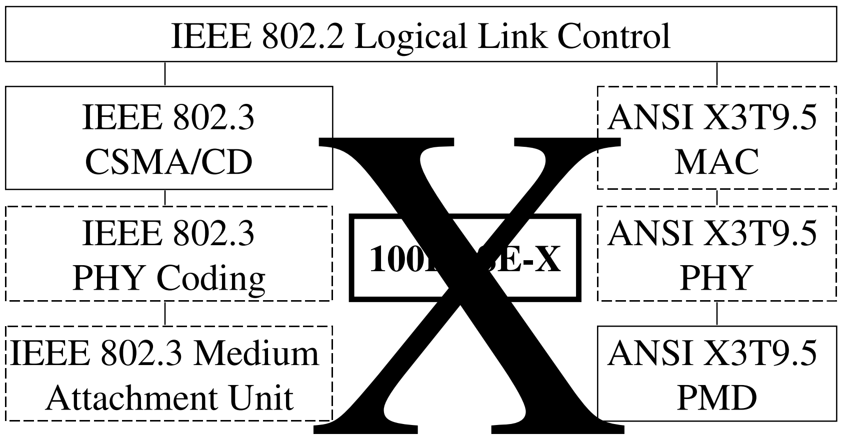
Fast Ethernet Standards

- **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

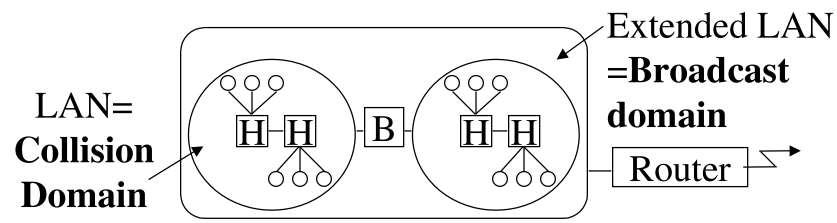


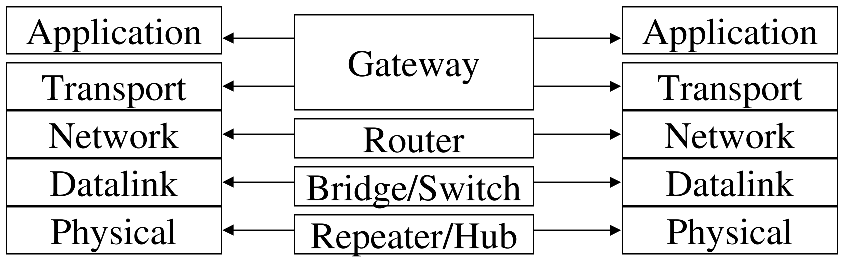
Interconnection Devices

- **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.

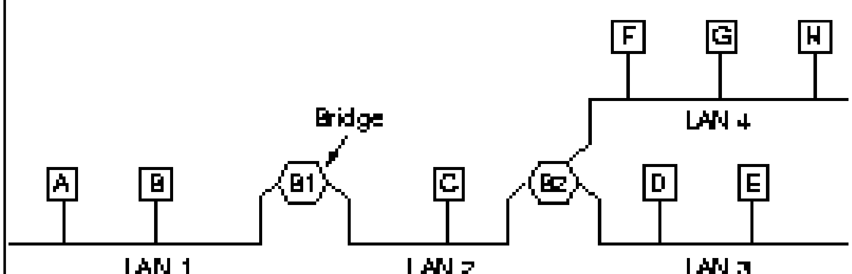
Interconnection Devices





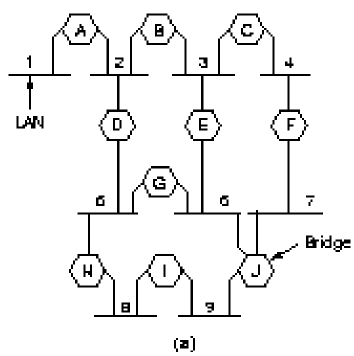
Transparent Bridges

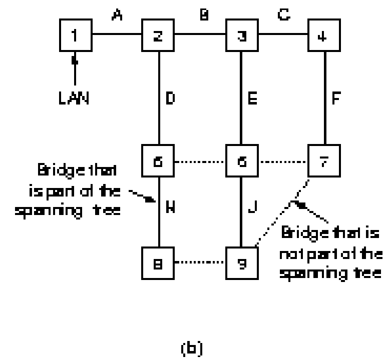
- Bridges learn the location of stations by monitoring source addresses
- Stations do not realize that there is a bridge between them $\Rightarrow$ Transparent



Transparent Bridges (cont)

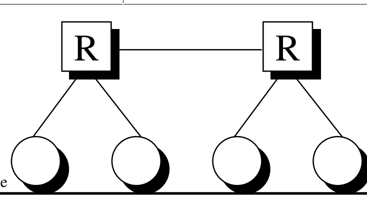
- They avoid loops by forming a spanning tree
  ⇒ Spanning tree bridges



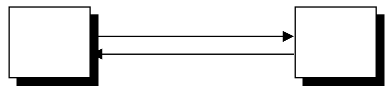


Ethernet vs Fast Ethernet

	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

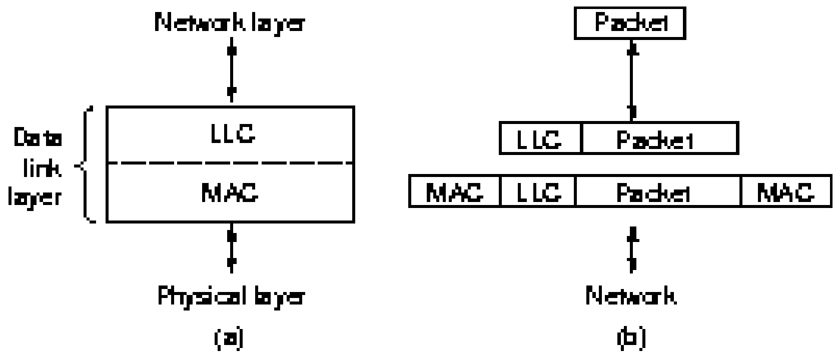


- Uses point-to-point links between TWO nodes
- Full-duplex bi-directional transmission
- Transmit any time
- Not yet standardized in IEEE 802
- Many vendors are shipping switch/bridge/NICs with full duplex
- No collisions $\Rightarrow$ 50+ Km on fiber.
- Between servers and switches or between switches

Gigabit Ethernet

- Uses switched-architecture, not shared => no GbE "hubs"
  - Micro-segmentation => 1 host per-switched segment
- Uses full-duplex Ethernet => no contention => no CSMA/CD !
- Uses multimode and single-mode fiber (though Broadcom recently has developed chips for UTP transmission)
- Only support for the 802.3 frame format, preservation of min/max frame sizes
- Since α larger, some minimal flow control is proposed

Logical Link Control



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

LLC Type 1

- Unacknowledged connectionless (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

LLC Type 2, 3

- Type 2: Acknowledged connection oriented (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

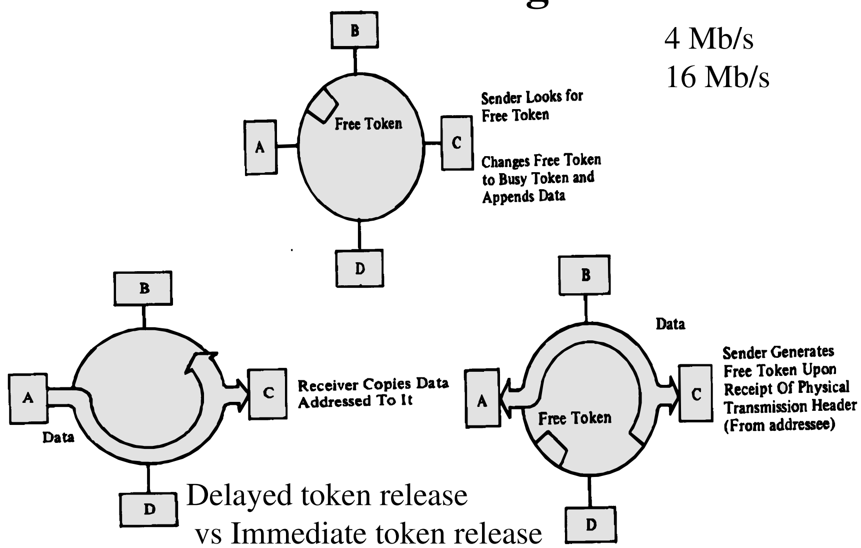
- Multiplexing allows multiple users (network layer protocols) to share a datalink
- Each user is identified by a "service access point (SAP)"

DSAP	SSAP	Control	Info
8	8	8	← Size in bits

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

Token Ring

4 Mb/s
16 Mb/s



Delayed token release
vs Immediate token release

Fig 9.18

Priorities

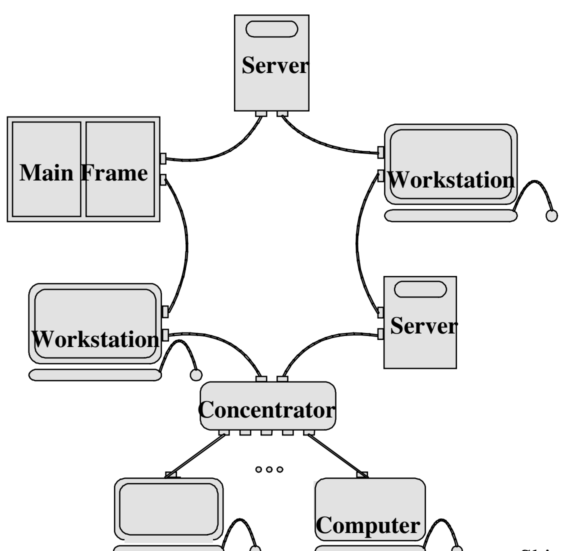
Received Priority	Received Reservation	Busy	
3	3	1	1 ← Size in bits

- 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 $\leq$ 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 ← 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}

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.

Dual-Ring of Trees Topology



Summary

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