Gigabit and Fast Ethernet: use compendium of tricks. However, subject to instrinsic limitations.

- Fast Ethernet (100Base-T) uses various physical layer options including that of FDDI (emulate CSMA/CD)
- 100Base-T uses same frame size
- 100VG-AnyLAN (IEEE 802.12) uses priority scheduling (not CSMA/CD)
- gigabit Ethernets use broadband signalling
- maintaining consistent frame format & backward compatibility is an important factor

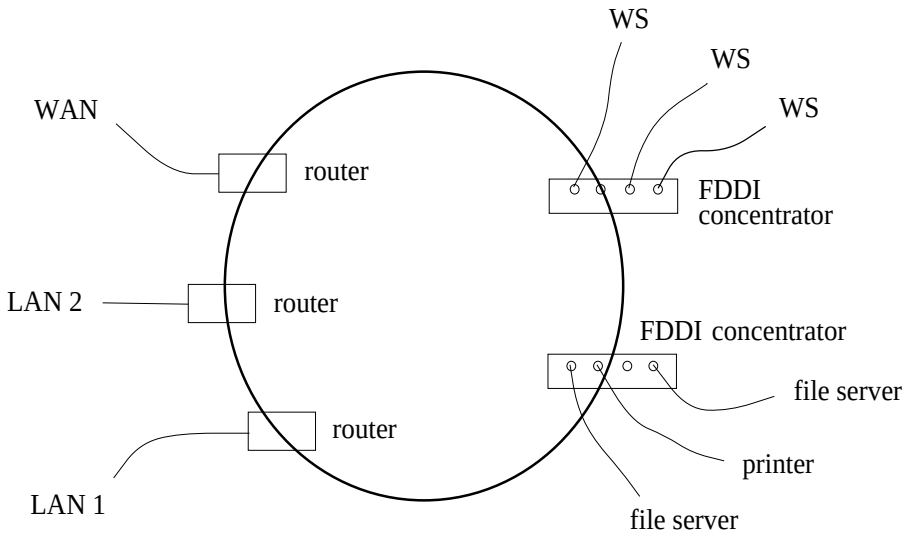
FDDI (Fiber Distributed Data Interface)

$\longrightarrow$ token ring architecture

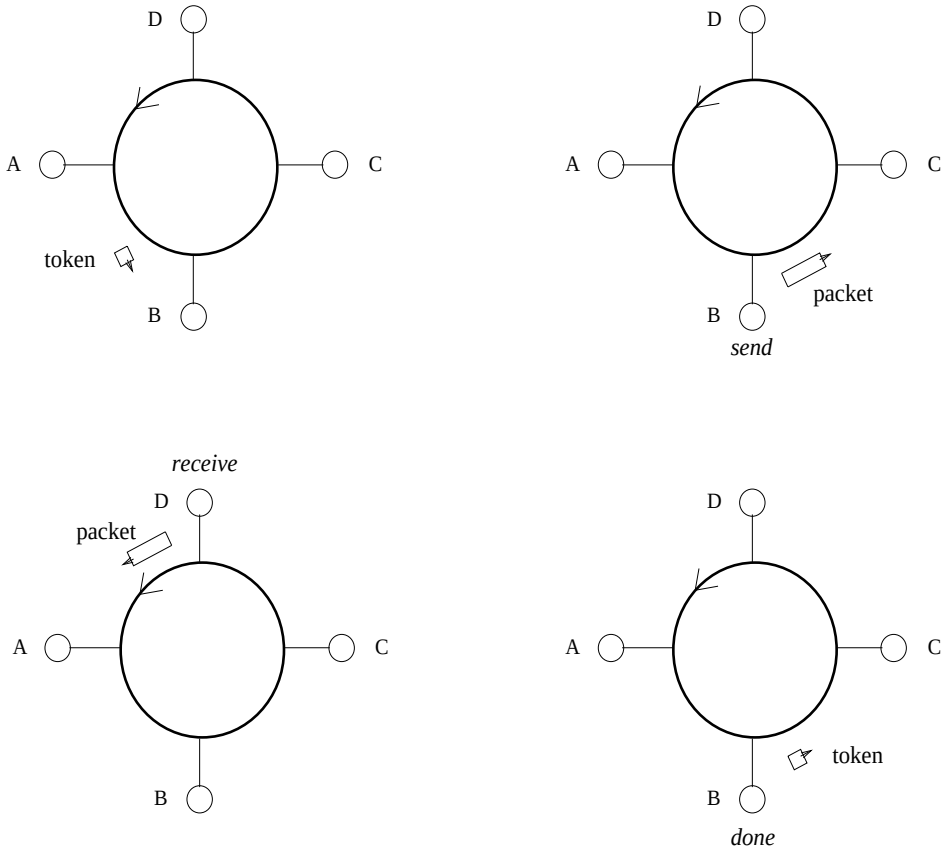
High-bandwidth extension of IBM 4 Mbps token ring and 16 Mbps IEEE 802.5 token ring standard.

$\longrightarrow$ 100 Mbps bandwidth

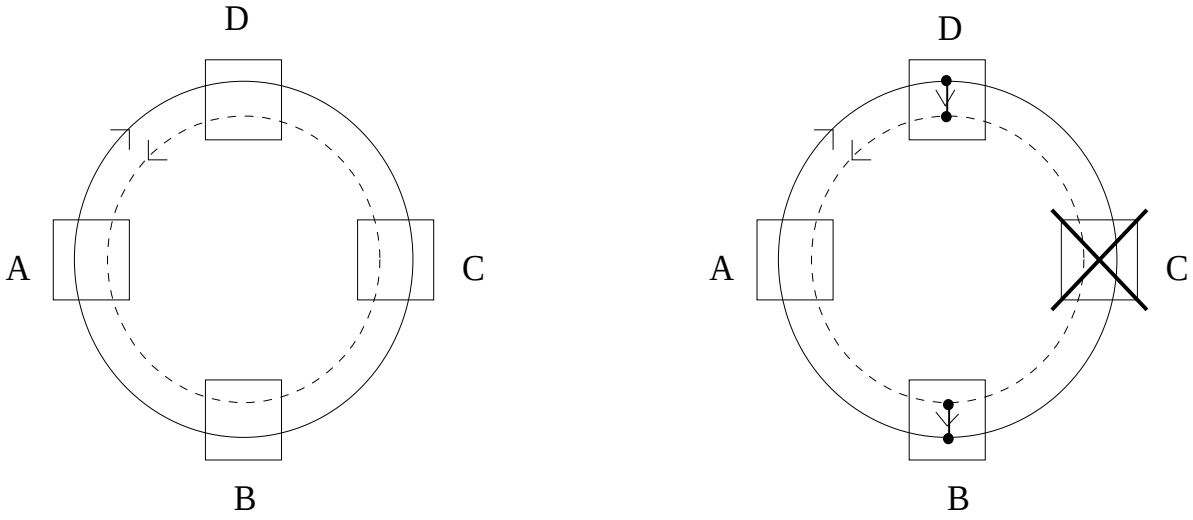
Mostly used as high-bandwidth LAN backbone.



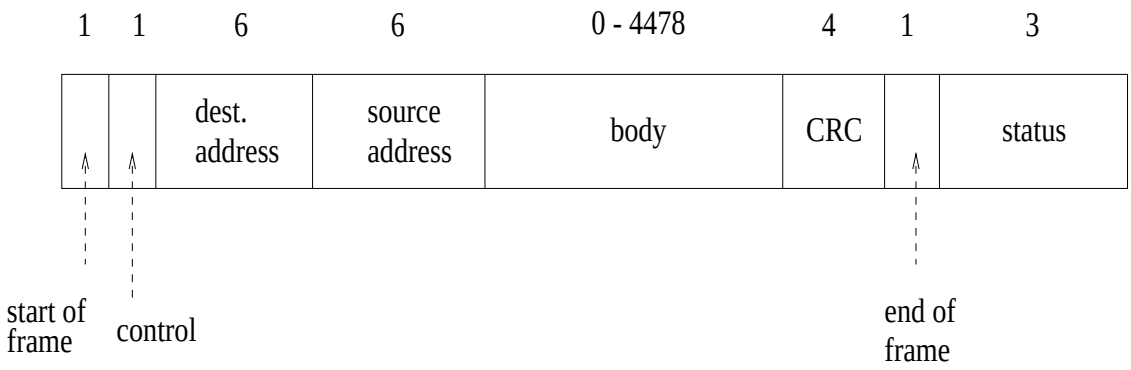
Basic operation:



Fault-tolerance:



- DAS (dual attachment station)
- SAS (single attachment station)



- frame size < 4500 B
- 4B/5B encoding
- ANSI
- supports IEEE 802.2 LLC
- synchronous/asynchronous data
- 2 km inter-station distance
- 200 km diameter (multimode fiber); 100 km circumference

Performance issues: fairness and efficiency

- TRT (token rotation time)
- THT (token holding time)

$$\text{TRT} = \text{no. of nodes} \times \text{THT} + \text{link latency}$$

To increase efficiency: increase THT

$\longrightarrow$ let station send as much as it needs

$\longrightarrow$ $\text{THT} \uparrow \implies \rho \uparrow$

To increase fairness: limit THT

$\longrightarrow$ limit station's one-time sending of data

To facilitate fairness: introduce TTRT (target token rotation time).

THT determining factor (assume TTRT is given):

- If TRT $>$ TTRT, then late; don't send asynchronous data.
- If TRT $\leq$ TTRT, then early; send asynchronous data for max { TTRT $-$ TRT, single frame time } duration.
- Synchronous frames get always sent.

How to set TTRT?

$\longrightarrow$ token claim process

$\longrightarrow$ initiate when needed (e.g., start-up)

- Each station submits *claim frame* containing TTRT *bid*.
- Smaller TTRT bid overrides higher TTRT bids.
  - Compare claim frame bid against own desired TTRT.
  - If less, then reset own TTRT to lower value.
  - If larger, then put lower bid on claim frame and forward.
- Winner: same bid value when claim frame makes full circle.

At the end of the day, consistent TTRT value among all stations.

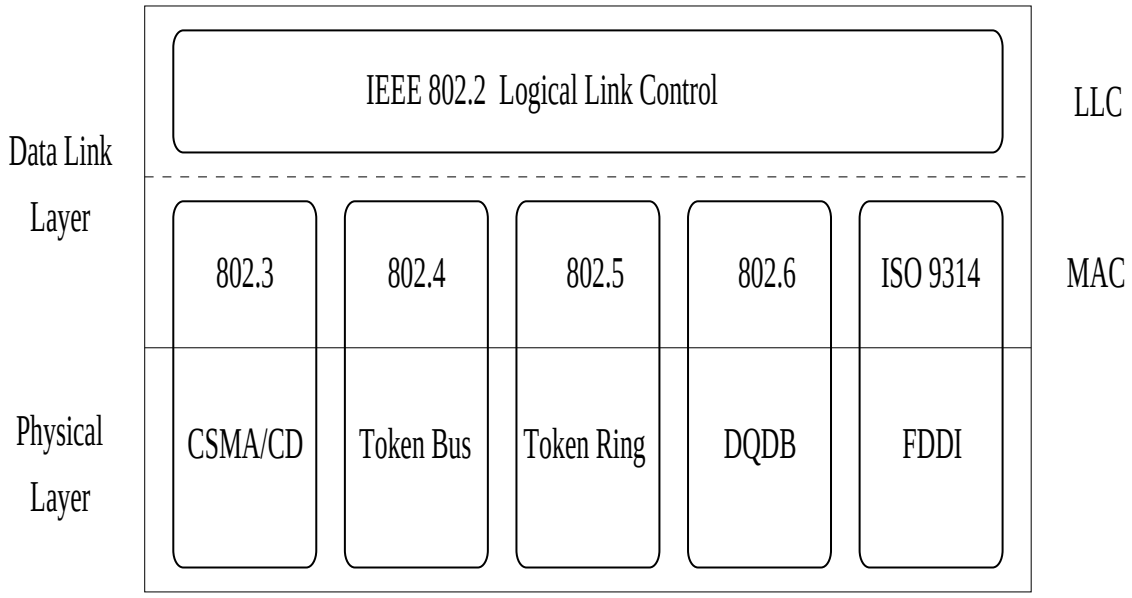
$\longrightarrow$ consensus problem

Last problem: When to reinsert token after sending data frame?

- immediate release (FDDI)
- delayed release (IEEE 802.5 token ring); problem of bit time and draining

So far, we have looked at architecture (hardware) and algorithms of direct-link media, i.e., data link layer.

Protocol specification of data link layer:



Logical link control: Isolation of common generic mechanisms including reliability and flow control.

$\longrightarrow$ similar to HDLC (point-to-point)

Medium access control: random access, deterministic access.

Lessons to be drawn:

- Although theory of direct-link communication exists, oftentimes, implementation is arbitrary and technology dependent (e.g., dual ring of FDDI, baseband/broadband & switched Ethernet).
- Emphasis on ease of standardization, implementation, and cost over efficiency.
- Efficiency pressure is a recent phenomenon. Integrated performance measure (QoS) has become important.
- Industry trend: increase bandwidth more and more; problematic fix to the problem.
- Computer networking tendency: shift away from data link issues (e.g., ATM over TCP/IP).