Ethernet MAC: CSMA/CD

- *CS (Carrier Sense)*: Can detect if some other node is using the link

  → rule: if so, abstein

- *MA (Multiple Access)*: Multiple nodes are allowed simultaneous access

  → rule: if channel seems silent, send

- *CD (Collision Detection)*: Can detect if simultaneous access has occured

  → rule: if collision, retry later

Wired vs. wireless media:

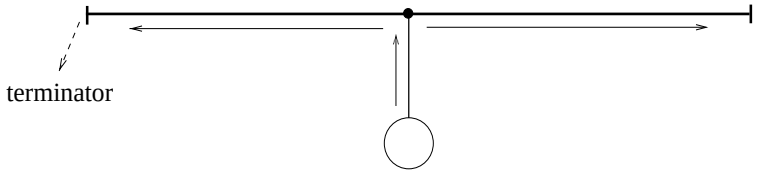
⟶ CD is a key difference

⟶ diffcult to detect collision while transmitting

Signal propagation and collision:

Bi-directional propagation

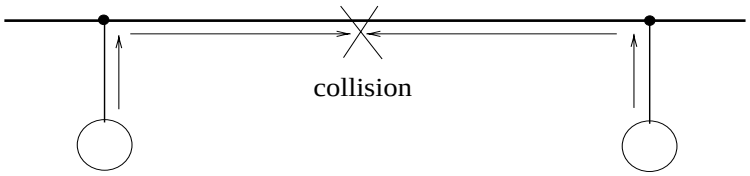
$\longrightarrow$ terminator absorbs signal: prevent bounce back



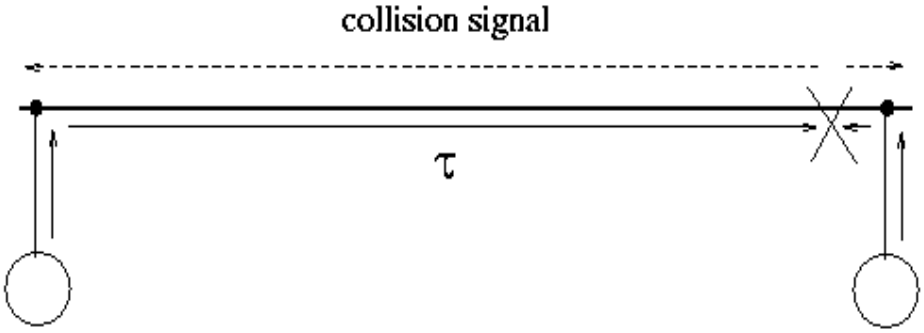
Best-case collision

$\longrightarrow$ meet in the middle

$\longrightarrow$ worst-case?



Worst-case collision scenario:



- sender needs to wait 2τ sec before detecting collision
- for 2500 m length, 51.2 μs round-trip time (2τ)
- enforce 51.2 μs slot time
- at 10 Mbps, 512 bits; i.e., minimum frame size

  $\rightarrow$ assures collision detection

Hence, upon detecting collision:

$\therefore$ make sure to transmit at least 512 bits

$\longrightarrow$ $2 \times$ delay-bandwidth product

$\longrightarrow$ $6 + 6 + 2 + 46 + 4 = 64$ B $= 512$ bits

When to retry: exponential backoff

1. Wait for $0 \leq X \leq 51.2$ μs before first retry
2. On i'th collision, wait for $0 \leq X \leq 2^{i-1}\, 51.2$ μs before next attempt
3. Give up if $i > 16$

$\longrightarrow$ a form of stop-and-wait (what's the ACK?)

$\longrightarrow$ pretty drastic backoff: is it necessary?

CSMA/CD Throughput

$\longrightarrow$ optimistic: best case scenario

Set-up:

- frame size F
- length of wire L
- bandwidth B
- slot time 2τ

  $\rightarrow \tau = L/\text{SOL}$

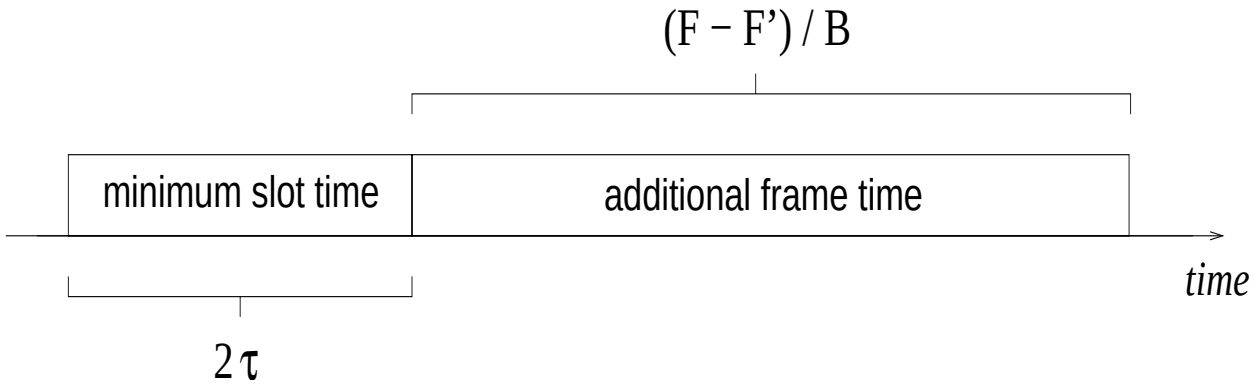
Facts:

- bits sent during 2τ

  $\rightarrow F' = 2\tau B$
- if $F' \geq F$ then done, else send $F - F'$ more bits

  $\rightarrow$ frame time: time elapsed to send frame

Snapshot over time:



Throughput (bits-over-time):

$$\text{throughput} = \frac{F}{2\tau + (F - F')/B}$$

Further calculation yields:

$$= \frac{F}{2L/\text{SOL} + (F - F')/B}$$

$$= \frac{1}{2L/(\text{SOL}\,F) + (F - F')/(BF)}$$

Given

$$\text{throughput} = \frac{1}{2L/(\text{SOL}\,F) + (F - F')/(BF)}$$

how do system design parameters L, F, and B influence throughput?

- If $L \uparrow$ then throughput $\downarrow$
- What about B and F?

Is the above scenario realistic?

$\longrightarrow$ ignored impact of collision under many users

Shape of throughput as a function of number of users is unimodal

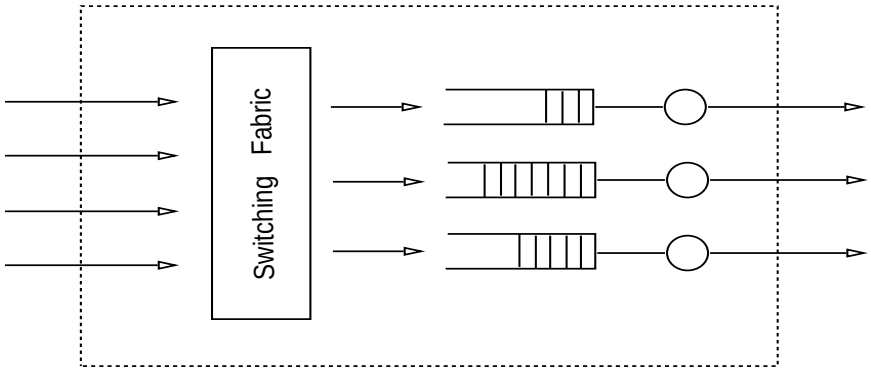
$\longrightarrow$ kind of "dome" shaped

In practice today (Feb. 19, 2004): switched Ethernet

- contention moved from bus to switch
- CSMA/CD is still there but secondary

  → for backward compatibility

Output-buffered switch:



- only NICs speak CSMA/CD
- transfer of Ethernet frames between NICs

  → switched
- when buffer overflow, same as "collision"

Most popular: FastEthernet (100 Mbps), 10Base-T (10 Mbps), Gigabit Ethernet

- FastEthernet (100Base-T) is switched

  → 100Base-T uses same frame size as 10Base-T

- Gigabit Ethernets use broadband signalling

  → good old baseband Manchester is gone

  → backward compatible frame format

- 100VG-AnyLAN (IEEE 802.12) uses priority scheduling (not CSMA/CD)

Gigabit Ethernet: popular backbone technology (e.g., Purdue Univ.)

To the desktop: FastEthernet

⟶ how fast can a PC send/receive?

FDDI (Fiber Distributed Data Interface)

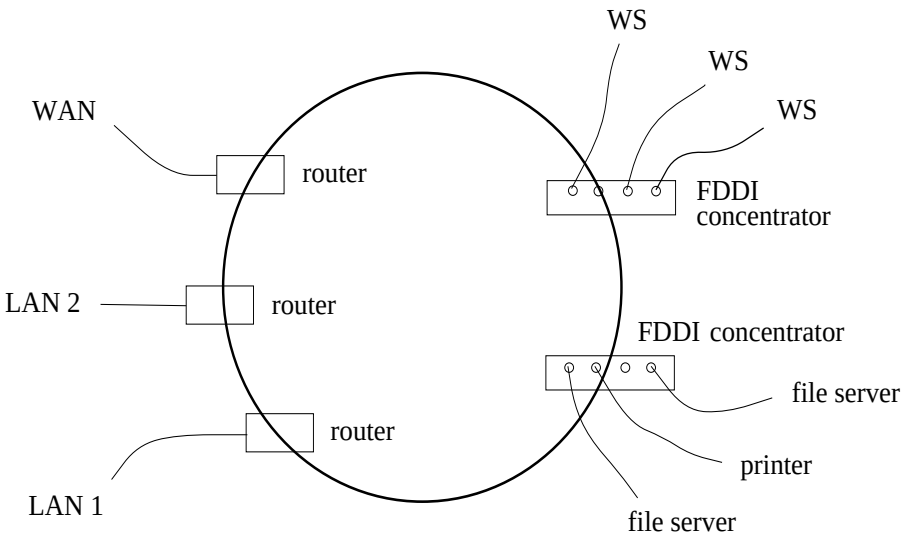
$\longrightarrow$ fiber-based token ring architecture

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

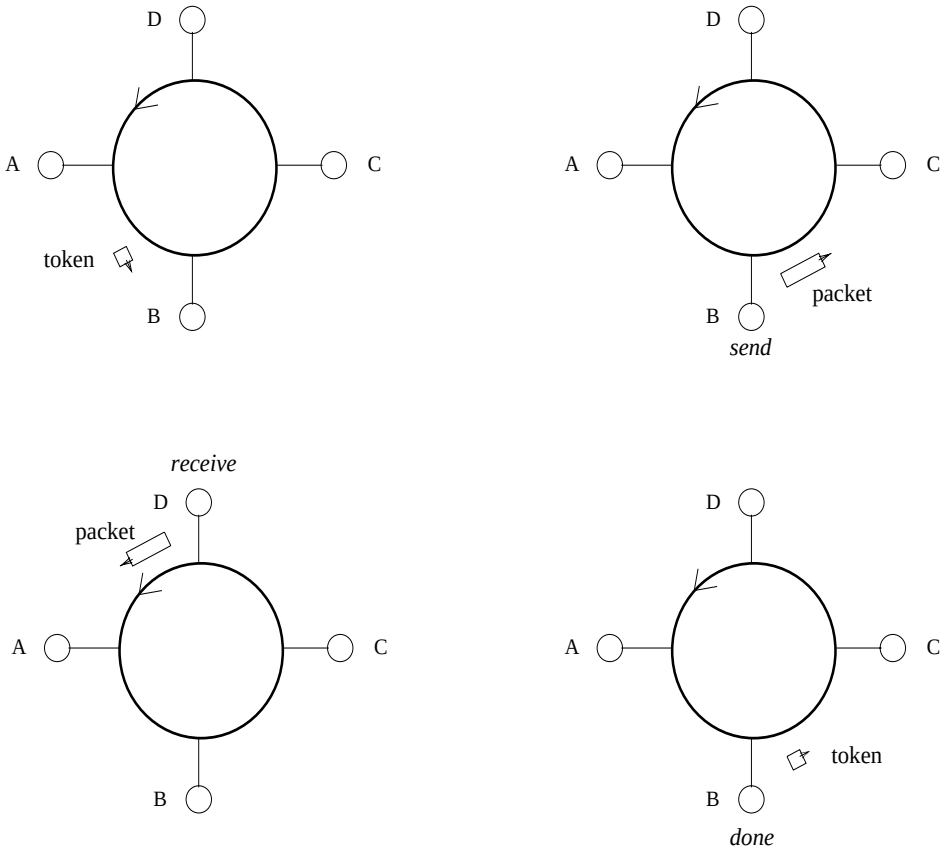
$\longrightarrow$ 100 Mbps bandwidth

Mostly used as high-bandwidth LAN backbone.

$\longrightarrow$ metropolitan/campus distance: MAN



Basic operation: B wishes to send to send to D



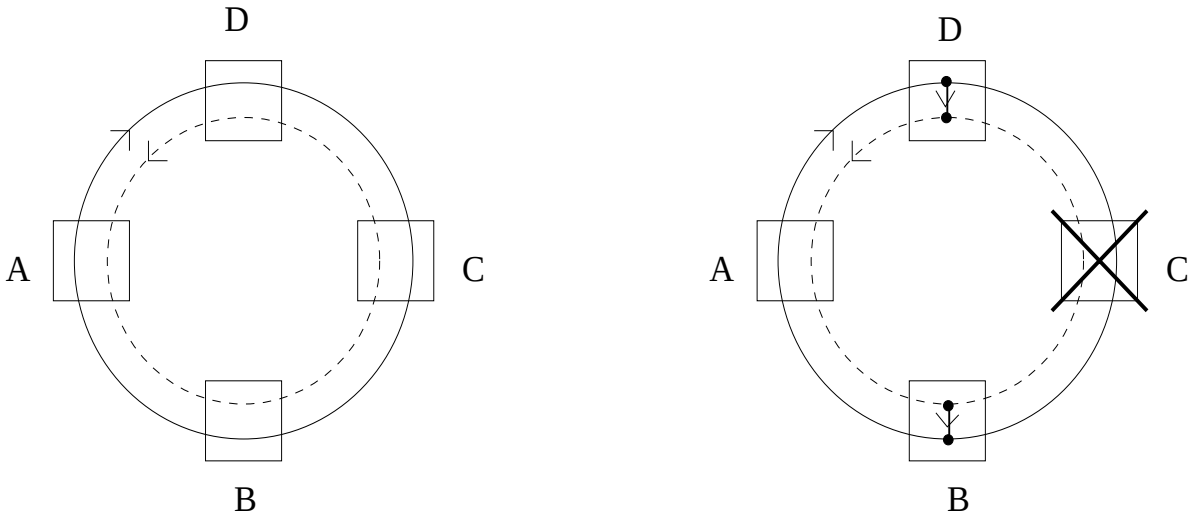
- wait for token
- grab token; send data
- wait for ACK; release token

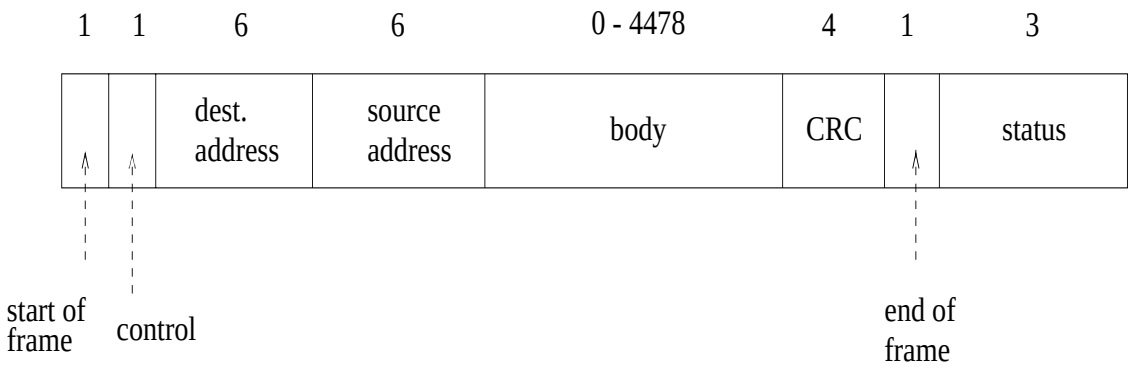
Fault-tolerance:

$\longrightarrow$ note: ring breaks down under single failure

$\longrightarrow$ two half duplex channels in opposite direction

$\longrightarrow$ 2-fold redundancy





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

Compare against Ethernet's CSMA/CD.

- $\longrightarrow$ round-robin reservation
- $\longrightarrow$ absence of MA and collision
- $\longrightarrow$ determinism vs. indeterminism
- $\longrightarrow$ imperfect QoS assurance
- $\longrightarrow$ performance vis-à-vis CSMA/CD?

Cooperative vs. noncooperative protocols

- $\longrightarrow$ robust if some users use selfish MAC?
- $\longrightarrow$ could be malicious: disruption is goal