Ethernet MAC: CSMA/CD

- **CS (Carrier Sense):** Can detect if some other node is using the link
  - → rule: if so, abstain
- **MA (Multiple Access):** Multiple nodes are allowed simultaneous access
  - → rule: if channel seems silent, send
- **CD (Collision Detection):** Can detect if simultaneous access has occurred
  - → rule: if collision, retry later

Wired vs. wireless media:

- → CD is a key difference
- → difficult to detect collision while transmitting
Signal propagation and collision:

Bi-directional propagation

\[ \rightarrow \quad \text{terminator absorbs signal: prevent bounce back} \]

Best-case collision

\[ \rightarrow \quad \text{meet in the middle} \]

\[ \rightarrow \quad \text{worst-case?} \]
Worst-case collision scenario:

- sender needs to wait $2\tau$ sec before detecting collision
- for 2500 m length, 51.2 $\mu$s round-trip time ($2\tau$)
- enforce 51.2 $\mu$s slot time
- at 10 Mbps, 512 bits; i.e., minimum frame size
  $\rightarrow$ assures collision detection
Hence, upon detecting collision:

\[ \therefore \text{make sure to transmit at least 512 bits} \]

\[ \rightarrow 2 \times \text{delay-bandwidth product} \]

\[ \rightarrow 6 + 6 + 2 + 46 + 4 = 64 \text{ B} = 512 \text{ bits} \]

When to retry: exponential backoff

1. Wait for \( 0 \leq X \leq 51.2 \mu s \) before first retry

2. On \( i \)'th collision, wait for \( 0 \leq X \leq 2^{i-1} 51.2 \mu s \) before next attempt

3. Give up if \( i > 16 \)

\[ \rightarrow \text{a form of stop-and-wait (what's the ACK?)} \]

\[ \rightarrow \text{pretty drastic backoff: is it necessary?} \]
CSMA/CD Throughput

→ optimistic: best case scenario

Set-up:
- frame size $F$
- length of wire $L$
- bandwidth $B$
- slot time $2\tau$

$\rightarrow \tau = \frac{L}{SOL}$

Facts:
- bits sent during $2\tau$

$\rightarrow F' = 2\tau B$

- if $F' \geq F$ then done, else send $F - F'$ more bits

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

\[
\frac{(F - F')}{B}
\]

Throughput (bits-over-time):

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

Further calculation yields:

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

\[
= \frac{1}{2L/(\text{SOL} F) + \frac{(F - F')}{(BF)}}
\]
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?

\[\rightarrow \text{ ignored impact of collision under many users} \]

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

\[\rightarrow \text{ kind of “dome” shaped} \]
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
  \[\rightarrow\text{ 100Base-T uses same frame size as 10Base-T}\]
- Gigabit Ethernets use broadband signalling
  \[\rightarrow\text{ good old baseband Manchester is gone}\]
  \[\rightarrow\text{ backward compatible frame format}\]
- 100VG-AnyLAN (IEEE 802.12) uses priority scheduling (not CSMA/CD)

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

To the desktop: FastEthernet

\[\rightarrow\text{ how fast can a PC send/receive?}\]
FDDI (Fiber Distributed Data Interface)

→ fiber-based token ring architecture

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

→ 100 Mbps bandwidth

Mostly used as high-bandwidth LAN backbone.

→ metropolitan/campus distance: MAN
Basic operation: $B$ wishes to send to $D$

- wait for token
- grab token; send data
- wait for ACK; release token
Fault-tolerance:

→ note: ring breaks down under single failure
→ two half duplex channels in opposite direction
→ 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.

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

Cooperative vs. noncooperative protocols

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