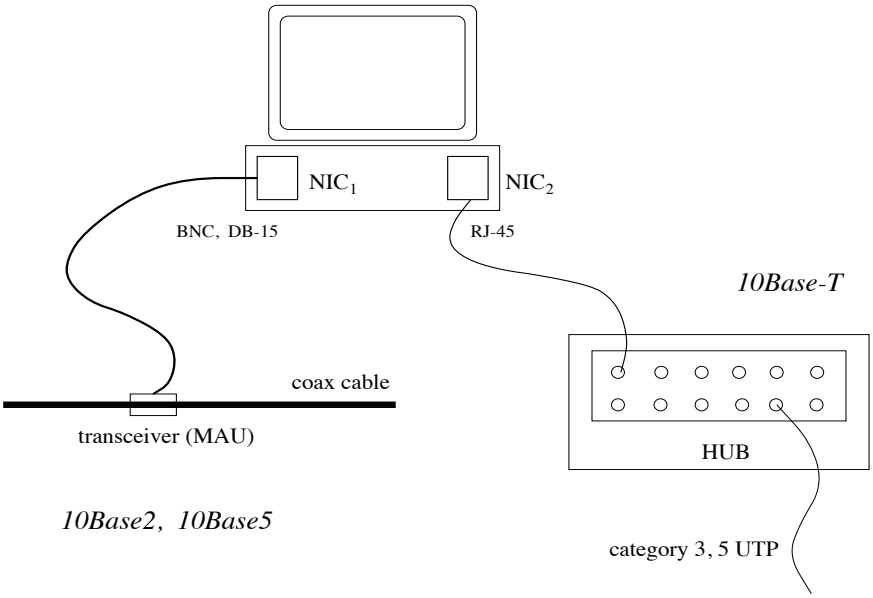
Ethernet

$\longrightarrow$ copper, fiber

Types (some just historical):

- 10Base2 (ThinNet): coax, segment length 200 m, 30 nodes/segment
- 10Base5 (ThickNet): coax, segment length 500 m, 100 nodes/segment
- 10Base-T: twisted pair, segment length 100 m, 1024 nodes/segment
- 100Base-T (Fast Ethernet): category 5 UTP, fiber (also 100VG-AnyLAN)
- Gigabit & 10 Gbps Ethernet: fiber, category 5 UTP
- 100 Gbps Ethernet

Connectivity example (stone age):



- single-homed vs. multi-homed
- unique 48-bit Ethernet address per NIC
- physical network: bus vs. hub vs. switch

  → very old vs. old vs. not-so-old

  → today: switched Ethernet

High-speed Ethernets have shorter network diameter

- 2500 m for 10 Mbps Ethernet
- 200 m for 100 Mbps Ethernet
- even shorter for 1 Gbps Ethernet

  $\rightarrow$ unless fully switched (later discussion)

  $\longrightarrow$ distance limitations: due to Ethernet protocol

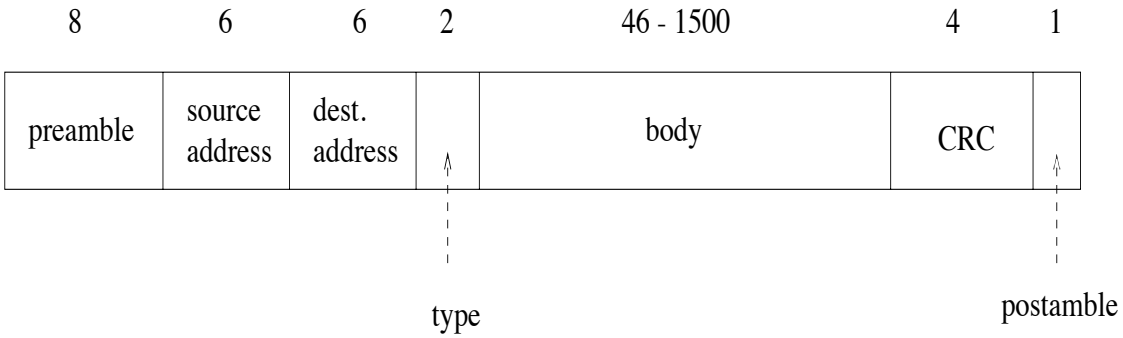
  $\longrightarrow$ creates complications for long-haul

  $\longrightarrow$ e.g., tens, hundreds, or thousands of miles

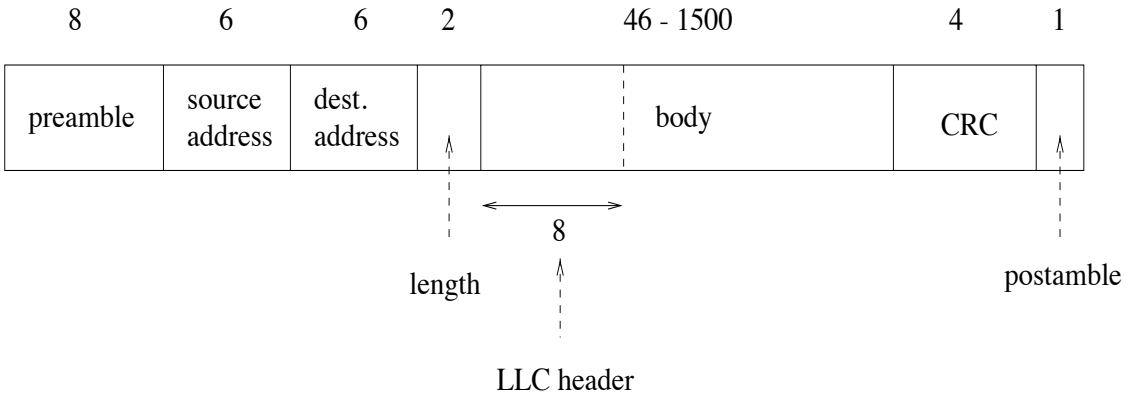
  $\longrightarrow$ 1, 10, 100 Gbps: tier-1 backbone speeds

  $\longrightarrow$ also multiples of 1 and 10 Gbps

DIX Ethernet frame:



IEEE 802.3 Ethernet frame:



$\longrightarrow$ IEEE 802.2 LLC (Logical Link Control)

$\longrightarrow$ two Ethernet types co-exist ~~(802.3 dominant)~~

Ethernet MAC protocol: CSMA/CD

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

  → just send

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

  → rule: if busy, wait until channel is not busy

  → works well in small areas: why?

- CD (Collision Detection): can detect if collision due to concurrent transmission has occured

  → rule: if collision, retry later

  → key question: when is later?

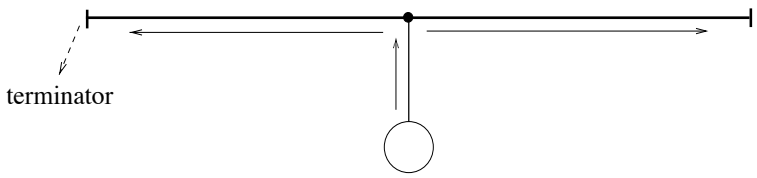
  → collision detection: more difficult in wireless environments

Collision detection mechanism:

Bi-directional signal propagation

$\rightarrow$ terminator absorbs signal: prevent bounce back

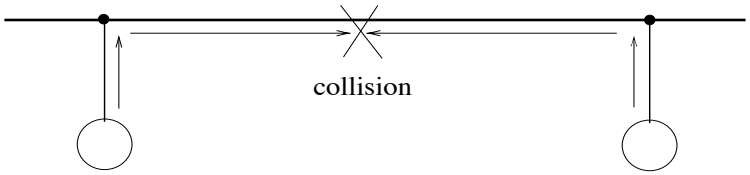
$\rightarrow$ can hear different signal from one transmitted



Collision: 2 stations

→ while transmitting data frame, hears collided signal

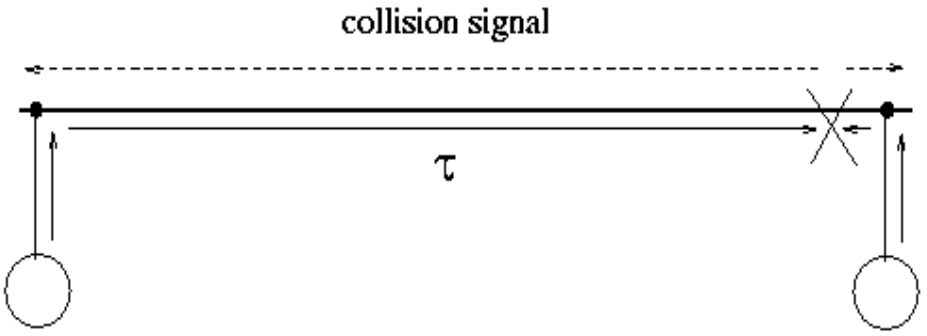
→ data frame cannot be too small



→ meet in the middle: best-case

→ why?

Worst-case collision scenario:



$\longrightarrow$ τ: one-way propagation delay

- sender needs to wait 2τ sec before detecting collision

  $\rightarrow$ time for echo to bounce back
- for 2500 m length, 51.2 μs round-trip time (2τ)
- enforce 51.2 μs slot time
- at 10 Mbps, 512 bits: minimum frame size

  $\rightarrow$ assures collision detection

  $\rightarrow$ wireless collision detection: why more difficult?

Transmit at least 512 bits

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

When to retry upon collision: use exponential backoff

1. Wait for random $0 \leq X \leq 51.2$ μs before 1st retry
2. Two consecutive collisions: wait for random $0 \leq X \leq 102.4$ μs before 2nd retry
3. Three consecutive collisions: wait for random $0 \leq X \leq 204.8$ μs before 3rd retry

2. i consecutive collisions: wait for $0 \leq X \leq 2^{i-1}\,51.2$ μs before next attempt

3. Give up if $i > 16$

$\rightarrow$ a form of stop-and-wait

$\rightarrow$ what's the ACK?

$\rightarrow$ guaranteed reliability?

$\rightarrow$ why exponential backoff?

Today: switched Ethernet

- not bus anymore but switch

  → contention moved from bus to "single point"

  → switch: a computer

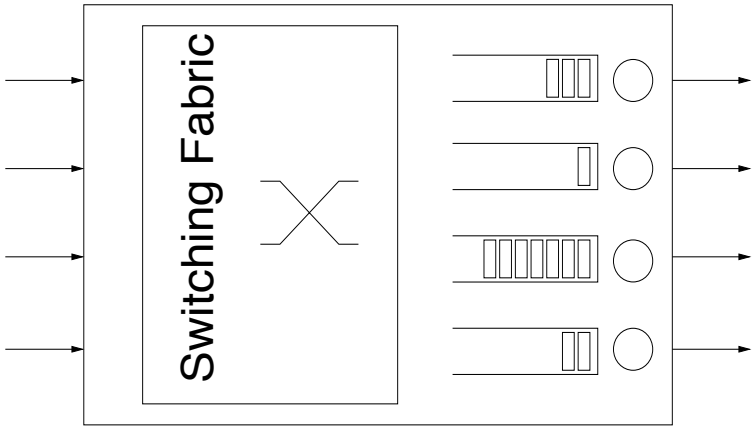
- Ethernet frames are logically scheduled

  → buffering, who goes first (FIFO, priority)

- no more physical collision

  → instead: buffer overflow

Diagram of 4-port switch:



→ output buffered switch

→ switches: both input and output buffers

→ switching fabric: hardware

→ functions: pure hardware, firmware, processes in OS

→ e.g., Cisco's router OS: IOS (Internet OS)

Note: a switch has nothing to do with CSMA/CD

→ it's not a shared bus medium with physical collisions

→ what does "switched" Ethernet mean?

Issue of backward compatibility:

- Ethernet switch emulates CSMA/CD

  → interoperate with legacy systems

  → host's CSMA/CD NIC card cannot tell difference

  → as if connected to a bus

- upon buffer overflow: send collision signal

  → switch emulates collision

  → transparent to legacy NIC

  → facilitates incremental deployment

Internet: new technology must respect legacy

→ otherwise deployment is difficult

→ key requirement of any practical solution

Long distance Ethernet: e.g., 1000Base-LX

$\longrightarrow$ what about length limit of CSMA/CD?

Medium-haul GigE/10GigE (802.3ae): 500m, 5km, 40km

- solution: disable CSMA/CD

  $\rightarrow$ switch-to-switch: disable at both ends

  $\rightarrow$ purely point-to-point link

  $\rightarrow$ backward compatibility: not an issue anymore

- flow control

  $\rightarrow$ send pause frame to prevent buffer overflow

QoS: IEEE 802.3p

$\longrightarrow$ frame tagging conveys priority

$\longrightarrow$ priority classes supported at switches

$\longrightarrow$ useful for VoIP (voice-over-IP)

Note: today's Ethernet is a hybrid mix of switch, CSMA/CD, short- and long-distance LAN

$\longrightarrow$ would not have been designed this way

$\longrightarrow$ result of legacy-respecting incremental changes