

Ethernet



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Types of Multiple Access Protocols

Three broad classes:

- **Channel partitioning**
 - divide channel into smaller "pieces" (time slots, frequency, code)
 - allocate piece to node for exclusive use
- **Random access**
 - channel not divided, allow collisions
 - "recover" from collisions
- **Centrally controlled/coordinated**
 - tightly coordinate shared access to avoid collisions



Examples of MAC protocols

- Channel partitioning
 - Time Division, Frequency Division, Code Division
- Random access
 - ALOHA, S-ALOHA, CSMA, CSMA/CD
 - CSMA/CD used in Ethernet
- Centrally controlled
 - polling from a central site
 - controlled by a token

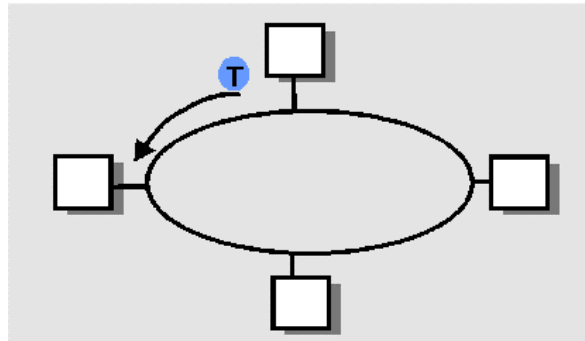
"Centrally Controlled" MAC protocols

Polling:

- master node "invites" slave nodes to transmit in turn
- concerns:
 - polling overhead (bandwidth & latency)
 - single point of failure (master)

Token passing:

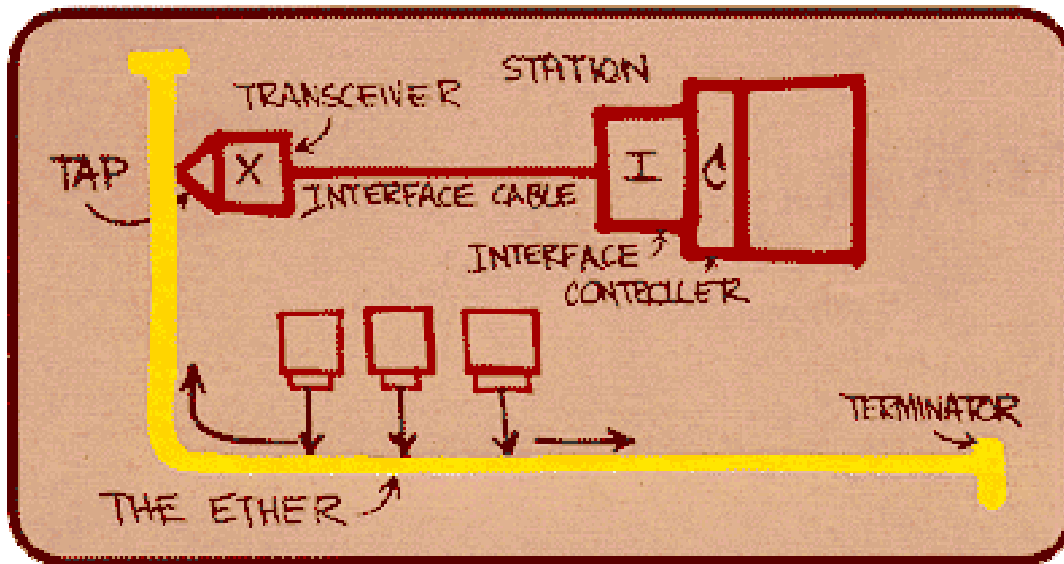
- control **token** passed from one node to next sequentially.
- transmit only when holding the token
- concerns:
 - token overhead (bandwidth & latency)
 - single point of failure (token)



Ethernet

"dominant" for local-area networks:

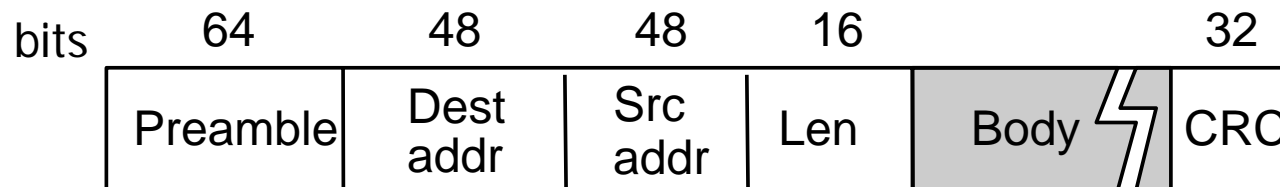
- Developed at Xerox PARC in 1970s
- First widely used LAN technology
- Random access multiple access control



Metcalfe's Ethernet sketch

Ethernet Frame Structure

Sending adapter encapsulates data payload in **Ethernet frame**



- **Preamble:**
 - 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
 - indicating the beginning of a frame, synchronizing receiver/sender clocks
- **Addresses:**
 - link layer addresses, different from IP addresses
- **Length:** indicates the length of the body field (max 1500bytes)
- **CRC:** checked at receiver
 - if error is detected, the frame is simply dropped



Connectionless, Unreliable

- **Connectionless:** No handshaking between sending and receiving adapter.
- **Unreliable:**
 - corrupted frames are simply dropped
 - no attempt is made on the receiver to detect and recover lost frames
 - corrupted or lost packets may be recovered by higher layer protocols, e.g. TCP



Ethernet uses CSMA/CD

- Random access, no synchronized clocks
- adapter doesn't transmit if it senses that some other adapter is transmitting, that is, **carrier sense**
- transmitting adapter aborts when it senses that another adapter is transmitting, that is, **collision detection**
- Before attempting a retransmission, adapter waits a random delay, that is, **random backoff**
 - why? how?



Ethernet's CSMA/CD (more)

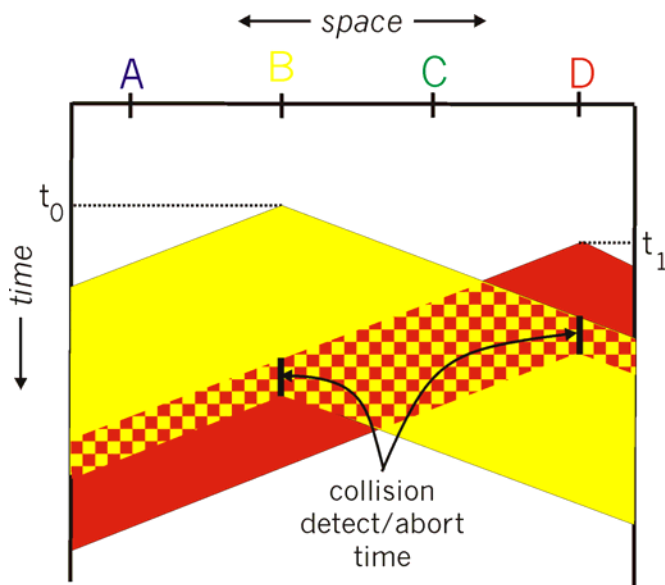
Exponential Backoff:

- Goal: adapt retransmission attempts to estimated current load
 - heavy load: random wait will be longer
- first collision: delay K units of time, K is randomly chosen from $\{0,1\}$
- after second collision: choose K from $\{0,1,2,3\}$...
- after ten collisions, choose K from $\{0,1,2,3,4,\dots,1023\}$

Backoff wait time:

- a unit of time is about 5 microsec for 100 Mbps Ethernet.
- for $K=1023$, wait time is about 5 millisecc.

Ethernet Efficiency



- t_{prop} = max prop between 2 nodes
- t_{trans} = time to transmit a frame

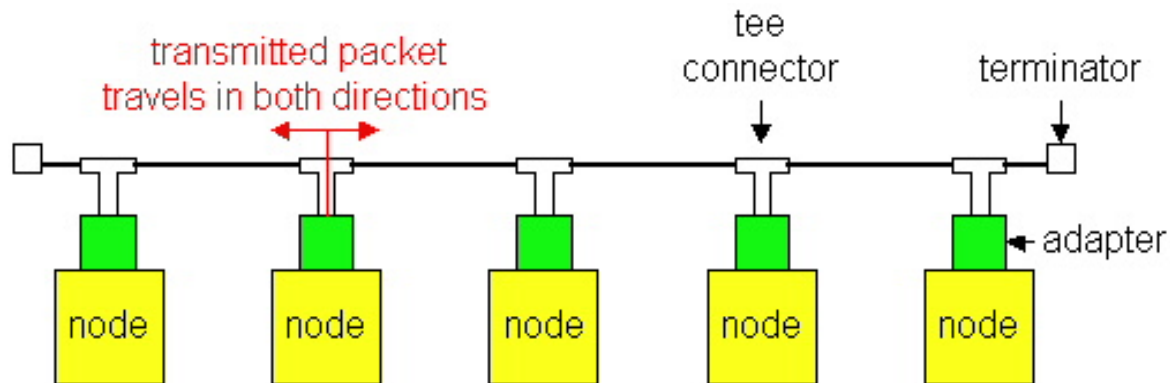
$$\text{efficiency} \approx \frac{1}{1 + 5t_{prop} / t_{trans}}$$

- Efficiency goes to 1 as t_{prop} goes to 0 or as t_{trans} goes to infinity

Much more efficient than ALOHA, but still decentralized and simple

Ethernet Technologies: 10Base2

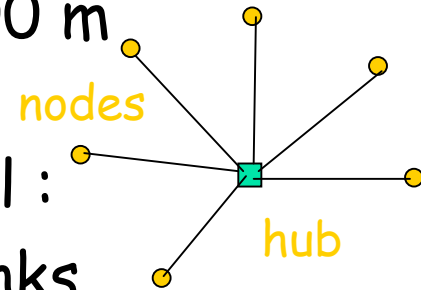
- **10**: 10Mbps; **2**: under 200 meters max cable length
- thin coaxial cable in a bus topology



- has become a legacy technology

10BaseT and 100BaseT

- 10/100 Mbps rate; latter called "fast ethernet"
- **T** stands for Twisted Pair
- Nodes connect to a hub: "star topology"; 100 m max distance between nodes and hub
- Hubs are essentially physical-layer bit-level :
 - bits coming in one link go out all other links
 - no collision detection, no frame buffering
 - may provide net management functionality
- Repeaters are physical-layer frame-level signal regenerators - avoid max distance limitation





Encoding

- 10BaseT, 10Base2 - Manchester encoding
- 100BaseT - 4B5B encoding
- Allows clocks in sending and receiving nodes to synchronize to each other
 - no need for a centralized, global clock among nodes
- Still remember their efficiencies??



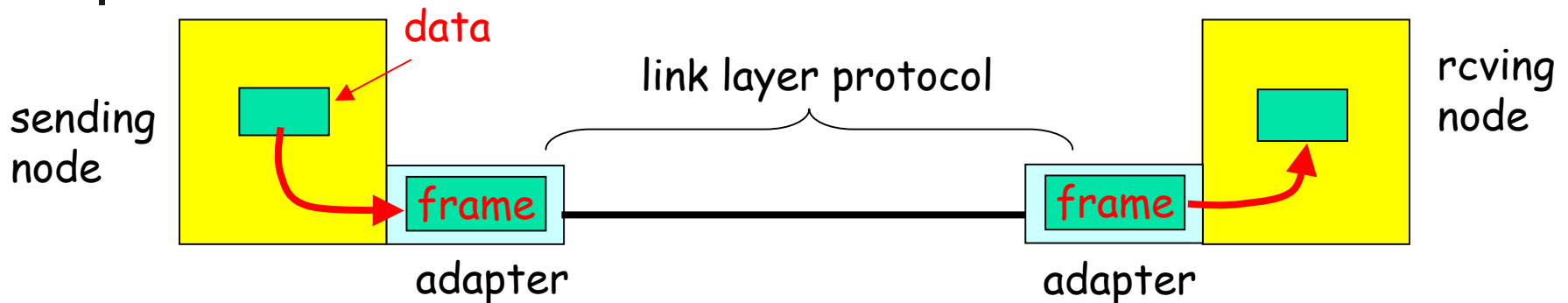
Gbit Ethernet

- use standard Ethernet frame format
- efficiency of CSMA/CD

$$\text{efficiency} = \frac{1}{1 + 5t_{prop} / t_{trans}}$$

- short distances between nodes to be efficient!
- fortunately today's Ethernet links are not shared
- 10 Gbps now!
 - optical fiber as well as copper cable
 - if latency doesn't change, what apps can benefit?

Where is link layer implemented?



- link layer implemented in "adaptor" (aka NIC)
 - Ethernet card, 802.11 card
- sending side:
 - encapsulates data in a frame
 - adds error checking bits, rdt, flow control, etc.
- receiving side
 - looks for errors, rdt, flow control, etc
 - extracts data, passes to OS at receiving node
- adapter is semi-autonomous
 - has its own processor/buffer



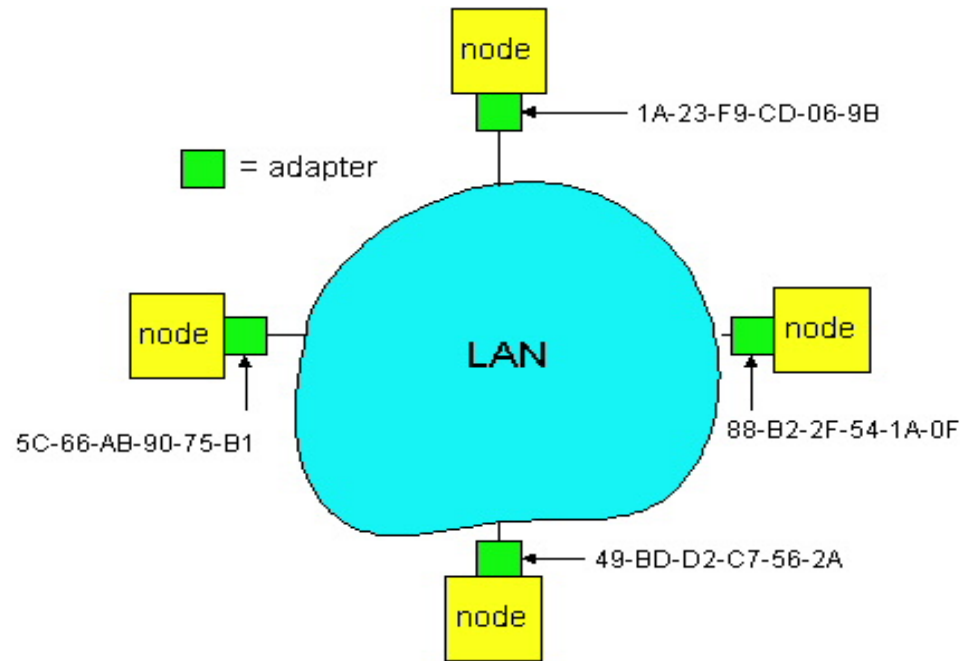
Interaction with the Host

- Control from the host
 - read/write control status registers
- Notifying the host
 - interrupts
- Moving data
 - direct Memory Access (DMA)
 - programmed I/O
- Device drivers (device-specific software executed by Host CPU)
 - initialize the adapter
 - manipulate the adapter (e.g. send a frame)
 - handle interrupts

Link-layer Addresses

Link-layer (or MAC, LAN) address:

- uniquely identifying each node (or adapter) connected to a shared link
⇒ integral to multiple access protocols
- 48 bits
- broadcast address - "FF-FF-FF-FF-FF-FF"





Link-layer Addresses (cont.)

- Universal uniqueness:
 - Link-layer address burned in the adapter ROM
 - no two adapters anywhere have the same address
- How is this achieved?
 - MAC address allocation administered by IEEE
 - manufacturer buys portion of MAC address space (to assure uniqueness)
- Impact:
 - portability: can move adaptor from one network to another (no configuration required!)
 - flat, no hierarchy
- Caveat:
 - OS may instruct the adapter to use a different MAC address

Coexistence of link-layer addresses and network-layer addresses.



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