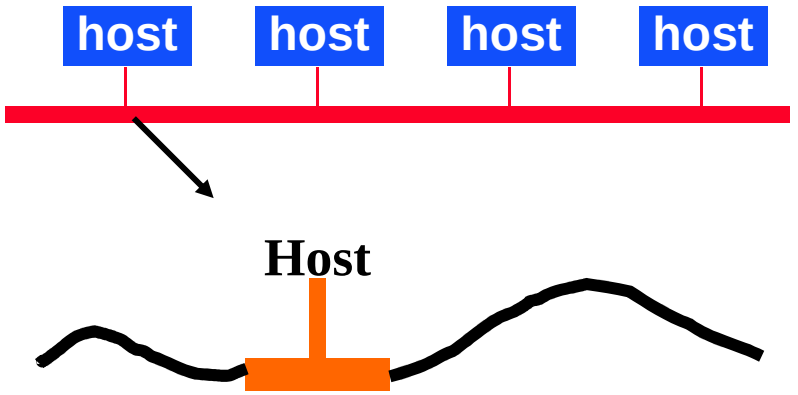
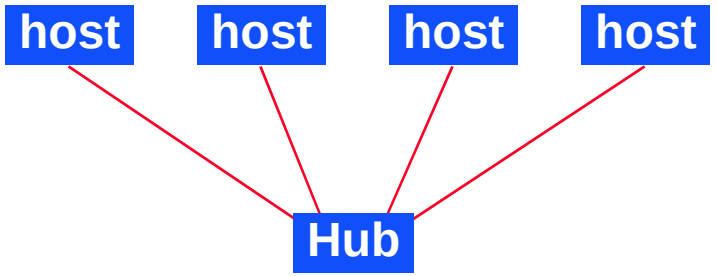
Ethernet Physical Refresher

- 10Mhz signal (baseband modulation)
- Nyquist limit says we should be able to get 20 Mbits/s from that.
- Manchester encoding solves runs of 1s and 0s problem
  - » Wastes 1/2 of the possible data rate - back to 10Mbps

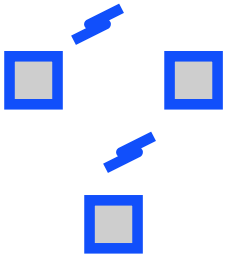
Ethernet Physical Layer

- **10Base2 standard based on thin coax.**
  - » **Thick coax no longer used**
  - » **Nodes are connected using thin coax cables and “T” connectors in a bus topology**
- **10-BaseT uses twisted pair and hubs.**
  - » **Hub acts as a concentrator**
- **The two designs have the same protocol properties.**
  - » **Key: electrical connectivity between all nodes**
  - » **Deployment is different**

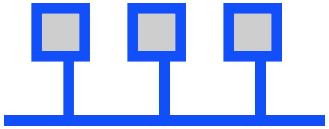




Ethernet over Time



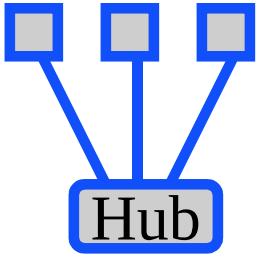
Aloha packet radio



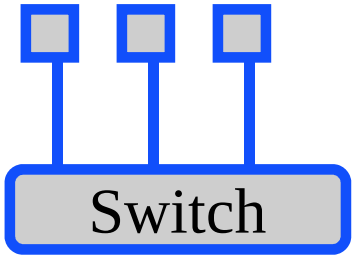
Ethernet on coax

10base-2 (thinnet)

10base-5 (thicknet)

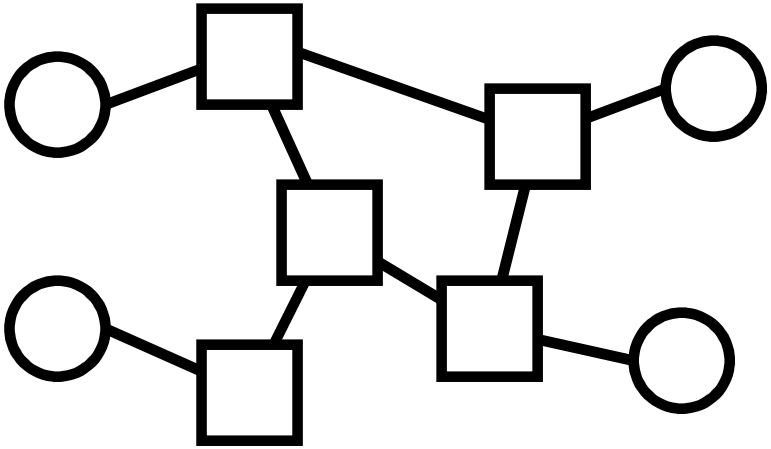


?baseT with hub (twisted pair)

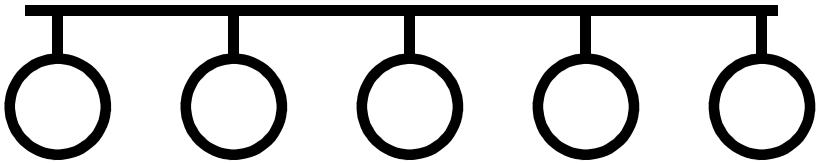


?baseT with switch (point to point links)

Datalink Layer Architectures



- Packet forwarding.
- Error and flow control.



- Media access control.
- Scalability.

Multiple Access Protocols

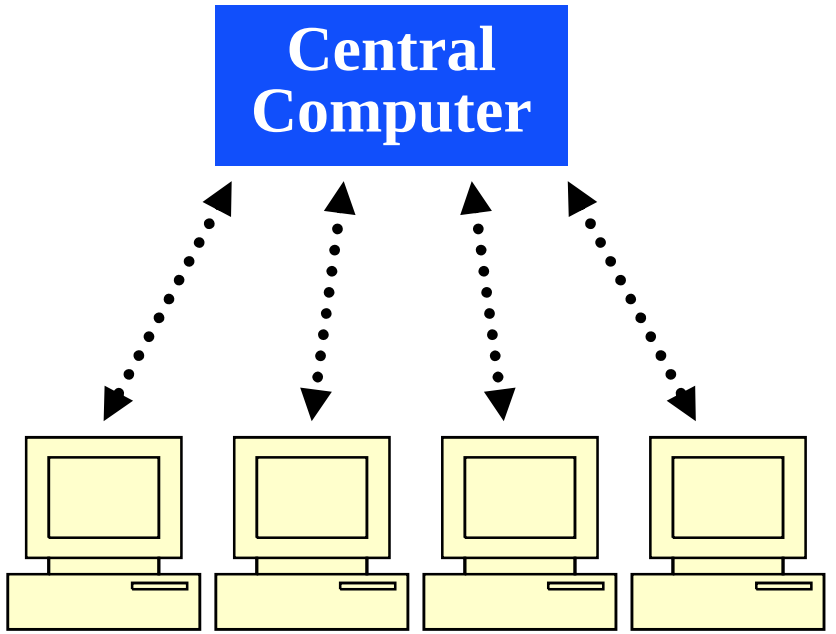
- **Prevent two or more nodes from transmitting at the same time over a broadcast channel.**
  - **If they do, we have a collision, and receivers will not be able to interpret the signal**
- **Several classes of multiple access protocols.**
  - **Partitioning the channel, e.g. frequency-division or time division multiplexing**
    - **With fixed partitioning of bandwidth – not flexible**
  - **Taking turns, e.g. token-based, reservation-based protocols, polling based**
  - **Contention based protocols, e.g. Aloha, Ethernet**

Contention-Based Protocol

- **Goal: share the communication channel among multiple hosts sharing it.**
- **Problem: how to arbitrate between the connected hosts.**
- **Desired properties:**
  - **High bandwidth utilization**
  - **Avoid starvation, achieve fairness**
  - **Simple solution**
- **Idea: access the channel in a random way - when collisions occur, recover.**
  - **Collision: two or more nodes transmitting at the same time**

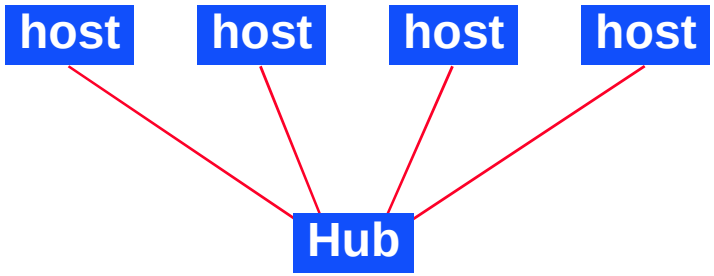
Aloha

- Node sends the message when it has data to send.
- If it receives an ack, it considers the transmission completed, otherwise it retransmits after a random delay.
- Simple, distributed protocol, but not very efficient
  - » 18% maximum utilization
- Slotted Aloha: more efficient.
  - » Transmit only in specific time slot
  - » Reduces chances of collision
  - » 37% maximum utilization



802.3 Ethernet

Broadcast technology

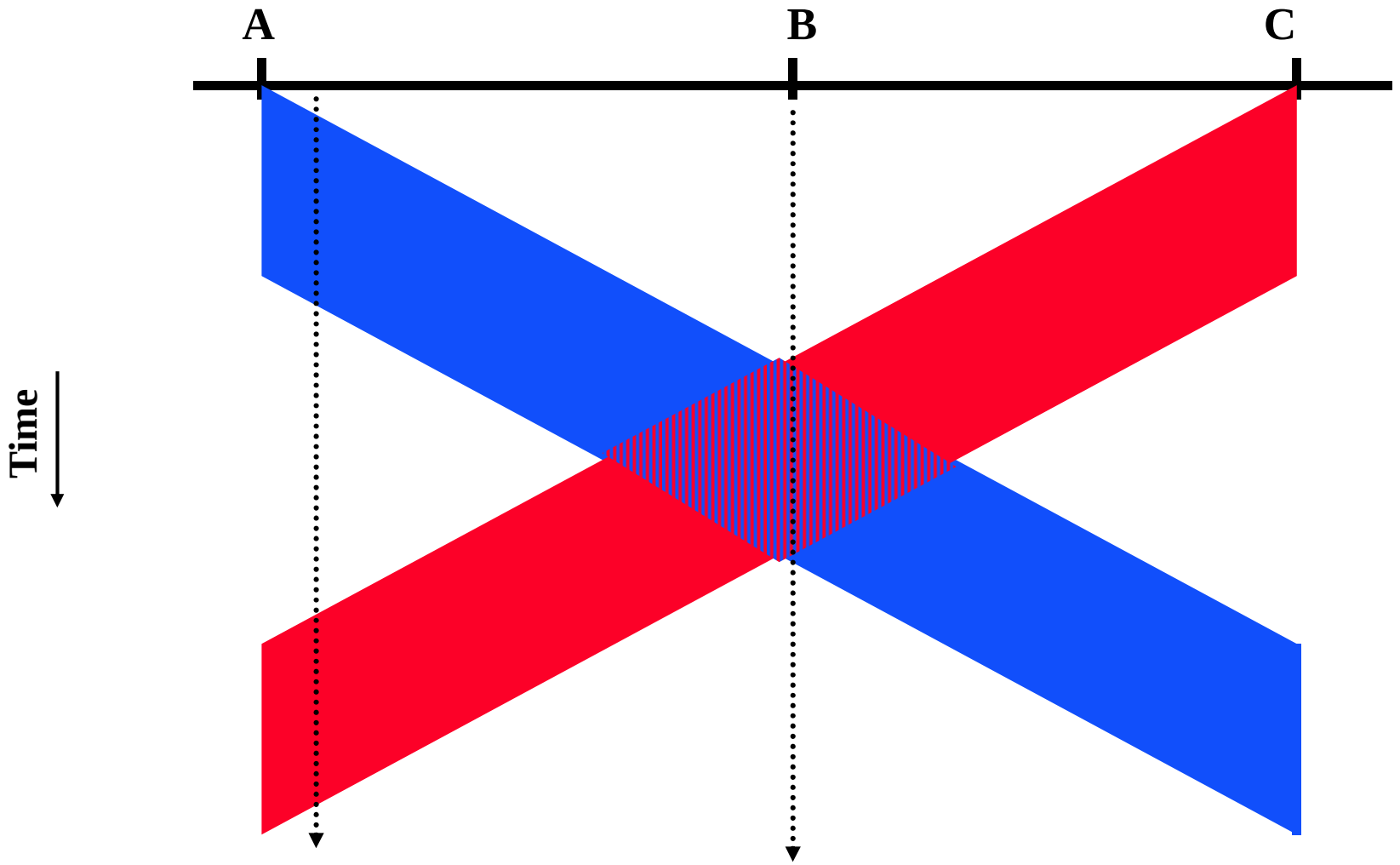


- **Carrier-sense multiple access with collision detection (CSMA/CD).**
  - » **MA = multiple access**
  - » **CS = carrier sense**
  - » **CD = collision detection**
- **Base Ethernet standard is 10 Mbs.**
  - » **Original design was ~2 Mbs**
  - » **Faster versions discussed later**

CSMA/CD Algorithm

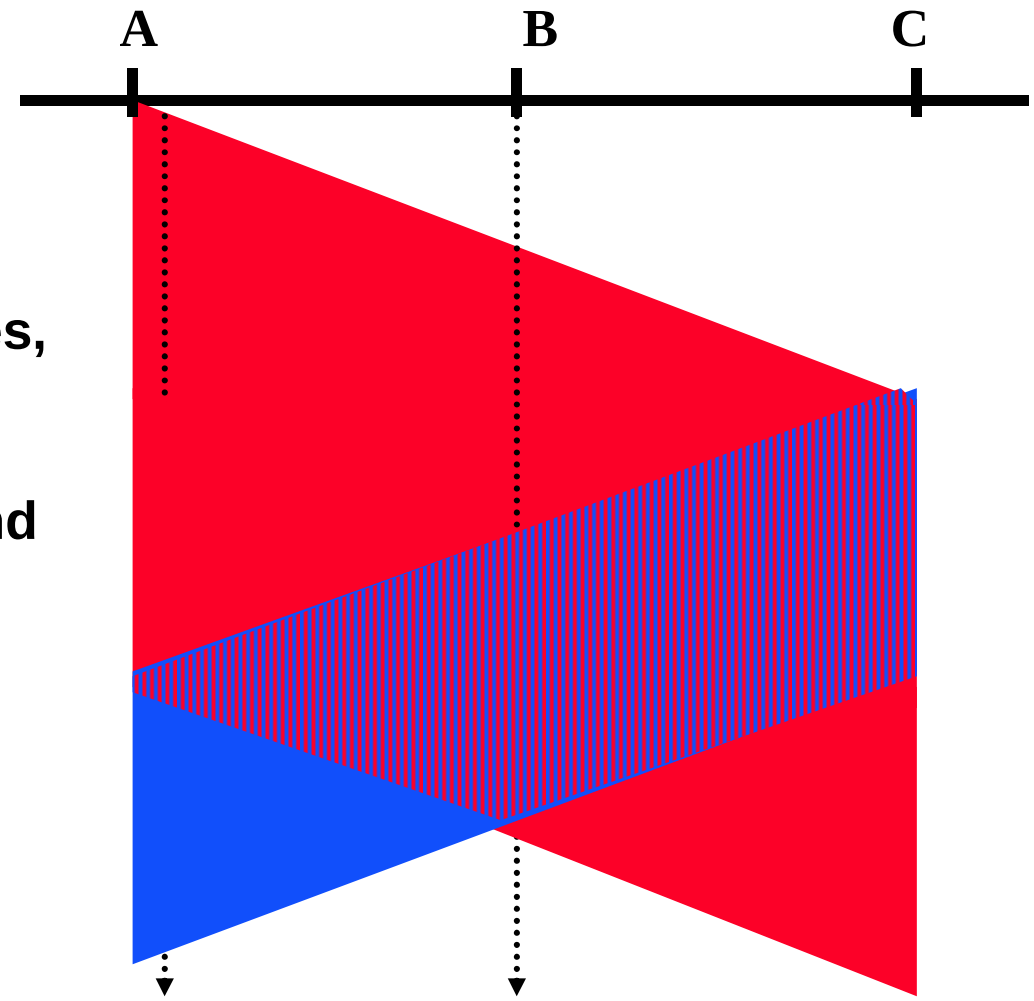
- Sense for carrier.
- If carrier present, wait until carrier ends.
  - » Sending would force a collision and waste time
- Send packet and sense for collision.
- If no collision detected, consider packet delivered.
- Otherwise, abort immediately, perform “exponential back off” and send packet again.
  - » Start to send at a random time picked from an interval
  - » Length of the interval increases with every retransmission

Collision Detection



Collision Detection: Implications

- All nodes must be able to detect the collision.
  - » Any node can be sender
- => Must either have short wires, long packets, or both.
- Can calculate length/distance based on transmission rate and propagation speed.
  - » Messy: propagation speed is media-dependent, low-level protocol details, ..
  - » Minimum packet size is 64 bytes
    - – Cable length ~256 bit times
  - » Example: maximum coax cable length is 2.5 km



Minimum Packet Size

- Give a host enough time to detect a collision.
- In Ethernet, the minimum packet size is 64 bytes.
  - » 18 bytes of header and 46 data bytes
  - » If the host has less than 46 bytes to send, the adaptor (pads) bytes to increase the length to 46 bytes
- What is the relationship between the minimum packet size and the size of LAN?

  LAN = (min frame size) * light speed / (2 * bandwidth)
- How did they pick the minimum packet size?

CSMA/CD: Some Details

- **Successive frames are separated by an “inter-frame” gap.**
  - » **Nodes must switch from “send” to “receive” mode**
  - » **Set to 9.6 μsec or 96 bit times**
- **When a sender detects a collision, it sends a “jam signal”.**
  - » **Make sure that all nodes are aware of the collision**
  - » **Length of the jam signal is 32 bit times**
  - » **Permits early abort - don’t waste max transmission time**
- **Exponential backoff operates in multiples of 512 bit times.**
  - » **Longer than a roundtrip time**
  - » **Guarantees that nodes that back off longer will notice the earlier retransmission before starting to send**

Traditional IEEE 802 Networks: MAC in the LAN and MAN

- Ethernet defined as IEEE 802.3.
- The IEEE 802.* set of standards defines a common framing and addressing format for LAN protocols.
  - » Simplifies interoperability
  - » Addresses are 48 bit strings, with no structure
- 802.3 (Ethernet)
- 802.4 (Token bus)
- 802.5 (Token ring)
- 802.6 (Distributed queue dual bus)
- 802.11 (Wireless LAN)
- 802.14 (Cable Modem)
- 802.15 (Wireless Personal Area networks - based on bluetooth)
- 802.16 (Broadband wireless access - “WiMAX”)

LAN Properties

- **Exploit physical proximity.**
  - » Often a limitation on the physical distance
  - » E.g. to detect collisions in a contention based network
  - » E.g. to limit the overhead introduced by token passing
- **Relies on single administrative control and some level of trust.**
  - » Broadcasting packets to everybody and hoping everybody (other than the receiver) will ignore the packet
  - » Token-based protocols: everybody plays by the rules
- **Broadcast: nodes can send messages that can be heard by all nodes on the network.**
  - » Almost essential for network administration
  - » Can also be used for applications, e.g. video conferencing
- **But broadcast fundamentally does not scale.**

Why Ethernet?

- **Easy to manage.**
  - » You plug in the host and it basically works
  - » No configuration at the datalink layer
- **Broadcast-based.**
  - » In part explains the easy management
  - » Some of the LAN protocols (e.g. ARP) rely on broadcast
    - – Networking would be harder without ARP
    - – Address Resolution Protocol (“who-has 18.31.0.114?” -> MAC address).
  - » Not having natural broadcast capabilities adds a lot of complexity to a LAN
    - – Example: ATM
- **Drawbacks.**
  - » Broadcast-based: limits bandwidth since each packets consumes the bandwidth of the entire network
  - » Distance (if shared)

802.3u Fast Ethernet

- **Apply original CSMA/CD medium access protocol at 100Mbps**
- **Must change either minimum frame or maximum diameter: change diameter**
- **Requires**
  - **2 UTP5 pairs (4B5B) or**
  - **4 UTP3 pairs (8B6T) or**
  - **1 fiber pair**
- **No more “shared wire” connectivity.**
  - **Hubs and switches only**

802.3z Gigabit Ethernet

- **Same frame format and size as Ethernet.**
  - **This is what makes it Ethernet**
- **Full duplex point-to-point links in the backbone are likely the most common use.**
  - **Added flow control to deal with congestion**
- **Alternative is half-duplex shared-medium access.**
  - **Cannot cut the diameter any more (set to 200m)**
  - **Raise the min frame time (256 bytes), but not frame size**
- **Choice of a range of fiber and copper transmission media.**
- **Defining “jumbo frames” for higher efficiency.**