Multiple Access

Readings: Peterson & Davie, 2.6.2, 2.7, 2.8.2

Multiple Access

- Multiple hosts sharing the same medium
- What are the new problems?

Shared Media

- Ethernet bus
- Radio channel
- Token ring network
- …

Multiple Access protocols

- Single shared broadcast channel
- Two or more simultaneous transmissions by nodes: interference
  - Collision if node receives two or more signals at the same time

Multiple Access Protocol

- Distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- Communication about channel sharing must use channel itself!
  - No out-of-band channel for coordination

Channel Partitioning

- Frequency Division Multiplexing
  - Each node has a frequency band
- Time Division Multiplexing
  - Each node has a series of fixed time slots
- What networks are these good for?

Computer Network Characteristics

- Transmission needs vary
  - Between different nodes
  - Over time
- Network is not fully utilized

Ideal Multiple Access Protocol

Broadcast channel of rate R bps

1. When one node wants to transmit, it can send at rate R.
2. When M nodes want to transmit, each can send at average rate R/M
3. Fully decentralized:
   - no special node to coordinate transmissions
   - no synchronization of clocks, slots
4. Simple

Random Access Protocols

- When node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes ➜ "collision",
- random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)
- Examples of random access MAC protocols:
  - slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA

Slotted ALOHA

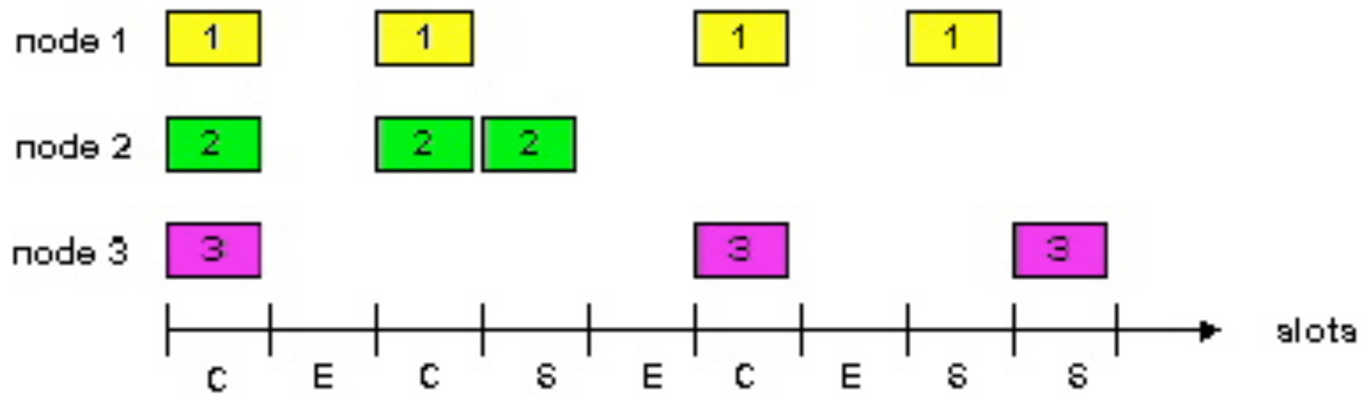
Assumptions

- all frames same size
- time is divided into equal size slots, time to transmit 1 frame
- nodes start to transmit frames only at beginning of slots
- nodes are synchronized
- if 2 or more nodes transmit in slot, all nodes detect collision

Operation

- when node obtains fresh frame, it transmits in next slot
- no collision, node can send new frame in next slot
- if collision, node retransmits frame in each subsequent slot with prob. p until success

Slotted ALOHA



<u>Pros</u>

- single active node can continuously transmit at full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- simple

<u>Cons</u>

- collisions, wasting slots
- idle slots
- nodes may be able to detect collision in less than time to transmit packet
- clock synchronization

Slotted Aloha efficiency

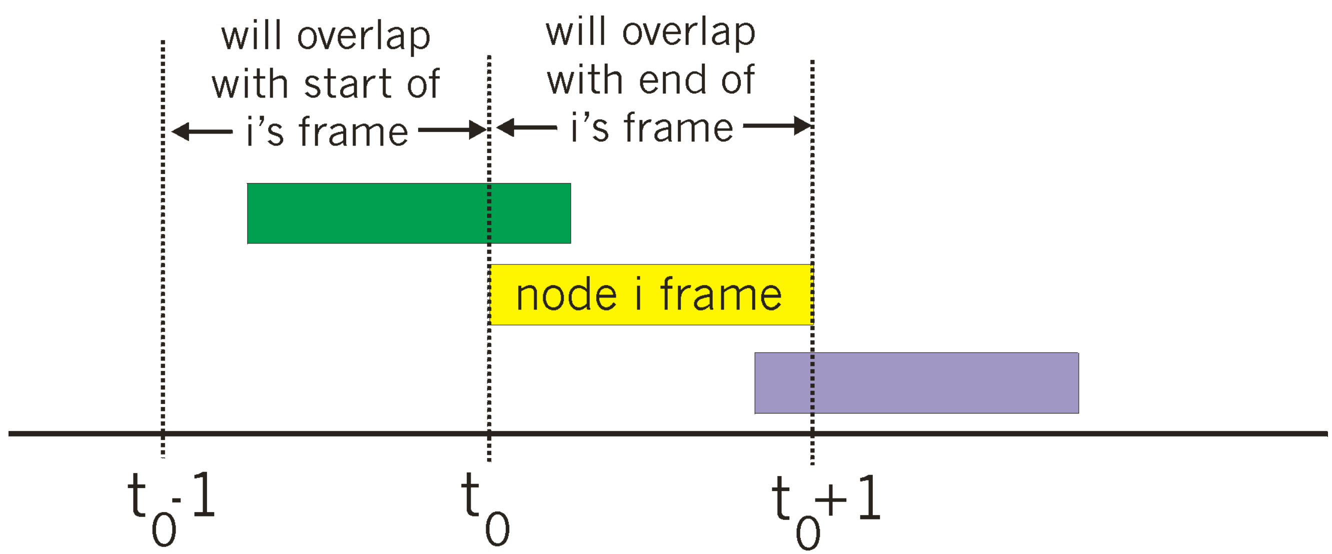
- **Efficiency** is the long-run fraction of successful slots when there are many nodes, each with many frames to send
- Suppose N nodes with many frames to send, each transmits in slot with probability *p*
- prob that node 1 has success in a slot = $p(1-p)^{N-1}$
- prob that any node has a success = $Np(1-p)^{N-1}$

Optimal choice of p

- For max efficiency with N nodes, find p* that maximizes
  $Np(1-p)^{N-1}$
- For many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as N goes to infinity, gives 1/e = .37
- Efficiency is 37%, even with optimal p

Pure (unslotted) ALOHA

- unslotted Aloha: simpler, no synchronization
- when frame first arrives
  - transmit immediately
- collision probability increases:
  - frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$



Pure Aloha efficiency

P(success by given node) = P(node transmits) ·

P(no other node transmits in $[t_0-1,t_0]$ ·

P(no other node transmits in $[t_0,t_0+1]$

$= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1}$

$= p \cdot (1-p)^{2(N-1)}$

… choosing optimum p and then letting n -> ∞ ...

Efficiency = 1/(2e) = .18

Even worse !

Carrier Sense Multiple Access

CSMA: listen before transmit:

If channel sensed idle: transmit entire frame

- If channel sensed busy, defer transmission

- Human analogy: don't interrupt others!

CSMA collisions

collisions *can* still occur:

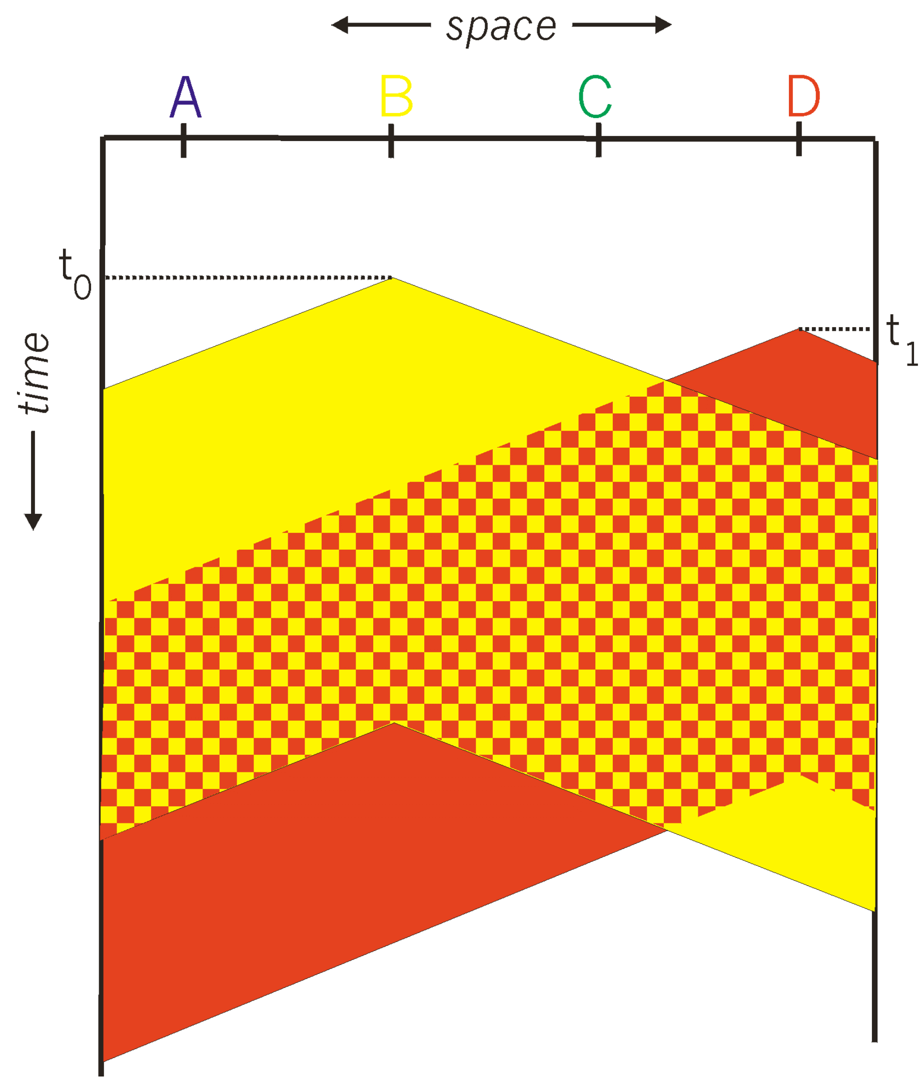
propagation delay means two nodes may not hear each other's transmission

collision:

entire packet transmission time wasted

note:

role of distance & propagation delay in determining collision probability



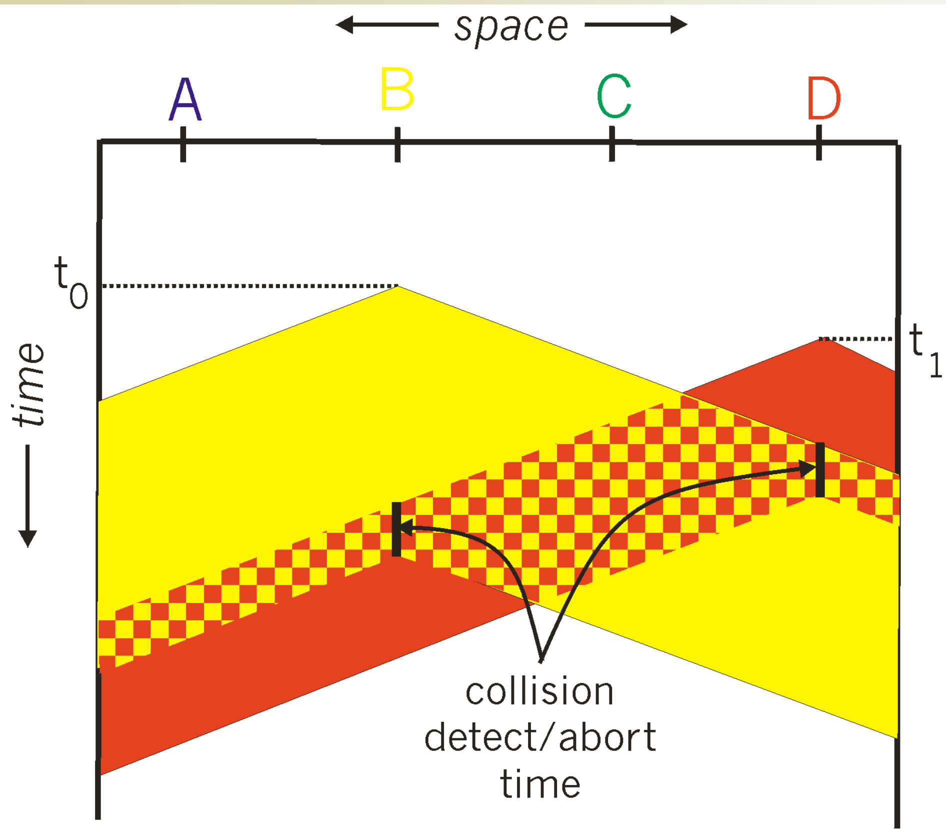
CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: receiver shut off while transmitting
- human analogy: the polite conversationalist

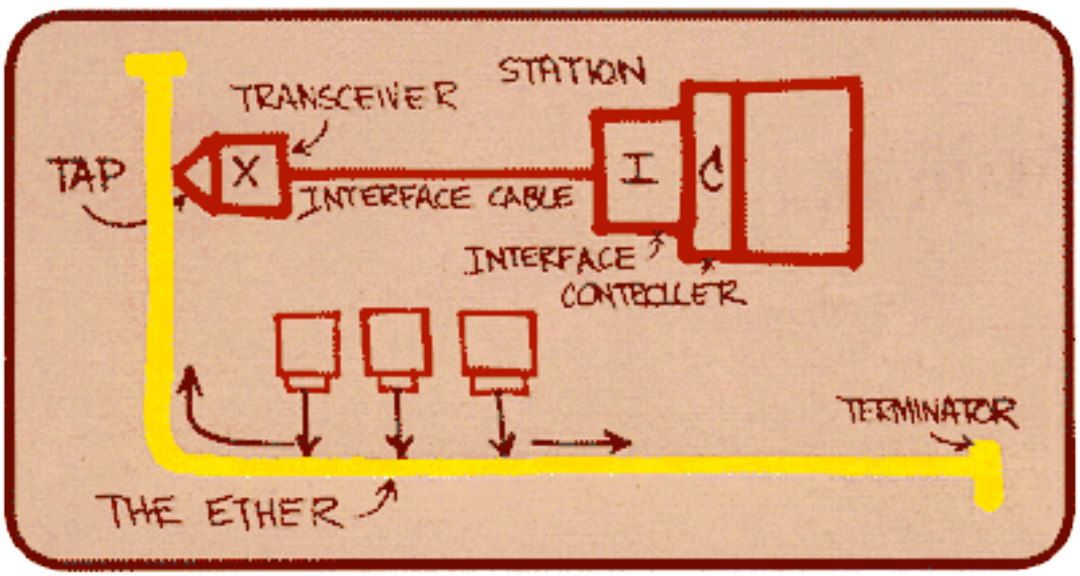
CSMA/CD collision detection



Ethernet

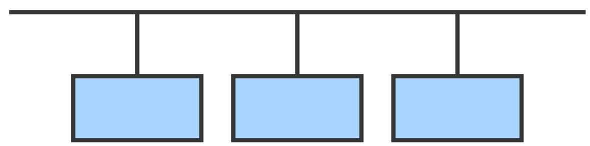
dominant wired LAN technology:

- cheap $20 for 100Mbs!
- first widely used LAN technology
- Simpler, cheaper than token LANs and ATM
- Kept up with speed race: 10 Mbps – 10 Gbps



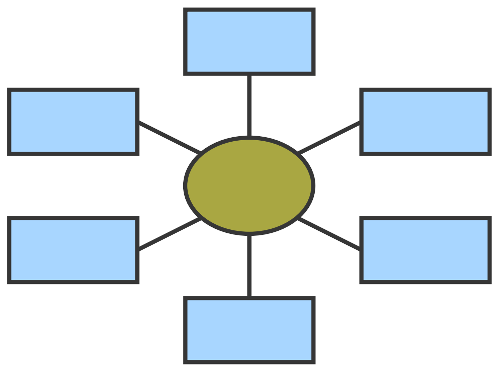
Metcalfe's Ethernet sketch

Ethernet Topologies



Bus Topology: Shared

All nodes connected to a wire



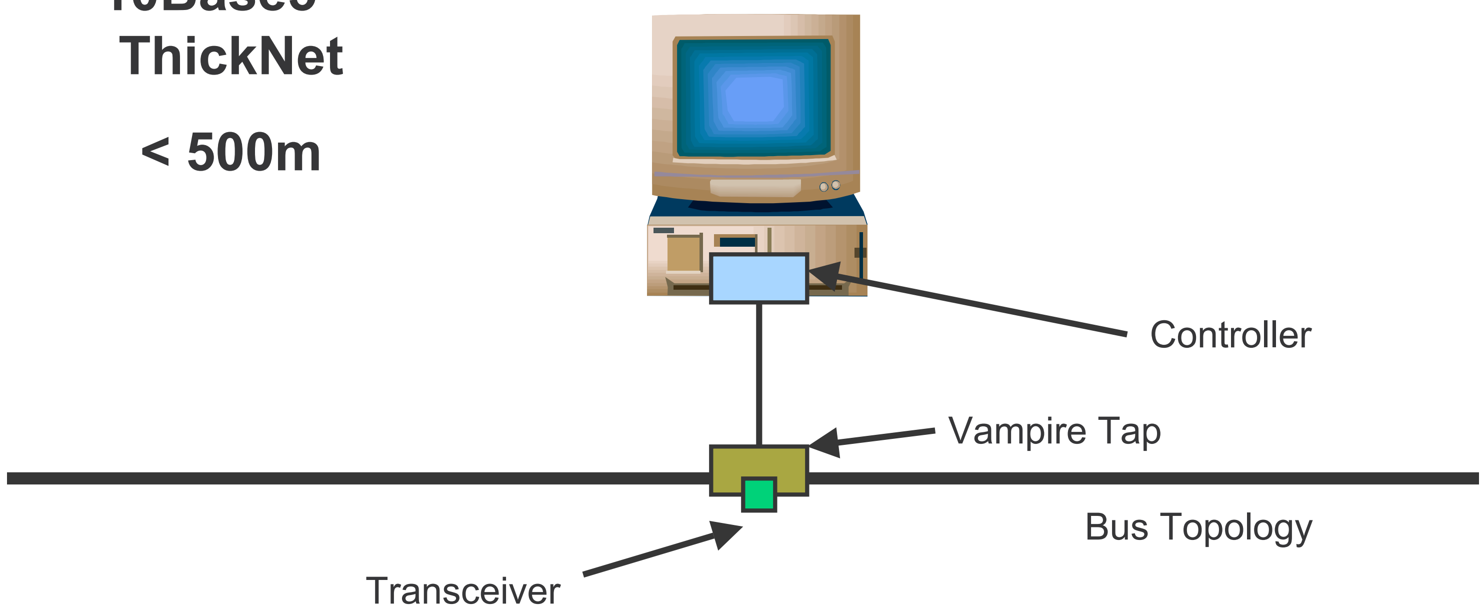
Star Topology:

All nodes connected to a central repeater

Ethernet Connectivity

10Base5 – ThickNet

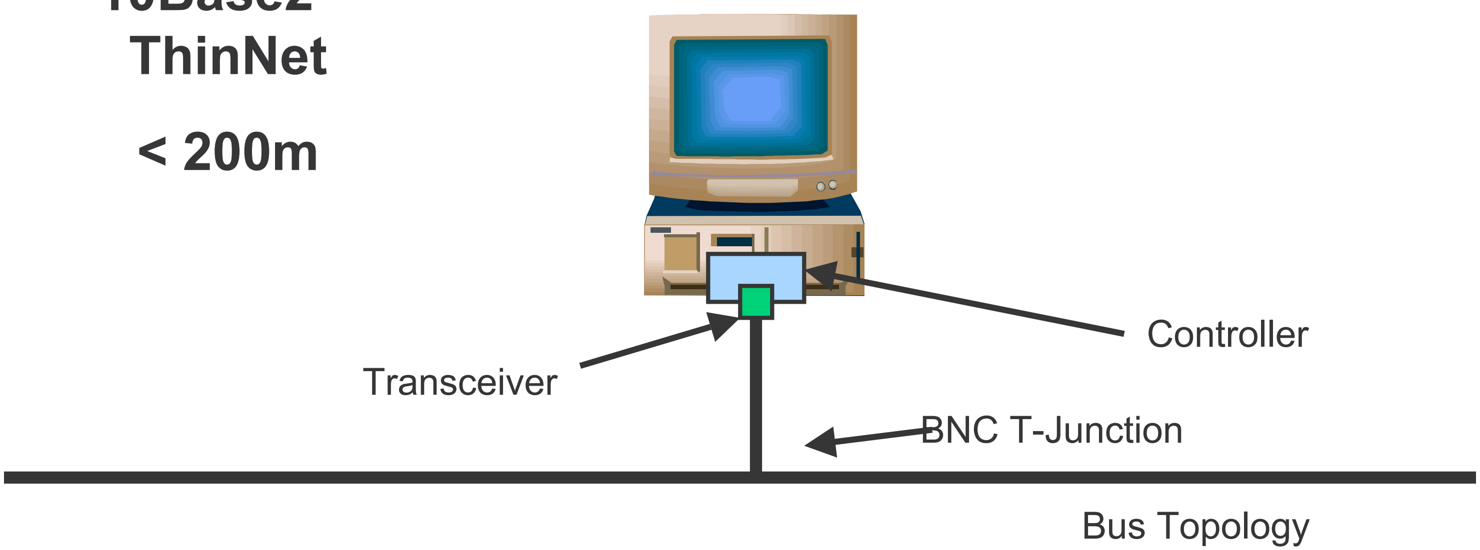
< 500m



Ethernet Connectivity

10Base2 – ThinNet

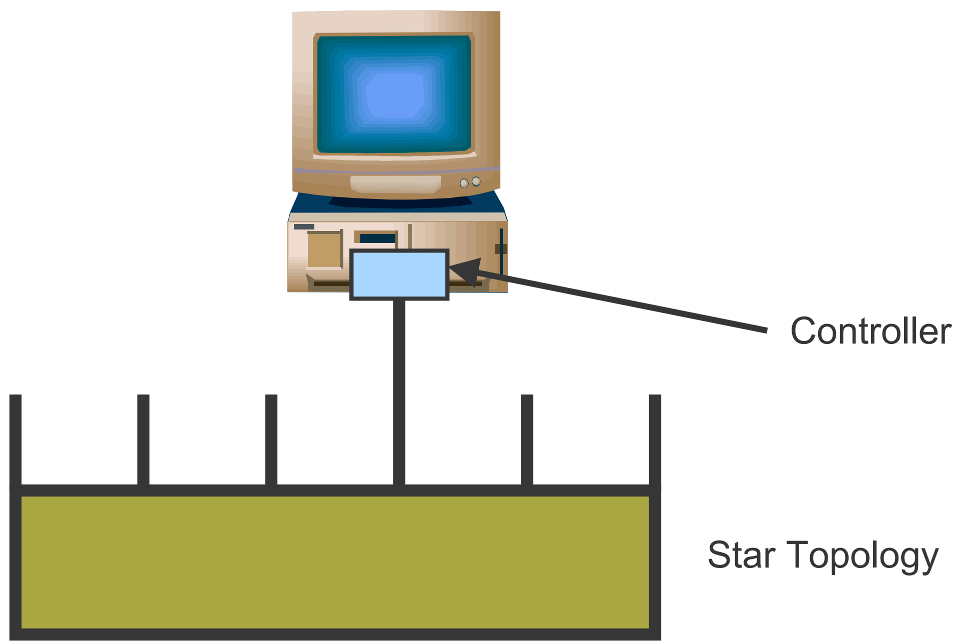
< 200m



Ethernet Connectivity

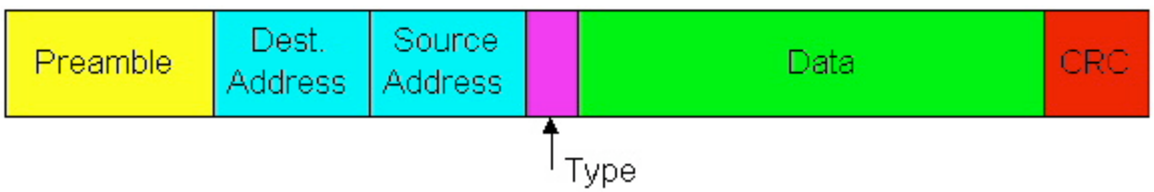
10BaseT

< 100m



Ethernet Frame Structure

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame

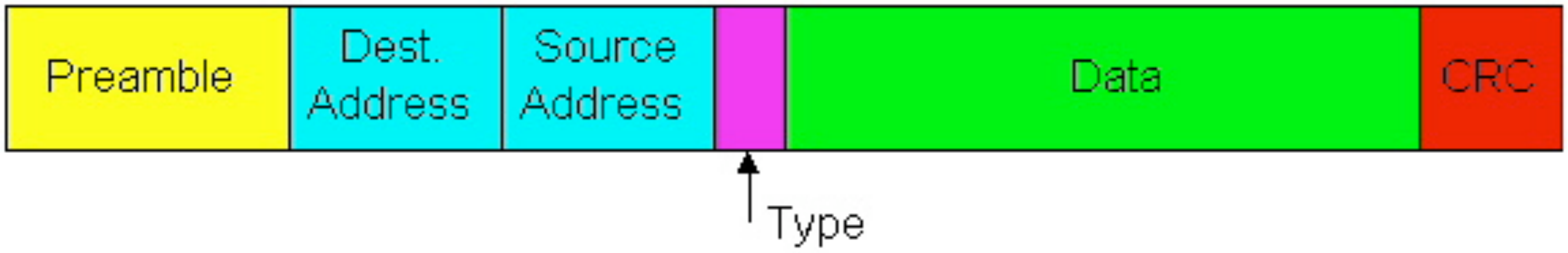


Preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- Used to synchronize receiver, sender clock rates (Manchester encoding)

Ethernet Frame Structure (more)

- Addresses: 6 bytes
  - if adapter receives frame with matching destination address, or with broadcast address (eg ARP packet), it passes data in frame to net-layer protocol
  - otherwise, adapter discards frame
- Type: indicates the higher layer protocol (mostly IP but others may be supported such as Novell IPX and AppleTalk)
- CRC: checked at receiver, if error is detected, the frame is simply dropped



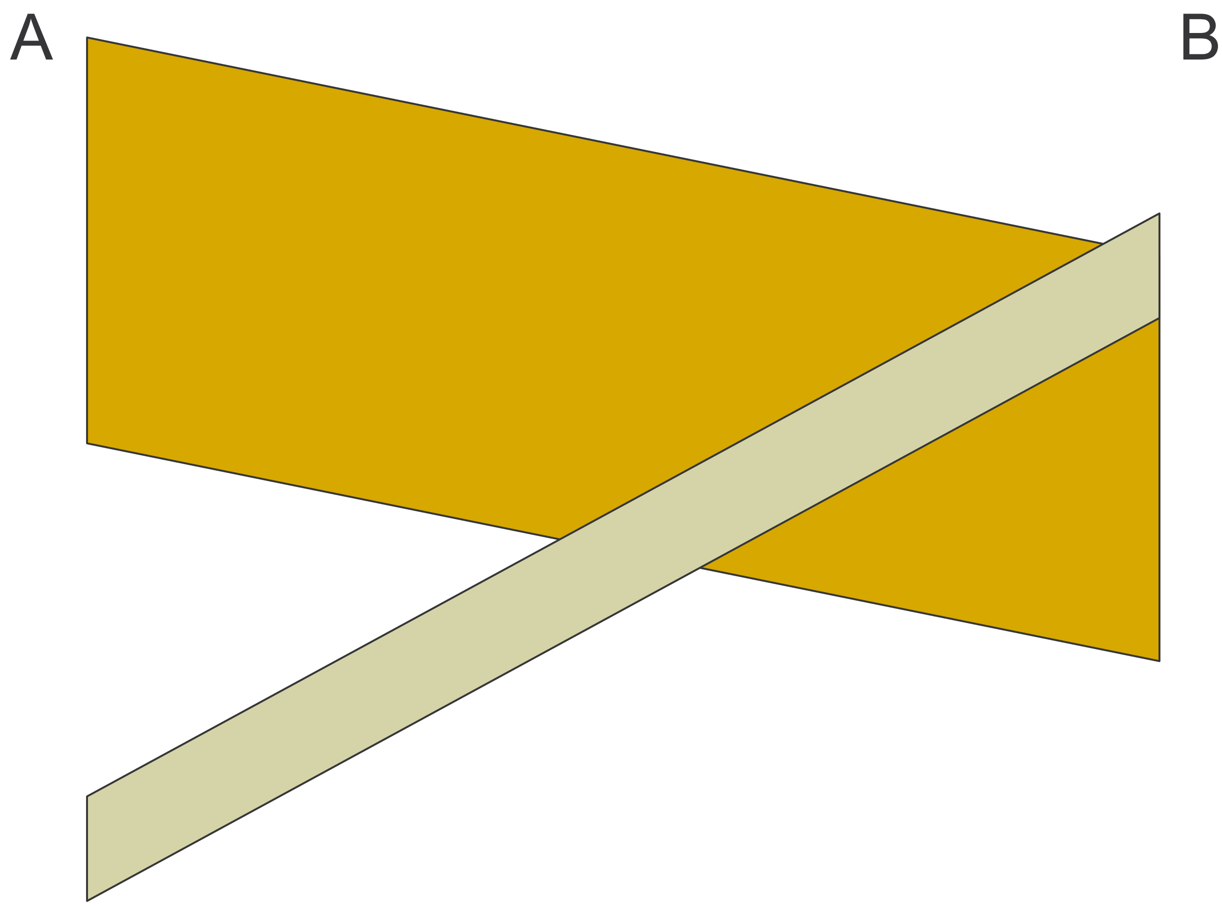
Ethernet Specifications

- Coaxial Cable
  - Up to 500m
- Taps
  - > 2.5m apart
- Transceiver
  - Idle detection
  - Sends/Receives signal
- Repeater
  - Joins multiple Ethernet segments
  - < 5 repeaters between any two hosts
- < 1024 hosts

Ethernet MAC Algorithm

- Sender/Transmitter
  - If line is idle (carrier sensed)
    - Send immediately
    - Send maximum of 1500B data (1527B total)
    - Wait 9.6 μs before sending again
  - If line is busy (no carrier sense)
    - Wait until line becomes idle
    - Send immediately
  - If collision detected
    - Stop sending and jam signal
    - Try again later

Collisions

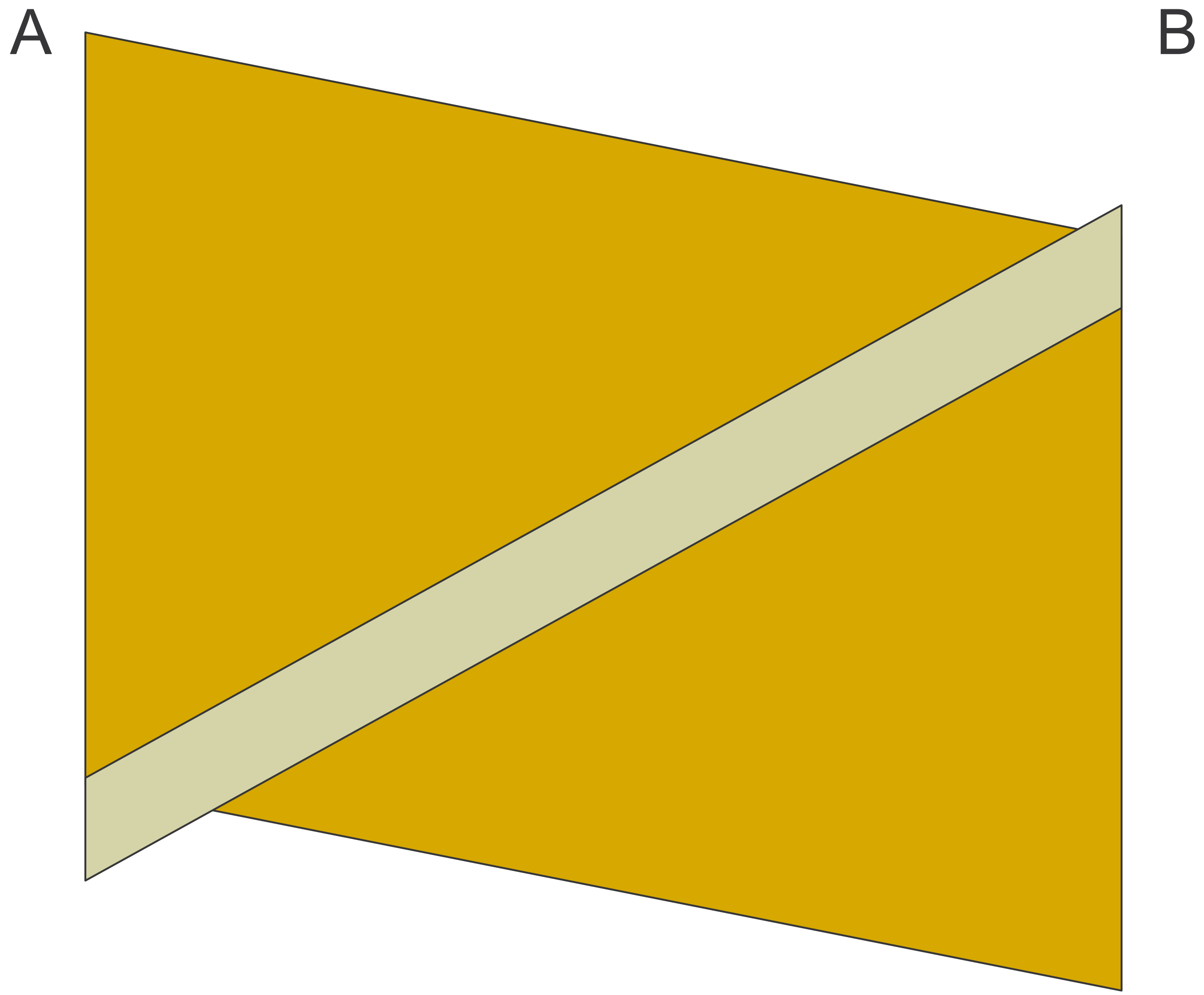


How can we ensure that A knows about the collision?

Collision Detection

- Example
  - Node A's message reaches node B at time T
  - Node B's message reaches node A at time 2T
  - For node A to detect a collision, node A must still be transmitting at time 2T
- 802.3
  - 2T is bounded to 51.2μs
  - At 10Mbps 51.2μs = 512b or 64B
  - Packet length ≥ 64B
- Jam after collision
  - Ensures that all hosts notice the collision

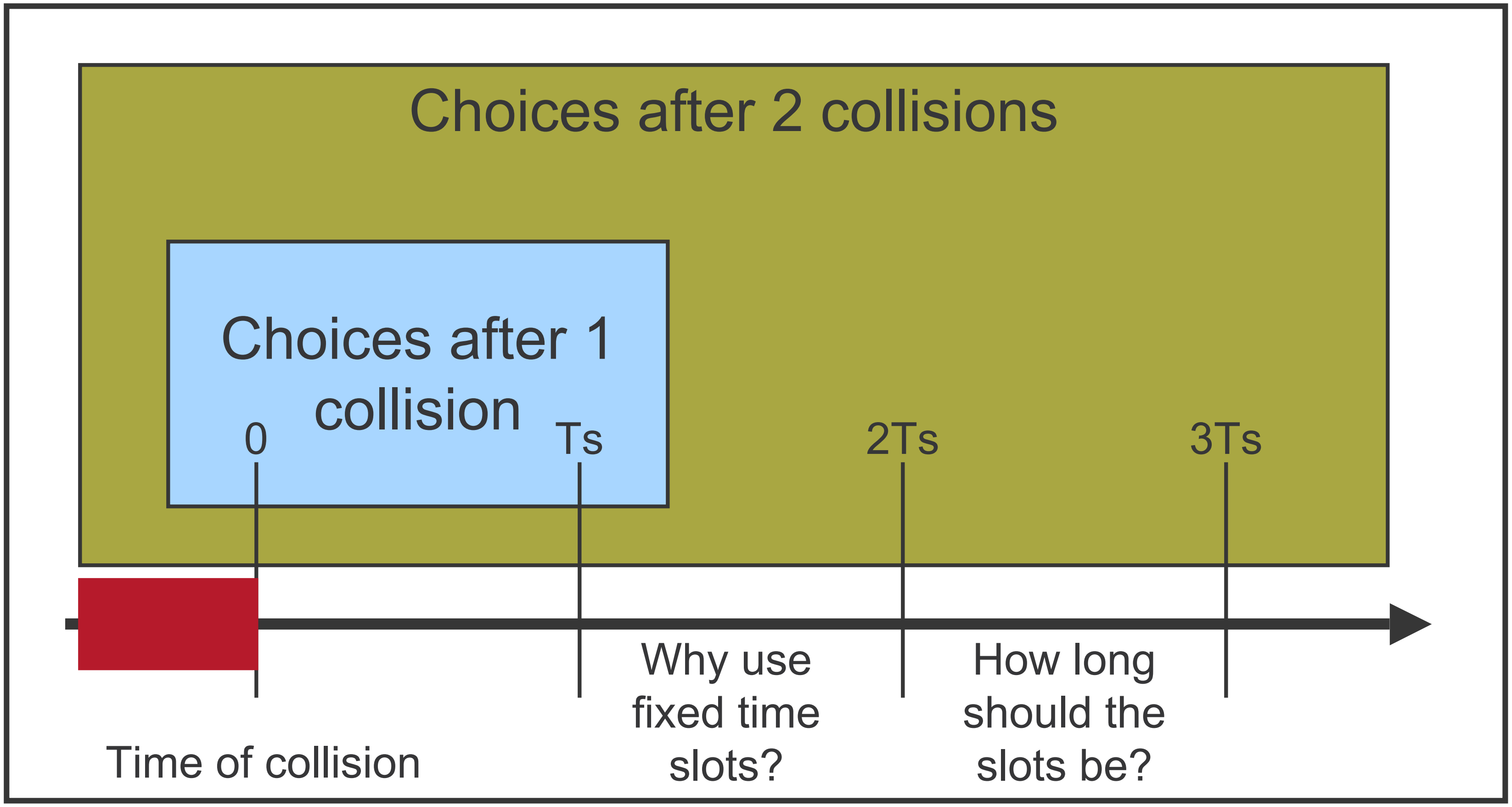
Collisions



Retransmission

- How long should a host wait to retry after a collision?
  - Binary exponential backoff
    - Maximum backoff doubles with each failure
    - After N failures, pick an N-bit number
    - 2^N discrete possibilities from 0 to maximum

Binary Exponential Backoff



Binary Exponential Backoff

- For 802.3, T = 51.2 μs
- Consider the following
  - k hosts collide
  - Each picks a random number from 0 to $2^{(N-1)}$
  - If the minimum value is unique
    - All other hosts see a busy line
    - Note: Ethernet RTT < 51.2 μs
  - if the minimum value is not unique
    - Hosts with minimum value slot collide again!
    - Next slot is idle
    - Consider the next smallest backoff value

CSMA/CD efficiency

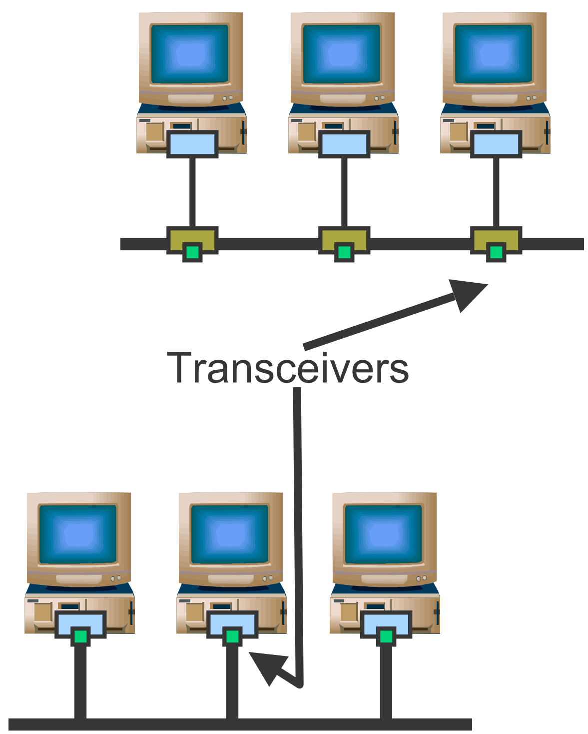
- t_{prop} = max prop between 2 nodes in LAN
- t_{trans} = time to transmit max-size frame
  - Efficiency = $1/(1+5 * t_{prop} / t_{trans})$
  - For 10 Mbit Ethernet, t_{prop} = 51.2 us, t_{trans} = 1.2 ms
  - Efficiency is 82.6%!
- Much better than ALOHA, but still decentralized, simple, and cheap
- Efficiency goes to 1 as t_{prop} goes to 0
- Goes to 1 as t_{trans} goes to infinity

Frame Reception

- Sender handles all access control
- Receiver simply pulls the frame from the network
- Ethernet controller/card
  - Sees all frames
  - Selectively passes frames to host processor
- Acceptable frames
  - Addressed to host
  - Addressed to broadcast
  - Addressed to multicast address to which host belongs
  - Anything (if in promiscuous mode)
    - Need this for packet sniffers/TCPDump

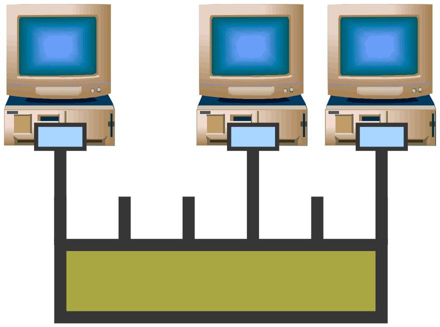
Collision Detection Techniques: Bus Topology

- Transceiver handles
  - Carrier detection
  - Collision detection
  - Jamming after collision
- Transceiver sees sum of voltages
  - Outgoing signal
  - Incoming signal
- Transceiver looks for
  - Voltages impossible for only outgoing



Collision Detection Techniques: Hub Topology

- Controller/Card handles
  - Carrier detection
- Hub handles
  - Collision detection
  - Jamming after collision
- Need to detect activity on all lines
  - If more than one line is active
    - Assert collision to all lines
    - Continue until no lines are active



10Mbps Ethernet Media

Name	Cable	Advantages	Max. Segment Length	Max Nodes on Segment
10Base5	Thick Coaxial (10mm)	Good for backbones	500m	100
10Base2	Thin Coaxial (5mm)	Cheapest system	200m	30
10BaseT	Twisted Pair (0.5mm)	Easy Maintenance	100m	1 (to hub)
10BaseFP	Fiber (0.1mm)	Best between buildings	500m	33
Extended segments may have up to 4 repeaters (total of 2.5km)				

100Mbps Ethernet Media

Name	Cable	Max. Segment Length	Advantages
100BaseT4	4 Twisted Pair	100m	Cat 3, 4 or 5 UTP
100BaseTX	Twisted Pair	100m	Full duplex on Cat 5 UTP
100BaseFX	Fiber Pair	100m	Full duplex, long runs
All hub based. Other types not allowed. Hubs can be shared or switched			

Ethernet in Practice

- Number of hosts
  - Limited to 200 in practice, standard allows 1024
- Range
  - Typically much shorter than 2.5km limit in standard
- Round Trip Time
  - Typically 5 or 10 μs, not 50
- Flow Control
  - Higher level flow control limits load (e.g. TCP)
- Topology
  - Star easier to administer than bus