



Lecture 22: Media Access Control

Multiple Access Problem

Broadcast channel of rate R bps, shared medium

- if two hosts send at the same time, **collision** results in no packet being received (interference)
- if no host is sending, channel goes idle
- we want to have only one host sending at a time

Media Access Control:

- determines which host gets to send next
- what to do when there's collision?

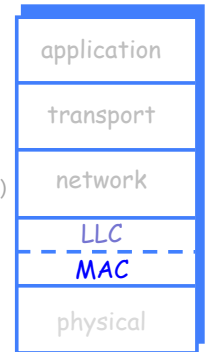
Duplex mode:

- **half duplex**: only one end can send at a time
- **full duplex**: both ends can send simultaneously

Data Link Layer

MAC topics:

- framing and MAC address assignment
- LAN forwarding
- IP to MAC address resolution
 - IP to MAC: Address Resolution Protocol (ARP)
 - MAC to IP: Dynamic Host Configuration Protocol (DHCP)
- media access control



Ideal Multiple Access Protocol

- when one host wants to send, it can send at rate R
- when M hosts want to send, each can send at an average rate of R/M
- fully decentralized:
 - **no** special **host to coordinate** transmissions
 - **no synchronization** of clocks, slots
 - **distributed algorithm** that determines how hosts share channel, i.e., determine when host can transmit
 - **no out-of-band channel** for coordination
 - coordination about channel sharing must use the channel itself!

Categorization of MAC Protocols

1. Random access:
 - Slotted ALOHA
 - ALOHA
 - Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
 - CSMA/CAvoidance
2. Token passing
3. Channel partitioning: TDMA, FDMA, CDMA

Standards:

- 802.3 (CSMA/CD), 802.3ab (GigE over twisted pair), 802.3z and 802.3ah (fiber)
- 802.4 (token bus)
- 802.5 (token ring)
- 802.11[bagn] (WiFi), 802.11a[dc]

Ethernet: CSMA/CD

Carrier Sense (CS):

1. check for presence of electrical signal (carrier) on wire before transmission
2. presence of carrier means someone else is sending, wait
3. start transmission if no carrier detected

Problem: collision

Random Access MAC Protocol

Characteristics:

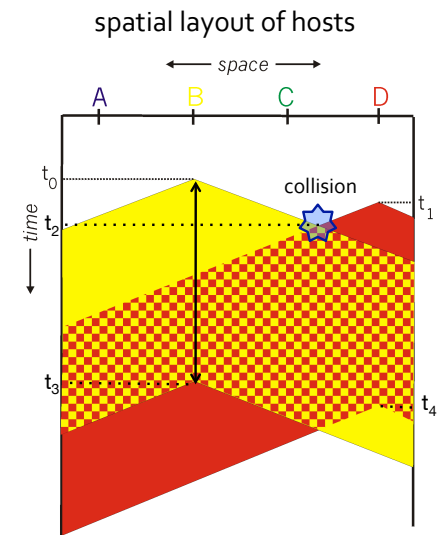
- sender transmits at full channel rate R bps
 - no prior coordination among nodes
- bits are propagated along the entire network
- destination recognizes that the frame is for itself
- destination grabs frame
- while one host is transmitting, all others must wait

Random access means:

- relies on collision to control access
- how to detect collisions?
- how to recover from collisions?

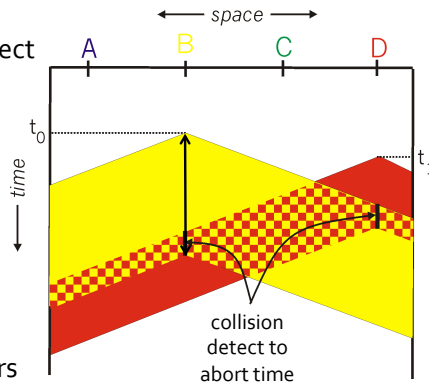
CSMA Collisions

- collisions occurs because due to propagation delay, two hosts may not hear of each other's transmission when they start transmitting (B at t_0 , D at t_1)
- when collision occurs (at t_2), entire frame transmission time (t_3-t_0 or, equivalently, t_4-t_1) is wasted
- note the role distance and propagation delay play in determining collision probability
- a collision is detected if power received is larger than power transmitted



Collision Detection (CD)

- 4. sender must continue to detect collision after transmission
 - on collision, frames must be retransmitted
 - problem: more collision
- 4. if adaptor detects collision while transmitting, aborts and sends jamming signal
- 5. after aborting, adaptor enters exponential back-off period



Jamming Signal and Exponential Back-off

Jamming signal: make sure all other transmitters are aware of collision; 48 bits

Exponential back-off: senders pick a uniformly distributed random delay between $[0, 2^0d]$ before retransmission. Why random?

If collision occurs again, pick another random delay between $[0, 2^1d], [0, 2^2d], [0, 2^3d], \dots$ hence (binary) exponential back-off

Retry at most 16 times, but cap back-off exponent at 10; for minimum frame size of 512 bits at 10 Mbps, max wait time is about 50 msec

CSMA/CD Summary

The CSMA/CD algorithm:

1. listen for carrier
2. if no carrier, send frame
3. listen for collision or jamming signal
4. if collision detected, send jamming signal
5. if collision or jamming signal detected, retransmit after exponential back-off

Carrier Sense (CS): listen before speaking, and don't interrupt

Collision Detection (CD): if someone else starts talking at the same time, shout them down

Exponential back-off: don't start talking again right away

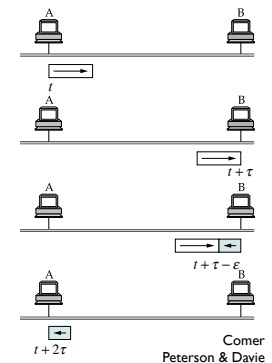
Historical Note:

Collision detection and retransmission with back-off was first used in the ALOHA and slotted ALOHA MAC algorithms from the University of Hawaii (1970) for access to satellite channels, but slotted ALOHA has no Carrier Sense and is less efficient

Collision Detection Time

How long must a sender listen for collision?

- let τ be the propagation time from one end of the wire to the other
- within τ time after the transmission of a frame (t), all nodes on the segment would have sensed carrier
- worst case scenario for collision: a node at the other end of the wire starts transmitting at time $t + \tau - \epsilon$
- the node closest to the collision sends out a jamming signal to ensure collision is detected by the other node
- it takes another τ period for the collision to get back to the original sender



Hence the original sender must listen for 2τ period

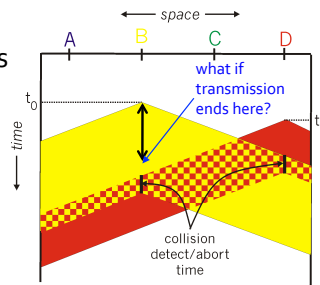
Minimum Frame Size

When a sender detects collision how does it know that the collision was caused by its packet?

Answer: sender must **hold carrier** for a period of 2τ , i.e., it must be transmitting for the whole 2τ period \Rightarrow each Ethernet frame must be at least $2\tau \times \text{linkspeed}$ long

Example:

- 10 Mbps Ethernet allows a maximum of 5 segments, each 500 m long
- speed of light $3 \times 10^8 \text{ m/s}$, but coax propagation only $2 \times 10^8 \text{ m/s}$
- round-trip propagation delay (2τ) on 2.5 km coax is $25 \mu\text{secs}$
- allowing for 4 repeaters makes end-to-end delay $50 \mu\text{secs}$
- $50 \mu\text{secs}$ at 10 Mbps is 62.5 bytes
- **802.3 standard** requires stations to hold carrier for **64 bytes or $51.2 \mu\text{secs}$**



CSMA/CD Efficiency (η)

t_{prop} = max propagation time between 2 hosts in the LAN

t_{trans} = time to transmit maximum-size frame

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

$\eta \rightarrow 1$ as $t_{\text{prop}} \rightarrow 0$ or as $t_{\text{trans}} \rightarrow \infty$

\Rightarrow larger frame size more efficient

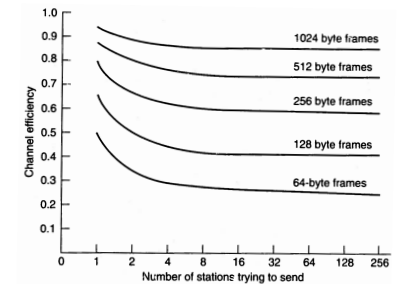
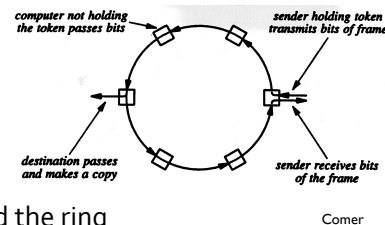


Fig. 4-23. Efficiency of 802.3 at 10 Mbps with 512-bit min frame size
Tanenbaum

Token Ring MAC Protocol

- a **token** goes around a ring network
- to send data, a node must first grab the token
- a frame sent from a source is passed from node to node around the ring
- destination recognizes own address and makes a copy of frame
- sender removes frame from ring
- each node can only transmit one frame at a time; must return token to the ring after each frame transmission



Why let the sender, instead of the receiver, remove frame from the ring?

Token Ring MAC Protocol

Token:

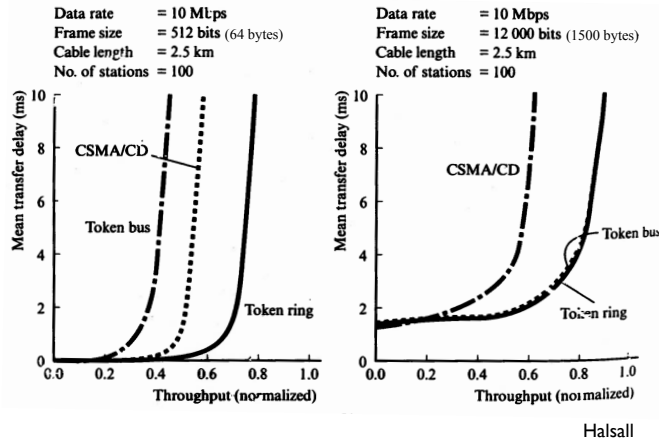
- a special bit pattern
- use bit-stuffing if data resembles token
- only one token on ring at a time (managed by a **monitor**)

IBM's token ring link speed is 16 Mbps

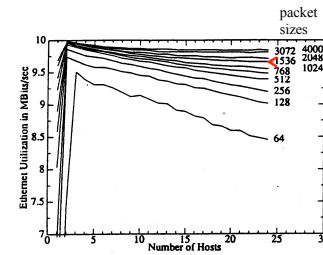
Token ring:

- advantage: no collision
- disadvantage:
 - requires a monitor (single point of failure)
 - latency

Token Ring Performance



CSMA/CD Efficiency (η)



Measured Capacity of an Ethernet: Myths and Reality

David R. Boggs
 Jeffrey C. Mogul
 Christopher A. Kent

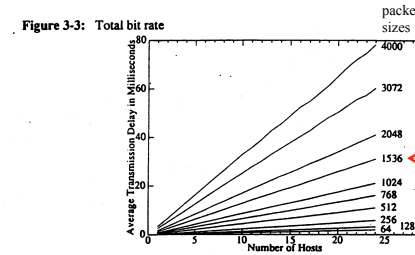
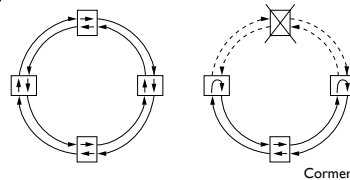


Figure 3-7: Average transmission delay

Other MAC Protocols

FDDI:

- operates at 100 Mbps
- uses the token ring MAC protocol
- for robustness, uses two counter-rotating rings
- if a link/node goes down, the dual-ring can be reconfigured to a single ring network (hence called **self-healing** network)



SLIP/PPP: serial line, point-to-point protocol, no need for media access control, just framing

ATM/Frame Relay/SONET: for backbone links