Overview

- Ethernet and Wi-Fi are both “multi-access” technologies
  - Broadcast medium, shared by many hosts
  - Simultaneous transmissions will result in collisions
- Media Access Control (MAC) protocol required
  - Rules on how to share medium
Media Access Control Protocols

• Channel partitioning
  – Divide channel into smaller “pieces” (e.g., time slots, frequency)
  – Allocate a piece to node for exclusive use
  – E.g. Time-Division-Multi-Access (TDMA) cellular network

• Taking-turns
  – Tightly coordinate shared access to avoid collisions
  – E.g. Token ring network

• Contention
  – Allow collisions
  – “recover” from collisions
  – E.g. Ethernet, Wi-Fi

Contention Media Access Control Goals

• Share medium
  – If two users send at the same time, collision results in no packet being received (interference)
  – If no users send, channel goes idle
  – Thus, want to have only one user send at a time

• Want high network utilization
  – TDMA doesn’t give high utilization

• Want simple distributed algorithm
  – no fancy token-passing schemes that avoid collisions
Evolution of Contention Protocols

Aloha
Developed in the 1970s for a packet radio network

Slotted Aloha
Improvement: Start transmission only at fixed times (slots)

CSMA
CSMA = Carrier Sense Multiple Access
Improvement: Start transmission only if no transmission is ongoing

CD = Collision Detection
Improvement: Stop ongoing transmission if a collision is detected (e.g. Ethernet)

(Pure) ALOHA

• **Topology:** Broadcast medium with multiple stations

• **Aloha Protocol:**
  – Whenever a station has data, it transmits immediately
  – Receivers ACK all packets
  – No ACK = collision. Wait a random time and retransmit
Simple, but Radical

- Previous attempts all partitioned channel
  - TDMA, FDMA, etc.

- Aloha optimized the common case (few senders) and dealt with collisions through retries

Trade-off Compared to TDMA

- In TDMA, you always have to wait your turn
  - delay proportional to number of sites

- In Aloha, can send immediately

- Aloha gives much lower delays, at the price of lower utilization (as we will see)
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 Mbps.
  - Original design was ~2 Mbps
  - 100Mbps, 1Gbps, 10Gbps

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
CSMA/CD: Some Details

- 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 48 bits
- Exponential backoff operates in multiples of 512 bit time.

CSMA collisions

Collisions can occur:
propagation delay means two nodes may not hear each other’s transmission

Collision:
entire packet transmission time wasted

Note:
role of distance and propagation delay in determining collision prob.
CSMA/CD (Collision Detection)

- Collisions detected within short time
- Colliding transmissions aborted, reducing channel wastage
- Easy in wired LANs:
  - measure signal strengths,
  - compare transmitted, received signals
- Difficult in wireless LANs
Minimum Packet Size

- Why put a minimum packet size?
- Give a host enough time to detect collisions
- In Ethernet, minimum packet size = 64 bytes (two 6-byte addresses, 2-byte type, 4-byte CRC, and 46 bytes of data)
- If host has less than 46 bytes to send, the adaptor pads (adds) bytes to make it 46 bytes
- What is the relationship between minimum packet size and the length of the LAN?

Minimum Packet Size (more)

\[
\frac{(\text{min\_frame\_size})}{(\text{bandwidth})} > 2 \cdot \frac{(\text{LAN\_length})}{\text{light\_speed}}
\]

\[
\text{LAN length} < \frac{(\text{min\_frame\_size})}{(\text{light\_speed})}/(2 \cdot \text{bandwidth}) = \frac{(8 \cdot 64b) \cdot (2.5 \cdot 10^8 \text{mps})}{(2 \cdot 10^7 \text{bps})} = 6400 \text{m approx}
\]
Exponential Backoff Algorithm

- Ethernet uses the exponential backoff algorithms to determine when a station can retransmit after a collision.

**Algorithm:**
- Set “slot time” equal to 512 bit time.
- After first collision wait 0 or 1 slot times.
- After i-th collision, wait a random number between 0 and $2^{i-1}$ time slots.
- Do not increase random number range, if $i=10$.
- Give up after 16 collisions.

CSMA/CD Contention Interval

- Contention slots end in a collision.
- Contention interval is a sequence of contention slots.
- Length of a slot in contention interval is 512 bit time.
Min packet size & slot time

- Min packet size is 512 bits
- Slot time is the transmission of 512 bits
- Coincident?
- If slot time is the transmission of 256 bits, then two stations picking 0 and 1 slot to wait respectively can still collide

Ethernet Frame Structure

- Sending adapter encapsulates IP datagram

  - Preamble:
    - 7 bytes with pattern 10101010 followed by one byte with pattern 101011
    - Used to synchronize receiver, sender clock rates

  Data

  - CRC

  Type (Length)
Ethernet Frame Structure (more)

- Addresses: 6 bytes, frame is received by all adapters on a LAN and dropped if address does not match
- Type: 2 bytes, is actually a length field in 802.3
- CRC: 4 bytes, checked at receiver, if error is detected, the frame is simply dropped
- Data payload: maximum 1500 bytes, minimum 46 bytes
  – If data is less than 46 bytes, pad with zeros to 46 bytes

Ethernet Addresses

- 48 bits long
- Globally unique
  – Burned into ROM of network cards
- Usually represented in hex: 00:a0:38:22:fe:33
  – First three bytes are manufacturer
  – Last three bytes are unique to device
- Also, one broadcast address ff:ff:ff:ff:ff:ff
  – All hosts receive packets sent to broadcast address
Ethernet Technologies: 10Base2

- 10: 10Mbps; 2: under 200 meters max cable length
- Thin coaxial cable in a bus topology
- Repeaters used to connect up to multiple segments
- Repeater repeats bits it hears on one interface to its other interfaces: physical layer device only!

10BaseT and 100BaseT

- 10/100 Mbps rate; latter called “fast ethernet”
- T stands for Twisted Pair
- Hub to which nodes are connected by twisted pair, thus “star topology”
10BaseT and 100BaseT (more)

- Max distance from node to Hub is 100 meters
- Hub can gather monitoring information, statistics for display to LAN administrators

- Hubs still preserve one collision domain
  - Every packet is forwarded to all hosts
- Use bridges to address this problem
  - Bridges forward a packet only to the destination leading to the destination
  - Next lecture

Gbit Ethernet

- Use standard Ethernet frame format
- Allows for point-to-point links and shared broadcast channels
- In shared mode, CSMA/CD is used; short distances between nodes to be efficient
- Full-Duplex at 1 Gbps for point-to-point links