High Level View

- Goal: share a communication medium among multiple hosts connected to it
- Problem: arbitrate between connected hosts
- Solution goals:
  - High resource utilization
  - Avoid starvation
  - Simplicity (non-decentralized algorithms)

Medium Access Protocols

- Channel partitioning
  - Divide channel into smaller “pieces” (e.g., time slots, frequency)
  - Allocate a piece to node for exclusive use
- Random access
  - Allow collisions
  - “recover” from collisions
- “Taking-turns”
  - Tightly coordinate shared access to avoid collisions

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
- Examples of random access MAC protocols:
  - Slotted ALOHA
  - CSMA and CSMA/CD
Slotted Aloha

- Time is divided into equal size slots (= packet transmission time)
- Node with new arriving pkt: transmit at beginning of next slot
- If collision: retransmit pkt in future slots with probability p, until successful.

Time

Slot

<table>
<thead>
<tr>
<th>Time</th>
<th>Node 1</th>
<th>Node 2</th>
<th>Node 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S</td>
<td>C</td>
<td>E</td>
</tr>
<tr>
<td>1</td>
<td>E</td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>E</td>
<td>S</td>
</tr>
<tr>
<td>3</td>
<td>S</td>
<td>C</td>
<td>E</td>
</tr>
<tr>
<td>4</td>
<td>E</td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>E</td>
<td>S</td>
</tr>
</tbody>
</table>

Success (S), Collision (C), Empty (E) slots

Slotted Aloha Efficiency

- What is the maximum fraction of successful transmissions?
- Suppose N stations have packets to send
  - Each transmits in slot with probability p
  - Prob. successful transmission S is (very approximated analysis!):

\[ S = p(1-p)^{N-1} \]

by a particular node: \( S = p(1-p)^{N-1} \)

by any of N nodes

\[ S = \text{Prob (only one transmits)} = Np(1-p)^{N-1} \Rightarrow 1/e = 0.37 \]

CSMA: Carrier Sense Multiple Access

- CS (Carrier Sense) means that each node can distinguish between an idle and a busy link

Sender operations:
- If channel sensed idle: transmit entire packet
- If channel sensed busy, defer transmission
  - Persistent CSMA: retry immediately with probability p when channel becomes idle
  - Non-persistent CSMA: retry after a random time interval

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

CSMA/CD collision detection

Overview

- Ethernet
  - Wireless (802.11)

Ethernet

- Dominant LAN technology
- CSMA/CD protocol
- Cheap $20 for 100Mbs!
**Ethernet Frame Structure**

- Sending adapter encapsulates IP datagram
  
  ![Ethernet Frame Structure Diagram]

- Preamble:
  - 7 bytes with pattern 10101010 followed by one byte with pattern 1010111
  - Used to synchronize receiver, sender clock rates

**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, indicates the higher layer protocol
  - E.g., IP, Novell IPX, AppleTalk
- CRC: 4 bytes, checked at receiver, if error is detected, the frame is simply dropped
- Data payload: maximum 1500 bytes, minimum 46 bytes

**Ethernet’s CSMA/CD**

- Sense channel, if idle
  - If detect another transmission
    - Abort, send jam signal
    - Delay, and try again
  - Else
    - Send frame
- Receiver accepts:
  - Frames addressed to its own address
  - Frames addressed to the broadcast address (broadcast)
  - Frames addressed to a multicast address, if it was instructed to listen to that address
  - All frames (promiscuous mode)

**Ethernet’s CSMA/CD (more)**

- Jam signal: make sure all other transmitters are aware of collision; 48 bits;
- Exponential back-off
  - Goal: adapt retransmission attempts to estimated current load
  - Heavy load: random wait will be longer
  - First collision: choose K from (0,1); delay is K x 512 bit transmission times
  - After second collision: choose K from (0,1,2,3)...
  - After ten or more collisions, choose K from (0,1,2,3,4,…,1023)
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)

- 1) Time = t; Host 1 starts to send frame
- 2) Time = t + d; Host 2 starts to send a frame just before it hears from Host 1's frame
- 3) Time = t + 2d; Host 1 hears Host 2's frame and detects collision

LAN length = (min_frame_size * light_speed / (2 * bandwidth)) = (8 * 64 / (2.5 * 10^8 /s) / (2 * 10^7 bps)) = 6400 m approx

Ethernet Technologies: 10Base2

- 10: 10Mbps; 2: under 200 meters max cable length
- Thin coaxial cable in a bus topology
- 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"
- CSMA/CD implemented at hub
10BaseT and 100BaseT (more)

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

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
- Uses hubs, called here “Buffered Distributors”
- Full-Duplex at 1 Gbps for point-to-point links

Interconnecting LANs

- Why not just one big LAN?
  - Limited amount of supportable traffic: on single LAN, all stations must share bandwidth
  - Limited length
  - Large “collision domain” (can collide with many stations)

Overview

- Ethernet
  - Wireless (802.11)
**Wireless (802.11)**

- Designed for use in limited geographical area (i.e., couple of hundreds of meters)
- Designed for three physical media (run at either 1Mbps or 2 Mbps)
  - Two based on spread spectrum radio
  - One based on diffused infrared

**Physical Link**

- Frequency hoping
  - Transmit the signal over multiple frequencies
  - The sequence of frequencies is pseudo-random, i.e., both sender and receiver use the same algorithm to generate their sequences
- Direct sequence
  - Represent each bit by multiple (e.g., $n$) bits in a frame; XOR signal with a pseudo-random generated sequence with a frequency $n$ times higher
- Infrared signal
  - Sender and receiver do not need a clear line of sight
  - Limited range; order of meters

**Collision Avoidance: The Problems**

- Reachability is not transitive: if A can reach C, and C can reach D, it doesn’t necessarily mean that A can reach D
- **Hidden nodes**: A and C send a packet to B; neither A nor C will detect the collision!
- **Exposed node**: B sends a packet to A; C hears this and decides not to send a packet to D (despite the fact that this will not cause interference!)

**Multiple Access with Collision Avoidance (MACA)**

- Before every data transmission
  - Sender sends a Request to Send (RTS) frame containing the length of the transmission
  - Receiver respond with a Clear to Send (CTS) frame
  - Sender sends data
  - Receiver sends an ACK; now another sender can send data
- When sender doesn’t get a CTS back, it assumes collision
Summary

- Arbitrate between multiple hosts sharing a common communication media
- Wired solution: Ethernet (use CSMA/CD protocol)
  - Detect collisions
  - Backoff exponentially on collision
- Wireless solution: 802.11
  - Use MACA protocol
  - Cannot detect collisions; try to avoid them