Announcements

- Homework #3 is

- Reading
  - Today: 3.5-3.6
Error Detection

- **Less bits are required**
  - if errors are infrequent, then this works better
  - assumes that retransmission is possible

- **Cyclic Redundancy Codes (CRC)**
  - Use a generator function $G(x)$ of degree $r$
  - let $M'$ be the message with $r$ 0’s on the end of it
  - divide $M'$ into $G(x)$ and compute remainder
    - use this as the $r$ bit CRC code
  - a code with $r$ bits will detect all burst errors less than $r$ bits
  - several $G$’s are standardized
    - CRC-12 = $x^{12} + x^{11} + x^3 + x^2 + x + 1$
    - CRC-16 = $x^{16} + x^{15} + x^2 + 1$
    - CRC-CCITT = $x^{16} + x^{12} + x^5 + 1$
  - 16 bit CRC will catch
    - all single and double bit errors
    - all errors with an odd number of bits
    - all burst errors of length less than 16
CRC Example

Frame: 1101011011
Generator: 10011
Message after appending 4 zero bits: 11010110000

Transmitted frame: 11010110111110
PPP Protocol

- **Link Protocol for Serial Lines**
  - Supports multiple network protocols: IP, IPX, CLNP, ...
  - designed for dialup or leased lines

- **Link Establishment**
  - configure-request: list of proposed options and values
  - configure- {ack/ nack}: will (won’t) use the requested option
  - NCP protocol
    - per network level protocol
    - used to establish network attributes (e.g. addresses)

<table>
<thead>
<tr>
<th>flag</th>
<th>Address</th>
<th>control</th>
<th>protocol</th>
<th>payload</th>
<th>checksum</th>
<th>flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>01111110</td>
<td>11111110</td>
<td>0001110</td>
<td>01111110</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From: *Computer Networks, 3rd Ed.* by Andrew S. Tanenbaum, (c)1996 Prentice Hall.
ATM Datalink Protocol

- **Header**
  - use CRC over the 32 bits of the header

- **How to find cell boundary?**
  - use shifty register to check for valid checksum
    - 1/256 chance of a random match
  - use HUNT mode to increase chances
    - after a good cell, skip to the next cell boundary
    - must receive $\delta$ cells with checksum matches

- **Detecting loss of synchronization**
  - one bad cell is probably an error
  - many bad cells is likely a slip (loss of sync)
  - if $\alpha$ bad cells are seen in a row, switch to hunt mode
Medium Access Layer

- **Broadcast Networks**
  - share a common resource for communication
    - bus, wire, air, etc.
  - need to coordination access to this resource

- **Limits of Static Channel Allocation**
  - suitable for constant rate traffic of similar speeds
  - however, bursty traffic results in poor channel utilization
  - consider one queue vs. separate queues for each person
    - $n$ queues with bursty arrival have mean delay $n$ times 1 queue

- **Dynamic Allocation**
  - only use channel when have something to send
  - need to control access to the channel
Shared Channel Model

- **Station model**
  - N independent stations
  - each wants to send $\lambda$ frames per second
  - a station may not send another frame until the first is sent

- **Single Channel Assumption**
  - all stations communicate over a single shared channel

- **Collisions:** two stations attempt to send at once
  - neither transmission succeeds

- **Time**
  - continuous time: frame transmissions can start anytime
  - discrete time: clock ensures all sends initiate at the start of a slot

- **Carrier Sense**
  - stations can tell if channel is in use before sending
  - stations must wait to know if channel was in use
Aloha

- **Stations**
  - ground based radio stations on islands

- **Pure Aloha**
  - send data a will, collisions will happen
  - on collision, wait a random amount of time & try again
  - use standard, fixed size packets
  - what is channel efficiency?
    - assume $S_{\text{new}}$ frames per frame time
    - assume $G$ total frames trying to be sent per frame time
    - $S = GP_0$
    - probability of $k$ frames generated during a frame time
      - $Pr[k] = G^k e^{-G}/k!$
    - $P_o = e^{-2G}$, so $S = Ge^{-2G}$
Performance of Aloha

Collides with the start of the shaded frame
Collides with the end of the shaded frame

$t_0$, $t_0 + t$, $t_0 + 2t$, $t_0 + 3t$

Vulnerable

$S$ (throughput per frame time)

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Slotted ALOHA: $S = Ge^{-G}$
Pure ALOHA: $S = Ge^{-2G}$

G (attempts per packet time)

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Aloha (cont.)

- **Slotted Aloha**
  - Use a central clock
  - Each station only sends at the start of frame
  - Reduces collision window by 1/2
    - \[ S = G e^{-G} \]
Carrier Sense Multiple Access

- **look before you leap!**
  - don’t send if someone else is sending

- **collisions are still possible**
  - propagation delay induces uncertainty into sensing
  - possible two hosts both start sending at the same time

- **persistence: when to send after detecting channel in use**
  - 1-persistent
    - as soon as the channel is free, starting sending
  - nonpersistent CSMA
    - if channel is sensed busy, wait a random time and try again
  - p-persistent CSMA
    - if slot is idle send with probability p, else wait for next idle slot