CSE 461: Midterm Review

Winter 2021
Administrivia

- **Midterm!**
  - February 8th, **Monday**, 12:30pm - 1:30pm PST
  - Different time zone?

- Assignment 3 due Feb 8th, **Monday**, 11pm
Network Components

- Parts of a Network
- Types of Links
- Protocols and Layers
- Encapsulation
Parts of a Network

- Parts of a Network

- Types of Links
  - Simplex
  - Full-duplex
  - Half-duplex
## Protocols and Layers

<table>
<thead>
<tr>
<th>Layer</th>
<th>Purpose</th>
<th>Protocols</th>
<th>Unit of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>Programs that use network service</td>
<td>HTTP, DNS</td>
<td>Message</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>Provides end-to-end data delivery</td>
<td>TCP, UDP</td>
<td>Segment</td>
</tr>
<tr>
<td><strong>Network</strong></td>
<td>Sends packets across multiple networks</td>
<td>IP</td>
<td>Packet</td>
</tr>
<tr>
<td><strong>Link</strong></td>
<td>Sends frames across a link</td>
<td>Ethernet, Cable</td>
<td>Frame</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td>Transmit bits</td>
<td>__</td>
<td>Bit</td>
</tr>
</tbody>
</table>
Protocols and Layers

**ADVANTAGES**
- Use information hiding to connect different systems
- Information reuse to build new protocols

**DISADVANTAGES**
- Adds overhead
- Hides information
Encapsulation
Physical Layer

- Coding: Clock Recovery
- Modulation
- Latency
- Media and Theoretical Limits
Coding: Clock Recovery

One answer - 4B/5B
- map every 4 data bits to 5 data bits
- such that there are no more than 3 zeros in a row
- invert signal level on a 1 to break up long runs of 1s
Modulation

- Baseband modulation allows signal to be sent directly on wire
  - NRZ signal of bits

- Passband modulation carries a signal by modulating a carrier
  - Amplitude shift keying
  - Frequency shift keying
  - Phase shift keying
Latency

- Latency = Transmission Delay + Propagation Delay
- Transmission Delay = \( \frac{M}{R} \) (sec)
- Propagation Delay = Length / Speed of Signals = \( \frac{\text{Length}}{\frac{2}{3}c} \) = \( D \) (sec)

Bandwidth-Delay Product = \( R \times D \) = \( BD \) (bits)

RTT = round-trip time
Media and Theoretical Limits

- **Media**
  - Wire, Fiber
  - Wireless: radiates signal over a region

- **Channel Limits**: how rapidly can we send information over a link?
  - Bandwidth (\(B\)), Signal Power (\(S\)), Noise Power (\(N\))
  - Shannon Capacity - maximum lossless info carrying rate

\[
C = B \log_2(1 + S/N) \text{ bits/sec}
\]
Link Layer

- Framing
- Error detection and correction
- Retransmissions
- Multiple Access
- Switching
Framing Methods

- How do we know where a bit sequence (frame) begins and ends?
  - Byte count
  - Byte stuffing
  - Bit stuffing

- Byte Count
Framing Methods

- **Byte Stuffing**
  - Replace ESC in data with ESC ESC, and replace FLAG in data with ESC FLAG

- **Bit Stuffing**
  - Sequences of 1s as flag, and then add 0 after each flag within data
Error Detection and Correction

- Add check bits to the message bits to let some errors be detected
- Add more check bits to let some errors be corrected
Hamming Distance

- HD between two codes (D1, D2)
  - the number of bit flips needed to change D1 to D2
  - D1 = 0110110101001
  - D2 = 0100000100001

- HD of a coding
  - the minimum error distance between any pair of codewords that cannot be detected

- For a Hamming distance of \( d + 1 \), up to \( d \) errors will be detected
- For a Hamming distance of \( 2d + 1 \), up to \( d \) errors can be corrected
## Error Detection Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Hamming Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity Bit</td>
<td>Add 1 check bit that is sum/XOR of d data bits</td>
<td>2</td>
</tr>
<tr>
<td>Internet Checksum</td>
<td>1s complement sum of 16 bit word</td>
<td>2</td>
</tr>
<tr>
<td>Cyclic Redundancy Check (CRC)</td>
<td>For n data bits, generate n+k bits that are evenly divisible by C</td>
<td>4</td>
</tr>
</tbody>
</table>
HD of Internet Checksum

\[
\begin{align*}
0001 & \\
f204 & \\
f4f5 & \\
f6f7 & \\
+ \quad 220c & \\
\hline & 2fffd \\
\hline & ffffd \\
+ \quad 2 & \\
\hline & fffff \\
\hline & 0000
\end{align*}
\]
Error Correction - Hamming Code

Hamming Distance = 3

Suppose we want to send a message M of 4 bits: 0101
We add k=3 check bits, because \( n = 2^k - k - 1 = 2^3 - 3 - 1 = 4 \)

So, we will have a \( n+k = 7 \) bit code, with check bits in positions 1, 2, 4
Each check bit is an XOR of certain positions.
Error Correction - Hamming Code

\[
\begin{array}{cccc}
421 & 421 & 421 \\
1 = 0b001 & 1 = 0b001 & 1 = 0b001 \\
2 = 0b010 & 2 = 0b010 & 2 = 0b010 \\
3 = 0b011 & 3 = 0b011 & 3 = 0b011 \\
4 = 0b100 & 4 = 0b100 & 4 = 0b100 \\
5 = 0b101 & 5 = 0b101 & 5 = 0b101 \\
6 = 0b110 & 6 = 0b110 & 6 = 0b110 \\
7 = 0b111 & 7 = 0b111 & 7 = 0b111 \\
\end{array}
\]

\[
\begin{array}{cccc}
0 & 1 & 0 & 0 \\
1 & 2 & 3 & 4 \\
p1 = b3+b5+b7 = 0+1+1 = 0 \\
\end{array}
\]

\[
\begin{array}{cccc}
1 & 0 & 0 & 1 \\
5 & 6 & 7 \\
p2 = b3+b6+b7 = 0+0+1 = 1 \\
p4 = b5+b6+b7 = 1+0+1 = 0 \\
\end{array}
\]

\[
\begin{array}{cccc}
0 & 1 & 0 & 0 \\
1 & 2 & 3 & 4 \\
p1 = 0+0+1+1 = 0, \quad p2 = 1+0+1+1 = 1, \\
p4 = 0+1+1+1 = 1 \\
\end{array}
\]

\[
\begin{array}{cccc}
0 & 1 & 0 & 0 \\
6 & 7 \\
\end{array}
\]

**Example, continued**

\[
\begin{array}{cccc}
0 & 1 & 0 & 0 \\
1 & 2 & 3 & 4 \\
\end{array}
\]

Syndrome = 1 1 0, flip position 6

Data = 0 1 0 1 (correct after flip!)
ARQ - Automatic Repeat Request

- ARQ
- Stop-and-wait
- Sliding window
Multiplexing

- Time Division Multiplexing - high rate at some times

- FDM - low rate all the time
Multiple Access

- **ALOHA**: Node just sends when it has traffic; if collision happens, wait for a random amount of time and try again.
  - Huge amount of loss under high load
- **CSMA (Carrier Sense Multiple Access)**: Listen before send.
  - Collision is still possible because of delay; good only when BD is small
- **CSMA/CD (Carrier Sense Multiple Access with Collision Detection)**: CSMA + Aborting JAM for the rest of the frame time
  - Minimum frame length of 2D seconds
- **CSMA “Persistence”**: CSMA + P(send) = 1 / N
  - Reduce the chance of collision
- **Binary Exponential Backoff (BEB)**: Doubles interval for each successive collision
  - Very efficient in practice
Issues with Wireless

**Hidden Terminal Problem:** nodes A and C are hidden terminals when sending to B

**Exposed Terminal Problem:** nodes B and C are exposed terminals when sending to A and D

MACA is a potential solution: Sender sends Request to Send(RTS) and receiver replies Clear To Send(CTS).
Switches

- **Backward Learning**
  - Learn the sender’s port by looking at the packets

- **Spanning Tree**
  - Elect the root node of the tree (Usually the switch with the lowest address)
  - Grow tree based on the shortest distance from the root
  - Ports not on the spanning tree are turned off
Network Layer

- Core protocols
  - IP
  - ICMP
  - ARP
  - DHCP
- Routing / Forwarding
  - Routing - decide where to send
  - Forward - send