CSE/EE 461 – Lecture 3

Bits and Bandwidth

Last Time …

- Protocols, layering and reference models

Your call
- Encode/decode messages
- Manage connections
- Reliability, congestion control
- Routing
- Framing, multiple access
- Symbol coding, modulation

The OSI Model

Application
  Presentation
  Session
  Transport
  Network
  Link
  Physical

“Netscape”
- HTTP
- TCP
- IP
- Ethernet

Sample Protocol Stack
### What's Inside a Packet

<table>
<thead>
<tr>
<th>Layer</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet Header</td>
<td>FROM=00:30:65:0f:ea:62, TO=00:30:64:9a:11:22, SIZE=200,...</td>
</tr>
<tr>
<td>IP Header</td>
<td>FROM=128.95.1.32, TO=28.2.5.1, SIZE=200-SIZEOF(Ehdr)</td>
</tr>
<tr>
<td>TCP Header</td>
<td>FROM=Port-5000, TO=Port-80, Byte#=23, SIZE=200-SIZEOF(Ehdr)-SIZEOF(IPHdr)</td>
</tr>
<tr>
<td>HTTP Hdr</td>
<td>HTTP v.1.0, Mosaic,... GET <a href="http://netscape.com/news.html">http://netscape.com/news.html</a></td>
</tr>
</tbody>
</table>

A Protocol is an ENCAPSULATION. One protocol’s *payload* may be another encapsulated protocol.

### This Lecture

- **Focus:** *How do we send a message across a wire?*
  - The physical/link layers:
    1. Different kinds of media
    2. Encoding bits
    3. Model of a link
1. It’s all just a wire.

- Different wires have different BW, Reliability, Distance, Power, etc properties.
  - Some wires aren’t even wires.

![Freq (Hz) Diagram](image)

Radio  Microwave IR  Light UV

Less  More

2. Bits and Signals

- Wires carry waves.
- Protocols need bits.
- Generate analog waveform (e.g., voltage) from digital data at transmitter and sample to recover at receiver

![Waveform Diagram](image)

- We send/recover symbols that are mapped to bits
  - Signal transition rate = baud rate, versus bit rate
- This is baseband transmission … learn more in a signals course
- Various encoding schemes to reduce errors
  - NRZ, NRZI, Manchester, 4B/5B, etc.
  - Goals are:
    - Make transitions clear
    - Don’t use too many signals for things other than data

L3.5  L3.6


• Need to send message, not just bits
  – Requires that we synchronize on the start of message reception at the far end of the link
  – Complete Link layer messages are called frames

• Common approach: Sentinels
  – Look for special control code that marks start of frame
  – And escape or “stuff” this code within the data region

3. Model of a Link

• Abstract model is typically all we will need
  – What goes in comes out altered by the model

• Other parameters that are important:
  – The kind and frequency of errors
  – Whether the media is broadcast or not
Message Latency

• How long does it take to send a message?

• Two terms:
  – Propagation delay = distance / speed of light in media
    • How quickly a message the wire
  – Transmission delay = message (bits) / rate (bps)
    • How quickly you can inject the message onto the wire
• Later we will see queuing delay …

Relationships

• Latency = Propagation + Transmit + Queue
• Propagation Delay = Distance/SpeedOfLight
• Transmit Time = MessageSize/Bandwidth
One-way Latency

- Dialup with a modem:
  - $D = 10\text{ms}$, $R = 56\text{Kbps}$, $M = 1000\text{ bytes}$
  - Latency = $10\text{ms} + (1024 \times 8)/(56 \times 1024)\text{ sec} = 153\text{ms}$!

- Cross-country with T3 (45Mbps) line:
  - $D = 50\text{ms}$, $R = 45\text{Mbps}$, $M = 1000\text{ bytes}$
  - Latency = $50\text{ms} + (1024 \times 8) / (45 \times 1000000)\text{ sec} = 50\text{ms}$!

- Either a slow link or long wire makes for large latency
- How does latency impact protocol design?

Messages Occupy “Space” On the Wire

- Consider a 1b/s network.
- How much space does 1 byte take?
- Suppose delay is 16 seconds.
- How many bits can the network “store”
- This is the BANDWIDTH-DELAY product
  - Measure of “data in flight.”
  - 1b/s * 16s = 16b
- Tells us how much data can be sent before a receiver sees any of it.
- Twice B.D. tells us how much data we could send before hearing back from the receiver something related to the first bit sent.
  - Implications?
A More Realistic Example

BD = 50ms * 45Mbps = 2.25 * 10^6 = 280KB

Throughput

- Measure of system’s ability to “pump out” data
- NOT the same as bandwidth
- Throughput = Transfer Size / Transfer Time
  - Eg, “I transferred 1000 bytes in 1 second on a 100Mb/s link”
    - BW?
    - Throughput?
  - Transfer Time = SUM OF
    - Time to get started shipping the bits
    - Time to ship the bits
    - Time to get stopped shipping the bits
- What’s the best we can do to “get started?”
  - Put something, get something
- Always more efficient to move big things
Latency and RTT

- Latency is typically the one way delay over a link
  - Arrival Time - Departure Time

- The round trip time (RTT) is twice the one way delay
  - Measure of how long to signal and get a response

Key Concepts

- We need to encode bits into signals so that we can recover them at the other end of the channel.
- We typically model links in terms of bandwidth and delay, from which we can calculate message latency
- Different media have different properties that affect their performance as links