CS 457 – Lecture 3
Performance Wrap-Up
and Link Layer Start
Fall 2011
Network latency

- Time to send a packet from point A to point B
  - sum of delays across each hop along the path

\[
\text{Delay}_{A-B} = \text{Delay}_{A-1} + \text{Delay}_{1-2} + \text{Delay}_{2-3} + \text{Delay}_{3-B}
\]

- RTT: round-trip-time

\[
\text{RTT}_{AB} = \text{Delay}_{A-B} + \text{Delay}_{B-A}
\]
Bandwidth and Latency

Bandwidth matters:
L large => L/R dominates
Increasing R reduces latency

Prop delay matters:
L small => L/R also small
Increasing R has no impact
Bandwidth-Delay Product

- **bandwidth**
  - 10Mbps
  - 20Mbps

- **time**

(bandwidth × delay) product: amount of data "in-the-pipe"

Determines how much data is in transit (and thus cannot be stopped)

- Propagation delay = 10ms
- Bandwidth = 1 Gbps
- 125KB data in the pipe
## Examples

<table>
<thead>
<tr>
<th>Link Type</th>
<th>Bandwidth</th>
<th>Distance</th>
<th>RTT</th>
<th>BW x Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dial-up</td>
<td>56Kb/s</td>
<td>10Km</td>
<td>87 µs</td>
<td>5 bits</td>
</tr>
<tr>
<td>Wireless Lan</td>
<td>54Mb/s</td>
<td>50m</td>
<td>0.33 µs</td>
<td>18 bits</td>
</tr>
<tr>
<td>Satellite</td>
<td>45 Mb/s</td>
<td>33,000 Km</td>
<td>230 ms</td>
<td>10 Mb</td>
</tr>
<tr>
<td>Cross-country fiber</td>
<td>10Gb/s</td>
<td>4,000 Km</td>
<td>40 ms</td>
<td>400 Mb</td>
</tr>
</tbody>
</table>
Store and Forward (1/2)

- **Store and Forward**: Entire packet must arrive at router before it can be transmitted on next link:
  - Let $d_{queue} = d_{prop} = 0$
  - Takes $d_{trans} = L/R$ seconds to transmit (push out) packet of $L$ bits on to link of $R$ bps

**Example:**
- $L = 8000$ bits (1000 bytes)
- $R = 2$ Mbps
- Delay(A-B) = $3L/R = 12$ msec
Store-and-Forward (2/2)

- A sends 5 packets to B
- L = 8000 bits, R = 2 Mbps
  - Dqueue = Dprop = 0
- How long does it take starting from A sending the first bit of first packet till B receives the last bit of the last packet?
Link Layer Protocols
The Internet Hourglass Design

[Deering98]
Topics

- Link-layer services (2.1 – 2.4)
  - Encoding, framing, and error detection
  - Error correction and flow control
  - Forms necessary background

- Reliable Transmission (2.5)
  - First look at an essential part of networking

- Ethernet, WiFi, Cellular (2.6, 2.7, 2.8)
  - How to share a transmission medium
  - Carrier sense, collision detection, and random access
Message, Segment, Packet, & Frame

WE ARE HERE IN THE LAYERS
Adaptors Communicating

- Link layer implemented in adaptor (network interface card)
  - Ethernet card, PCMCIA card, 802.11 card
- Sending side:
  - Encapsulates datagram in a frame
  - Adds error checking bits, flow control, etc.
- Receiving side
  - Looks for errors, flow control, etc.
  - Extracts datagram and passes to receiving node
Point to Point Data Links

• One sender, One receiver, One link: easier than broadcast link:
  – no Media Access Control
  – no need for explicit MAC addressing
  – e.g., dialup link, ISDN line

• Popular Point-to-Point DLC protocols:
  – PPP (point-to-point protocol)
  – HDLC: High level data link control
PPP Design Requirements [RFC 1557]

- **Packet framing**: encapsulation of network-layer datagram in data link frame
  - carry network layer data of any network layer protocol (not just IP) *at same time*
  - ability to demultiplex upwards
- **Bit transparency**: must carry any bit pattern in the data field
- **Error detection** (no correction)
- **Connection liveness**: detect, signal link failure to network layer
- **Network layer address negotiation**: endpoint can learn/configure each other’s network address
PPP non-requirements

• No error correction/recovery
• No flow control
• Out of order delivery OK
• No need to support multipoint links (e.g., polling)
  • Error recovery, flow control, data re-ordering
    • all relegated to higher layers!
PPP Data Frame

- **Flag**: delimiter (framing)
- **Address**: does nothing (only one option)
- **Control**: does nothing; in the future possible multiple control fields
- **Protocol**: upper layer protocol to which frame delivered (e.g., PPP-LCP, IP, IPCP, etc)

```
<table>
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<tr>
<th>flag</th>
<th>control</th>
<th>address</th>
<th>protocol</th>
<th>info</th>
<th>check</th>
<th>flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>01111110</td>
<td>11111111</td>
<td>00000011</td>
<td>protocol</td>
<td>info</td>
<td>check</td>
<td>01111110</td>
</tr>
</tbody>
</table>
```

flag
---
control
address
protocol
info
check
flag
PPP Data Frame

- **info**: upper layer data being carried
- **check**: cyclic redundancy check for error detection
**Byte Stuffing**

- “data transparency” requirement: data field must be allowed to include flag pattern <01111110>
  - **Q:** is received <01111110> data or flag?

- **Sender:** adds (“stuffs”) extra < 01111110> byte after each < 01111110> **data** byte

- **Receiver:**
  - two 01111110 bytes in a row: discard first byte, continue data reception
  - single 01111110: flag byte
Byte Stuffing

- flag byte pattern
- pattern in data to send

Flag byte pattern plus stuffed byte in transmitted data
What’s Next

• Read Chapter 1, 2.1 - 2.5

• Next Lecture Topics from Chapter 2.1- 2.5
  – Link Layer Basics
  – Reliable Transmission
    • Critical Topic In Networking

• Homework 2
  – Due Thursday

• Project 1
  – Report your group to cs457@cs by Thurs
  – Deadline Extended to Friday 9/16
Ethernet Frame Structure

- Sending adapter encapsulates packet in frame

- **Preamble**: synchronization
  - Seven bytes with pattern 10101010, followed by one byte with pattern 10101011
  - Used to synchronize receiver, sender clock rates