Data link layer: Ethernet

- Broadcast network

- CSMA-CD: Carrier Sense Multiple Access with Collision Detection
  - recall the "standing in a circle, drinking beer and telling stories" analogy
- Packetized – fixed
- Every computer has a unique physical address
  - 00-08-74-C9-C8-7E

Network layer: IP

- Internet Protocol (IP)
  - routes packets across multiple networks, from source to destination
- Every computer has a unique Internet address
  - 172.30.192.251
- Individual networks are connected by routers that have physical addresses (and interfaces) on each network

- A really hairy protocol lets any node on a network find the physical address on that network of a router that can get a packet one step closer to its destination
- Packet format

  physical address payload

  IP address payload
• A separate really hairy protocol, DNS (the Domain Name Service), maps from intelligible names (lazowska.org) to IP addresses (174.61.234.236)
• So to send a packet to a destination
  – use DNS to convert domain name to IP address
  – prepare IP packet, with payload prefixed by IP address
  – determine physical address of appropriate router
  – encapsulate IP packet in Ethernet packet with appropriate physical address
  – blast away!
• Detail: **port number** gets you to a specific address space on a system
  – a process can “register” for a port, and some are always used: 25=SMTP, 80=web server, 20=FTP, 22=ssh, etc.

**Transport layer: TCP**

• **TCP: Transmission Control Protocol**
  – manages to fabricate reliable multi-packet messages out of unreliable single-packet datagrams
  – analogy: sending a book via postcards — what’s required?

<table>
<thead>
<tr>
<th>physical address</th>
<th>payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP address</td>
<td>payload</td>
</tr>
<tr>
<td>TCP info</td>
<td>payload</td>
</tr>
</tbody>
</table>

**Summary**

• Using TCP/IP and lower layers, we can get multi-packet messages delivered reliably from address space A on machine B to address space C on machine D, where machines B and D are many heterogeneous network hops apart, without knowing any of the underlying details
• Higher protocol layers facilitate specific services
  – email: smtp
  – web: http
  – file transfer: ftp
  – remote login: telnet