## Open Systems Interconnection (OSI) Reference Model

<table>
<thead>
<tr>
<th>Upper Layers</th>
<th>Lower Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Layer (7)</td>
<td>Physical Layer (1)</td>
</tr>
<tr>
<td>Presentation Layer (6)</td>
<td>802.3, 802.11, 802.15</td>
</tr>
<tr>
<td>Session Layer (5)</td>
<td>FDDI, ATM, ISDN</td>
</tr>
<tr>
<td>Transport Layer (4)</td>
<td>TCP/IP, UDP/PUP</td>
</tr>
<tr>
<td>Network Layer (3)</td>
<td>IP, ARP, ICMP, RARP</td>
</tr>
<tr>
<td>Data Link Layer (2)</td>
<td>Ethernet II, 802.3 SNAP</td>
</tr>
<tr>
<td>Physical Layer (1)</td>
<td>Physical Medium</td>
</tr>
</tbody>
</table>

- Email: PDP/SMIP, PDP/25
- News: UserNet
- Web Services: HTTP
- File Transfer: FTP
- Host Sessions: Telnet
- Directory Services: DNS
- Network Mgmt: SNMP, ICMP, IGMP
- File Services: NIS, RPC, Portmapper

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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

- Packet format

  physical address | payload

- Interface listens for its address, interrupts OS when a packet is received
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
• 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>
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<tr>
<th>physical address</th>
<th>payload</th>
</tr>
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<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