Interfacing Processors and Peripherals

- **I/O Design** affected by many factors (expandability, resilience)
- **Performance:**
  - access latency
  - throughput
  - connection between devices and the system
  - the memory hierarchy
  - the operating system
- **A variety of different users** (e.g., banks, supercomputers, engineers)

```
Processor
  └── interrupts
     ├── Cache
     └── Memory–I/O bus
         └── Main memory
             ├── I/O controller
             │    └── Disk
             └── I/O controller
                 └── Graphics output
                     └── I/O controller
                         └── Network
```
I/O

• Important but neglected

“The difficulties in assessing and designing I/O systems have often relegated I/O to second class status”

“courses in every aspect of computing, from programming to computer architecture often ignore I/O or give it scanty coverage”

“textbooks leave the subject to near the end, making it easier for students and instructors to skip it!”

• GUILTY!

— we won’t be looking at I/O in much detail

— be sure and read Chapter 8 in its entirety.

— you should probably take a networking class!
### I/O Devices

- **Very diverse devices**
  - behavior (i.e., input vs. output)
  - partner (who is at the other end?)
  - data rate

<table>
<thead>
<tr>
<th>Device</th>
<th>Behavior</th>
<th>Partner</th>
<th>Data rate (KB/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyboard</td>
<td>input</td>
<td>human</td>
<td>0.01</td>
</tr>
<tr>
<td>Mouse</td>
<td>input</td>
<td>human</td>
<td>0.02</td>
</tr>
<tr>
<td>Voice input</td>
<td>input</td>
<td>human</td>
<td>0.02</td>
</tr>
<tr>
<td>Scanner</td>
<td>input</td>
<td>human</td>
<td>400.00</td>
</tr>
<tr>
<td>Voice output</td>
<td>output</td>
<td>human</td>
<td>0.60</td>
</tr>
<tr>
<td>Line printer</td>
<td>output</td>
<td>human</td>
<td>1.00</td>
</tr>
<tr>
<td>Laser printer</td>
<td>output</td>
<td>human</td>
<td>200.00</td>
</tr>
<tr>
<td>Graphics display</td>
<td>output</td>
<td>human</td>
<td>60,000.00</td>
</tr>
<tr>
<td>Modem</td>
<td>input or output</td>
<td>machine</td>
<td>2.00-8.00</td>
</tr>
<tr>
<td>Network/LAN</td>
<td>input or output</td>
<td>machine</td>
<td>500.00-6000.00</td>
</tr>
<tr>
<td>Floppy disk</td>
<td>storage</td>
<td>machine</td>
<td>100.00</td>
</tr>
<tr>
<td>Optical disk</td>
<td>storage</td>
<td>machine</td>
<td>1000.00</td>
</tr>
<tr>
<td>Magnetic tape</td>
<td>storage</td>
<td>machine</td>
<td>2000.00</td>
</tr>
<tr>
<td>Magnetic disk</td>
<td>storage</td>
<td>machine</td>
<td>2000.00-10,000.00</td>
</tr>
</tbody>
</table>
I/O Example: Disk Drives

• To access data:
  — seek: position head over the proper track (8 to 20 ms. avg.)
  — rotational latency: wait for desired sector (.5 / RPM)
  — transfer: grab the data (one or more sectors) 2 to 15 MB/sec
I/O Example: Buses

- Shared communication link (one or more wires)
- Difficult design:
  - may be bottleneck
  - length of the bus
  - number of devices
  - tradeoffs (buffers for higher bandwidth increases latency)
  - support for many different devices
  - cost
- Types of buses:
  - processor-memory (short high speed, custom design)
  - backplane (high speed, often standardized, e.g., PCI)
  - I/O (lengthy, different devices, standardized, e.g., SCSI)
- Synchronous vs. Asynchronous
  - use a clock and a synchronous protocol, fast and small
    but every device must operate at same rate and
clock skew requires the bus to be short
  - don’t use a clock and instead use handshaking
• Let’s look at some examples from the text
  
  “Performance Analysis of Synchronous vs. Asynchronous”
  “Performance Analysis of Two Bus Schemes”
Other important issues

- **Bus Arbitration:**
  - daisy chain arbitration (not very fair)
  - centralized arbitration (requires an arbiter), e.g., PCI
  - self selection, e.g., NuBus used in Macintosh
  - collision detection, e.g., Ethernet

- **Operating system:**
  - polling
  - interrupts
  - DMA

- **Performance Analysis techniques:**
  - queuing theory
  - simulation
  - analysis, i.e., find the weakest link (see “I/O System Design”)

- **Many new developments**