Input / Output

CSE 410 - Computer Systems

October 29, 2001

Readings and References

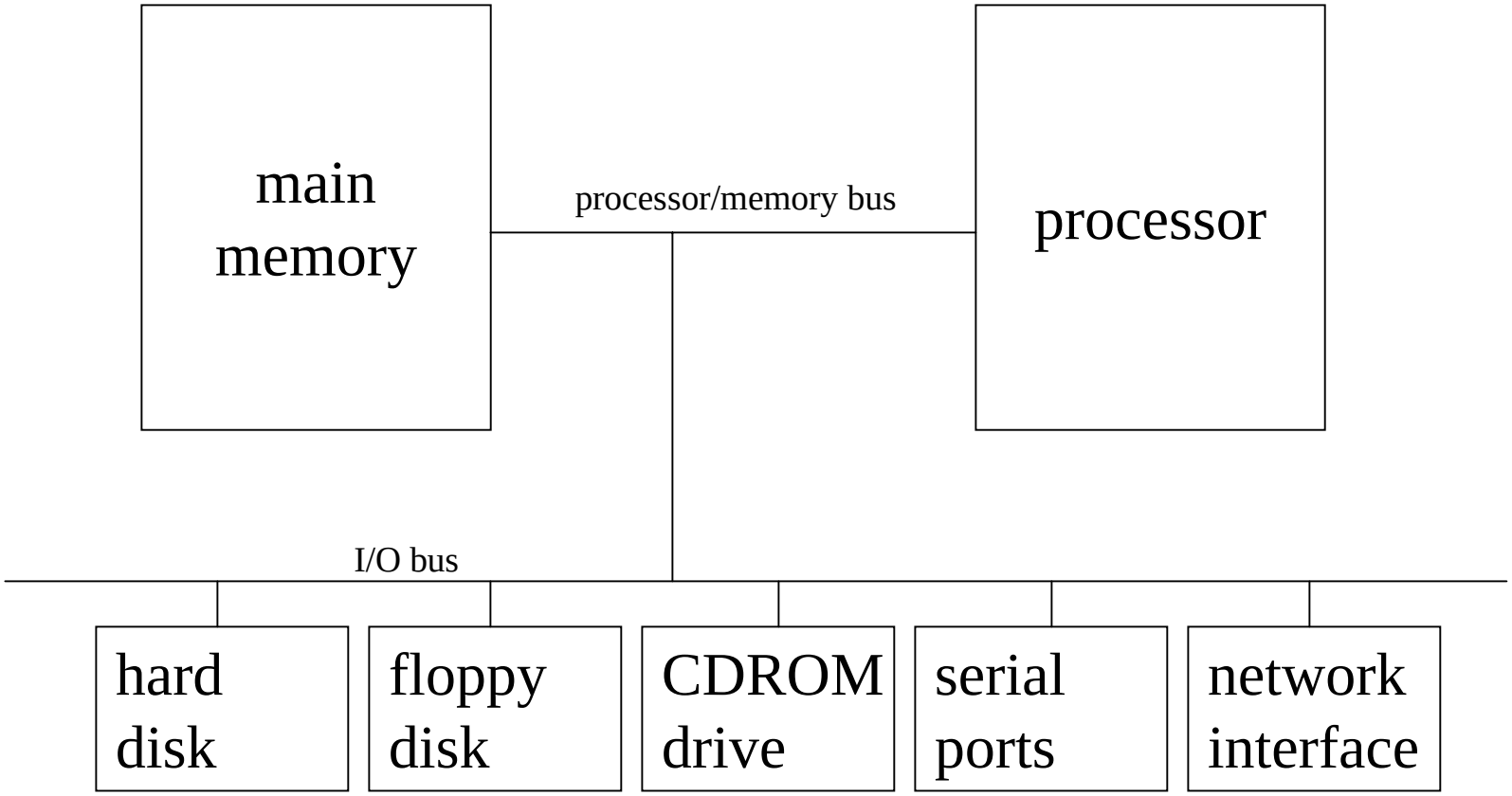
- Reading
  - Sections 8.1-8.3, *Computer Organization & Design*, Patterson and Hennessy

- Other References

Why Input and Output?

- Everything we have done so far is based on moving data / instructions between main memory and the CPU
- How does the information get into main memory and out to the user?
  - during manufacture: burn it in
  - during operation: input / output

A typical organization



Types of I/O devices

- Behavior
  - input only (keyboard, mouse, sensor)
  - output only (monitor, LED display, actuator)
  - input and output (network, disk, tape, CD-RW)
- Partner
  - human or machine
- Data rate
  - negligible to KiloBytes/Second to MegaB/S

Three Characteristic Devices

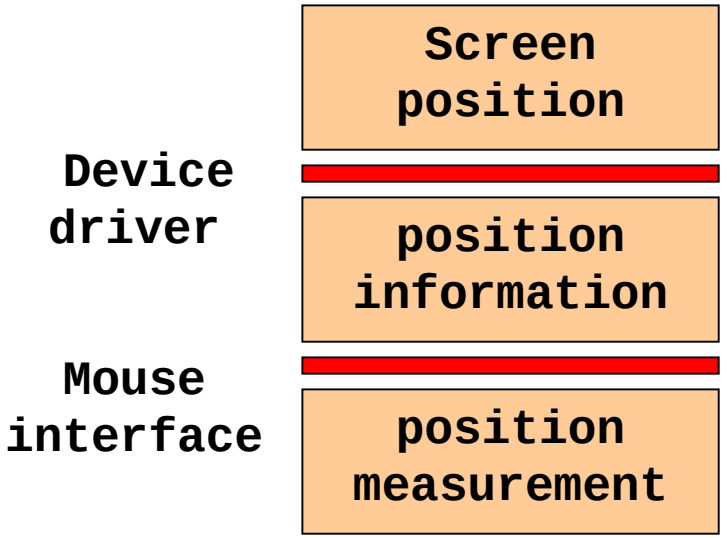
- Mouse
  - input only; human; .01-.02 KB/s
- Magnetic disks
  - input and output; machine; 100-10,000 KB/s
- Networks
  - input and output; machine; 500-6000 KB/s

Detecting Mouse Motion

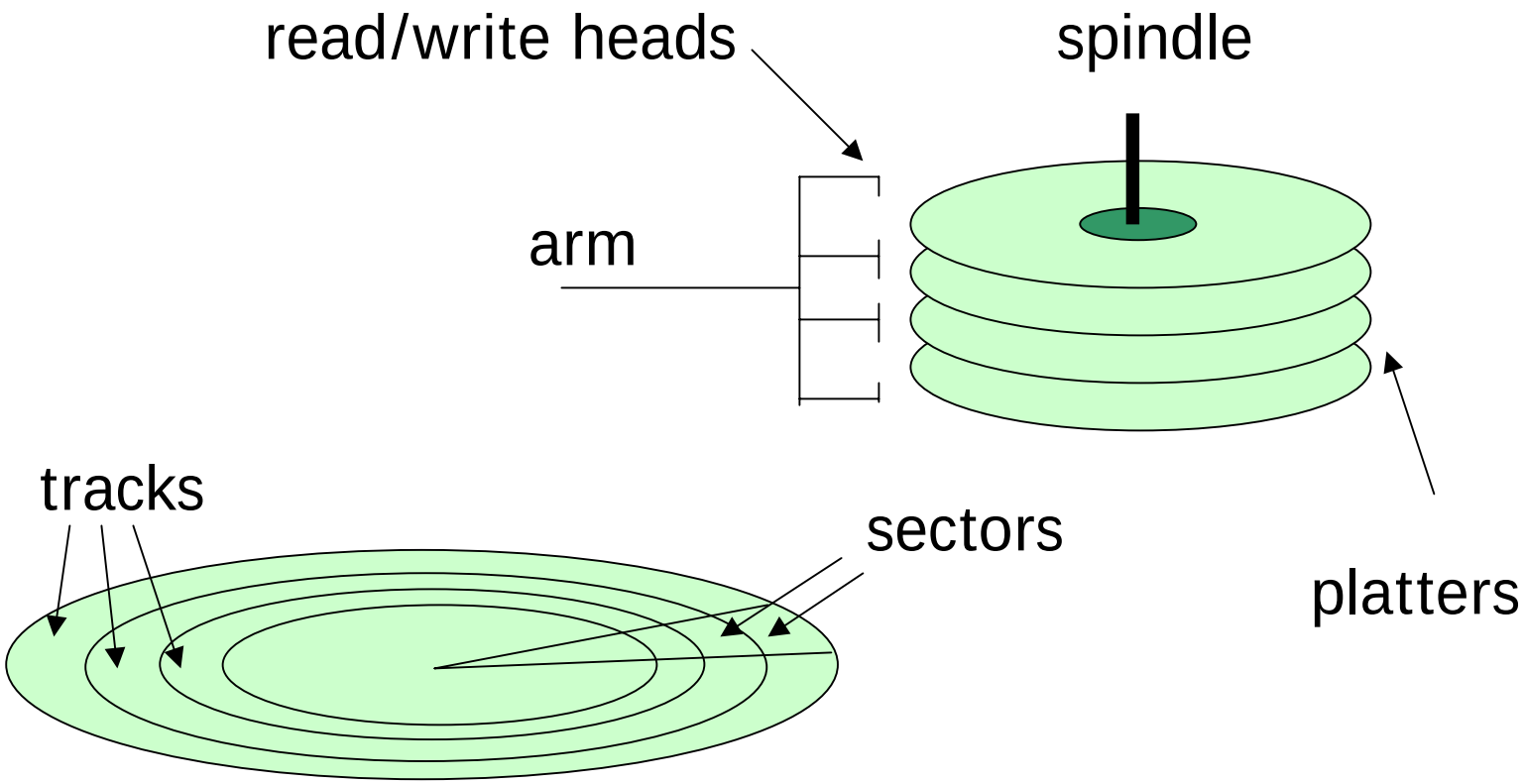
- Mechanical
  - Two perpendicular wheels on the inside connected to potentiometers
- Optical
  - LED and a photodetector on the bottom
- Optomechanical
  - The wheels have slots; an LED shines through them
- Lots of others
  - embedded microprocessor in the mouse

Mouse Interfaces

- Pointing device must provide
  - Status of each button
  - Position in X and Y
- Software must interpret the input
  - Double clicks
  - Limits to motion, speed



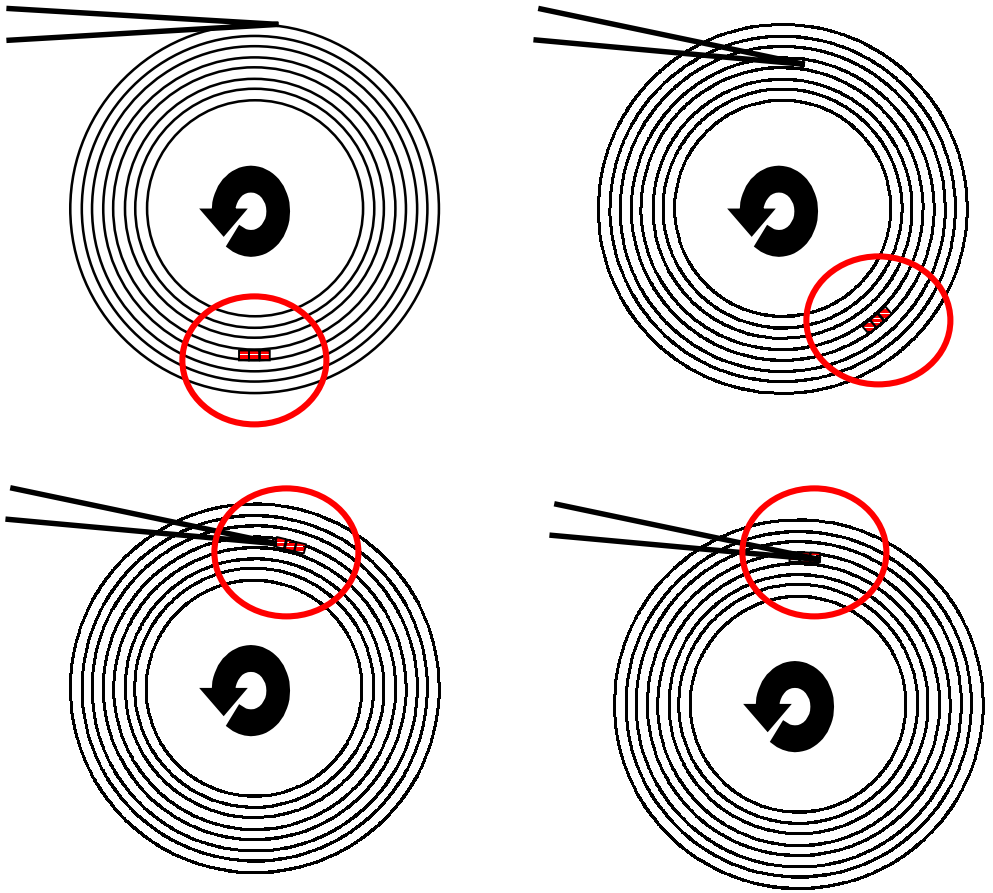
Anatomy of a Magnetic Disk



cylinder: all tracks at the same radius, one/two per platter

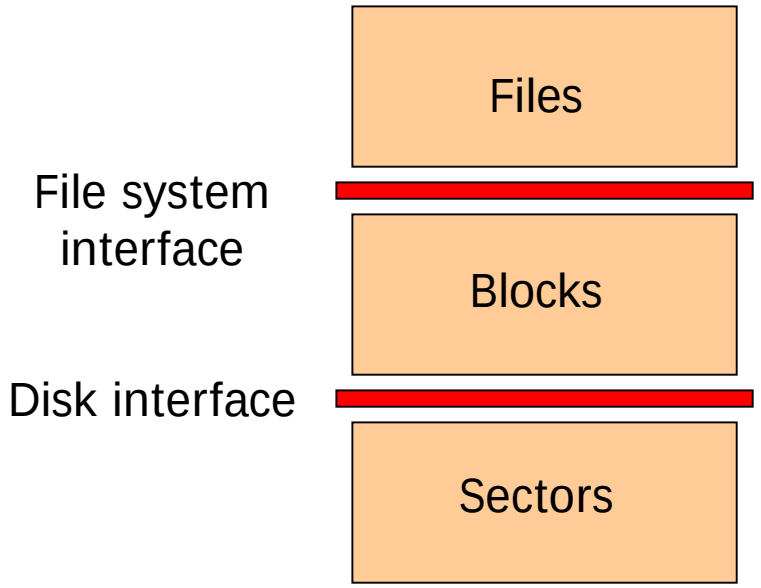
Accessing Data from a Disk

- First, the disk arm moves over the right cylinder: *seek time*
- Next, wait for the data to rotate under the disk arm: *rotational delay*, (on average half the time for one revolution)
- Finally, read the data from the disk: *transfer time*
- At this point, the data is in the *disk controller* and can be transferred to memory



Disk Interface

- Only two data transfer operations on a disk:
  - read block, write block
- Hidden behind the interface:
  - block ↔ sector mappings
- Unknown to the disk:
  - contents of the blocks/sectors



Disk Specifications

- Consider the disk in my laptop
  - 5GB IBM DJSA-205 (from device manager)
- Specifications (from IBM data sheet)
  - rotation speed 4200 RPM
    - rotational delay = 60 * 1/4200 * 0.5 = 7.1 ms
  - seek times
    - avg: 12.0 ms, 1 track: 2.5 ms, full stroke: 23.0 ms
  - layout
    - heads: 1, cylinders: 22784 (user), 10336 (actual)
    - sectors per track: 293-560

Data Transfer Specifications

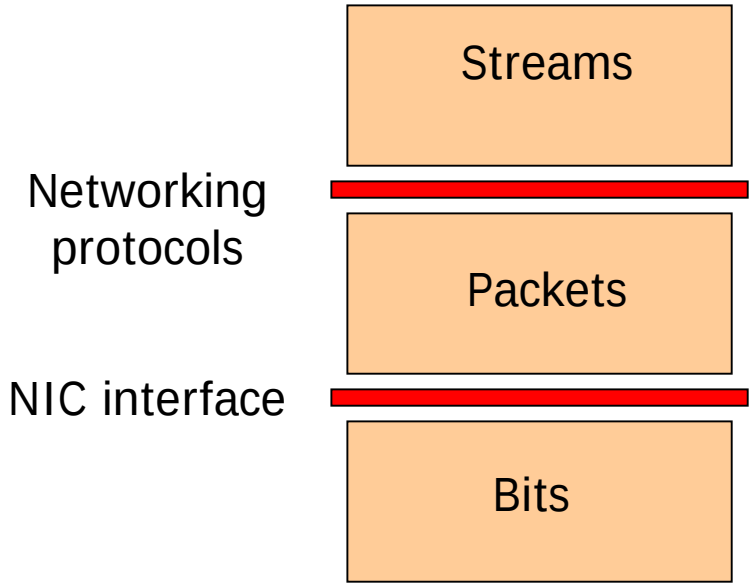
- Data buffer
  - 512 Kbytes on board the disk
- Media Transfer rate
  - 108.8 to 202.9 Mbits / sec
- Interface Transfer rate
  - Ultra-DMA mode 4: 66.6 Mbytes/sec
  - PIO mode 4: 16.6 Mbytes/sec

Networks

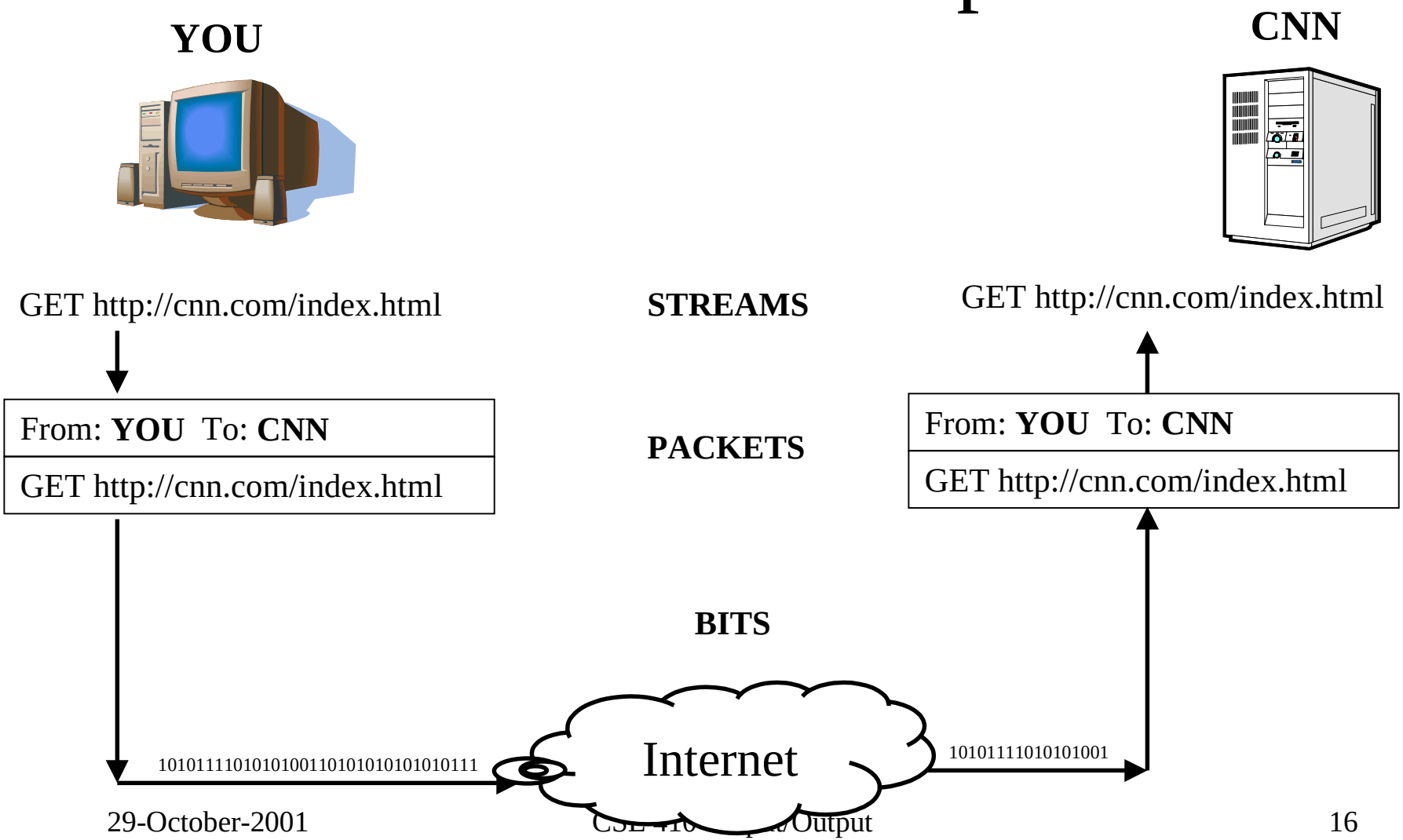
- The device that lets a system connect to a network: *network interface card*
- Listens for data on the network important to this system
- Bundles the bits into packets and signals the OS when a packet is complete
- Also takes packets from OS and sends them as bits on the wire

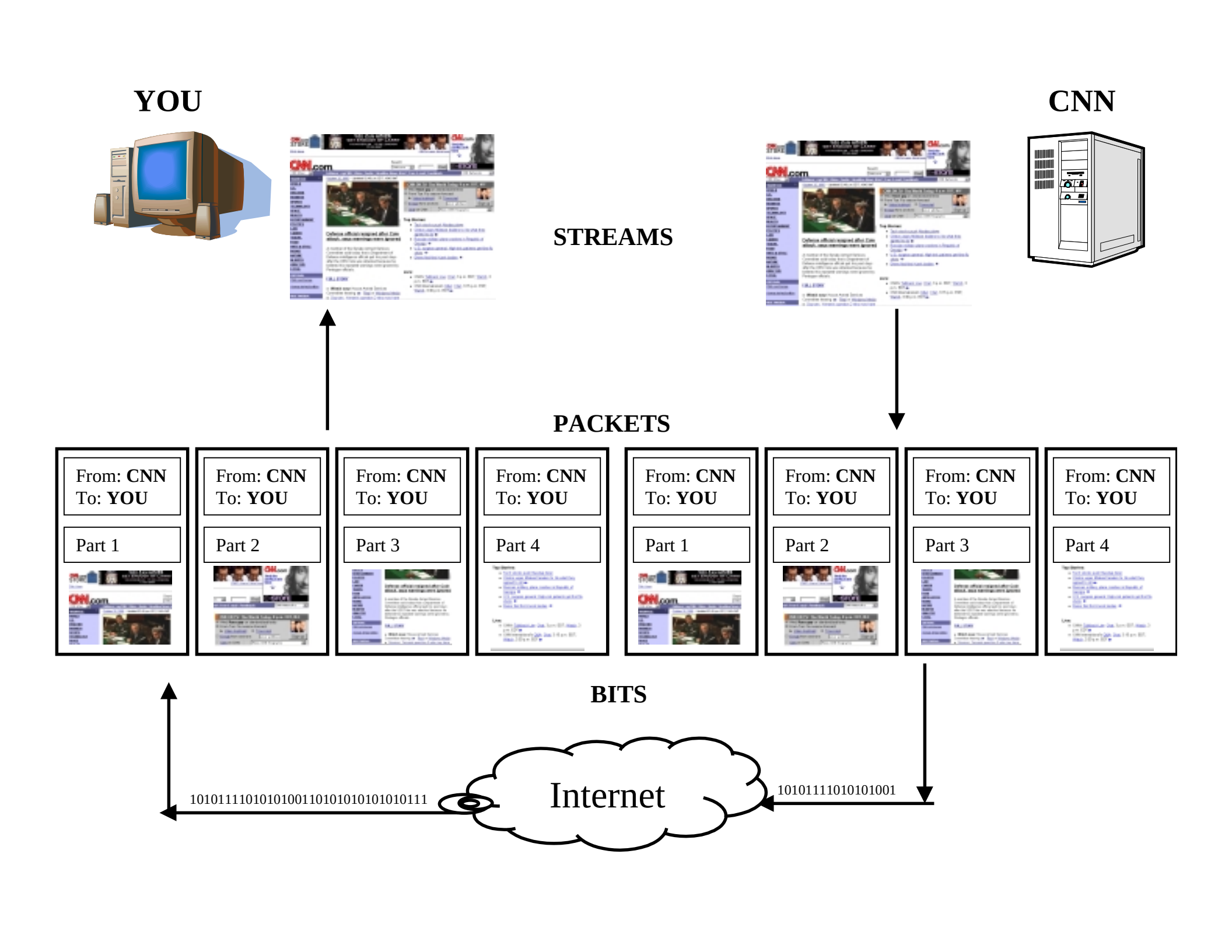
Networking Interfaces

- OS puts extra packets in to define where stream begins and ends
- NIC puts extra bits in to define where packets begin and end



Network Example




YOU
CNN
STREAMS
PACKETS
From: CNN
To: YOU
Part 1
Part 2
Part 3
Part 4
From: CNN
To: YOU
Part 2
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To: YOU
Part 3
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Part 1
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Part 3
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Part 4
BITS
Internet
10101111010101001101010101010111
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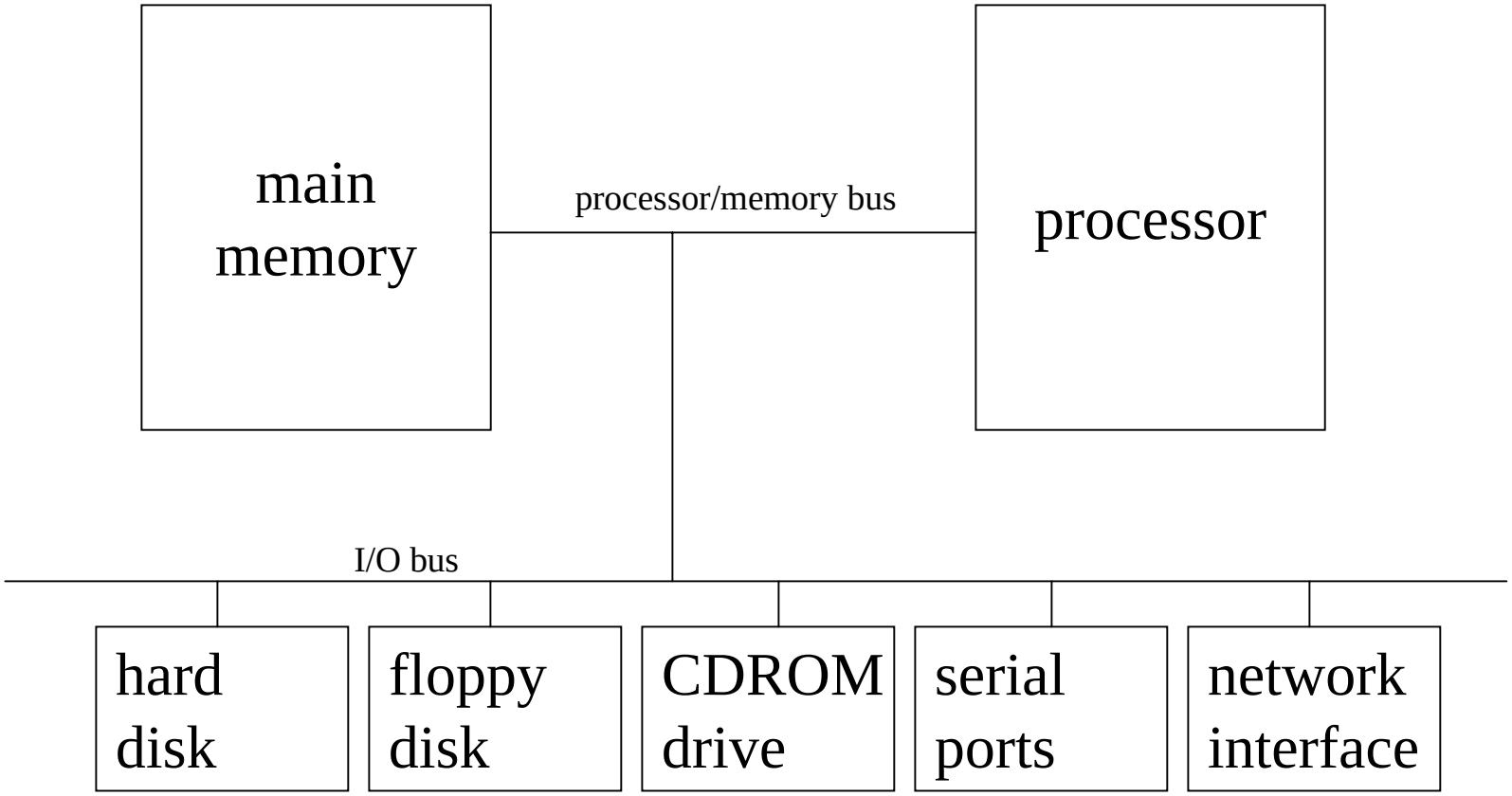
A typical organization



Commands to I/O Devices

- Memory-mapped I/O
  - A special region of memory is set aside for a device
  - Loads and stores to addresses in this region are interpreted as commands to the device
  - Provides easy access control via the memory system
- Special I/O instructions

Device to Processor

- The device has some information for the processor. Two ways to convey it:
  - Issue an interrupt
  - Wait for the processor to ask for it - *polling*
- Which is better, interrupt-driven I/O or polling? Depends on:
  - time sensitivity of data
  - whether data is expected

Device to Memory

- *Direct Memory Access (DMA)* allows devices and memory to communicate without involvement of processor
- Processor sets up the transaction
- Device and memory transfer the data
- Device interrupts processor to signal completion
- The processor gets a lot of other work done while transfer is happening

Performance Issues in I/O

- Processors double in speed every 18 months
- Networks double in speed more slowly, perhaps every 3 years
- Disks improve more slowly, because they are limited by mechanical factors
  - however, bit density has gone up rapidly

The I/O Bottleneck

- System A: processor speed = 100 MHz; disk transfer takes 10 ms
  - How many clock cycles elapse while disk transfer takes place?
- System B: processor speed = 400 MHz; disk transfer *still* takes 10 ms
  - How many clock cycles now?