CHAPTER 6

Storage and I/O

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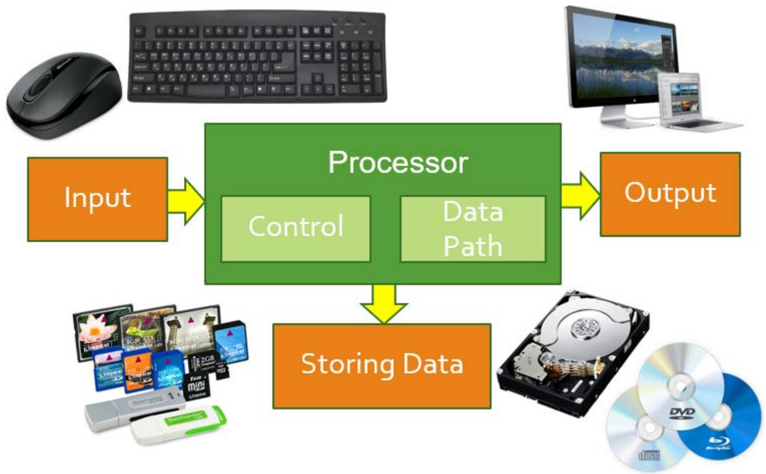
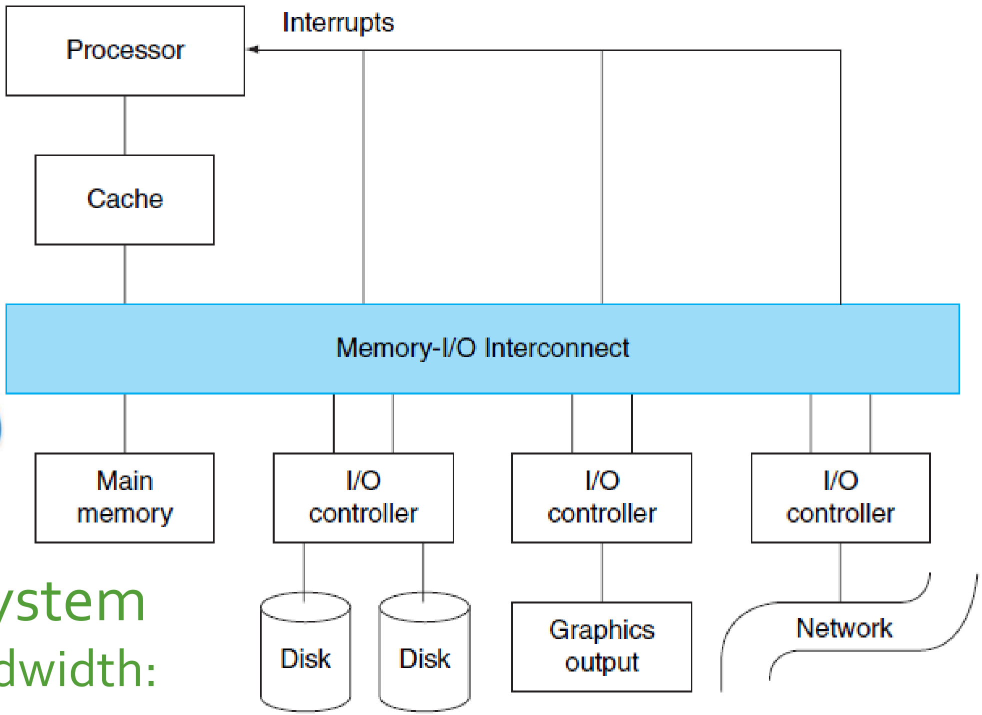
Collage of arts, media and Technology

Major Components of a Computer





- Important metrics for an I/O system
  - **Performance** - access latency/bandwidth: depend on aspect of devices/system, memory hierarchy, OS, connection between device
  - **Expandability** - for I/O devices
  - **Dependability** – quality of service: can data be restored when there's failure
  - **Cost, size, weight**
  - **Security**

characteristics of I/O device

- Three characteristics of I/O device (mice, graphics displays, disks, and networks)
  - ***Behavior****:* Input (read once), output (write only, cannot be read), or storage (can be reread and usually rewritten).
  - ***Partner****:* Either a human or a machine is at the other end of the I/O device, either feeding data on input or reading data on output.
  - ***Data rate****:* The peak rate at which data can be transferred between the I/O device and the main memory or processor.

Device	Behavior	Partner	Data rate (Mbit/sec)
Keyboard	Input	Human	0.0001
Mouse	Input	Human	0.0038
Voice input	Input	Human	0.2640
Sound input	Input	Machine	3.0000
Scanner	Input	Human	3.2000
Voice output	Output	Human	0.2640
Sound output	Output	Human	8.0000
Laser printer	Output	Human	3.2000
Graphics display	Output	Human	800.0000–8000.0000
Cable modem	Input or output	Machine	0.1280–6.0000
Network/LAN	Input or output	Machine	100.0000–10000.0000
Network/wireless LAN	Input or output	Machine	11.0000–54.0000
Optical disk	Storage	Machine	80.0000–220.0000
Magnetic tape	Storage	Machine	5.0000–120.0000
Flash memory	Storage	Machine	32.0000–200.0000
Magnetic disk	Storage	Machine	800.0000–3000.0000

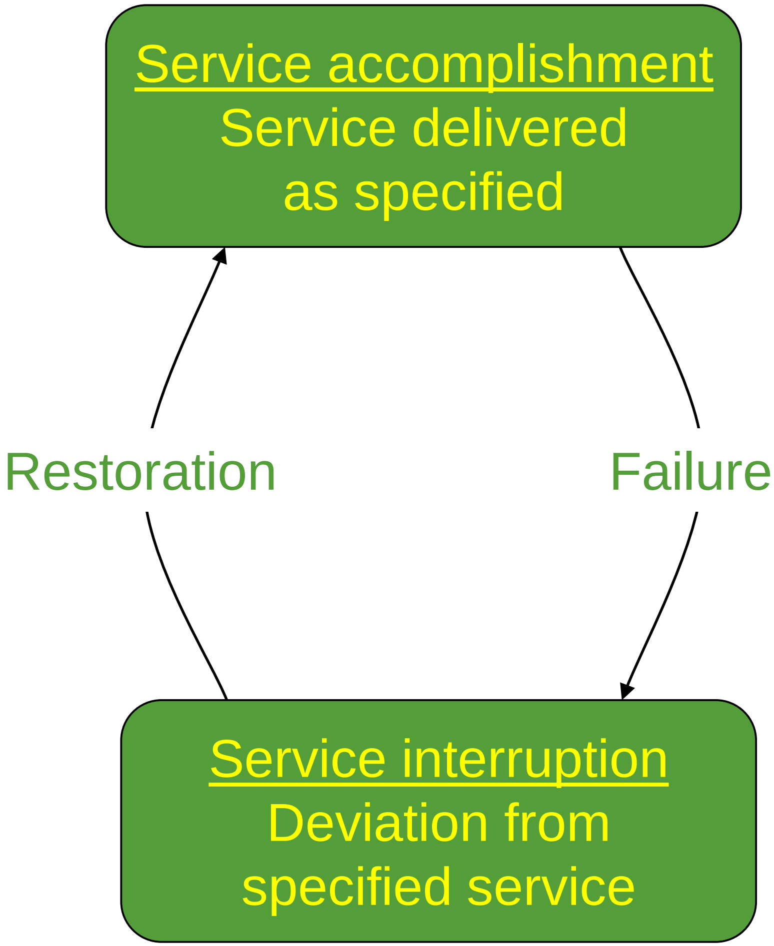
I/O performance

- How we should assess I/O performance often depends on the application. (system throughput. I/O bandwidth)
- Which performance measurement is best may depend on the environment
  - In many multimedia applications, most I/O requests are for long
  - Tag process from many units throughout USA, it's mostly cares about processing a large number of forms in a given time which come from the different part, so simultaneous transfer data is important
- I/O bandwidth can be measured in two different ways:
  - 1. How much data can we move through the system in a certain time?
  - 2. How many I/O operations can we do per unit of time?

I/O performance

- To accomplish a task, if the **I/O requests** are extremely large, response time will depend heavily on bandwidth
- If accessed data is small, and low latency per access will deliver the best response time.
- the three classes of desktop, server, and embedded computers are sensitive to I/O dependability and cost.
  - Desktop and embedded systems are more focused on response time and diversity of I/O devices
  - server systems are more focused on throughput and expandability of I/O devices.

Dependability



- *Computer system* ***dependability*** *is the quality of delivered service such that reliance can justifiably be placed on this service.*
- Fault: failure of a component
  - May or may not lead to system failure

Dependability Measures

- Failures can be permanent or intermittent.
- The latter is the more difficult case; it is harder to diagnose the problem when a system oscillates between the two states. Permanent failures are far easier to diagnose.
- This definition leads to two related terms: reliability and availability.

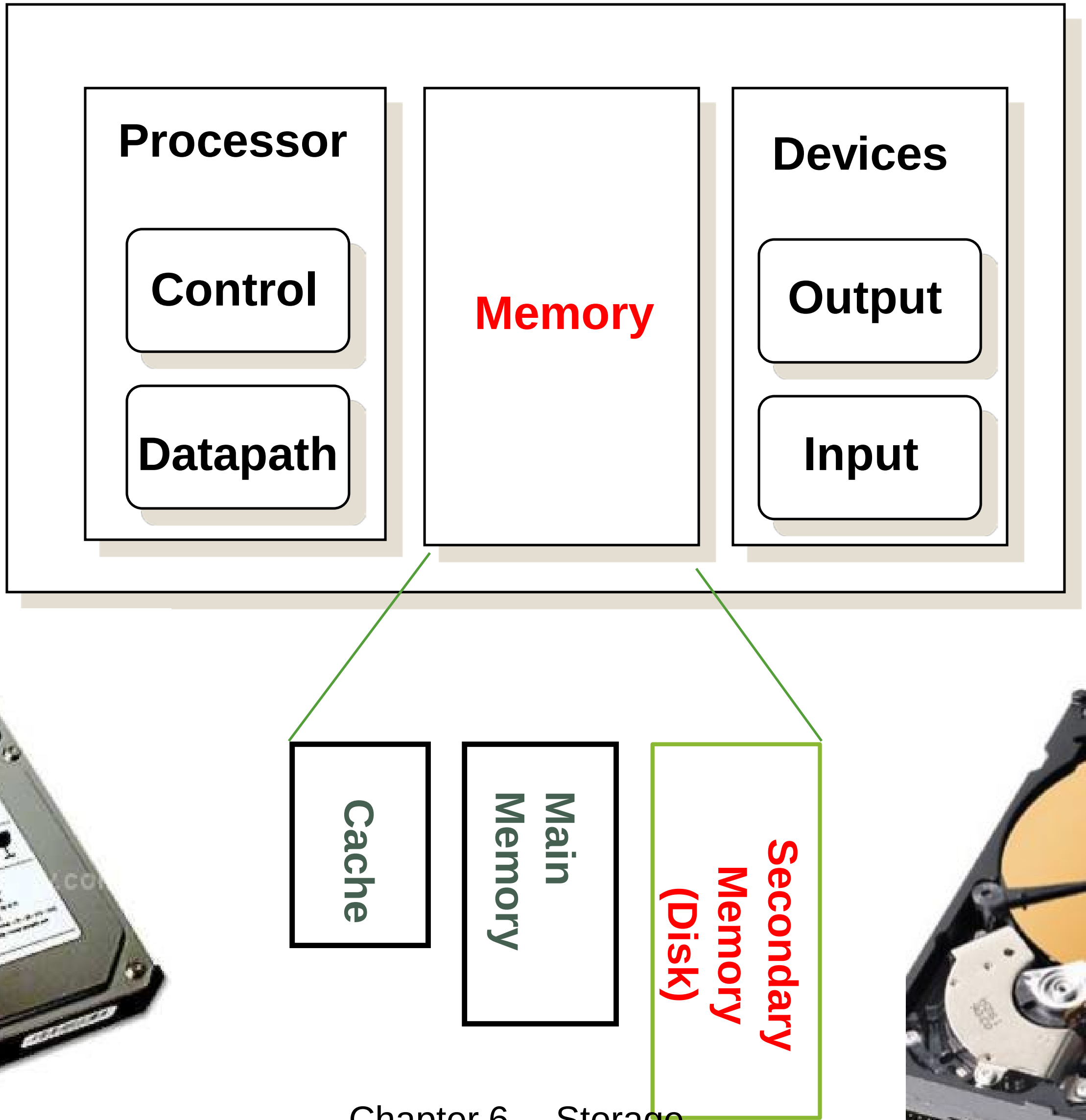
Dependability Measures

- ***Reliability***: measure of the continuous service accomplishment—or, equivalently, of the time to failure—from a reference point.
  - mean time to failure (MTTF)
  - Service interruption: mean time to repair (MTTR)
  - Mean time between failures (MTBF)
  - MTBF = MTTF + MTTR

Dependability Measures

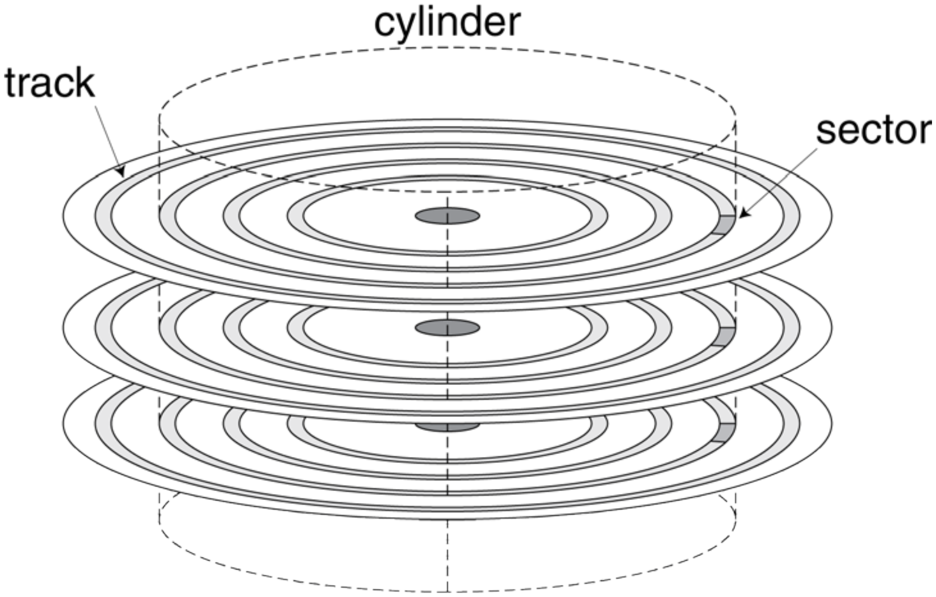
- ***Availability*** measure of service accomplishment with respect to the alternation between the two states of accomplishment and interruption.
- MTTF / (MTTF + MTTR)
- three ways to improve MTTF:
  - 1. *Fault avoidance:* Preventing fault occurrence by construction.
  - 2. *Fault tolerance:* Using redundancy to allow the service to comply with the service specification despite faults occurring,
  - 3. *Fault forecasting:* Predicting the presence and creation of faults, which applies to hardware and software faults, allowing the component to be replaced before it fails.
- Shrinking MTTR can help availability as much as increasing MTTF.

Major Components of a Computer

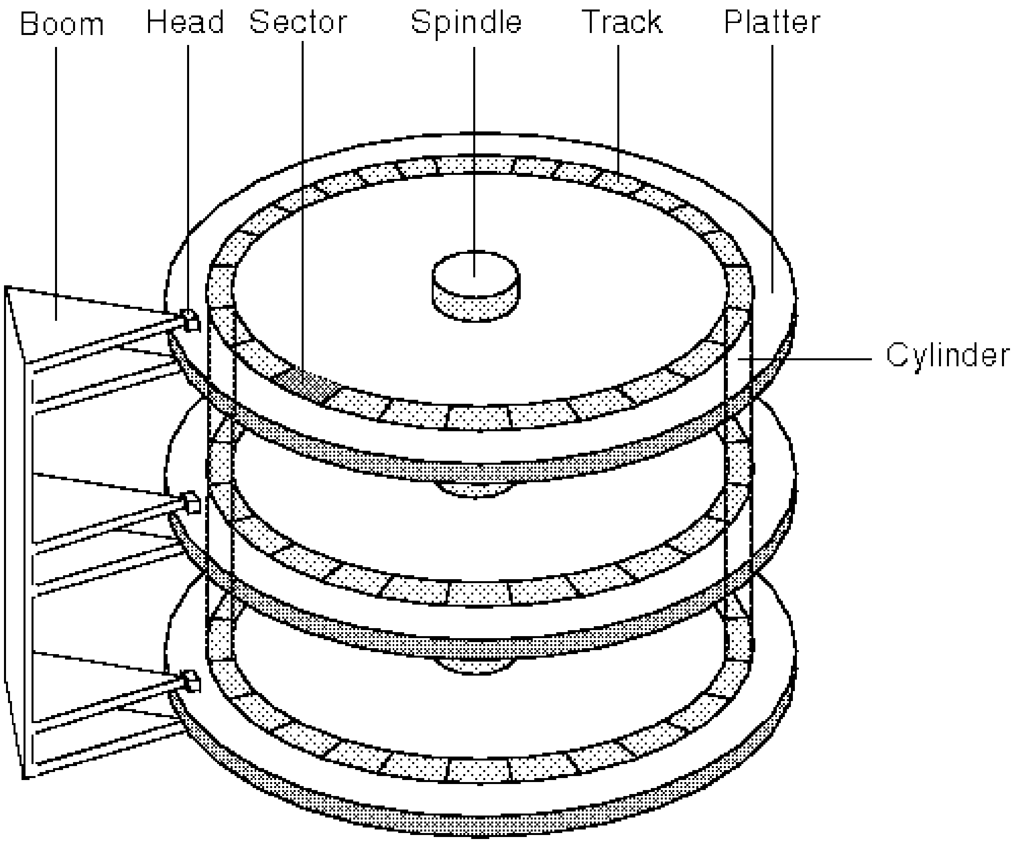


Disk Storage

- ***Nonvolatile***
- Rotating magnetic storage

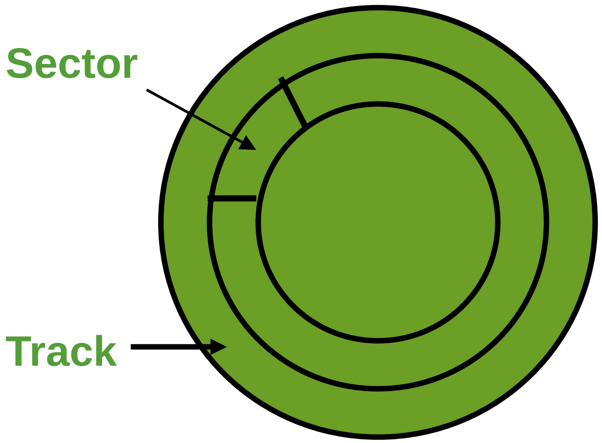


Disk Storage



- **HD features** – for performance consideration
  - seek times
  - Rotational latency
  - Transfer time
  - Buffer/cache size

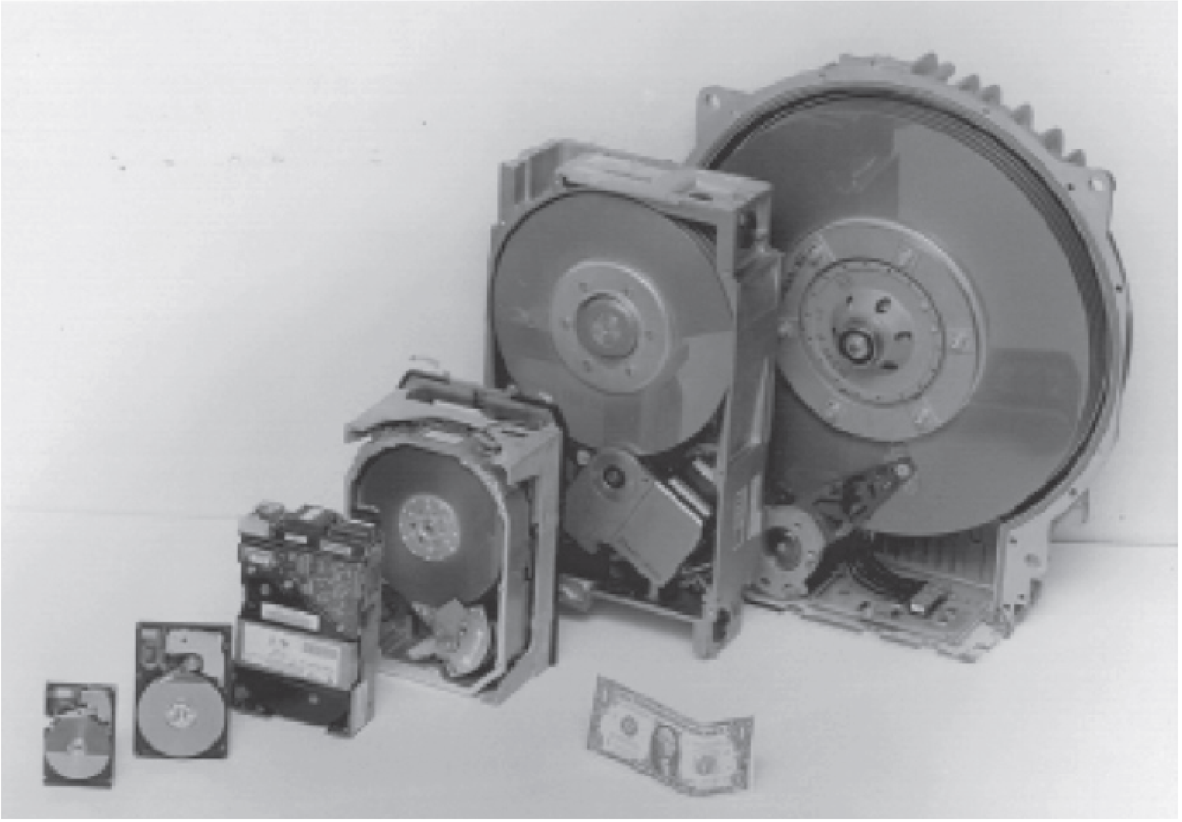
Magnetic Disk



- Purpose
  - Long term, nonvolatile storage
  - Lowest level in the memory hierarchy
    - slow, large, inexpensive
- General structure
  - A rotating ***platter*** coated with a magnetic surface
  - A moveable read/write ***head*** to access the information on the disk
- Typical numbers
  - 1 to 4 platters (each with 2 recordable surfaces) per disk of 1″ to 3.5″ in diameter
  - ***Rotational speeds*** of 5,400 to 15,000 RPM (Revolution Per Minute)
  - 10,000 to 50,000 ***tracks*** per surface
    - cylinder - all the tracks under the head at a given point on all surfaces
  - 100 to 500 ***sectors*** per track
    - the smallest unit that can be read/written (typically 512B)

Magnetic Disk Characteristic

- Disk densities have continued to increase for more than 50 years. The impact of this compounded improvement in density and the reduction in physical size of a disk drive

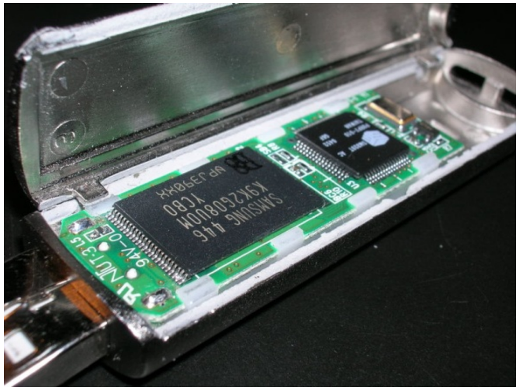


Flash Storage

- Many have tried to invent a technology to replace disks, and many have failed because these product are unattractive in the marketplace : CCD memory, bubble memory, and holographic memory.
- However, flash memory is popularity in cell phones, digital cameras, and MP3 players, there is a large market to pay for the investment in improving flash memory technology.

Flash Storage

- Nonvolatile semiconductor storage
  - 100× – 1000× faster *than disk*
  - Smaller, lower power, more robust
  - But more $/GB (between disk and DRAM)



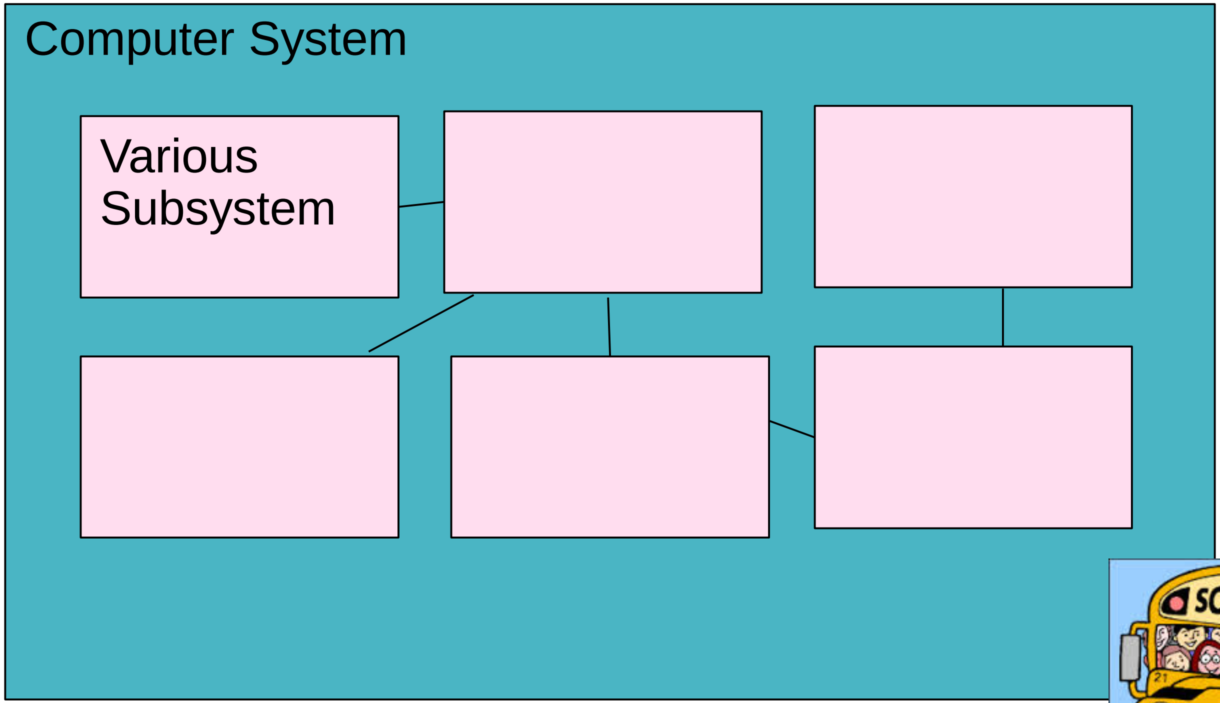
Flash Storage

- Although its cost per gigabyte is higher than disks, it comes in smaller capacities.
- That’s why the flash memory is popular in mobile devices parts.
- Write limits are one reason flash memory is not popular in desktop and server computers.
  - However, in 2008 the first laptops are being sold with flash memory instead of hard disks at a considerable price premium to offer **faster boot times, smaller size, and longer battery life**.
  - Combining both ideas, *hybrid hard disks* a gigabyte of flash memory so that laptops can boot more quickly and save energy

Flash Storage

Feature	Kingston	Transend	RiDATA
Capacity (GB)	8	16	32
Bytes/sector	512	512	512
Transfer rates (MB/sec)	4	20r-18w	68r-50w
MTTF	>1,000,000	>1,000,000	***>4,000,000***
Price (2008)	~ $30	~ $70	~ $300

Connecting



- Processor, Memory, I/O device

Bus (Pros)

- A **bus** uses one set of wires to connect multiple subsystems.
  - versatility
    - single set of wires is shared in multiple ways
      - cost-effective
    - single connection scheme
      - new devices can easily be added
      - peripherals can be moved between computer systems
  - low cost

Bus (Cons)

- Bus creates a communication bottleneck
- limiting the maximum I/O throughput.
  - When I/O must pass through a single bus, the bandwidth of that bus limits the maximum I/O throughput.
  - the maximum bus speed is limited by physical factors:
    - the length of the bus
    - the number of devices
    - variety devices
      - varying latencies
      - varying data transfer rates
      - clock

Bus

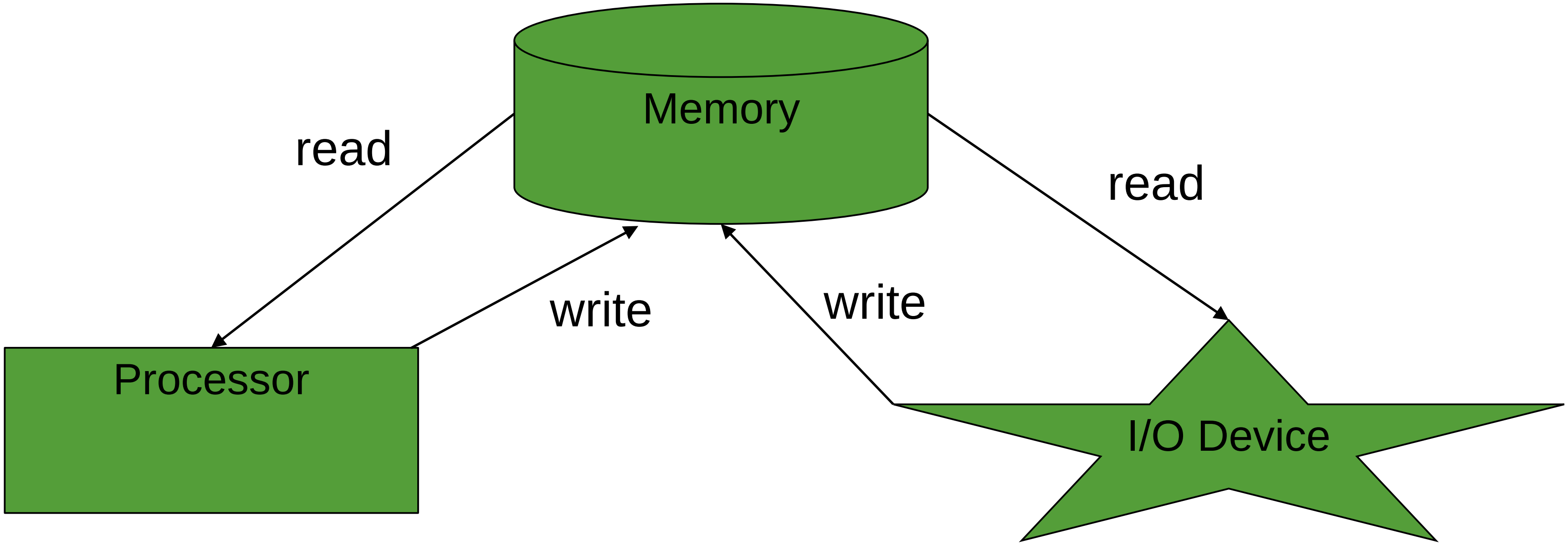
- **processor-memory buses**
  - short, high speed
  - matched to the memory system so as to maximize memory-processor bandwidth.
- **I/O buses**
  - Lengthy
  - many types of devices connected to them
  - have a wide range in the data bandwidth of the devices connected to them.
  - I/O buses do not typically interface directly to the memory
- **backplane bus**
  - A bus that is designed to allow processors, memory, and I/O devices to coexist on a single bus.
- **Other bus**
  - emerged for special functions, such as graphics buses.

Connection Basics

- **I/O transaction**
  - *A sequence of operations over the interconnect*
    - may includes a request and a response
    - may carry data.
  - A transaction initiated by a single request and may take many individual bus operations.
  - Include two parts
    - Sending the address
    - receiving or sending the data

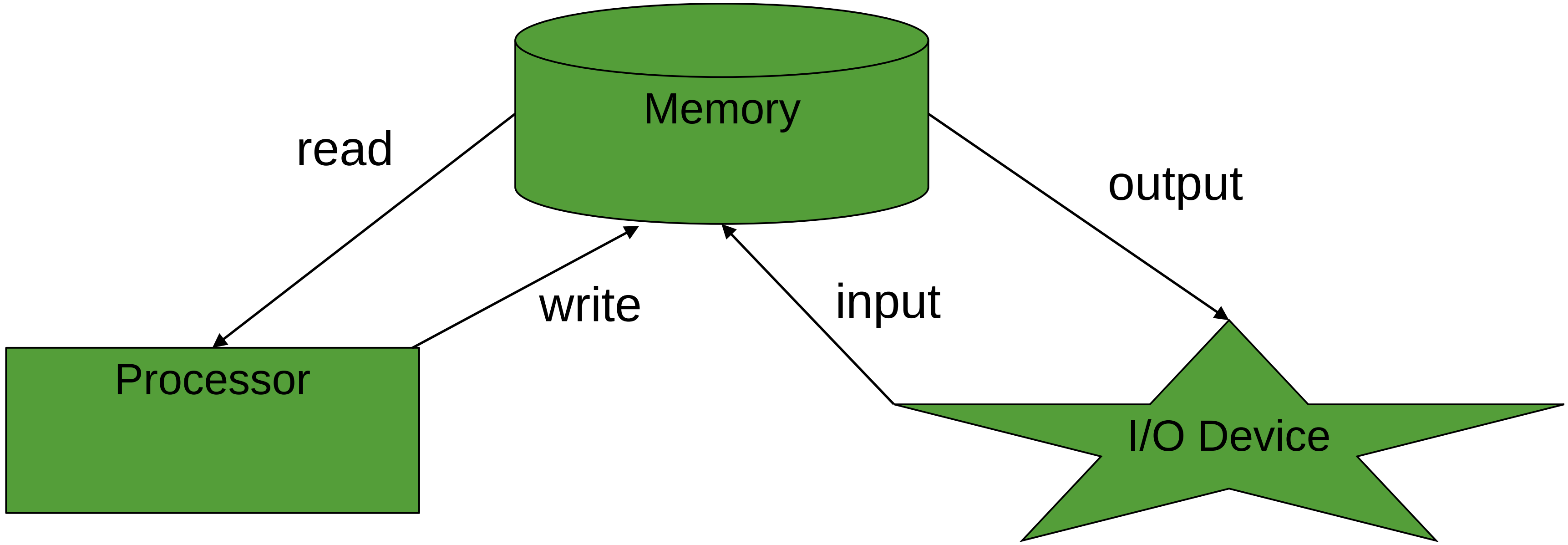
Bus transaction

- Typically define by what they do to **memory**.
  - A ***read*** transaction transfers data ***from*** **memory** to either the processor or an I/O device
  - A ***write*** transaction writes data ***to*** **the memory**



Bus transaction

- definition by what they do to **<u>processor</u>**.
  - an ***input*** operation is inputting data from the device **<u>to memory</u>**, where the processor can ***read*** it
  - an ***output*** operation is outputting data to a device **<u>from memory</u>** where the processor ***wrote*** it.



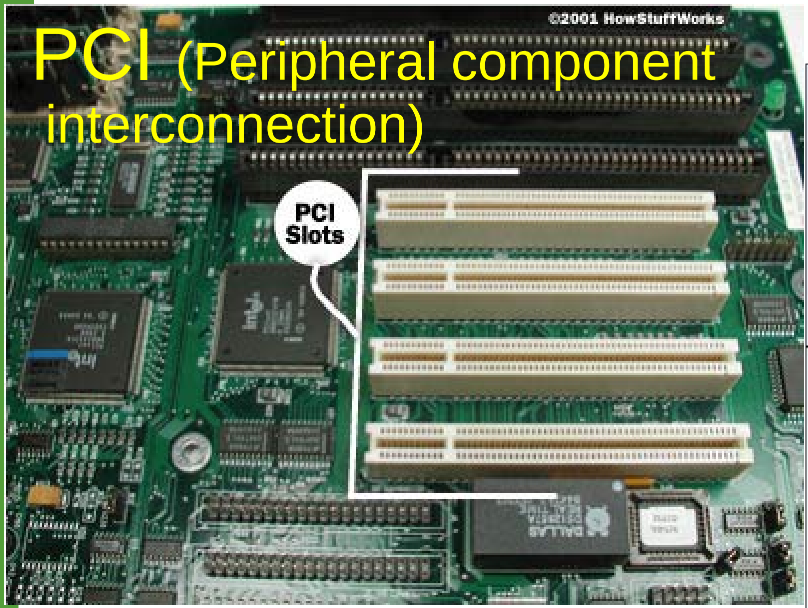
Connection Basics

- The I/O interconnect serves as a way of ***expanding*** the machine and connecting new peripherals ->

Standards

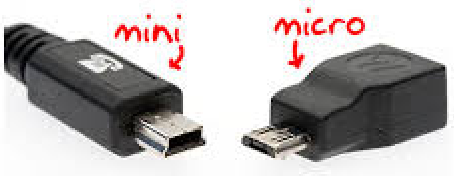
- assures the *computer designer* that peripherals will be available for a new machine
- ensures the *peripheral builder* that users will be able to hook up their new equipment

Five popular I/O standards



IDE (integrated drive electronics)

SATA (standard advanced technology attachment)



Serial Attached SCSI (SAS)

VGA

Thundlebolt

Firewire

Bus

- **synchronous bus** :
  - includes a clock in the control lines
  - protocols for communication are relate to the clock, predetermined, and involves little logic, so the bus can run fast, and the interface logic will be small.
  - However, device on the bus must run at the *same clock rate*.
  - synchronous buses cannot be long if they are fast because of the clock skew

Bus

- **Asynchronous bus**
  - uses a handshaking protocol for coordinating usage rather than a clock
    - handshaking protocol : steps used to coordinate asynchronous bus transfers in which the sender and receiver proceed to the next step only when both parties agree that the current step has been completed.
  - can accommodate devices of differing speeds
  - the bus can be lengthened without worrying about clock skew or synchronization problems.