CSE 3320
Operating Systems
Computer and Operating Systems Overview

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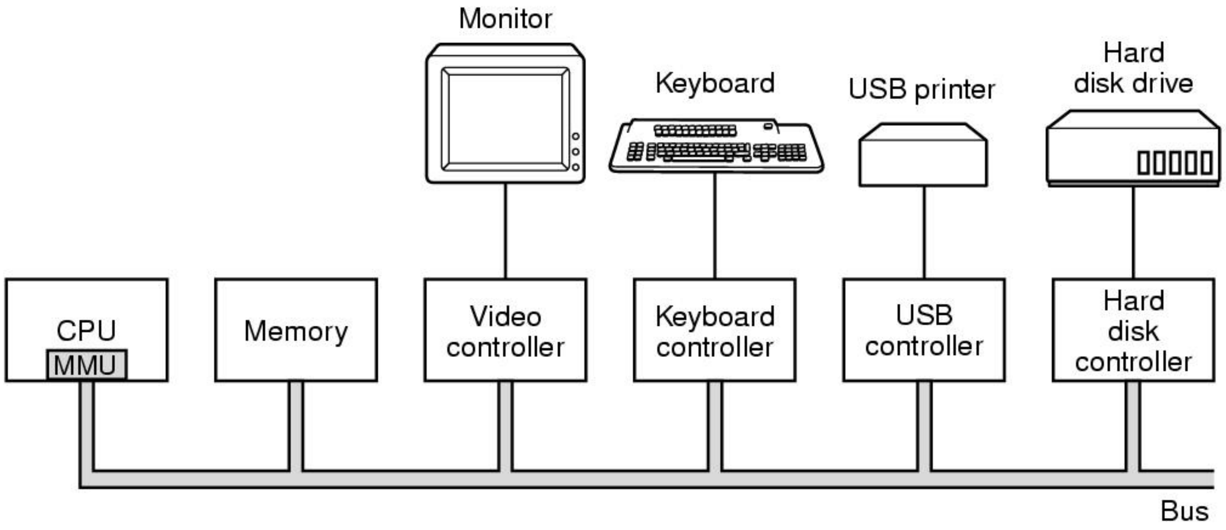
Overview

- Recap of last class
  - What is an operating system ?
  - Functionalities of operating systems
  - Types of operating systems
- Computer hardware review
- Operating system organization

Computer Hardware Review

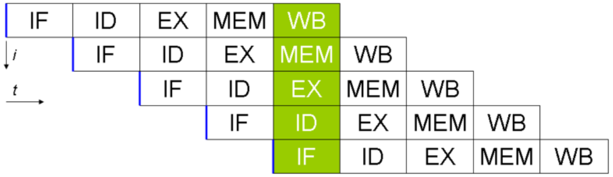
- Basic components of a simple personal computer



- CPU: data processing
- Memory: volatile data storage
- Disk: persistent data storage
- NIC: inter-machine communication
- Bus: intra-machine communication

Central Processing Unit (CPU)

- Components
  - Arithmetic Logic Unit (ALU)
  - Control Unit (CU)
- Clock rate
  - The speed at which a CPU is running
- Data storage
  - General-purpose registers: EAX, EBX …
  - Special-purpose registers: PC (EIP), SP, IR …
- Parallelism
  - Instruction-level parallelism
  - Thread-level parallelism
    - Hyper-threading: duplicate units that store architectural states
    - Replicated: registers. Partitioned: ROB, load buffer… Shared: reservation station, caches



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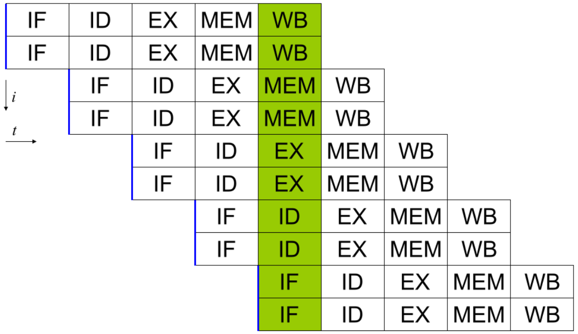

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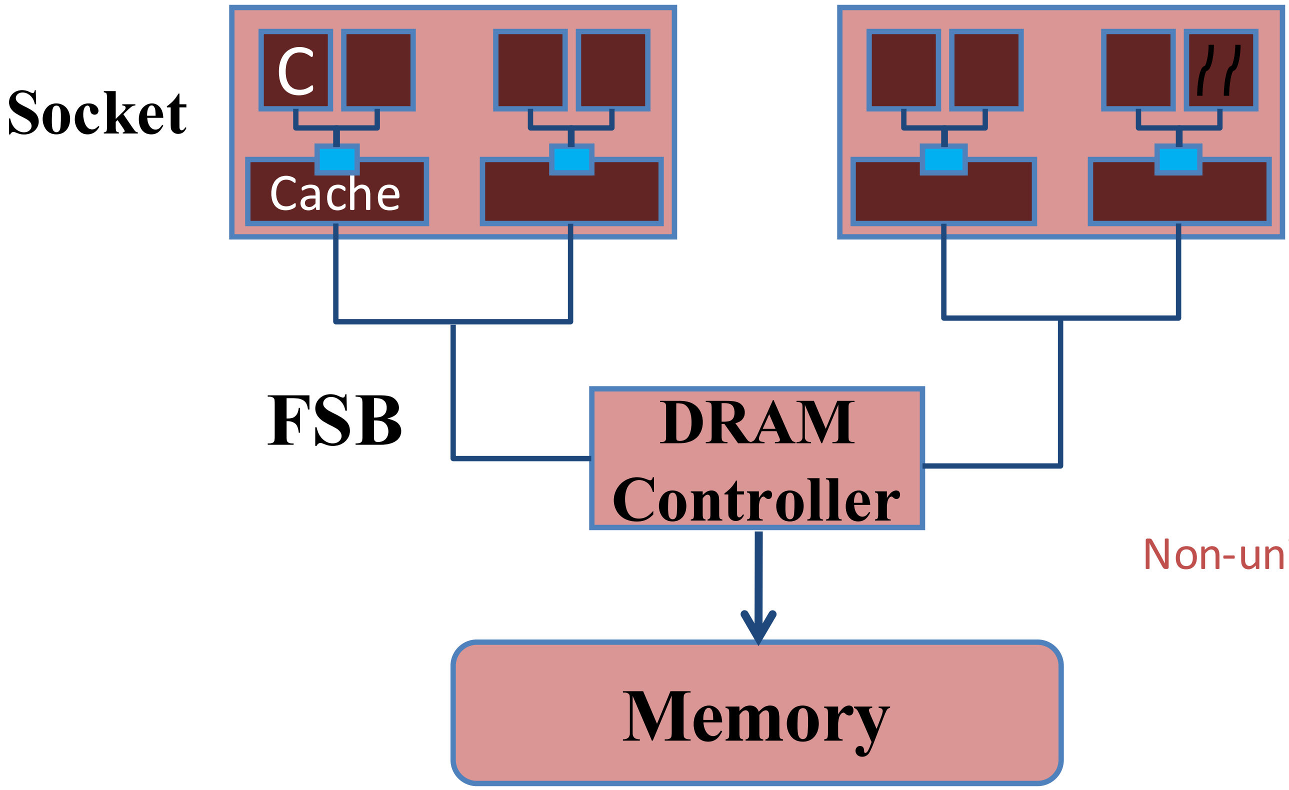
Multi-Core Processors

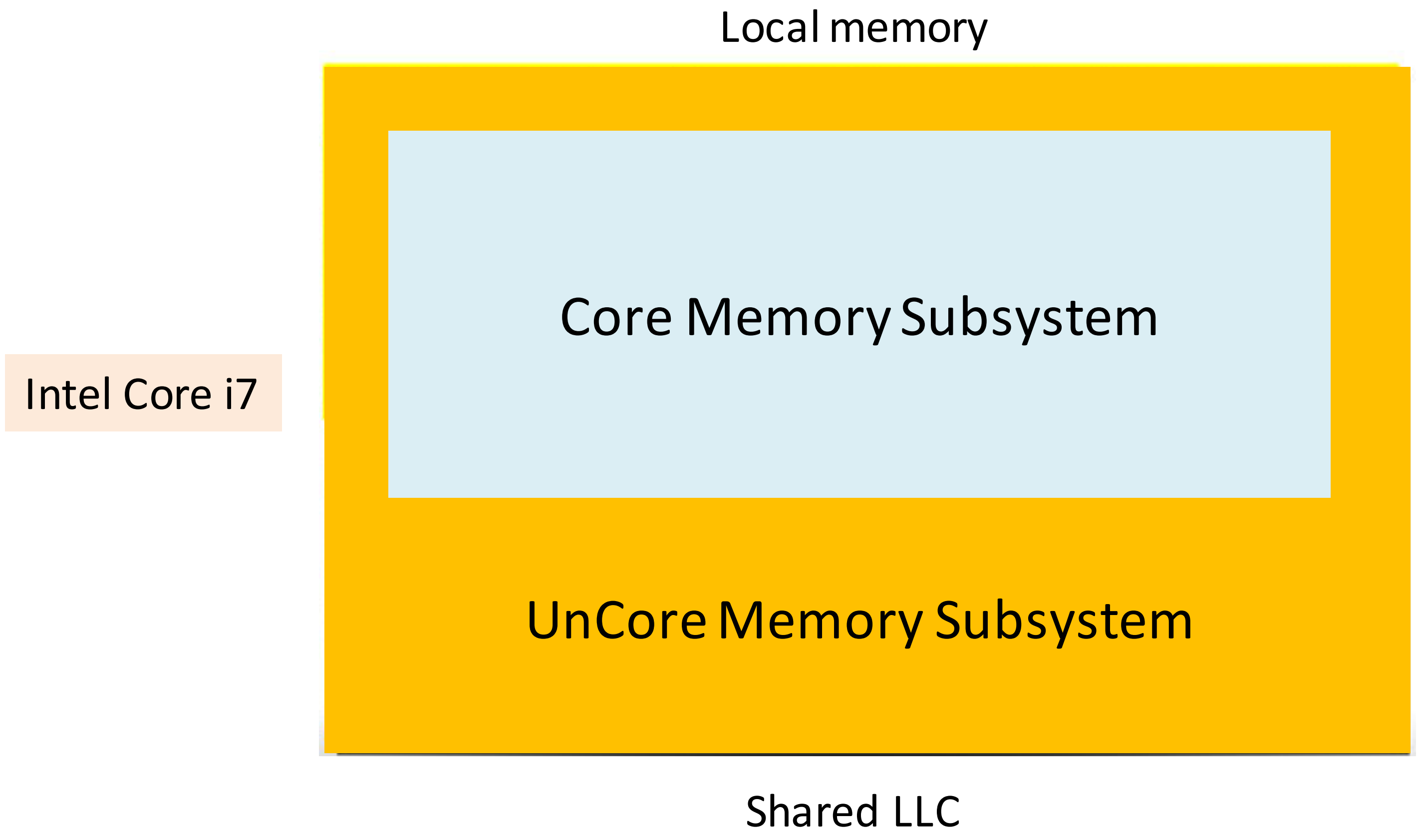
- Multiple CPUs on a single chip



Non-uniform performance

A schematic view of Intel Core 2

Multi-Core Processors: NUMA



Local memory

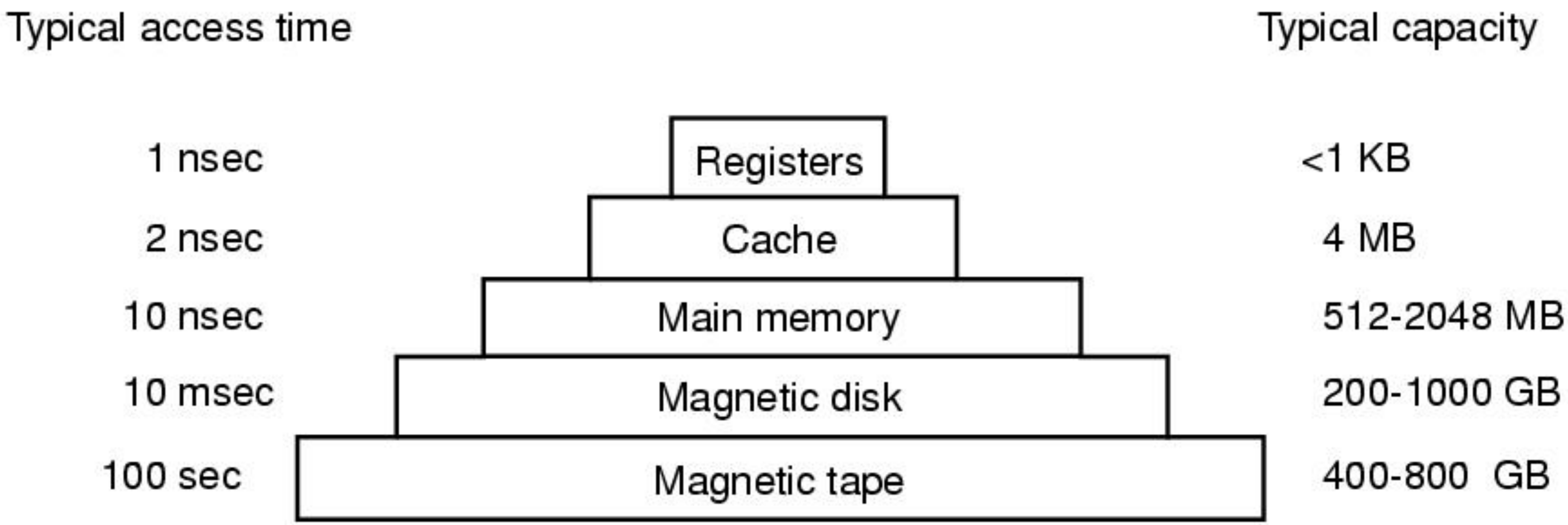
Intel Core i7

Core Memory Subsystem

UnCore Memory Subsystem

Shared LLC

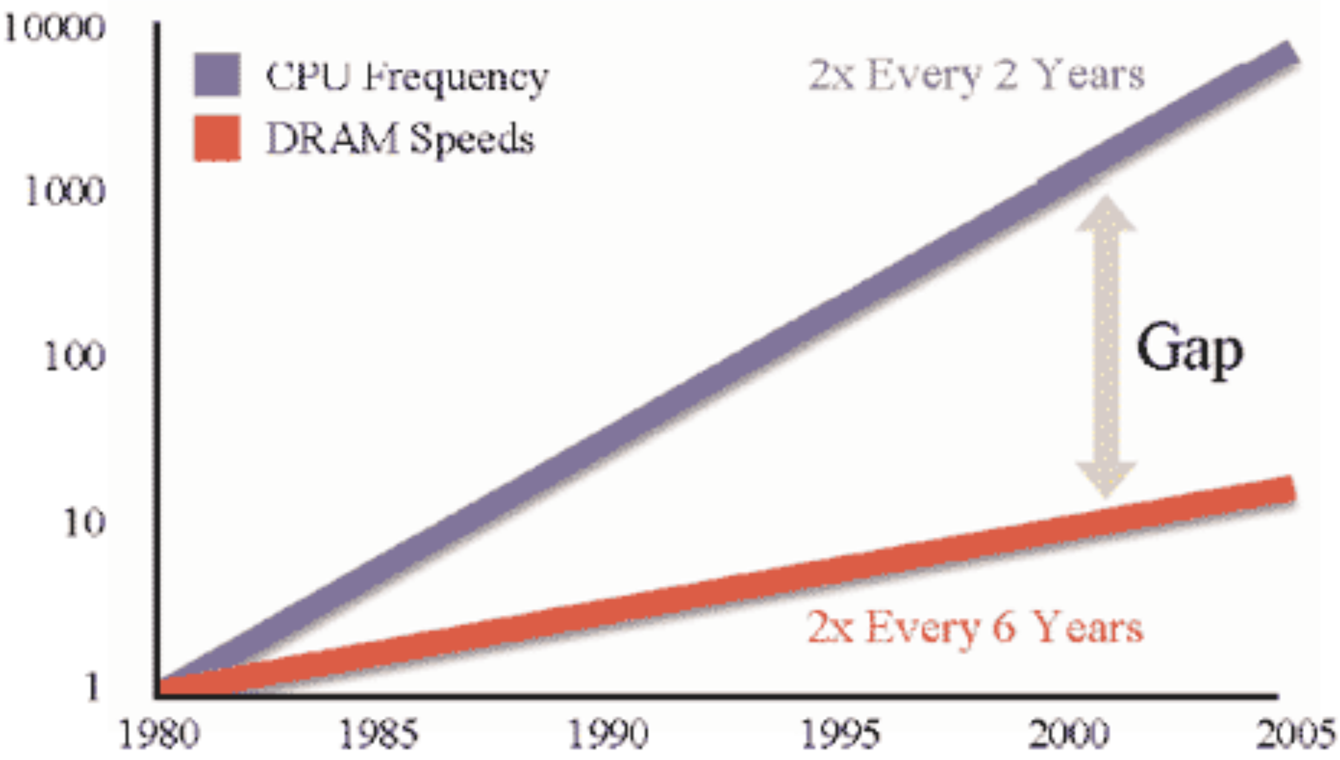
Memory



Typical access time		Typical capacity
1 nsec	Registers	<1 KB
2 nsec	Cache	4 MB
10 nsec	Main memory	512-2048 MB
10 msec	Magnetic disk	200-1000 GB
100 sec	Magnetic tape	400-800 GB

A typical memory hierarchy

Why Cache is important ?

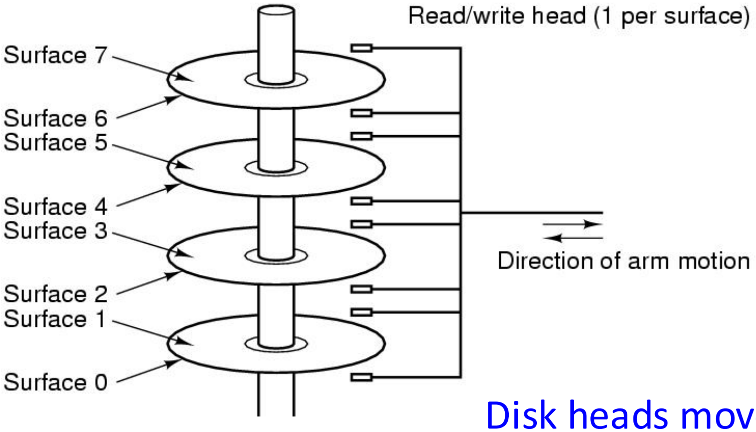


- A larger size than registers
- A much faster speed than memory
- Concurrent accesses to memory when cache misses occur

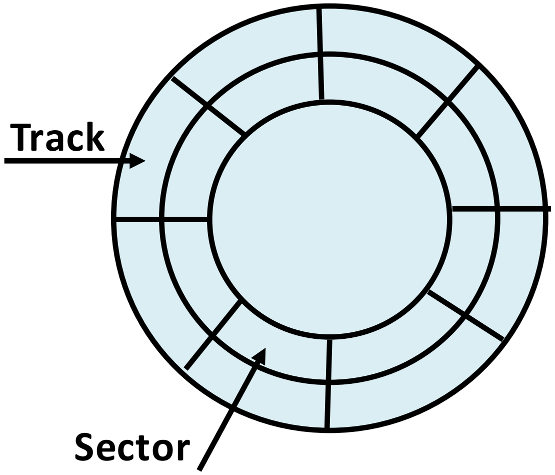
More on CPU Cache

- Cache management
  - When to put a new item into the cache.
  - Which cache line to put the new item in.
  - Which item to remove from the cache when a slot is needed.
  - Where to put a newly evicted item in the larger memory.
  - When to write dirty item back to memory

Hard Disks



Disk heads move together



- A stack of platters, a surface with a magnetic coating
- Typical numbers (depending on the disk size):
  - 500 to 2,000 tracks per surface
  - 32 to 128 sectors per track
    - A sector is the smallest unit that can be read or written
- Originally, all tracks have the same number of sectors:
  - “Constant” bit density: record more sectors on the outer tracks

Magnetic Disk Characteristics

- Disk head: each side of a platter has separate disk head
- Read/write data is a three-stage process:
  - Seek time: position the arm over the proper track
  - Rotational latency: wait for the desired sector to rotate under the read/write head
  - Transfer time: transfer a block of bits (sector) under the read-write head

- Long seek time
- Only one request at a time
- Throughput is dependent on data size

- Average seek time as reported by the industry:
  - Typically in the range of 8 ms to 15 ms
  - (Sum of the time for all possible seek) / (total # of possible seeks)
- Due to locality of disk reference
  - Actual average seek time may only be 25% to 33% of the advertised number

CPU v.s. Hard Disks

- Similarity
  - Time-sharing
- Differences (execution vehicle v.s. storage device)
  - CPU
    - Cache reuse -> temporal locality
    - Easy to switch between sharing parties -> fine grain, overhead sensitive
    - Usually multiple CPUs-> load balancing
    - Multiple execution modes -> energy saving
  - Hard disks
    - Almost no data reuse, but faster to read adjacent data -> spatial locality
    - Expensive to switch between sharing parties -> coarse grain
    - Striping or replication required if using multiple disks -> coordination

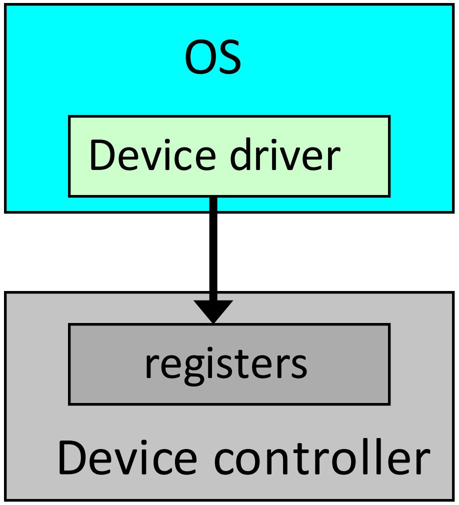
Memory Management

- Multiprogramming
  - How to *protect* the programs from one another and the kernel from them all?
  - How to handle *relocation* ?

Virtual memory space/address → Physical memory space/address

I/O Devices

- Device controller
  - To provide a simple interface of device control to OS
- Device driver
  - The software that talks to a controller, giving it commands and accepting responses



Interactions between OS and I/O Devices

- The OS gives commands to the I/O devices
- The I/O device notifies the OS when the I/O device has completed an operation or has encountered an error
- Data is transferred between memory and an I/O device

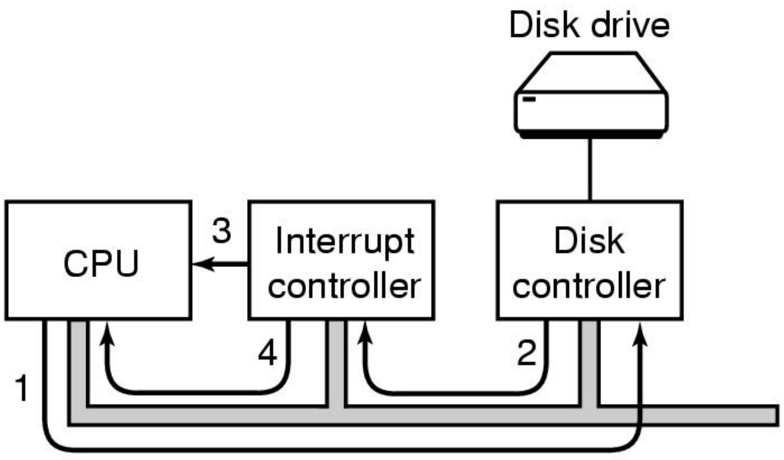
How I/O Devices Notify the OS ?

- Polling
  - The I/O device put information in a status register
  - The OS periodically check the status register
- Interrupt
  - Whenever an I/O device needs attention from the processor, it interrupts the processor from what it is currently doing
- DMA
  - Delegate I/O responsibility from CPU

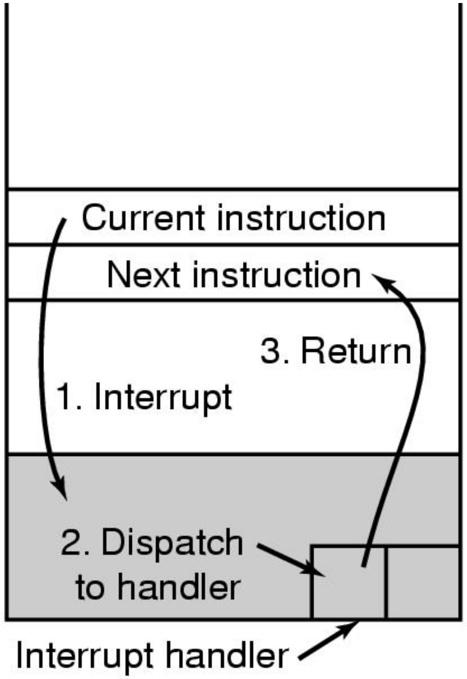
Interrupts

- Interrupts
  - An interruption of the normal sequence of execution
  - Improves processing efficiency
  - Allows the processor to execute other instructions while an I/O operation is in progress
  - A suspension of a process caused by an event external to that process and performed in such a way that the process can be resumed
- Types of interrupts
  - I/O
  - Program (exception)
    - arithmetic overflow
    - division by zero
    - reference outside user's memory space
  - Timer, Hardware failure

I/O Interrupt



(a)



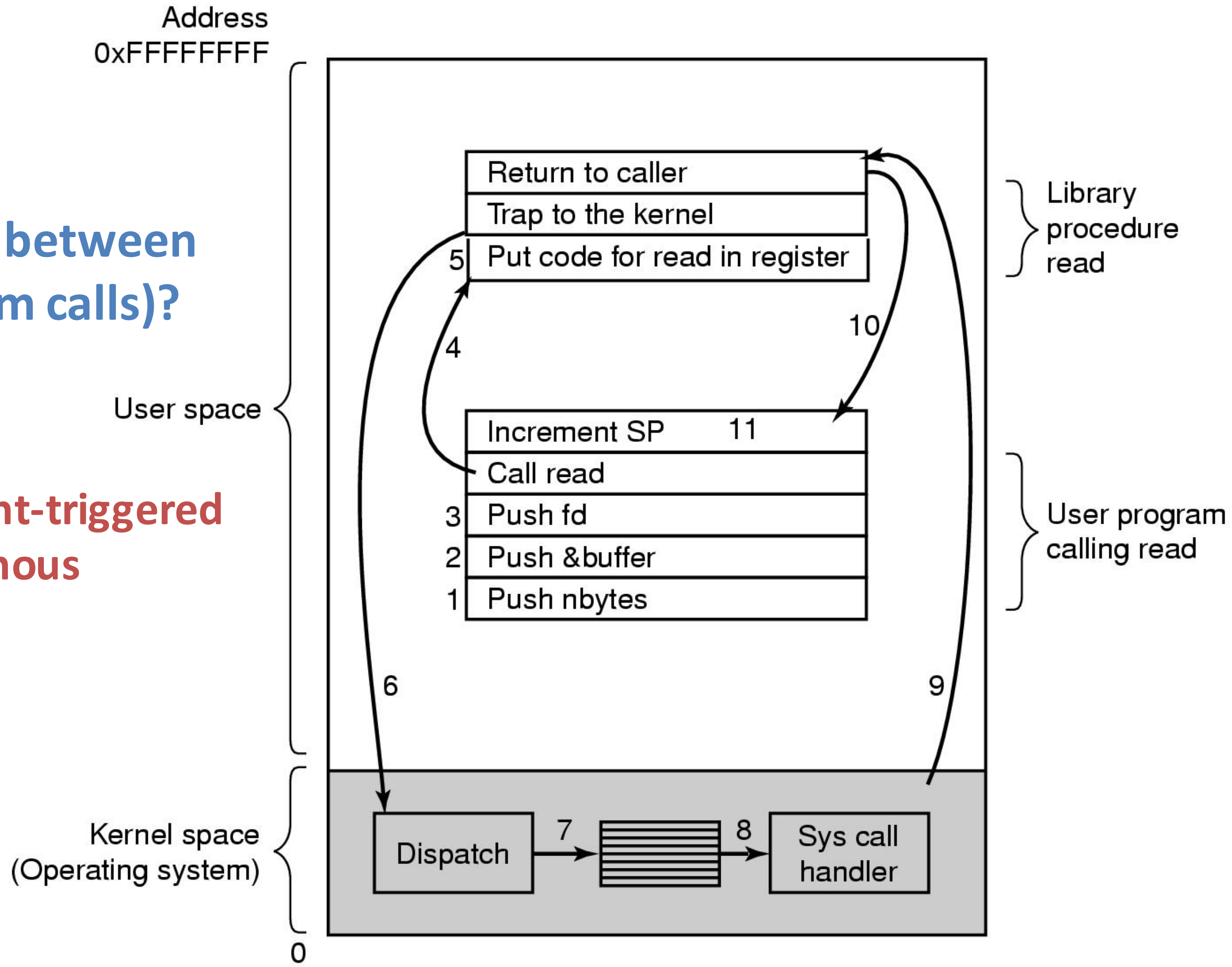
(b)

1. CPU writes cmds in to device registers
2. The device signals interrupt controller
3. Interrupt controller informs a CPU
4. The CPU accepts the interrupt and triggers the service routine

System Calls

What is the key difference between interrupts and traps (system calls)?

- **program-triggered vs. event-triggered**
- **synchronous vs. asynchronous**



There are 11 steps in making the system call read (fd, buffer, nbytes)

Operating System Components

- Process management
- Memory management
- File and storage
- Networking

Process Management

- Process: a fundamental OS concept
  - Memory address space
  - Some set of registers
  - Protection domain
  - Resource allocation unit
- OS responsibilities for process management
  - Process creation and deletion
  - Process scheduling, suspension, and resumption
  - Inter-process communication and synchronization

Memory Management

- Memory
  - A large array of addressable words and bytes
- OS responsibilities for memory management
  - Allocate and de-allocate memory space
  - Keep memory space efficiently utilized
  - Keep track of which part of memory are used and by whom

Design goals: *transparency* and *efficiency*

File and Storage Management

- A file is a collection of data (usually) stored on disk with a unique name
  - Programs
  - Data
  - Devices (UNIX & Linux)
- OS responsibilities for file management
  - Organize directories and files
  - Map files onto disk
- OS responsibilities for disk management
  - Disk space management
  - Disk scheduling

Summary

- Computer hardware
  - Time-sharing: CPU, disk
  - Space-sharing: memory, disk
- OS components
  - Process management
  - Memory management
  - File and storage management
- Additional readings and practice
  - Section 1.6 and try the following Linux commands
    - Who, uname, ls, cat, cp, rm, mv, cd, mkdir, touch, chmod
    - Use “man” to see the manual of above commends
  - Write an C program with an output to the screen
    - Strace –o trace.txt ./YOUR_PROG
    - See the system calls triggered (execve, write, …)
    - http://unix.stackexchange.com/questions/797/understanding-the-linux-kernel-source
  - Check the VMware tutorial on course website