# CISC 3320 MW3
# Operating System Overview

Hui Chen

Department of Computer & Information Science

CUNY Brooklyn College

# Acknowledgement


- This slides are a revision of the slides by the authors of the textbook

# Outline

- Defining Operating Systems
  - Discussion, Definition of operating systems
- Computer system organization overview
  - Tiers of Storage, Memory/Storage hierarchy, Caching
- Computer system architecture overview
  - Single vs multiprocessor; multi-chip vs multi-core
- Operating system structure
  - Multiprogramming vs. timesharing
- Operating system operations
  - Interrupt-driven, dual- or multi-mode, timer
- Operating system resources management
- Protection and privacy

# Defining Operating Systems

- Discussion
- Definition of operating systems
  - What does an operating system do?
- Design goals

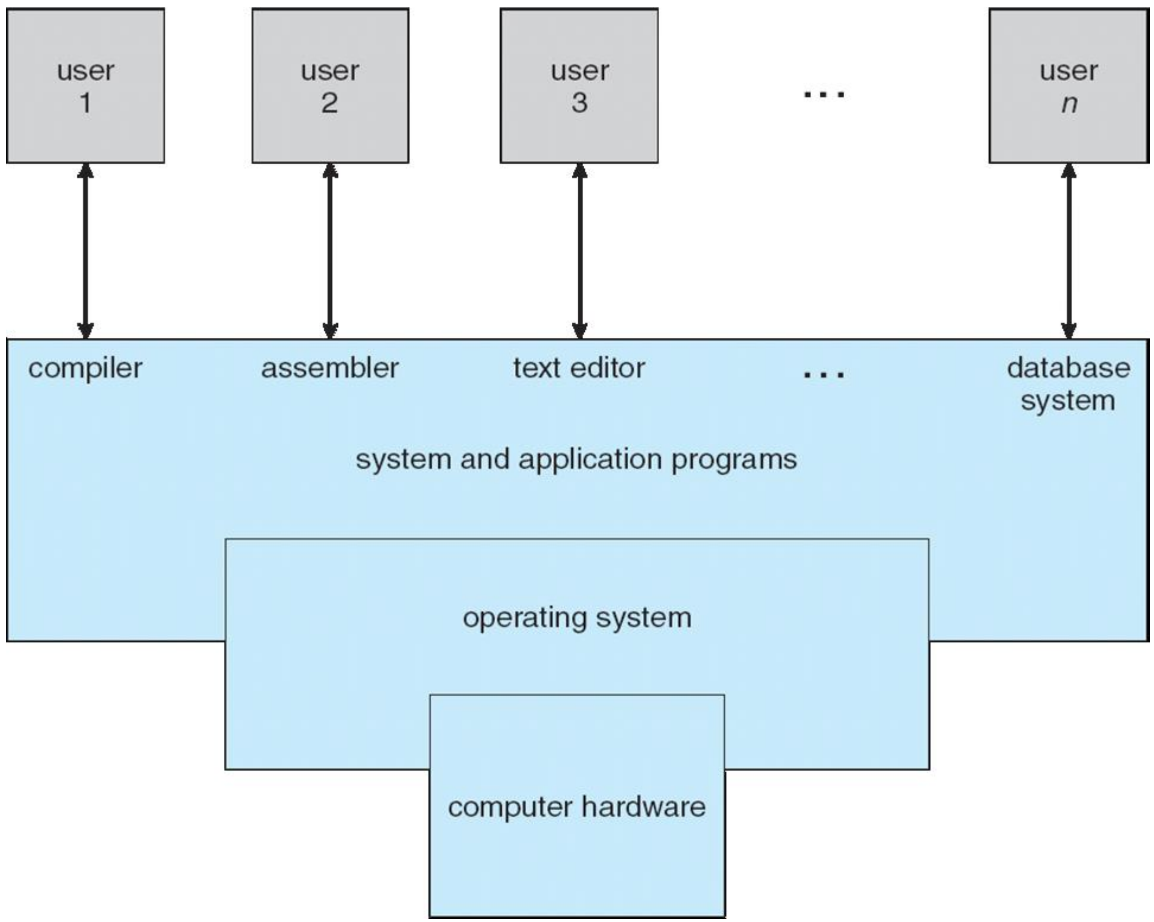
# Discussion Questions?

- Where are computers?
- Why should we learn operating systems?

# Discussion Questions

- What is an operating system?

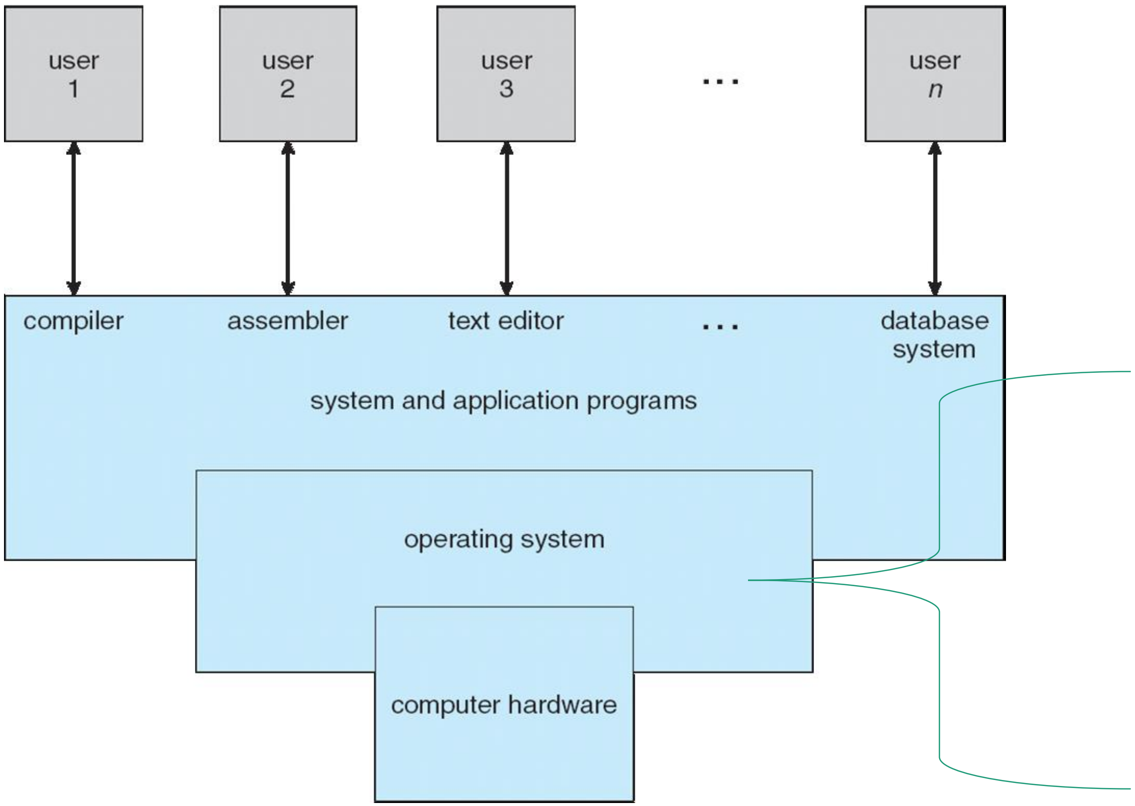
# A Computer System: Four Components



# Computer System Components

- Hardware: provides basic computing resources
  - CPU, memory, I/O devices
- Operating system
  - Controls and coordinates use of hardware among various applications and users
- Application programs: define the ways in which the system resources are used to solve the computing problems of the users
  - Word processors, compilers, web browsers, database systems, video games
- Users
  - People, machines, other computers

# Defining Operating Systems




An OS controls and coordinates use of hardware among various applications and users, and servers two major roles

# Role of Operating Systems

- An OS controls and coordinates use of hardware among various applications and users, and servers two major roles
- As a resource allocator
  - Manages all resources
  - Decides between conflicting requests for efficient and fair resource use
- As a control program
  - Controls execution of programs to prevent errors and improper use of the computer

# But, No Universally Accepted Definition

- "Everything a vendor ships when you order an operating system" is a good approximation
  - But varies wildly
- "The one program running at all times on the computer" is the kernel.
- Everything else is either
  - a system program (ships with the operating system) , or
  - an application program.

# Design Goals?

- Users want convenience, ease of use and good performance
  - Don’t care about resource utilization
- But shared computer such as mainframe or minicomputer must keep all users happy
- Users of dedicate systems such as workstations have dedicated resources but frequently use shared resources from servers
- Handheld computers are resource poor, optimized for usability and battery life
- Some computers have little or no user interface, such as embedded computers in devices and automobiles

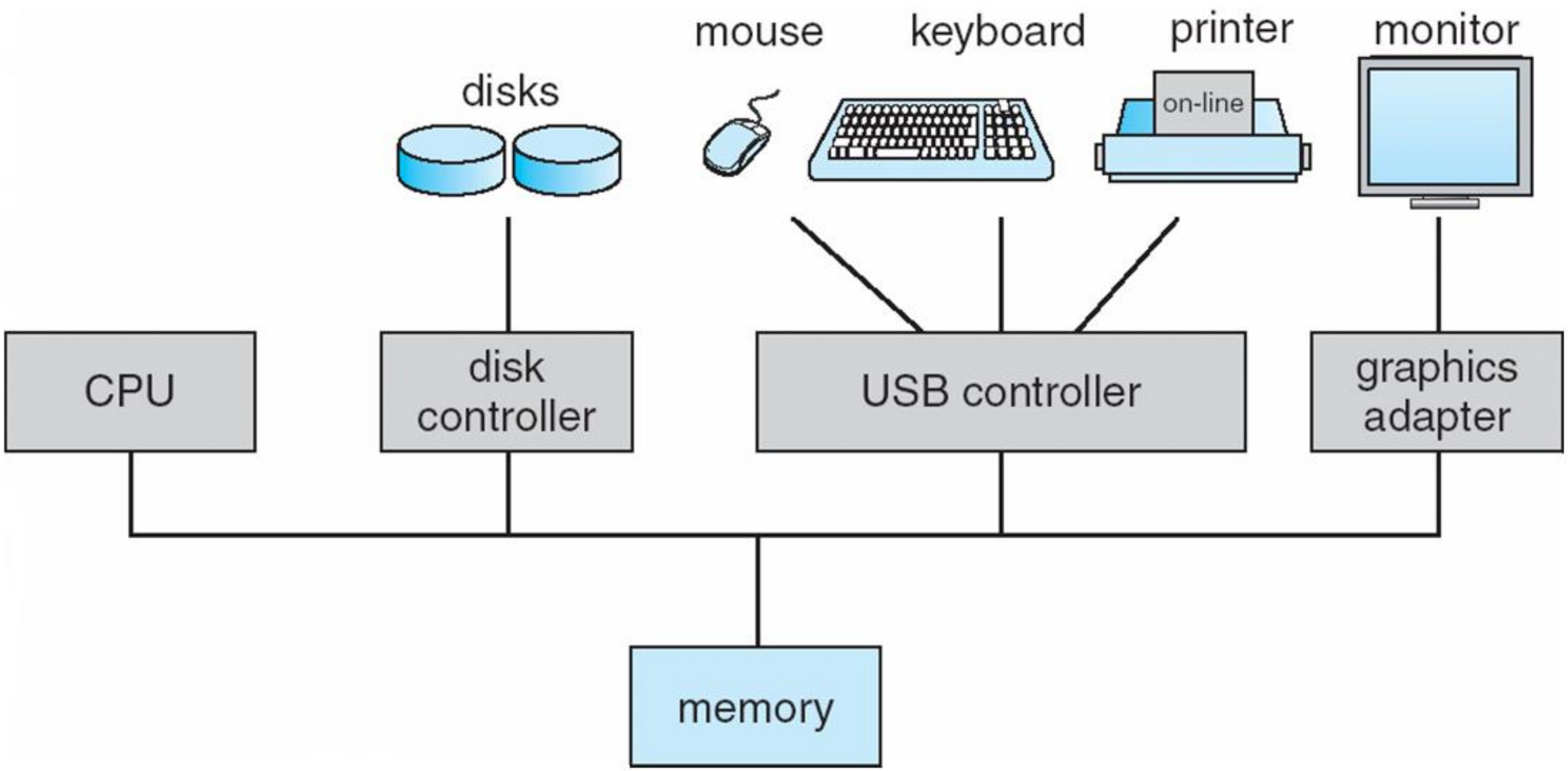
# Questions?

- What are major components of computer systems?
- What is an operating system?
- What are examples of conflicting design goals?

# Overview of Computer System Organization

- Computer-system operation
  - Bootstrap
  - Interrupts
- Tiers of Storage
- Memory/Storage hierarchy
- Caching

# A Typical Computer



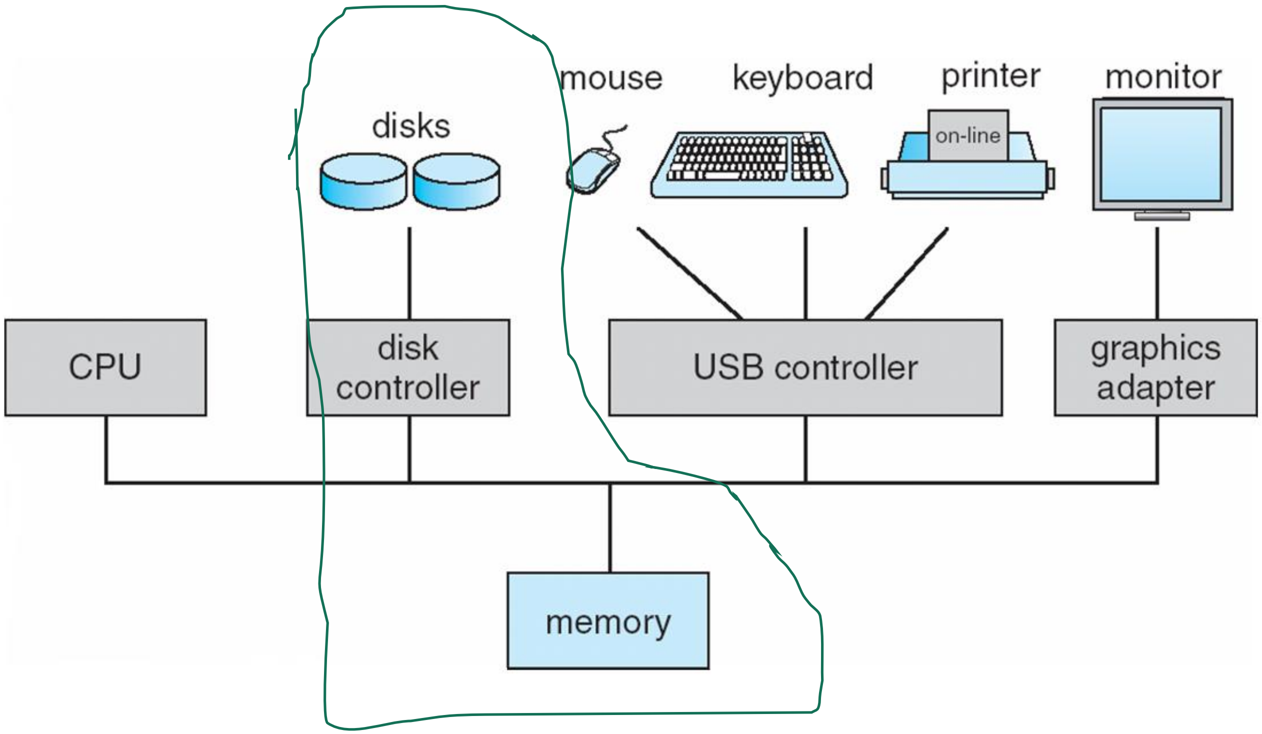
# Bootstrap program and Computer Startup

- Bootstrap program is loaded at power-up or reboot
  - Typically stored in ROM or EPROM, generally known as firmware
  - Initializes all aspects of system
  - Loads operating system kernel and starts execution

# Interrupt

- Hardware or software triggers events called interrupts
  - Hardware may trigger an interrupt at any time by sending a signal to the CPU
  - Software may trigger an interrupt by executing a special operation called a system call
- The events “interrupts” the CPU
  - CPU stops what it is doing, transfers execution at a fixed location
  - The fixed location contains the starting address where the service routine is located
  - Concept of interrupt vector

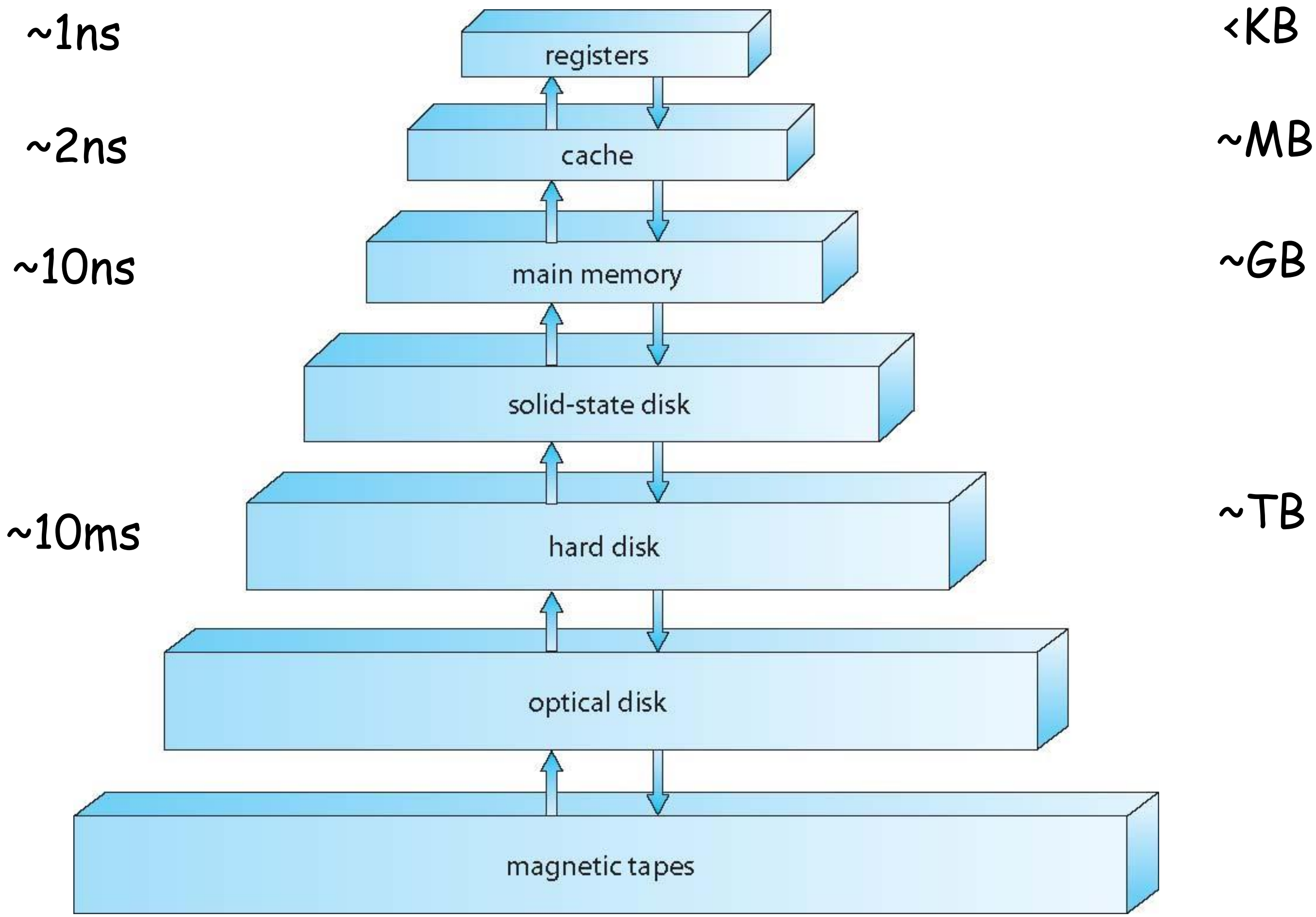
# Storage Structure



# Storage Hierarchy

- Storage systems organized in hierarchy
  - Speed
  - Cost
  - Volatility

# Storage-Device (or Memory) Hierarchy

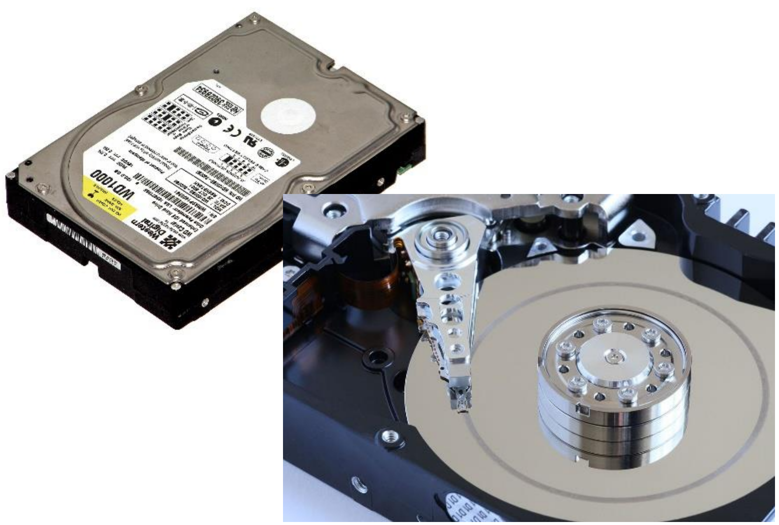


# Main Memory

- Main memory – only large storage media that the CPU can access directly
  - Random access, typically volatile

# Secondary Storage

- Secondary storage – extension of main memory that provides large nonvolatile storage capacity



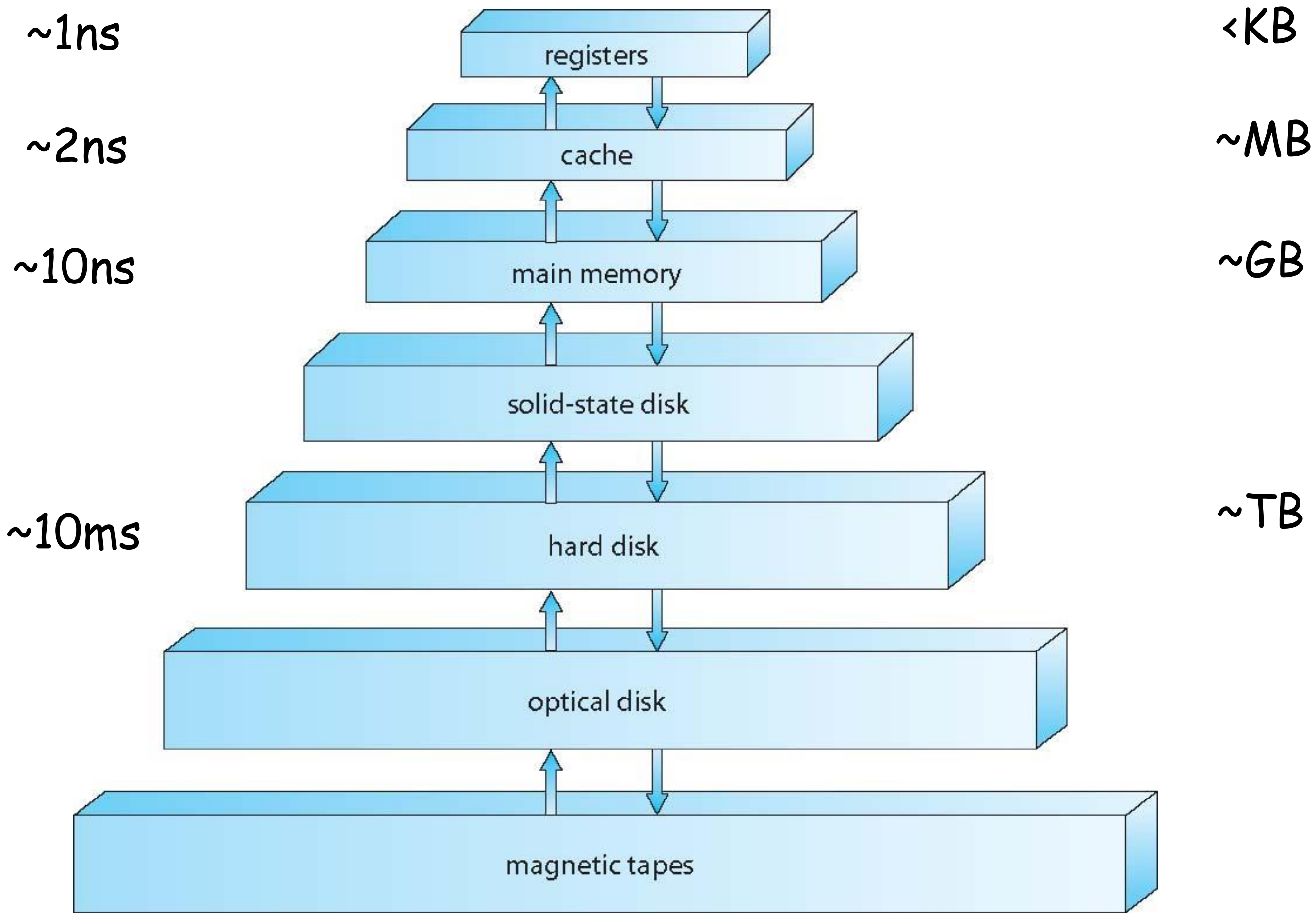

# Secondary Storage Devices

- Hard disks – rigid metal or glass platters covered with magnetic recording material
  - Disk surface is logically divided into tracks, which are subdivided into sectors
  - The disk controller determines the logical interaction between the device and the computer
- Solid-state drives – faster than hard disk drives, nonvolatile
  - Various technologies, becoming more popular

# Caching

- Information in use copied from slower to faster storage temporarily
  - e.g., main memory can be viewed as a cache for secondary storage

# Cache Memory and Caching



# Caching Principle

- Important principle, performed at many levels in a computer (in hardware, operating system, software)
- Faster storage (cache) checked first to determine if information is there
    - If it is, information used directly from the cache (fast)
    - If not, data copied to cache and used there
- Cache smaller than storage being cached
    - Cache management important design problem
    - Cache size and replacement policy

# Questions?

- How is storage organized?
- How does storage-device hierarchy look like? Why is storage organized in this fashion?
- What is caching?

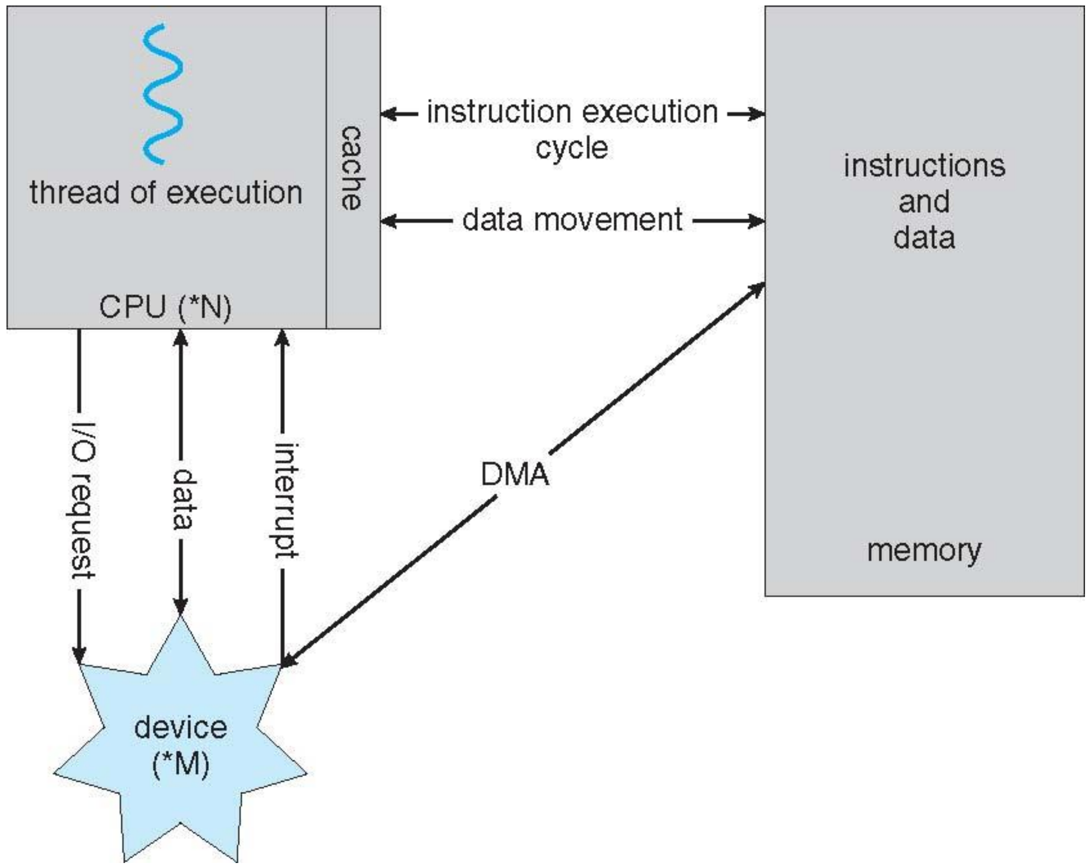
# Overview of Computer System Architecture

- Single-processor system
  - von Neumann Architecture
- Multiprocessor system
- Clustered Systems

# Single Processor System

- Many systems use a single general-purpose processor
  - Most systems have special-purpose processors, but they do not run user programs
    - Example: Disk-controller processor

# A von Neumann Architecture



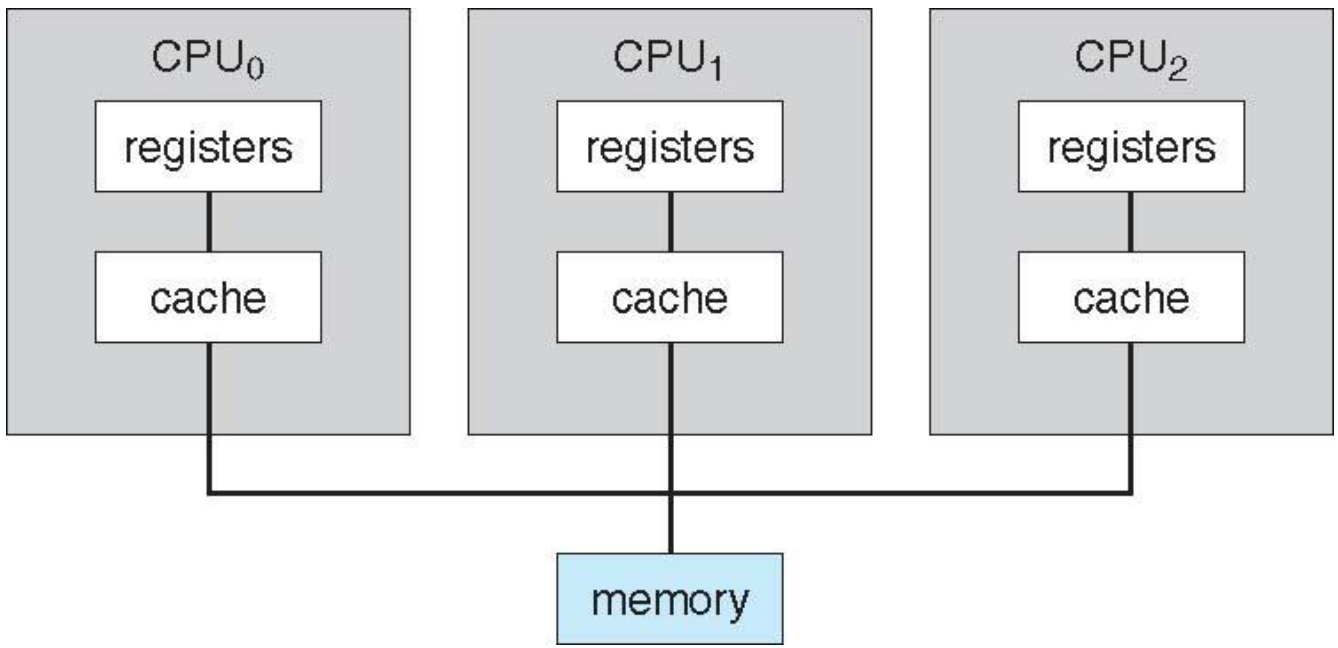
# Multiprocessor System

- Multiprocessors systems growing in use and importance
  - Also known as parallel systems, tightly-coupled systems
- Advantages include:
  1. Increased throughput
  2. Economy of scale
  3. Increased reliability – graceful degradation or fault tolerance
- Two types:
  1. Asymmetric Multiprocessing – each processor is assigned a specie task.
  2. Symmetric Multiprocessing – each processor performs all tasks

# Types of Multiprocessor Systems

- Asymmetric multiprocessing
- Symmetric multiprocessing (SMP)

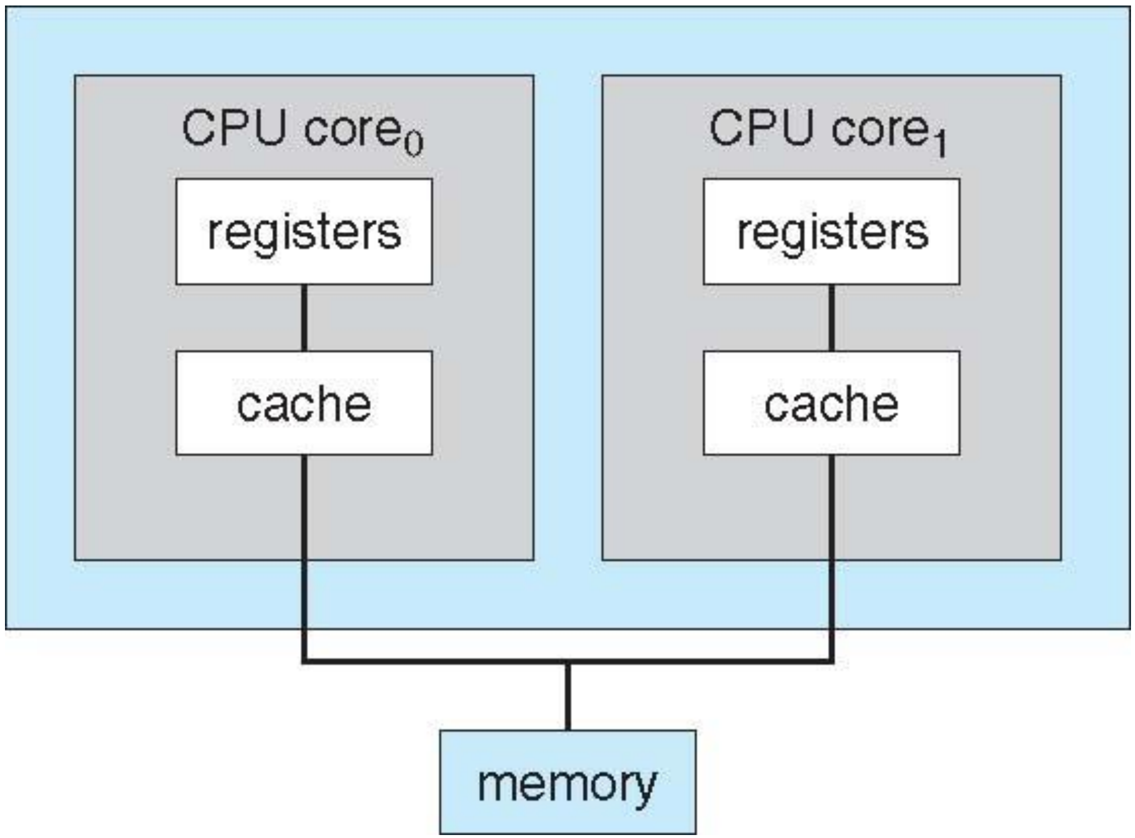
# Symmetric Multiprocessing Architecture



# Multi-chip and Multicore

- Multi-chip vs. multicore
- Multi-core design: multiple CPU cores on a single chip
  - On-chip communication is faster than between-chip communication

# A Dual-Core Design



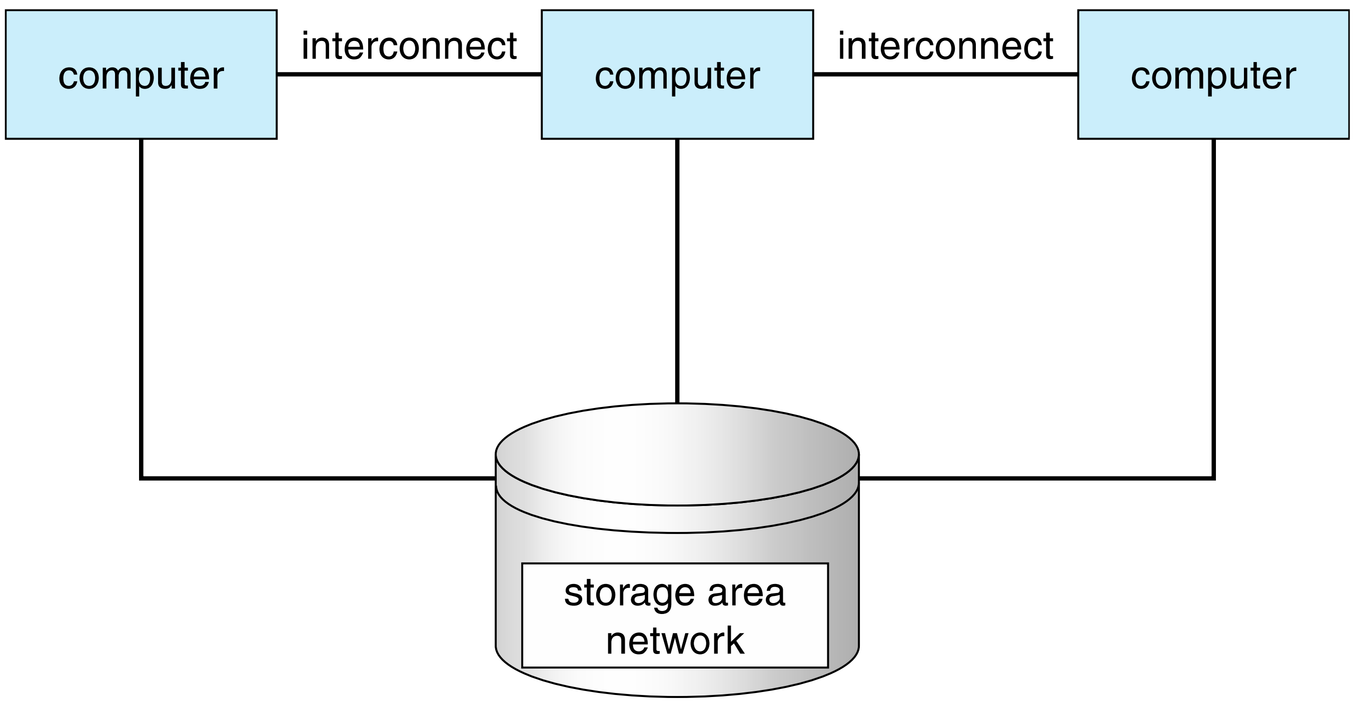
# Memory Access

- Memory access on multiprocessor systems can be either
  - Uniform memory access (UMA)
  - Non-uniform memory access (NUMA)

# Clustered Systems

- Like multiprocessor systems, but multiple systems working together
  - Usually sharing storage via a storage-area network (SAN)
  - Provides a high-availability service which survives failures
    - Asymmetric clustering has one machine in hot-standby mode
    - Symmetric clustering has multiple nodes running applications, monitoring each other
  - Some clusters are for high-performance computing (HPC)
    - Applications must be written to use parallelization
  - Some have distributed lock manager (DLM) to avoid conflicting operations

# Clustered Systems: Example



# Questions?

- Single processor system vs. multiprocessor system
- Multi-chip vs multi-core design
- Memory access: UMA vs NUMA
- Cluster systems

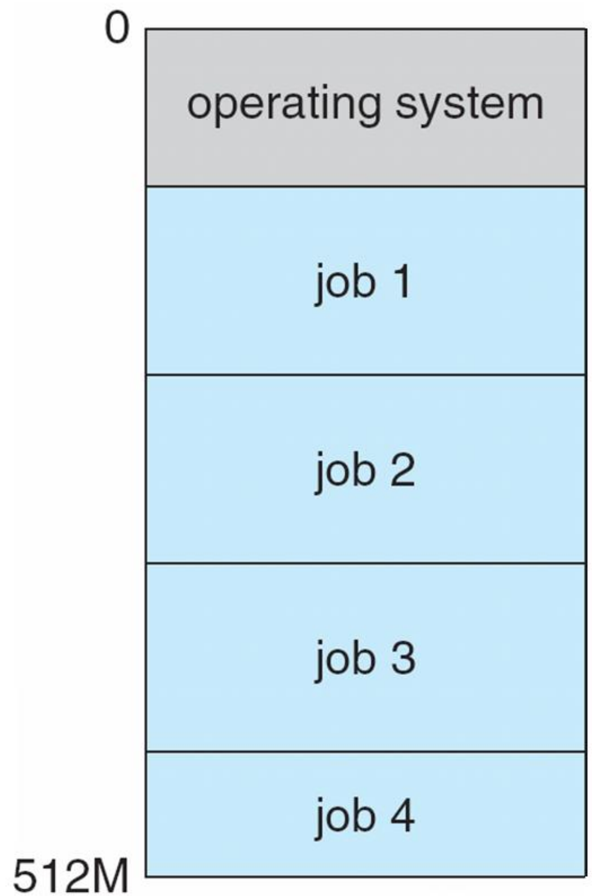
# Overview of Operating System Structure

- Multiprogramming (batch system)
- Multitask (time sharing)

# Multiprogramming

- Organizing jobs so that the CPU always has a program to execute.
- Multiprogramming (Batch system) needed for efficiency
  - Single user cannot keep CPU and I/O devices busy at all times
  - Multiprogramming organizes jobs (code and data) so CPU always has one to execute
  - A subset of total jobs in system is kept in memory
  - One job selected and run via job scheduling
  - When it has to wait (for I/O for example), OS switches to another job

# Memory Layout for Multiprogrammed System



# Timesharing

- Timesharing (multitasking) is logical extension of multiprogramming in which CPU switches jobs so frequently that users can interact with each job while it is running, creating interactive computing
  - Response time should be < 1 second
  - Each user has at least one program executing in memory ⇨process
  - If several jobs ready to run at the same time ⇨ CPU scheduling
  - If processes don’t fit in memory, swapping moves them in and out to run
  - Virtual memory allows execution of processes not completely in memory

# Questions?

- Multiprogramming vs timesharing

# Overview of Operating System Operations

- Interrupt-driven operation
- Dual-mode operation
- Multi-mode operation

# Interrupt-Driven Operation

- Modern operating systems are interrupt driven.
  - Hardware and software interrupts
- Hardware interrupt by one of the devices
- Software interrupt (exception or trap):
  - Software error (e.g., division by zero)
  - Request for operating system service
  - Other process problems include infinite loop, processes modifying each other or the operating system

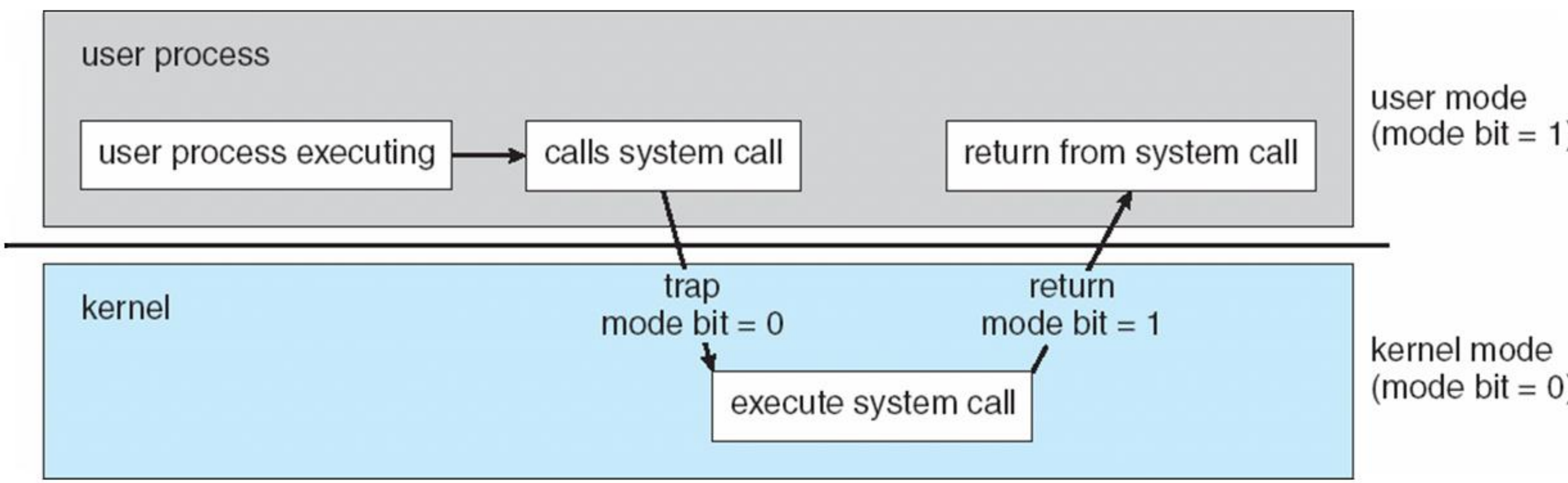
# Dual-Mode Operation

- To distinguish between the execution of operating system code and user-defined code
- With hardware support, differentiate between different modes
  - User mode and kernel mode
- Dual-mode operation allows OS to protect itself and other system components

# User Mode and Kernel Mode

- User mode and kernel mode
- Mode bit provided by hardware
  - Provides ability to distinguish when system is running user code or kernel code
  - Some instructions designated as privileged, only executable in kernel mode
  - System call changes mode to kernel, return from call resets it to user

# Transition from User to Kernel Mode



# Multi-Mode Operations

- Increasingly CPUs support multi-mode operations
  - i.e. virtual machine manager (VMM) mode for guest VMs

# Timer

- To ensure an operating system to maintain control over the CPU
  - e.g., timer to prevent infinite loop / process hogging resources
  - Timer is set to interrupt the computer after some time period
  - Keep a counter that is decremented by the physical clock.
  - Operating system set the counter (privileged instruction)
  - When counter zero generate an interrupt
  - Set up before scheduling process to regain control or terminate program that exceeds allotted time

# Questions?

- Interrupt-driven operation
- Dual-mode operation
- Multi-mode operation
- Role of Timer

# Overview of OS Resource Management

- Process management
- Memory management
- Storage management
- Mass-storage (disk) management
- I/O subsystem
- Protection and privacy

# Process Management

- A process is a program in execution. It is a unit of work within the system. Program is a passive entity, process is an active entity.
- Process needs resources to accomplish its task
  - CPU, memory, I/O, files
  - Initialization data
- Process termination requires reclaim of any reusable resources
- Single-threaded process has one program counter specifying location of next instruction to execute
  - Process executes instructions sequentially, one at a time, until completion
- Multi-threaded process has one program counter per thread
- Typically system has many processes, some user, some operating system running concurrently on one or more CPUs
  - Concurrency by multiplexing the CPUs among the processes / threads

# Process Management Activities

- The operating system is responsible for the following activities in connection with process management:
  - Creating and deleting both user and system processes
  - Suspending and resuming processes
  - Providing mechanisms for process synchronization
  - Providing mechanisms for process communication
  - Providing mechanisms for deadlock handling

# Memory Management

- To execute a program all (or part) of the instructions must be in memory
- All (or part) of the data that is needed by the program must be in memory.
- Memory management determines what is in memory and when
  - Optimizing CPU utilization and computer response to users
- Memory management activities
  - Keeping track of which parts of memory are currently being used and by whom
  - Deciding which processes (or parts thereof) and data to move into and out of memory
  - Allocating and deallocating memory space as needed

# Storage Management

- OS provides uniform, logical view of information storage
  - Abstracts physical properties to logical storage unit - **file**
  - Each medium is controlled by device (i.e., disk drive, tape drive)
    - Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)
- File-System management
  - Files usually organized into directories
  - Access control on most systems to determine who can access what
  - OS activities include
    - Creating and deleting files and directories
    - Primitives to manipulate files and directories
    - Mapping files onto secondary storage
    - Backup files onto stable (non-volatile) storage media

# Mass-Storage Management

- Usually disks used to store data that does not fit in main memory or data that must be kept for a “long” period of time
- Proper management is of central importance
- Entire speed of computer operation hinges on disk subsystem and its algorithms
- OS activities
  - Free-space management
  - Storage allocation
  - Disk scheduling
- Some storage need not be fast
  - Tertiary storage includes optical storage, magnetic tape
  - Still must be managed – by OS or applications
  - Varies between WORM (write-once, read-many-times) and RW (read-write)

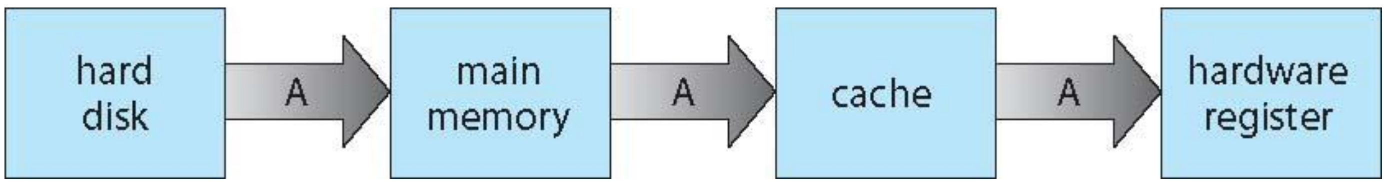
# Performance of Various Levels of Storage

- Movement between levels of storage hierarchy can be explicit or implicit

| Level | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Name | registers | cache | main memory | solid state disk | magnetic disk |
| Typical size | < 1 KB | < 16MB | < 64GB | < 1 TB | < 10 TB |
| Implementation technology | custom memory with multiple ports CMOS | on-chip or off-chip CMOS SRAM | CMOS SRAM | flash memory | magnetic disk |
| Access time (ns) | 0.25 - 0.5 | 0.5 - 25 | 80 - 250 | 25,000 - 50,000 | 5,000,000 |
| Bandwidth (MB/sec) | 20,000 - 100,000 | 5,000 - 10,000 | 1,000 - 5,000 | 500 | 20 - 150 |
| Managed by | compiler | hardware | operating system | operating system | operating system |
| Backed by | cache | main memory | disk | disk | disk or tape |

# Migration of Data from Disk to Register

- Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy




- Multiprocessor environment must provide cache coherency in hardware such that all CPUs have the most recent value in their cache
- Distributed environment situation even more complex
  - Several copies of a datum can exist
  - Various solutions covered in Chapter 17

# I/O Subsystem

- One purpose of OS is to hide peculiarities of hardware devices from the user
- I/O subsystem responsible for
  - Memory management of I/O including buffering (storing data temporarily while it is being transferred), caching (storing parts of data in faster storage for performance), spooling (the overlapping of output of one job with input of other jobs)
  - General device-driver interface
  - Drivers for specific hardware devices

# Protection and Security

- Protection – any mechanism for controlling access of processes or users to resources defined by the OS
- Security – defense of the system against internal and external attacks
  - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- Systems generally first distinguish among users, to determine who can do what
  - User identities (user IDs, security IDs) include name and associated number, one per user
  - User ID then associated with all files, processes of that user to determine access control
  - Group identifier (group ID) allows set of users to be defined and controls managed, then also associated with each process, file
  - Privilege escalation allows user to change to effective ID with more rights

# Questions?

- How does an OS manage the computer resources?
  - Process management
  - Memory management
  - Storage management
  - Mass-storage (disk) management
  - I/O subsystem
- Protection and privacy