CS3600 — Systems and Networks

NORTHEASTERN UNIVERSITY

Lecture 1: Overview and Introduction

Prof. Alan Mislove (amislove@ccs.neu.edu)

What is an Operating System?

What is an Operating System?

- A program that acts as an intermediary between a user of a computer and the computer hardware

What is an Operating System?

- A program that acts as an intermediary between a user of a computer and the computer hardware

What is an Operating System?

- A program that acts as an intermediary between a user of a computer and the computer hardware

- Operating system goals:
  - Execute user programs and make solving user problems easier
  - Make the computer system convenient to use
  - Use the computer hardware in an efficient manner

What is an Operating System?

- A program that acts as an intermediary between a user of a computer and the computer hardware

- Operating system goals:
  - Execute user programs and make solving user problems easier
  - Make the computer system convenient to use
  - Use the computer hardware in an efficient manner

- Rest of this lecture:
  - Background
  - Overview of topics we'll cover in this half of the course

Why study operating systems?

- Maturing field
  - Most people only use one OS

- But, lots of new technology
  - High performance computing
  - Distributed computing
  - Cloud computing
  - Fault-tolerant computing

- OS issues faced in many places
  - Security, protection, resource management

- New devices need OSes
  - iPhones, iPads, (Galaxy Tabs)

Outline

- OS Definition

- OS interface with subsystems
  - I/O systems
  - Storage systems

- Basic functionality
  - Protecting resources
  - Managing resources
    - Processes
    - Memory
    - Storage

What do Operating Systems do?

What do Operating Systems do?

- Depends on the point of view
- Users want convenience, **ease of use**
  - Don't care about **resource utilization**
- But shared computer such as **mainframe** or **minicomputer** must keep all users happy
- Users of dedicated 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

Operating System Definition

- OS is a **resource allocator**
  - Manages all resources
  - Decides between conflicting requests for efficient and fair resource use
- OS is a **control program**
  - Controls execution of programs to prevent errors and improper use of the computer

Operating System Definition (Cont.)

- But, no universally accepted definition
- "Everything a vendor ships when you order an operating system" is good approximation
  - But varies wildly (IE, anyone?)
- "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.

Outline

- ~~OS Definition~~

- OS interface with subsystems
  - I/O systems
  - Storage systems

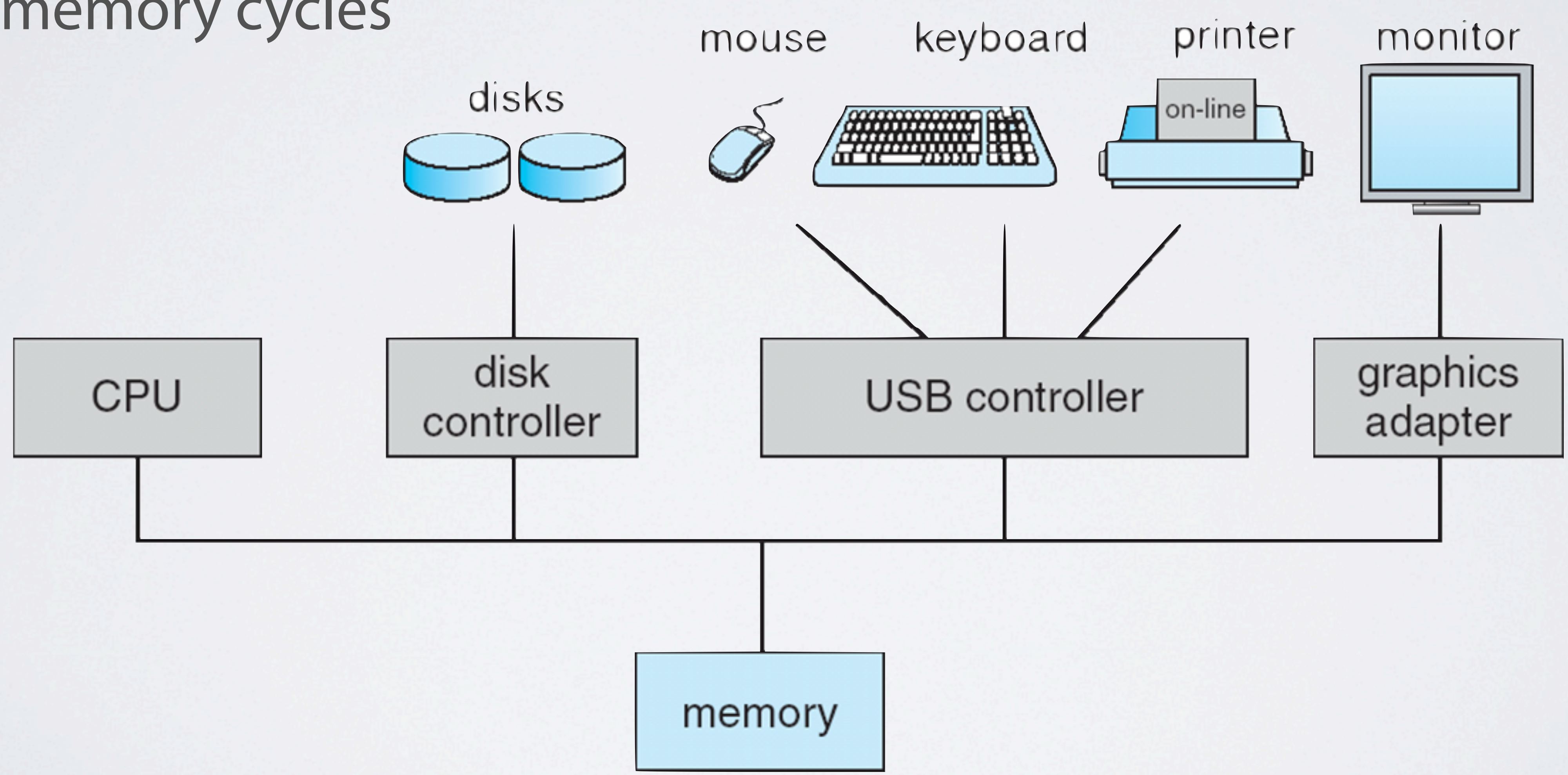
- Basic functionality
  - Protecting resources
  - Managing resources
    - Processes
    - Memory
    - Storage

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
- Will not focus on bootstrapping in this course (take CS5600)

Computer System Organization

- Computer-system operation
  - One or more CPUs, device controllers connect through common bus providing access to shared memory
  - Concurrent execution of CPUs and devices competing for memory cycles



How do the devices communicate?

- I/O devices and the CPU can execute concurrently
- Each device controller is in charge of a particular device type
- Each device controller has a local buffer
- CPU moves data from/to main memory to/from local buffers
- I/O is from the device to local buffer of controller
- Device controller informs CPU that it has finished its operation by causing an interrupt

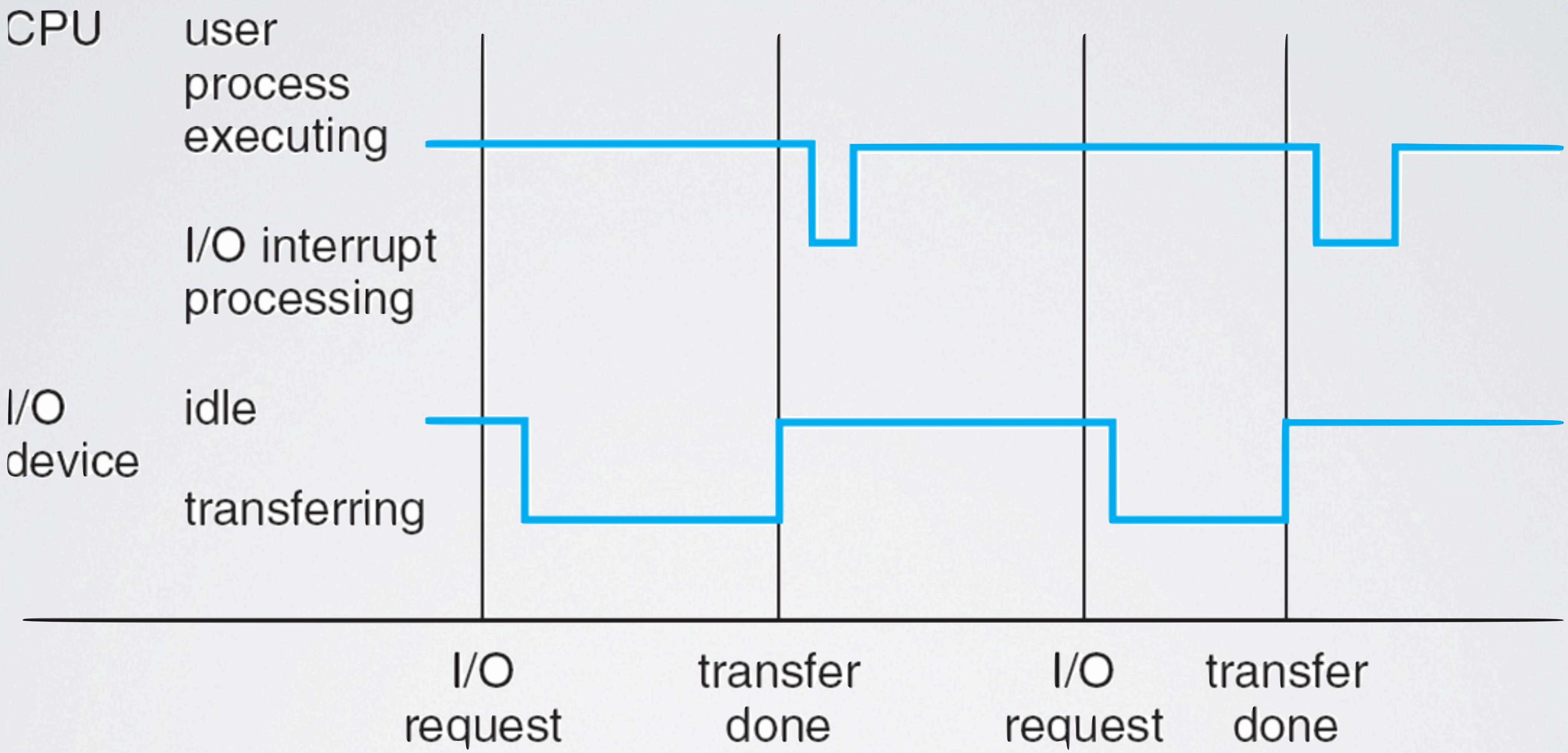
Common Functions of Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the **interrupt vector**, which contains the addresses of all the service routines
- Interrupt architecture must save the address of the interrupted instruction
- Incoming interrupts are *disabled* while another interrupt is being processed to prevent a *lost interrupt*
- A *trap* is a software-generated interrupt caused either by an error or a user request
- An operating system is **interrupt driven**

Interrupt Handling

- The operating system preserves the state of the CPU by storing registers and the program counter
- Determines which type of interrupt has occurred:
- Separate segments of code determine what action should be taken for each type of interrupt

Interrupt Timeline



I/O Structure: Two options

I/O Structure: Two options

- After I/O starts, control returns to user program only upon I/O completion
  - Wait instruction idles the CPU until the next interrupt
  - Wait loop (contention for memory access)
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing

I/O Structure: Two options

- After I/O starts, control returns to user program only upon I/O completion
  - Wait instruction idles the CPU until the next interrupt
  - Wait loop (contention for memory access)
  - At most one I/O request is outstanding at a time, no simultaneous I/O processing

- After I/O starts, control returns to user program without waiting for I/O completion
  - **System call** – request to the operating system to allow user to wait for I/O completion
  - **Device-status table** contains entry for each I/O device indicating its type, address, and state
  - Operating system indexes into I/O device table to determine device status and to modify table entry to include interrupt

Storage Structure: Many levels

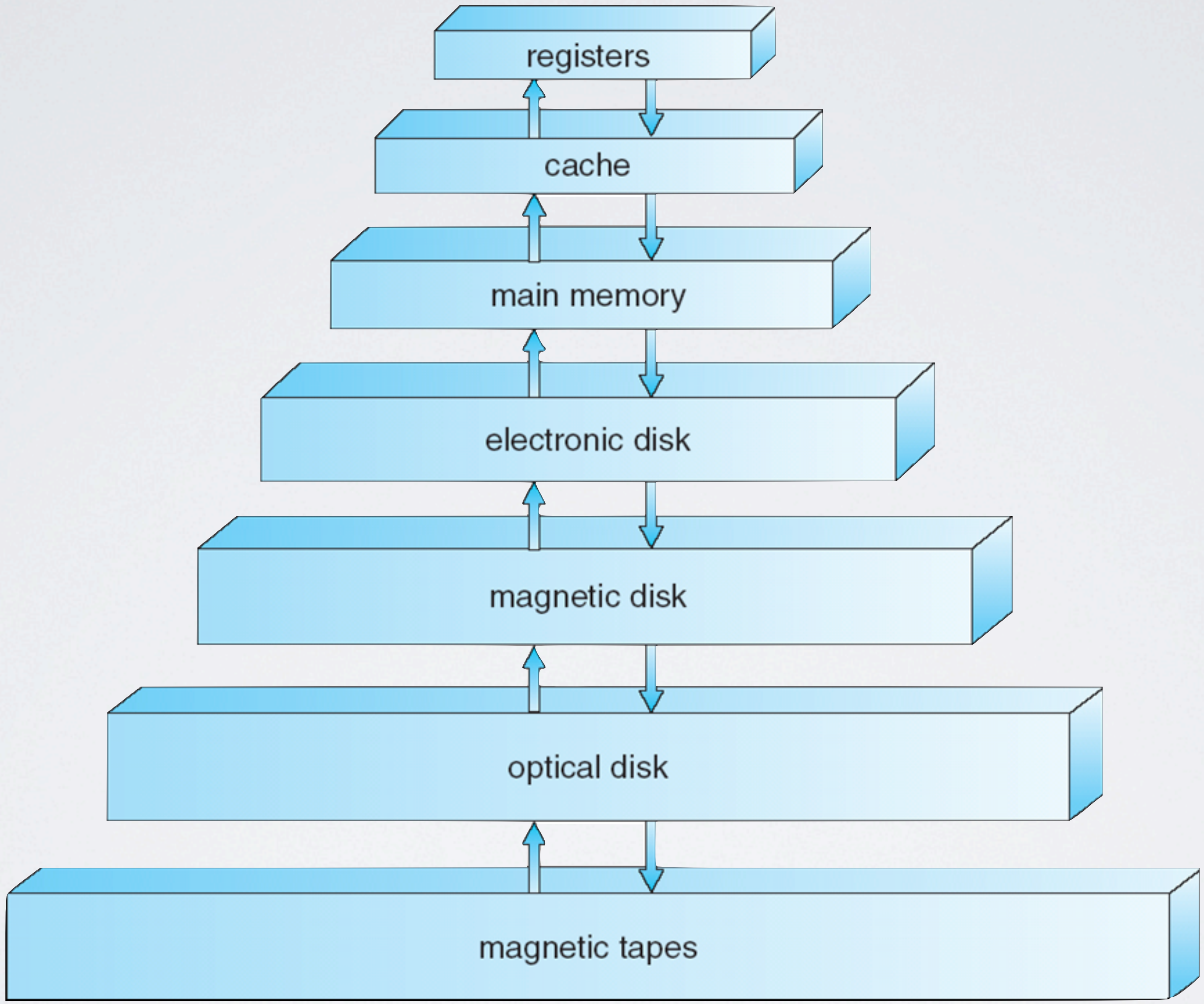
- Main memory – only large storage media that the CPU can access directly
  - **Random access**
  - Typically **volatile**
- Secondary storage – extension of main memory that provides large **nonvolatile** storage capacity
- Magnetic disks – rigid metal or glass platters covered with magnetic recording material
  - Disk surface is logically divided into **tracks**, which are subdivided into **sectors**
- SSDs – solid-state memory disks with no moving parts

Storage Hierarchy

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

- **Caching** – copying information into faster storage system; main memory can be viewed as a *cache* for secondary storage

Storage-Device Hierarchy



Caching

- Important principle, performed at many levels in a computer (in hardware, operating system, software)
- Information in use copied from slower to faster storage temporarily
- 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

Outline

- ~~OS Definition~~

- ~~OS interface with subsystems~~
  - ~~I/O systems~~
  - ~~Storage systems~~

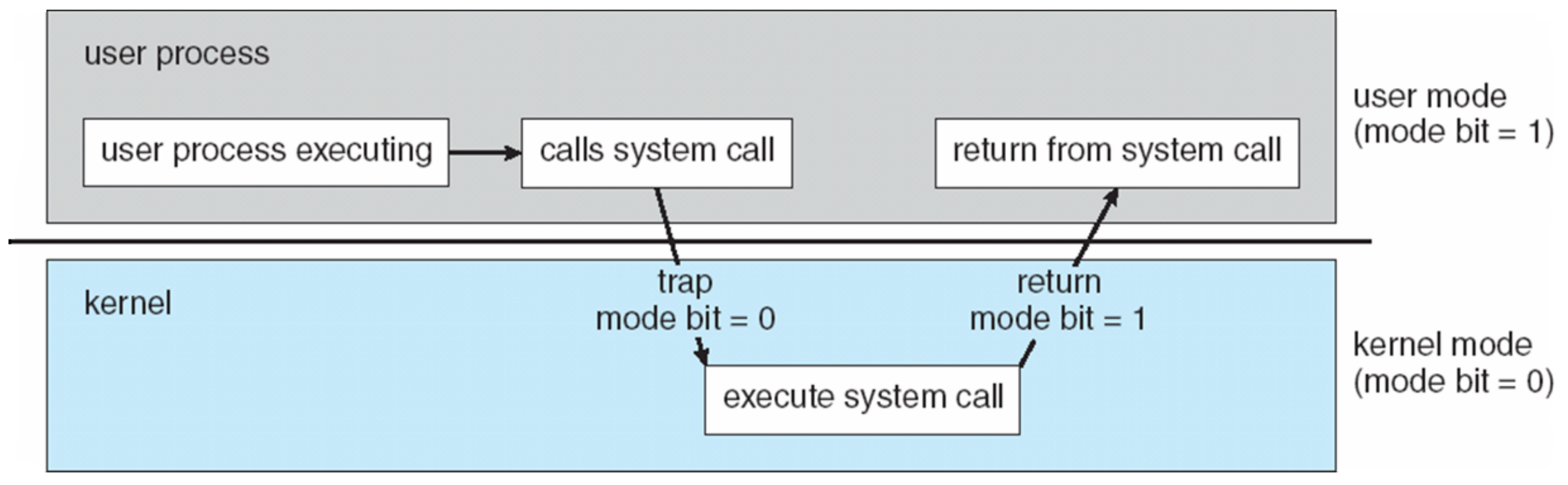
- Basic functionality
  - Protecting resources
  - Managing resources
    - Processes
    - Memory
    - Storage

How do we protect resources?

- Interrupt driven by hardware
- Software error or request creates **exception** or **trap**
  - 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 allows OS to protect itself and other system components
  - **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

How to prevent processes hogging CPU?

- Timer to prevent infinite loop / process hogging resources
  - Set interrupt after specific period
  - Operating system decrements counter
  - When counter zero generate an interrupt
  - Set up before scheduling process to regain control or terminate program that exceeds allotted time



How do we protect a process's memory?

- Rogue processes could access any part of memory
  - Even parts that are not their's
- Kernel memory, other processes' memory, etc
- Many OSes has little protection against such processes
  - Mac OS 9, e.g.
- How to protect against this?
  - Need to only allow processes to mess with their own memory
- Requires user/kernel privilege separation
  - Why?

Processes

- Definition: 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