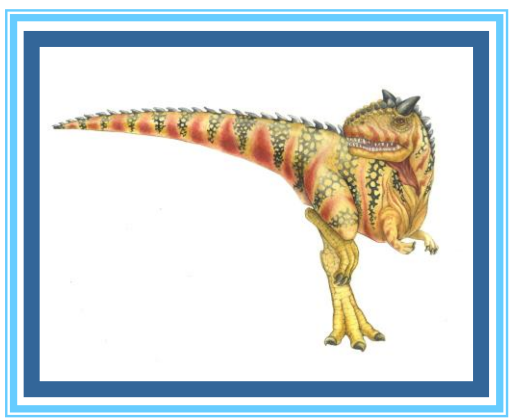
Chapter 1: Introduction



Chapter 1: Introduction

- What Operating Systems Do
- Computer-System Organization
- Computer-System Architecture
- Operating-System Structure (overview of Chapter 2)
- Operating-System Operations
- Process Management (overview of Chapters 3-7)
- Memory Management (overview of Chapters 8-9)
- Storage Management (overview of Chapters 10-13)
- Protection and Security (overview of Chapters 14-15)
- Kernel Data Structures
- Computing Environments
- Open-Source Operating Systems

Overview in this chapter, study in detail later on

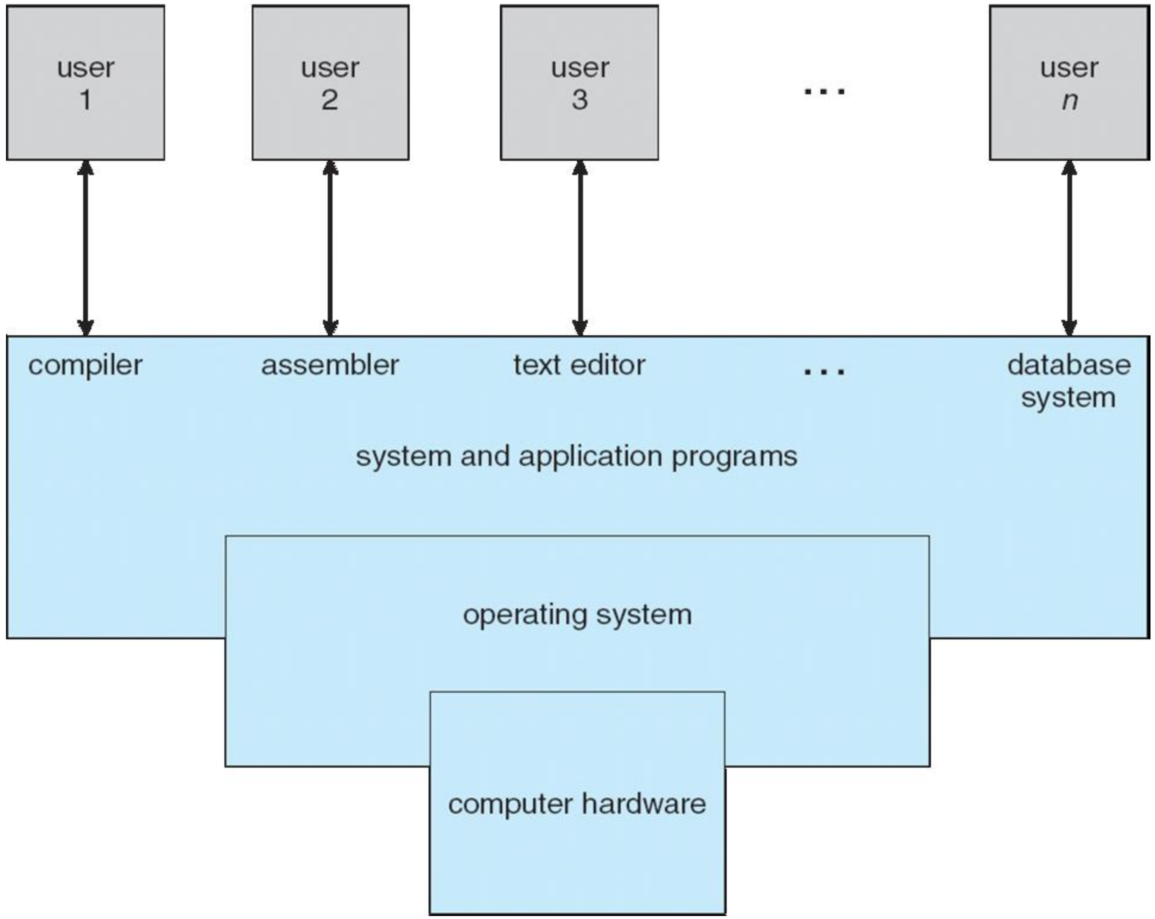
Objectives

- To describe the basic organization of computer systems
  - Quick recap of previous Lecture
- To provide a grand tour of the major components of operating systems
- To give an overview of the many types of computing environments
  - Most were overviewed in Lecture 1
- To explore several open-source operating systems

Recap: What is an Operating System?

- OS is 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

Four Components of a Computer System

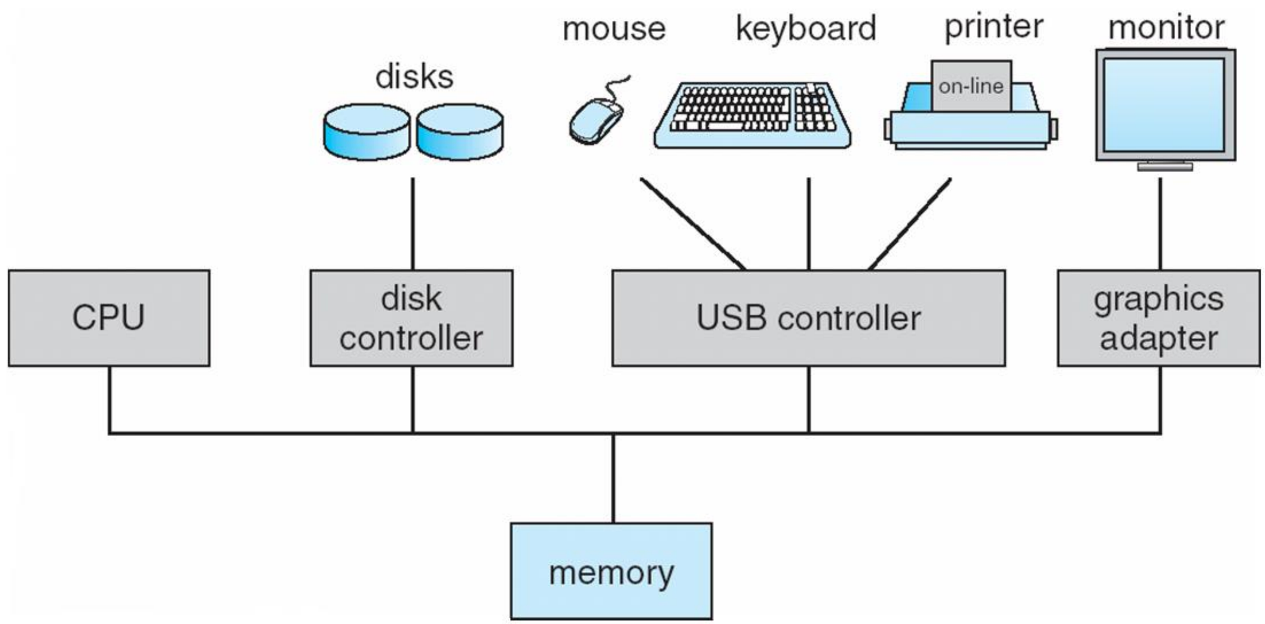


Computer Startup

- **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
    - We will come back to it

Computer System Organization

- Computer-system operation
  - One or more CPUs, device controllers connect through common bus providing access to shared memory



Computer-System Operation

- 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

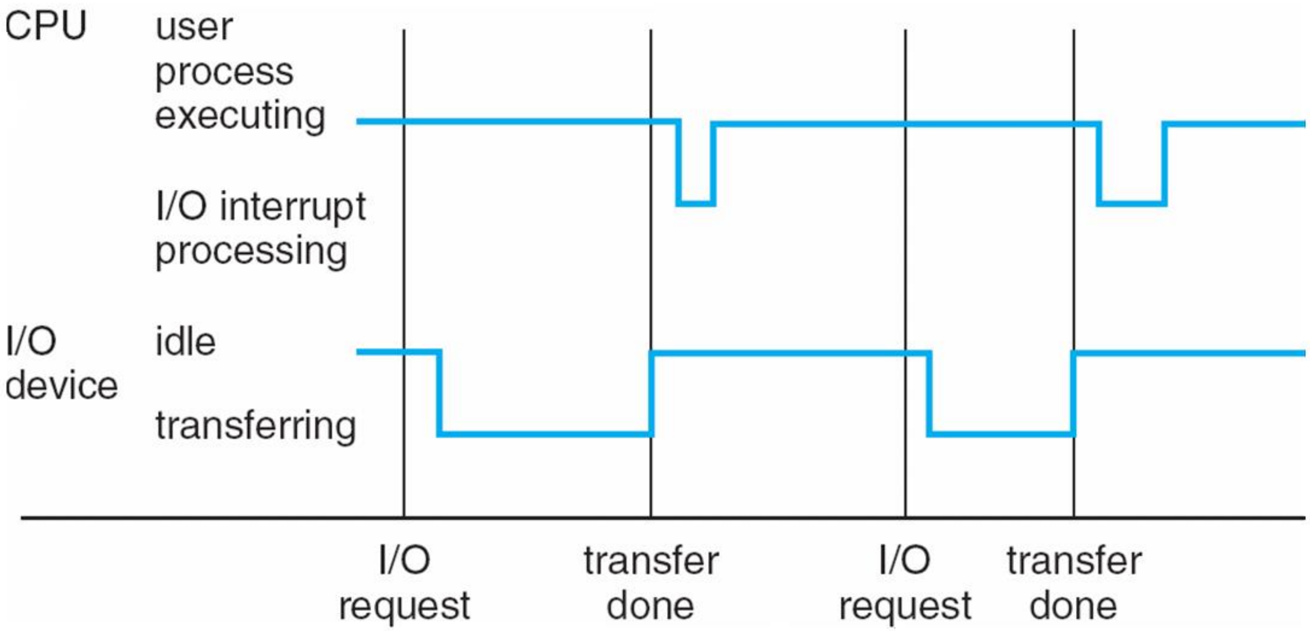
Common Functions of Interrupts

- 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
- A **trap** or **exception** is a software-generated interrupt caused either by an error or a user request
- An operating system is **interrupt driven**

Interrupt Handling

- The OS preserves the state of the CPU by storing registers and the program counter
- Determines which type of interrupt has occurred:
  - **polling**
    - The interrupt controller polls (send a signal out to) each device to determine which one made the request
  - **vectored** interrupt system
- Separate segments of code determine what action should be taken for each type of interrupt

Interrupt Timeline



I/O Structure

- Synchronous (blocking) I/O
  - Waiting for I/O to complete
  - Easy to program, not always efficient
  - Wait instruction idles the CPU until the next interrupt
  - At most one I/O request is outstanding at a time
    - no simultaneous I/O processing
- Asynchronous (nonblocking) I/O
  - After I/O starts, control returns to user program without waiting for I/O completion
  - Harder to program, more efficient
  - **System call** – request to the OS to allow user to wait for I/O completion (polling periodically to check busy/done)
  - **Device-status table** contains entry for each I/O device indicating its type, address, and state

Storage Definitions and Notation Review

The basic unit of computer storage is the **bit**. A bit can contain one of two values, 0 and 1. All other storage in a computer is based on collections of bits. Given enough bits, it is amazing how many things a computer can represent: numbers, letters, images, movies, sounds, documents, and programs, to name a few. A **byte** is 8 bits, and on most computers it is the smallest convenient chunk of storage. For example, most computers don't have an instruction to move a bit but do have one to move a byte. A less common term is **word**, which is a given computer architecture's native unit of data. A word is made up of one or more bytes. For example, a computer that has 64-bit registers and 64-bit memory addressing typically has 64-bit (8-byte) words. A computer executes many operations in its native word size rather than a byte at a time.

Computer storage, along with most computer throughput, is generally measured and manipulated in bytes and collections of bytes.
A **kilobyte**, or **KB**, is 1,024 bytes
a **megabyte**, or **MB**, is $1{,}024^2$ bytes
a **gigabyte**, or **GB**, is $1{,}024^3$ bytes
a **terabyte**, or **TB**, is $1{,}024^4$ bytes
a **petabyte**, or **PB**, is $1{,}024^5$ bytes

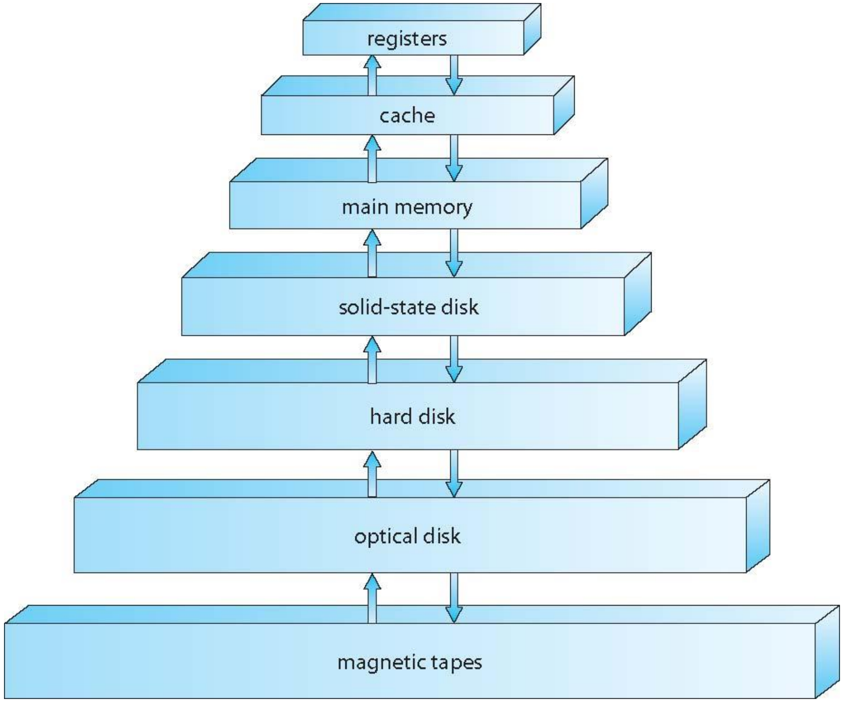
Computer manufacturers often round off these numbers and say that a megabyte is 1 million bytes and a gigabyte is 1 billion bytes. Networking measurements are an exception to this general rule; they are given in bits (because networks move data a bit at a time).

Storage Structure

- 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
- 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 disks** – faster than hard disks, nonvolatile
  - Various technologies
  - Becoming more popular

Storage Hierarchy

- Storage systems organized in hierarchy
  - Speed
  - Cost (per byte of storage)
  - Volatility
- **Device Driver** for each device controller to manage I/O
  - Provides uniform interface between controller and kernel



Performance of Various Levels of Storage

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

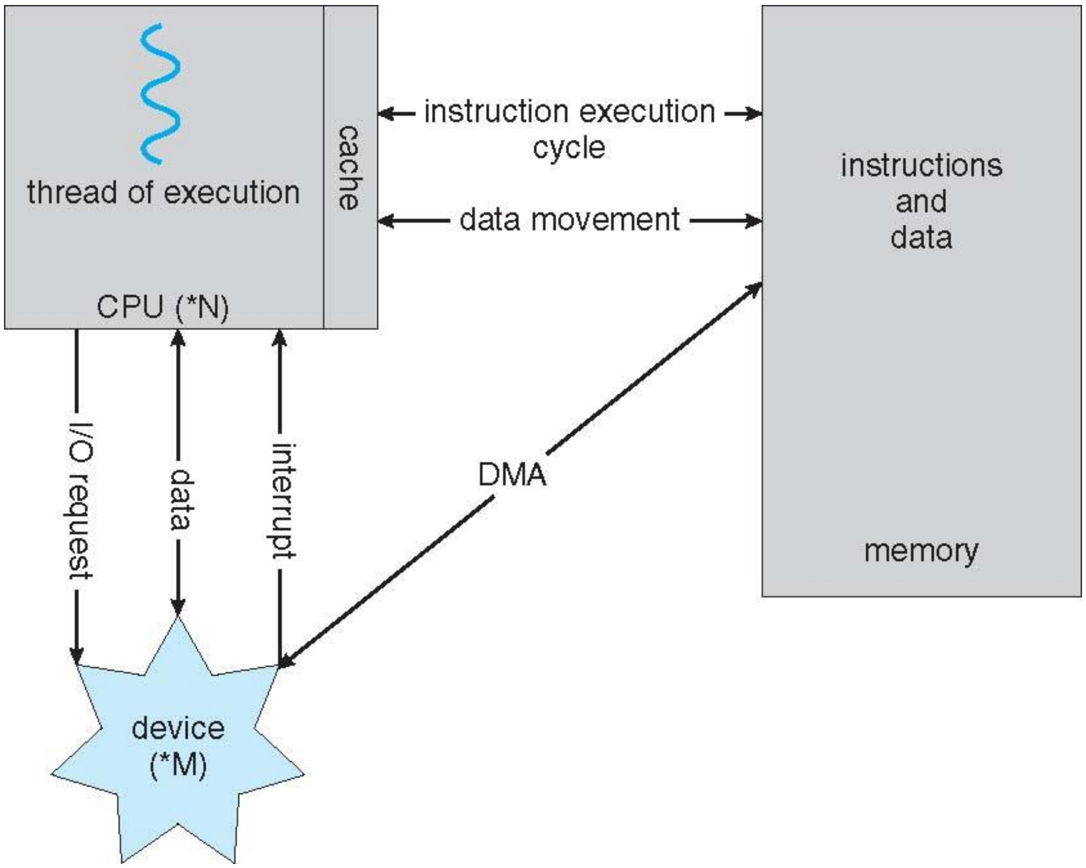
Caching

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

Direct Memory Access Structure

- Typically used for I/O devices that generate data in blocks, or generate data fast
- Device controller transfers blocks of data from buffer storage directly to main memory without CPU intervention
- Only one interrupt is generated per block, rather than the one interrupt per byte

How a Modern Computer Works

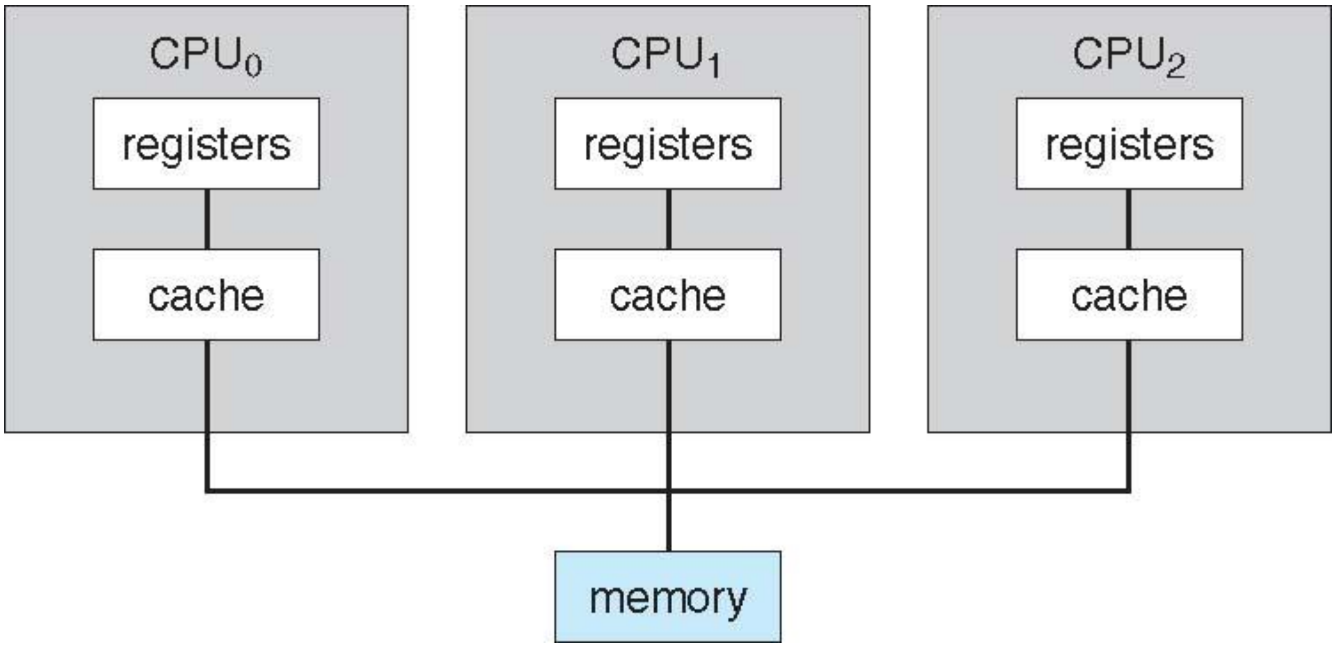


A von Neumann architecture

Computer-System Architecture

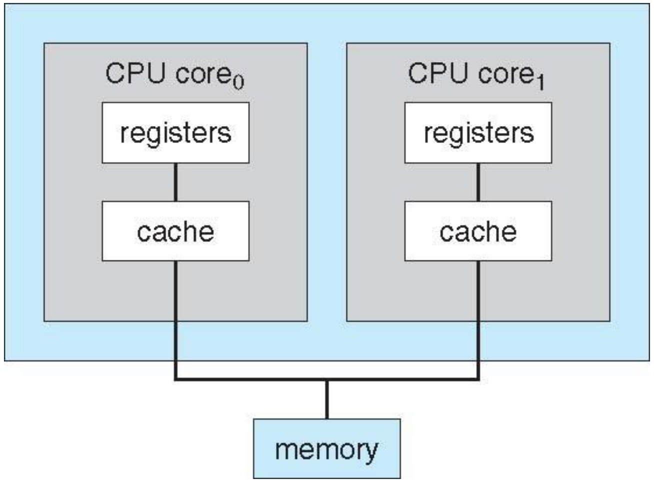
- Most systems use a single general-purpose processor
  - Most systems have special-purpose processors as well
- **Multiprocessors** systems growing in use and importance
  - Also known as **parallel systems**, **tightly-coupled systems**
  - Advantages include:
    1. **Increased throughput**
    2.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

Symmetric Multiprocessing Architecture

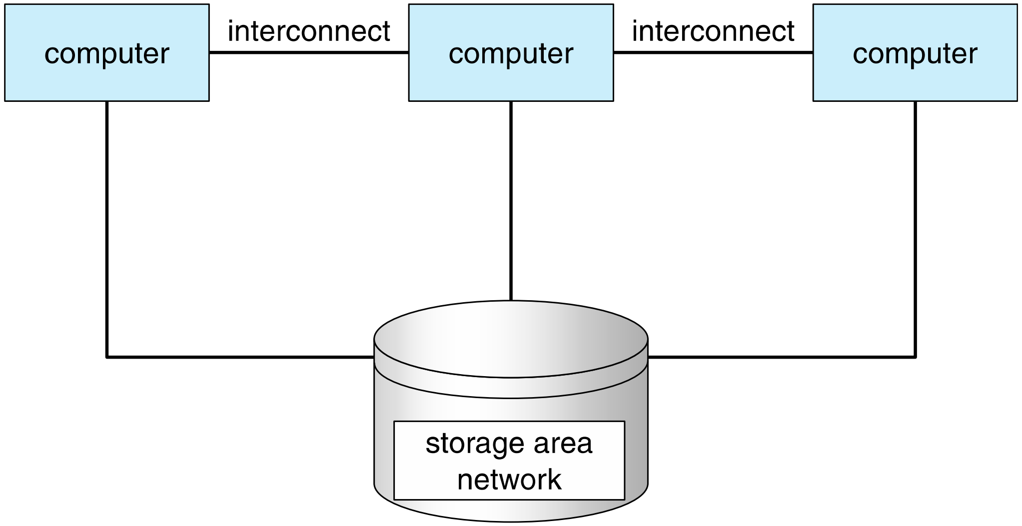


A Dual-Core Design

- **Multicore**
  - Several cores on a single chip
  - On chip communication is faster than between-chip
  - Less power used



Clustered Systems

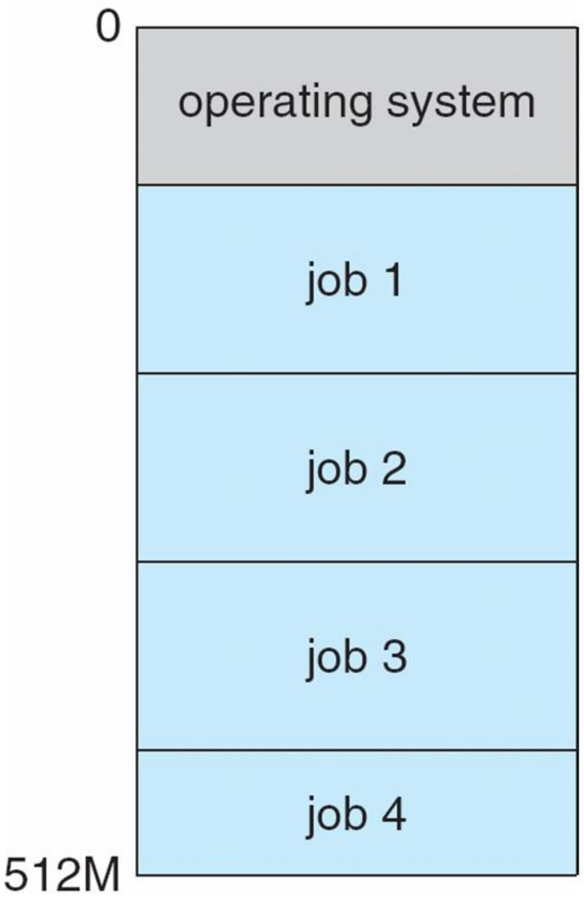


- Like multiprocessor systems, but multiple systems working together
  - Provides a **high-availability** service which survives failures
    - **Asymmetric clustering** has one machine in hot-standby mode
    - **Symmetric clustering** has multiple nodes running applications, monitoring each other
  - Some clusters are for **high-performance computing (HPC)**
    - Applications must be written to use **parallelization**

Operating System Structure

- **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
- **Timesharing** (**multitasking**) is logical extension 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

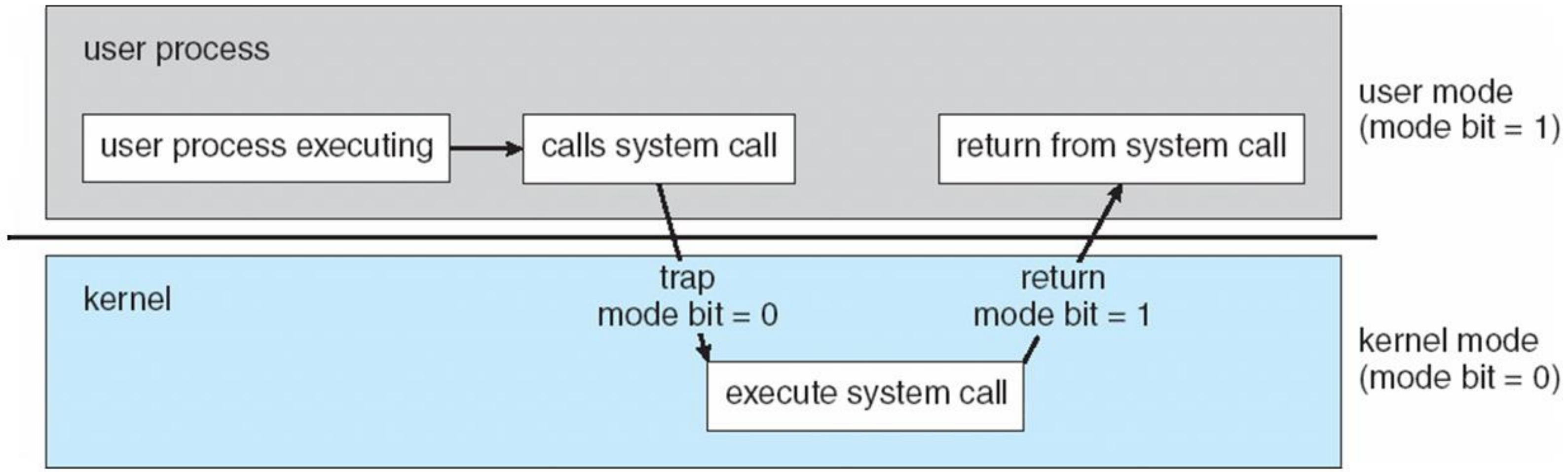
Memory Layout for Multiprogrammed System



Operating-System Operations

- **Interrupt driven** (hardware and software)
  - 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

Operating-System Operations (cont.)



- **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

Using timer for preventing certain events

- 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

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
- 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
  - Different devices, same view
  - 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
  - Disk is slow, its I/O is often a bottleneck
- OS activities
  - Free-space management
  - Storage allocation
  - Disk scheduling

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),
  - 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
  - Access control for users and groups

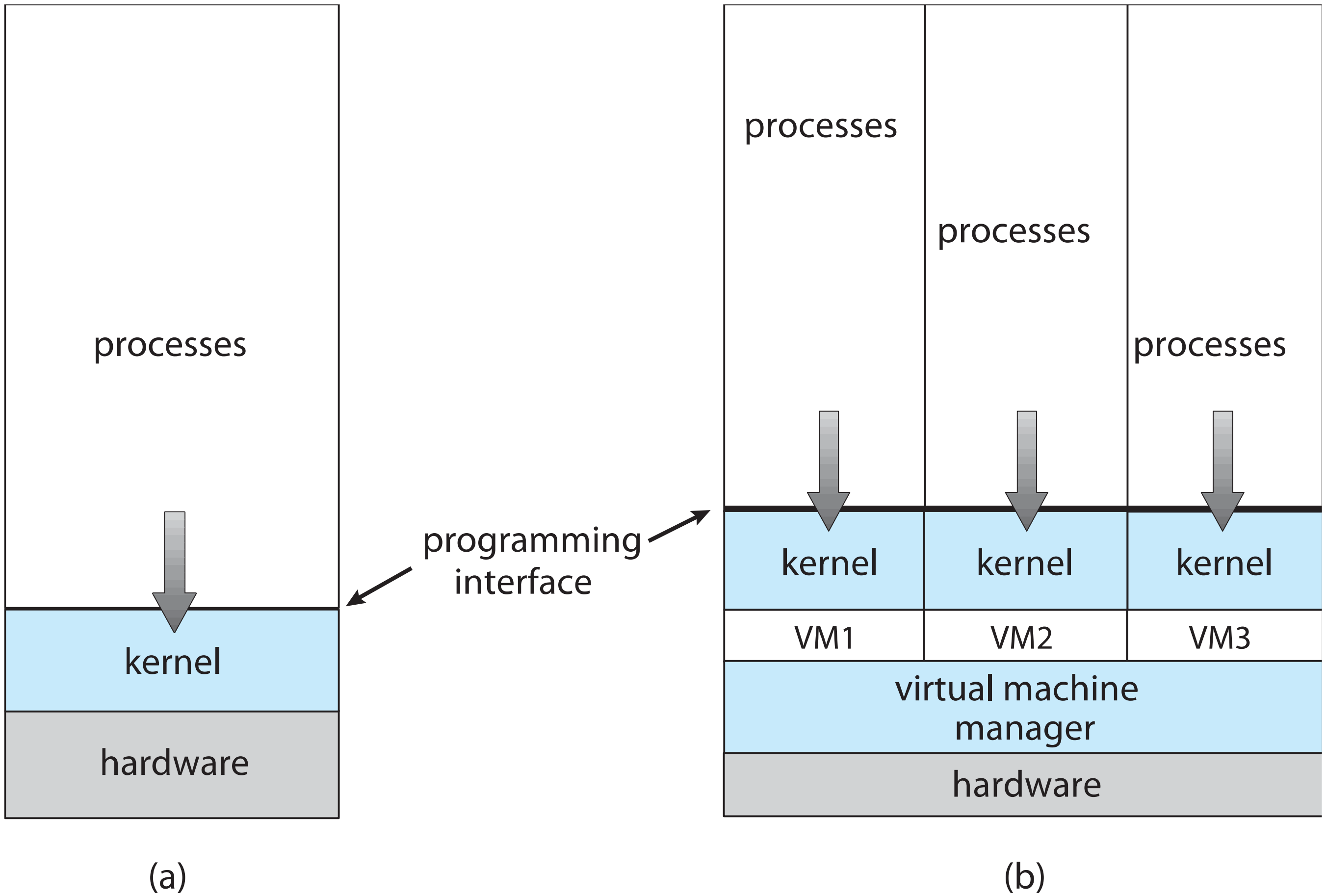
Computing Environments

- Recall from Lecture 1:
- Stand-alone general purpose machines
- Mobile:
  - Handheld smartphones, tablets, etc
- Distributed computing
- Client-server computing
- Peer-to-Peer computing
- Cloud-computing
- Real-Time systems
- Embedded Systems

Computing Environments - Virtualization

- **Virtualization** (more details in Chapter 16, which will not be tested)
  - **Host** OS, natively compiled for CPU
  - **VMM** - virtual machine manager
    - Creates and runs virtual machines
  - VMM runs **guest** OSes, also natively compiled for CPU
  - Applications run within these guest OSes
  - Example: Parallels for OS X running Win and/or Linux and their apps
  - Some VMM'es run within a host OS
  - But, some act as a specialized OS
    - Example. VMware ESX: installed on hardware, runs when hardware boots, provides services to apps, runs guest OSes
- Vast and growing industry
- Use cases
  - Developing apps for multiple different OSes on 1 PC
  - Very important for **cloud computing**
    - Executing and managing **compute environments** in data centers

Computing Environments - Virtualization



End of Chapter 1