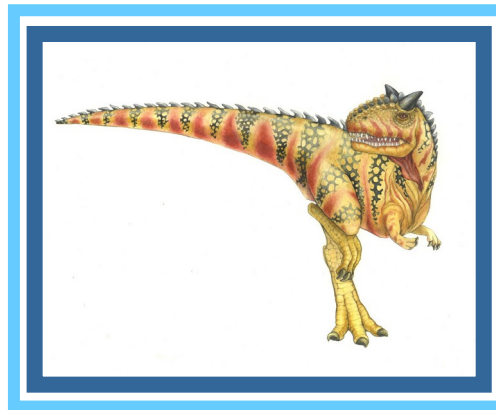


Introduction





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





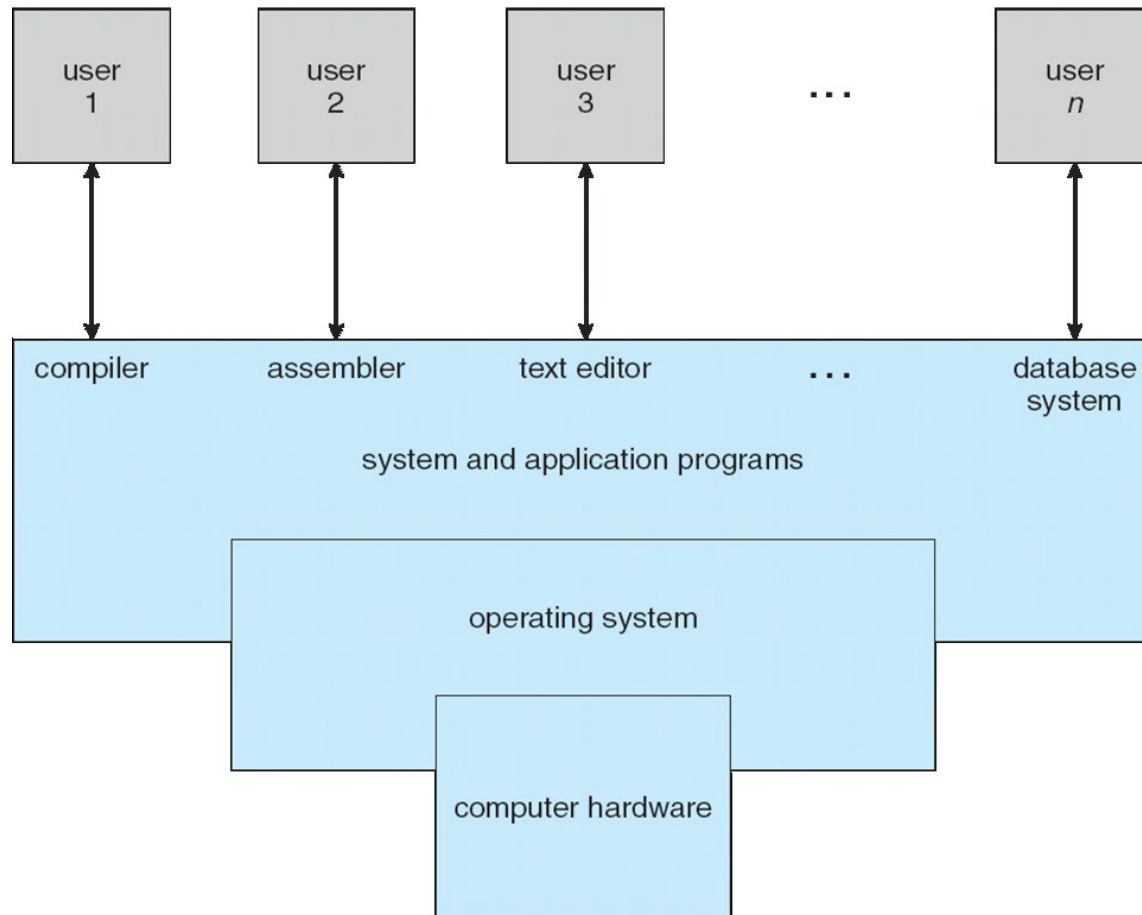
Computer System Structure

- Computer system can be divided into four 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





Four Components of a Computer System





What Operating Systems Do

- Depends on the point of view
- Users want convenience, **ease of use** and **good performance**





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.)

- “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.





Computer Startup

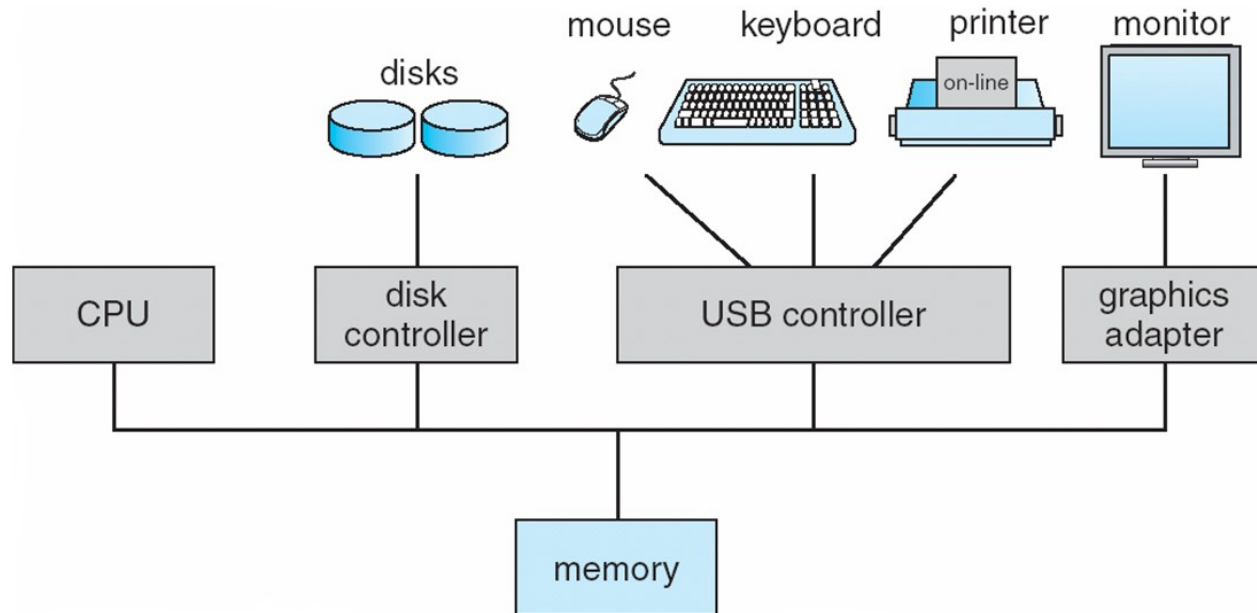
- **bootstrap program** is loaded at power-up or reboot
 - Typically stored in ROM or EPROM, generally known as **firmware**
 - Initializes all aspects of system
 - Loads operating system kernel and starts execution





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





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**





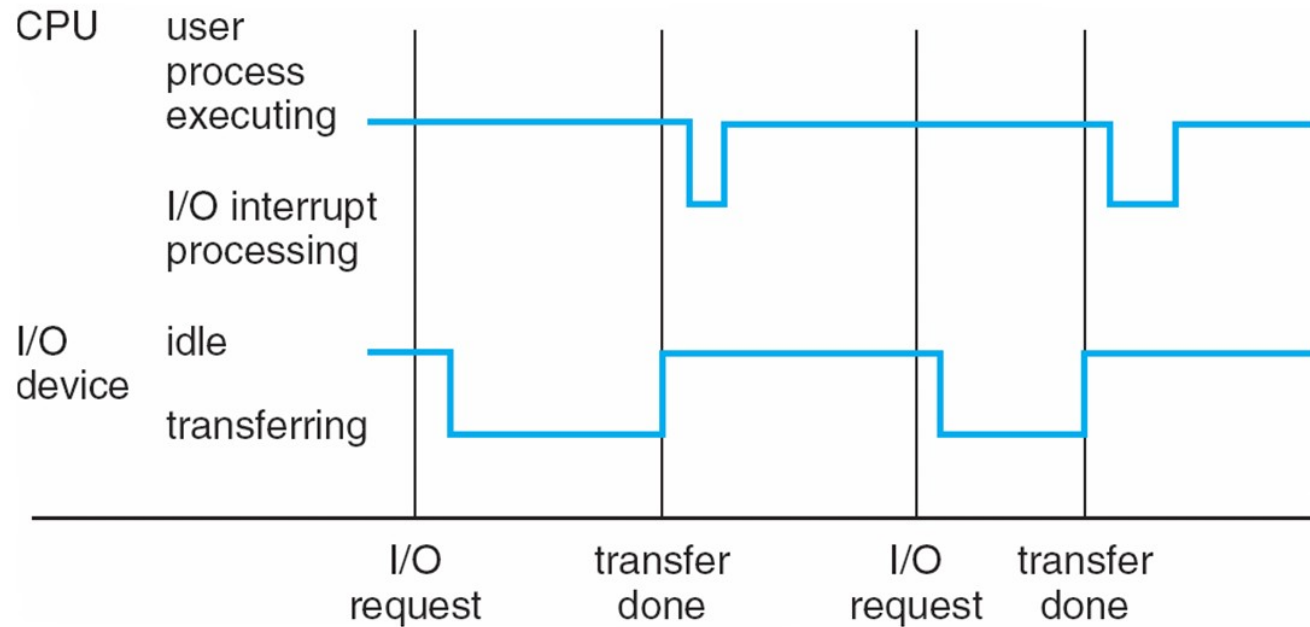
Common Functions of Interrupts

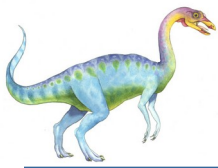
- Interrupt transfers control to the interrupt service routine generally, through the **interrupt vector**, which contains the addresses of all the service routines
- Interrupt architecture must save the address of the interrupted instruction
- A **trap** or **exception** is a software-generated interrupt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





Interrupt Timeline





I/O Structure

- 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 OS 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
 - OS indexes into I/O device table to determine device status and to modify table entry to include interrupt





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





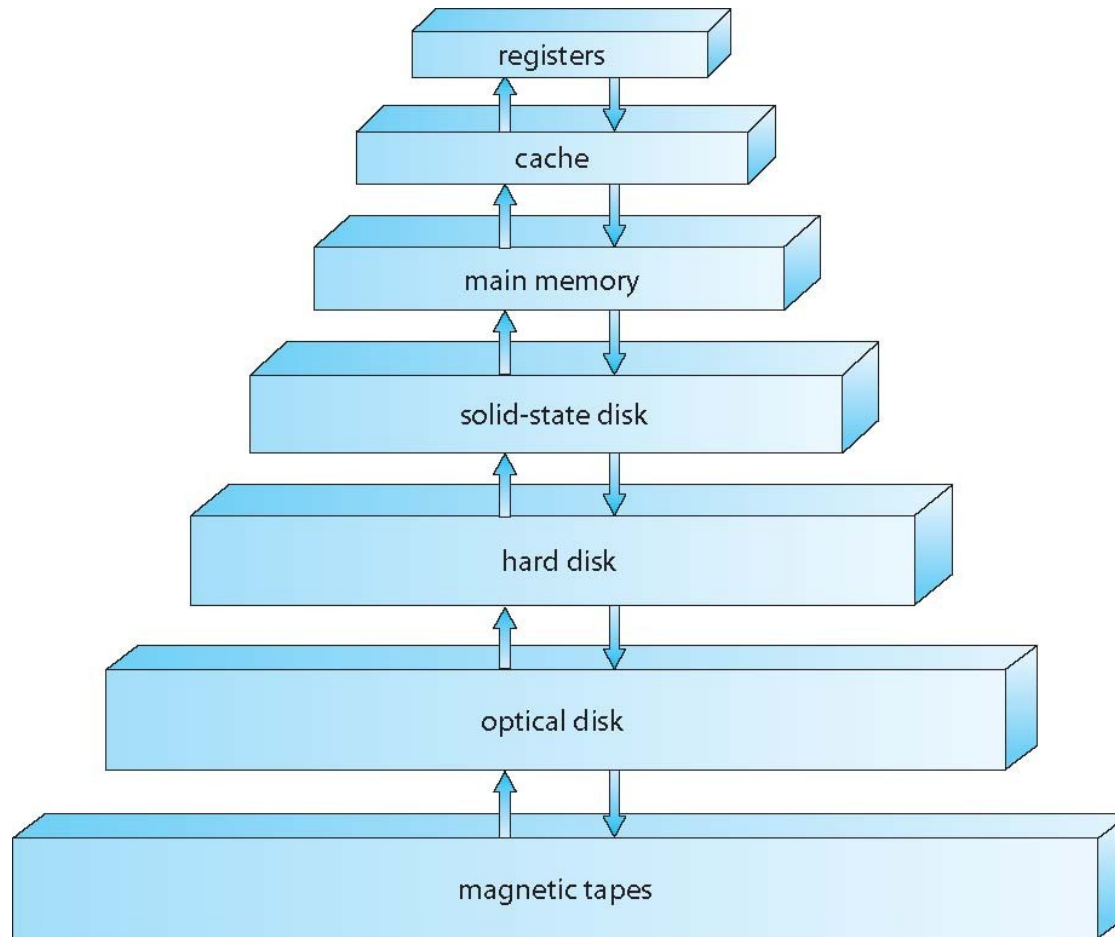
Storage Hierarchy

- Storage systems organized in hierarchy
 - Speed
 - Cost
 - Volatility
- **Caching** – copying information into faster storage system; main memory can be viewed as a cache for secondary storage
- **Device Driver** for each device controller to manage I/O
 - Provides uniform interface between controller and kernel





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





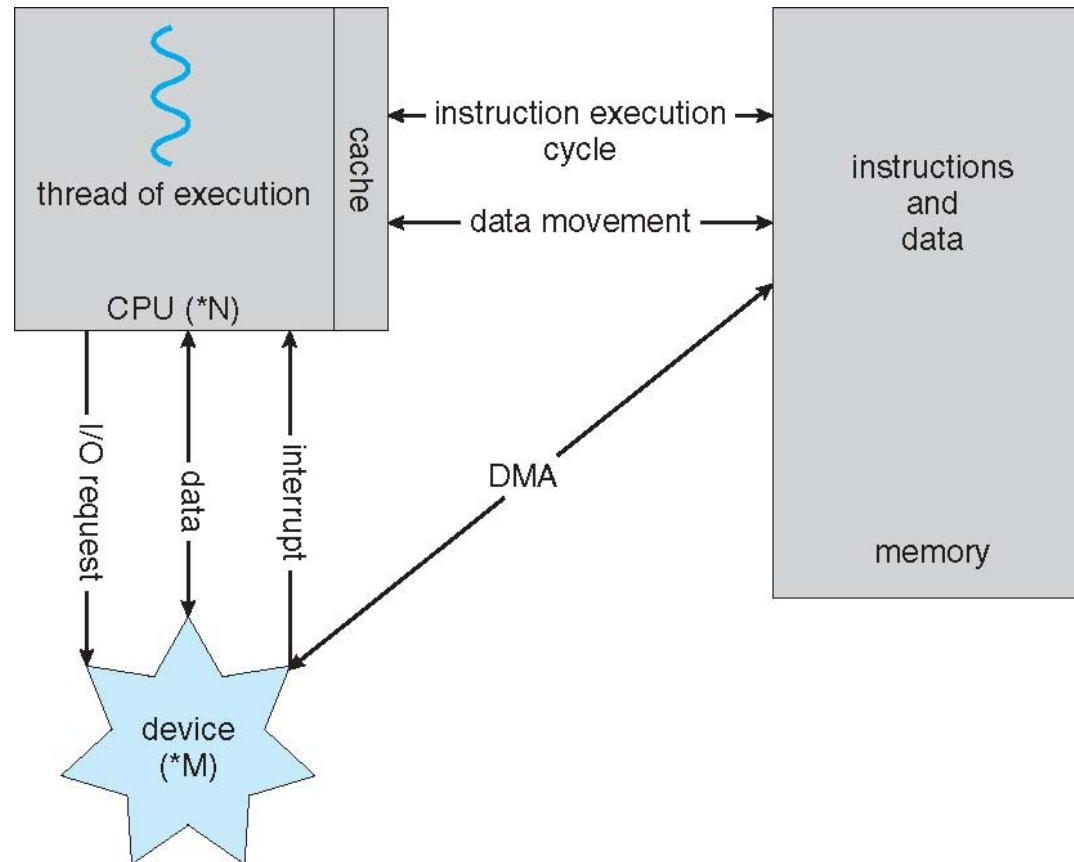
Direct Memory Access Structure

- Used for high-speed I/O devices able to transmit information at close to memory speeds
- 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





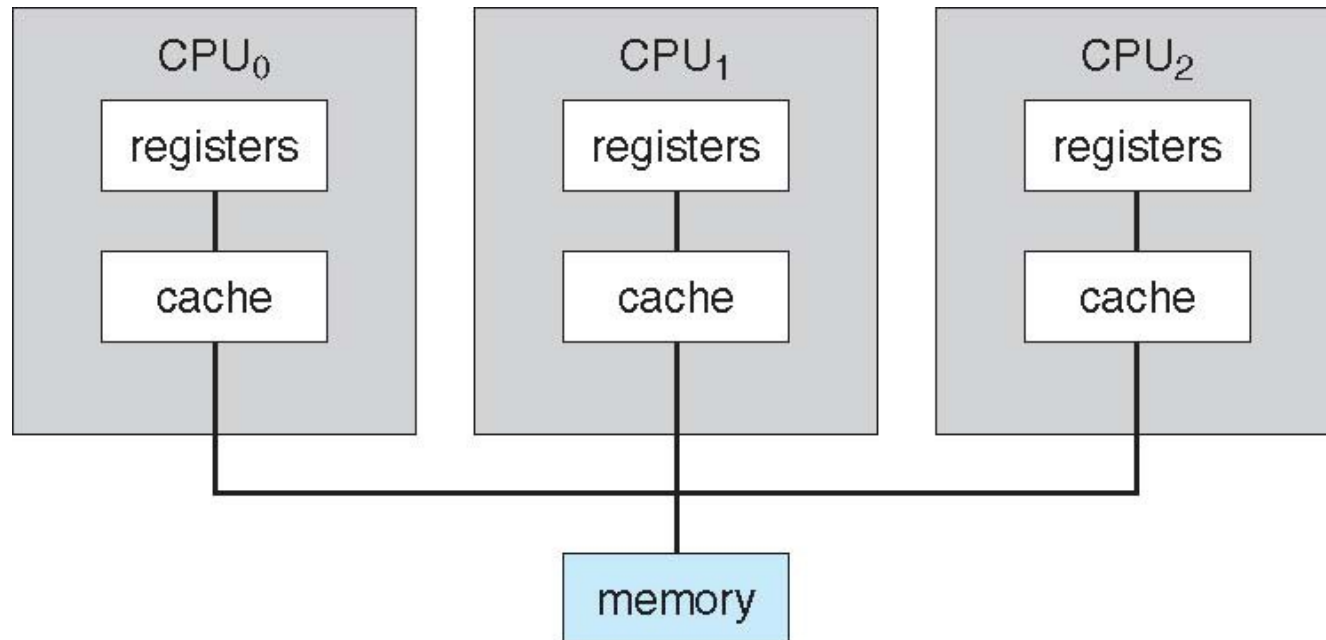
Computer-System Architecture

- 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





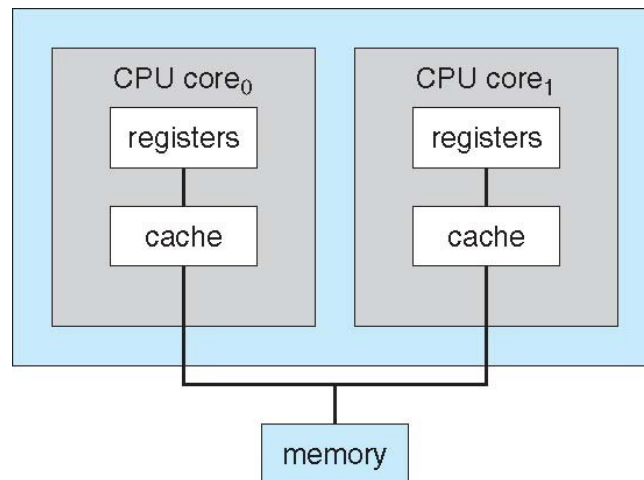
Symmetric Multiprocessing Architecture





A Dual-Core Design

- Multi-chip and **multicore**
- Systems containing all chips
 - Chassis containing multiple separate systems





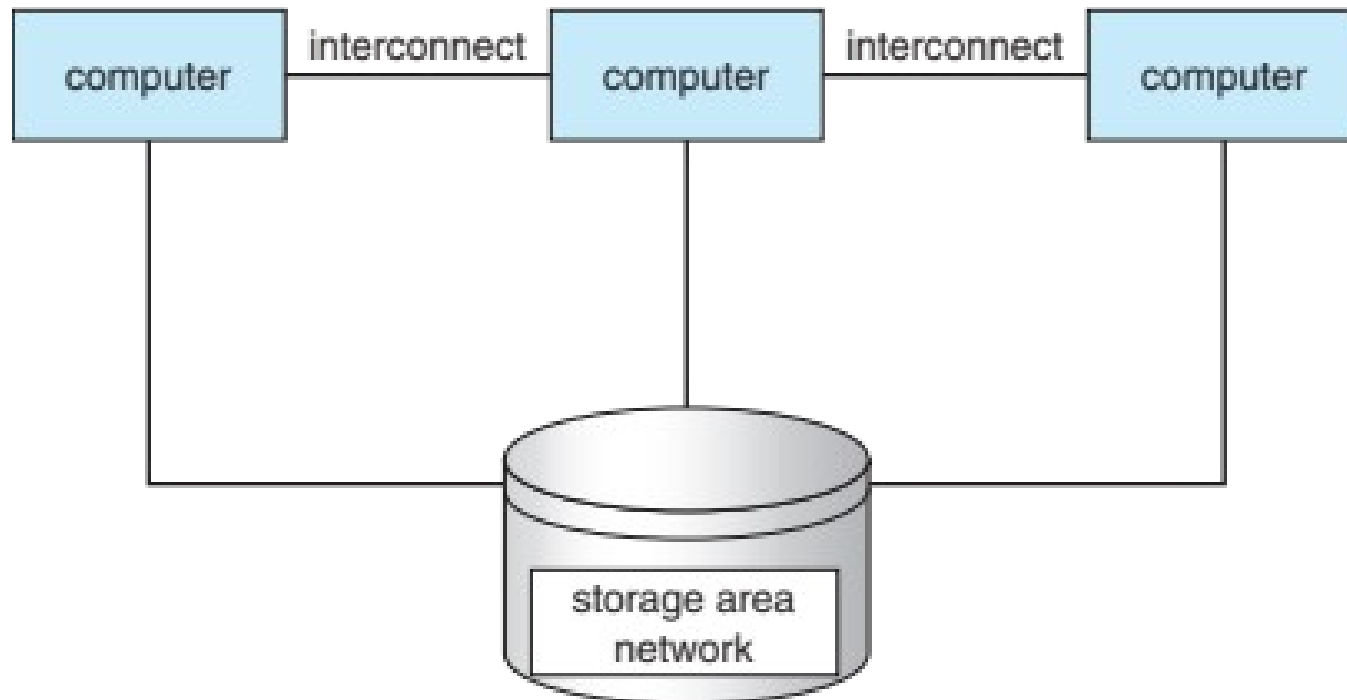
Clustered Systems

- 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

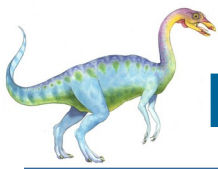




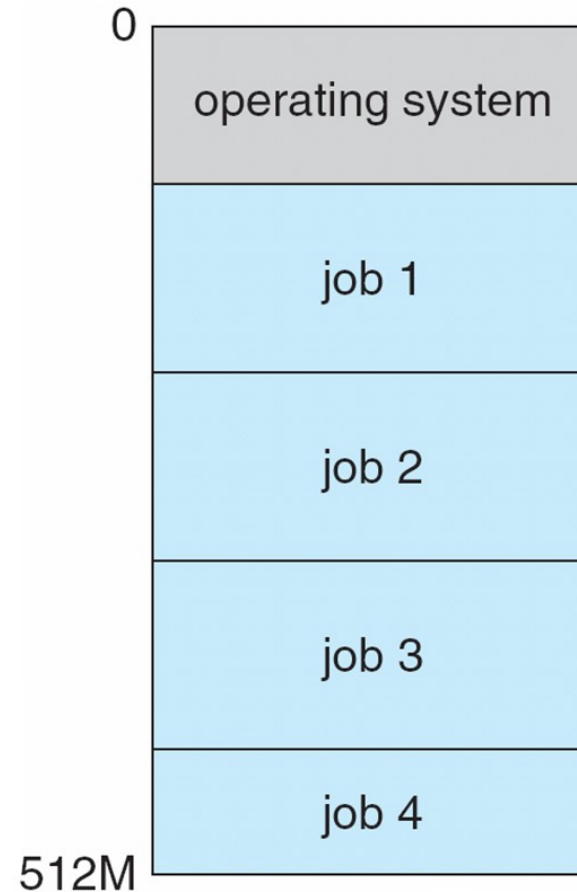
Operating System Structure

- **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 (applications are running)** and
 - **kernel mode (the computer enters when accessing hardware resources)**
 - **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
- Increasingly CPUs support multi-mode operations
 - i.e. **virtual machine manager (VMM)** mode for guest **VMs**





Transition from User to Kernel Mode

- 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

