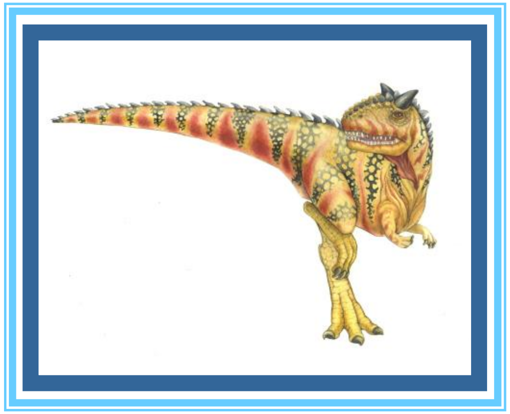
Chapter 1: Introduction



Chapter 1: Introduction

- What Operating Systems Do
- Computer-System Organization
- Computer-System Architecture
- Operating-System Structure
- Operating-System Operations
- Process Management
- Memory Management
- Storage Management
- Protection and Security
- Distributed Systems
- Special-Purpose Systems
- Computing Environments
- Open-Source Operating Systems

Objectives

- To provide a grand tour of the major operating systems components
- To provide coverage of basic computer system organization

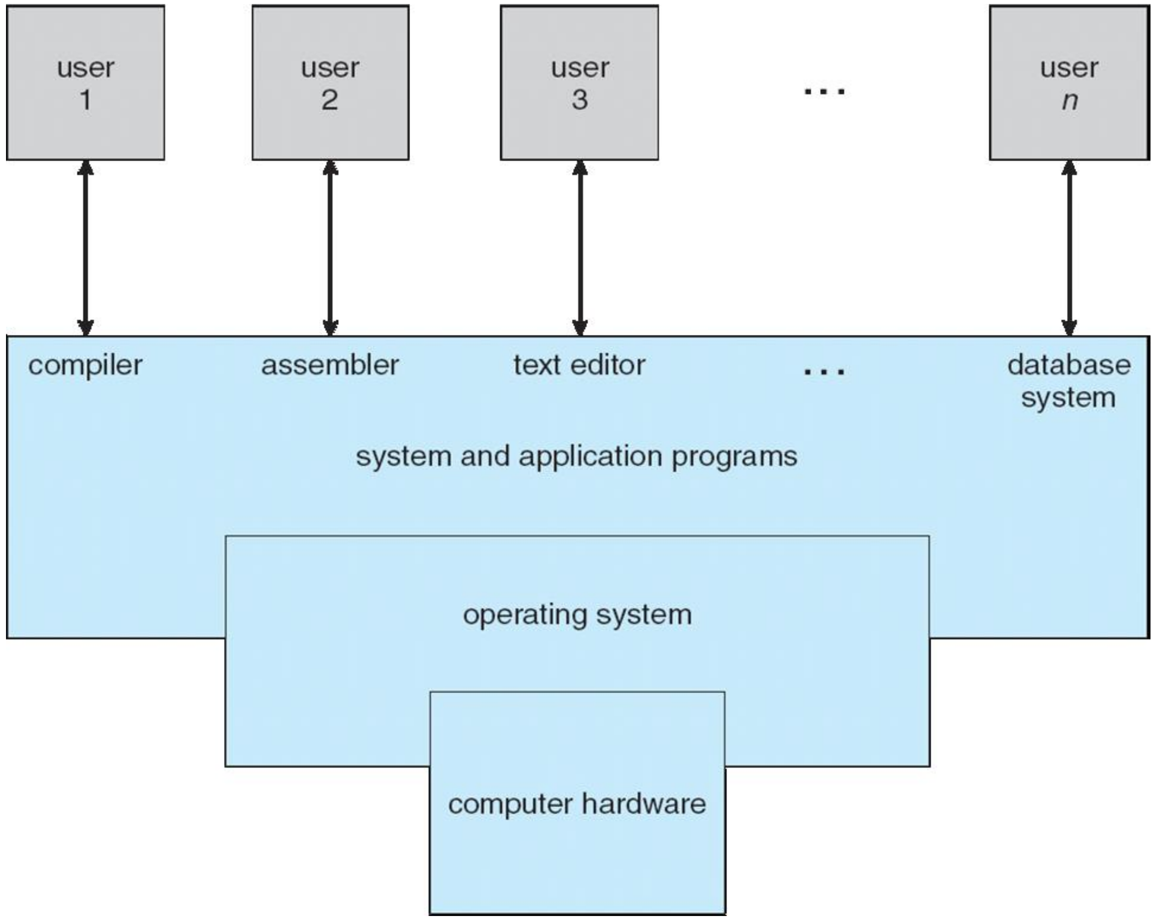
What is an Operating System?

- 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**
  - 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

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.)

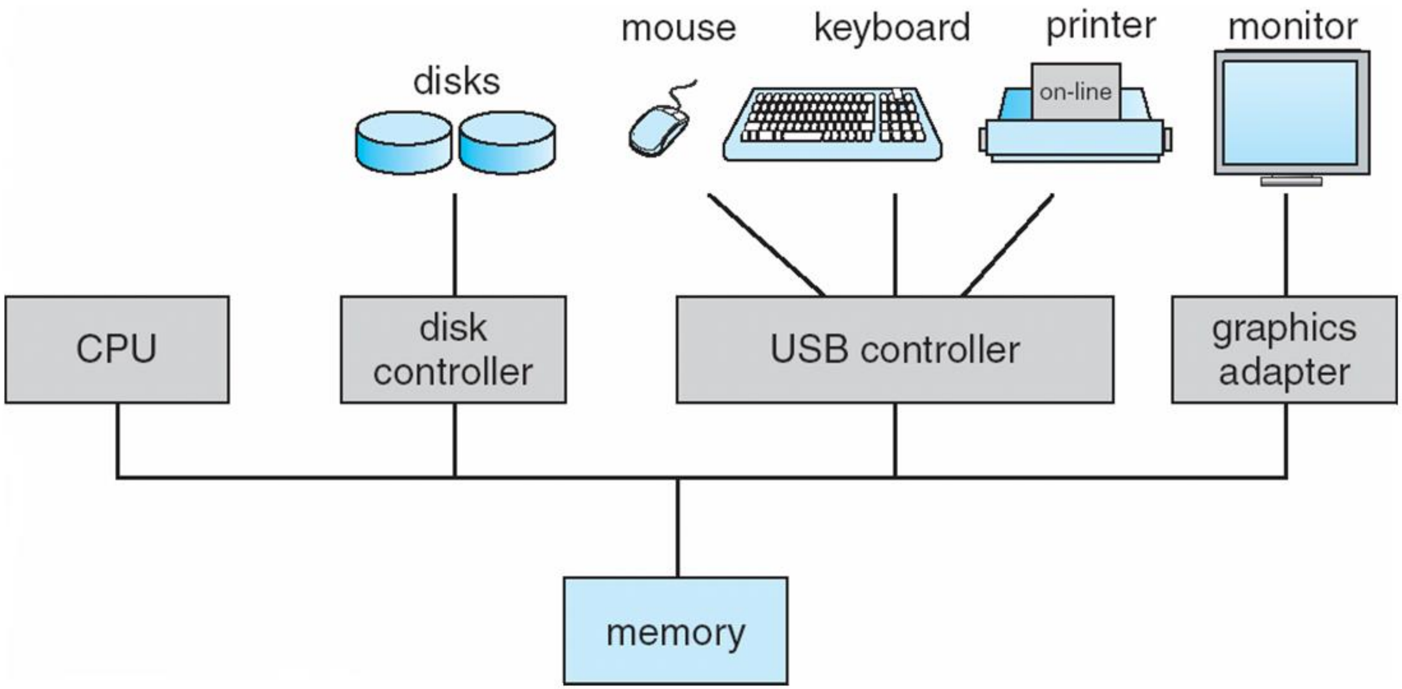
- No universally accepted definition
- "Everything a vendor ships when you order an operating system" is good approximation
  - But varies wildly
- "The one program running at all times on the computer" is the **kernel**. Everything else is either a system program (ships with the operating system) or an application program.

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

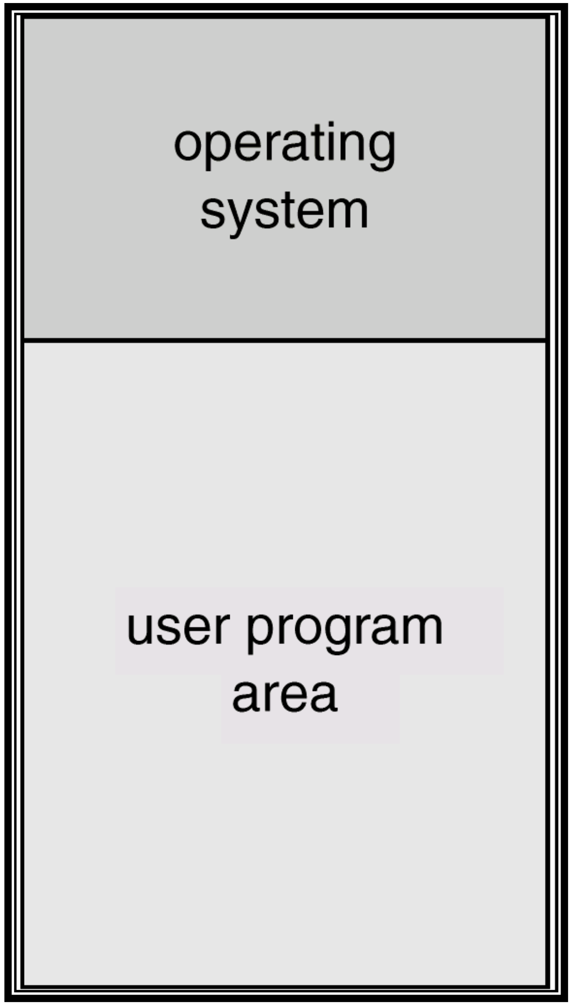
Common Functions of Interrupts

- 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
- 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**

Mainframe Systems

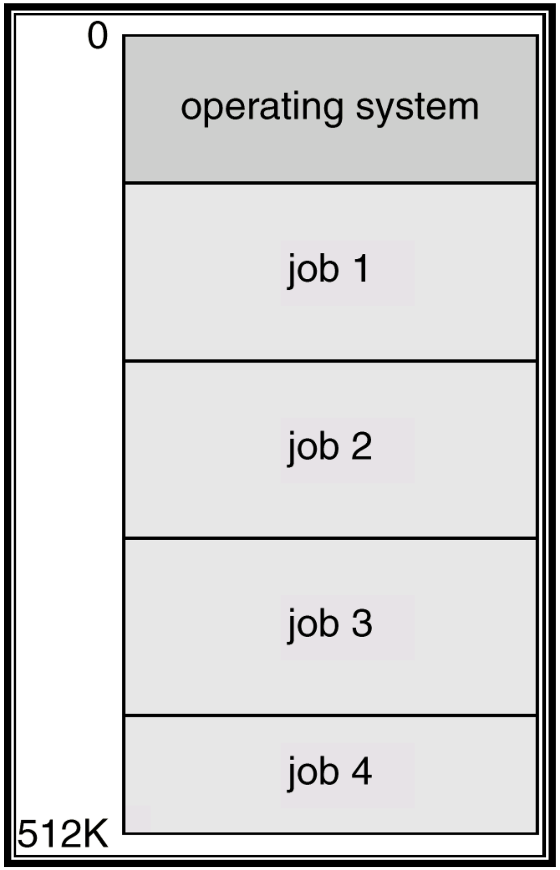
- Reduce setup time by batching similar jobs
- Automatic job sequencing – automatically transfers control from one job to another. First rudimentary operating system.
- Resident monitor
  - initial control in monitor
  - control transfers to job
  - when job completes control transfers back to monitor

Memory Layout for a Simple Batch System



Multiprogrammed Batch Systems

Several jobs are kept in main memory at the same time, and the
CPU is multiplexed among them.



Time-Sharing Systems–Interactive Computing

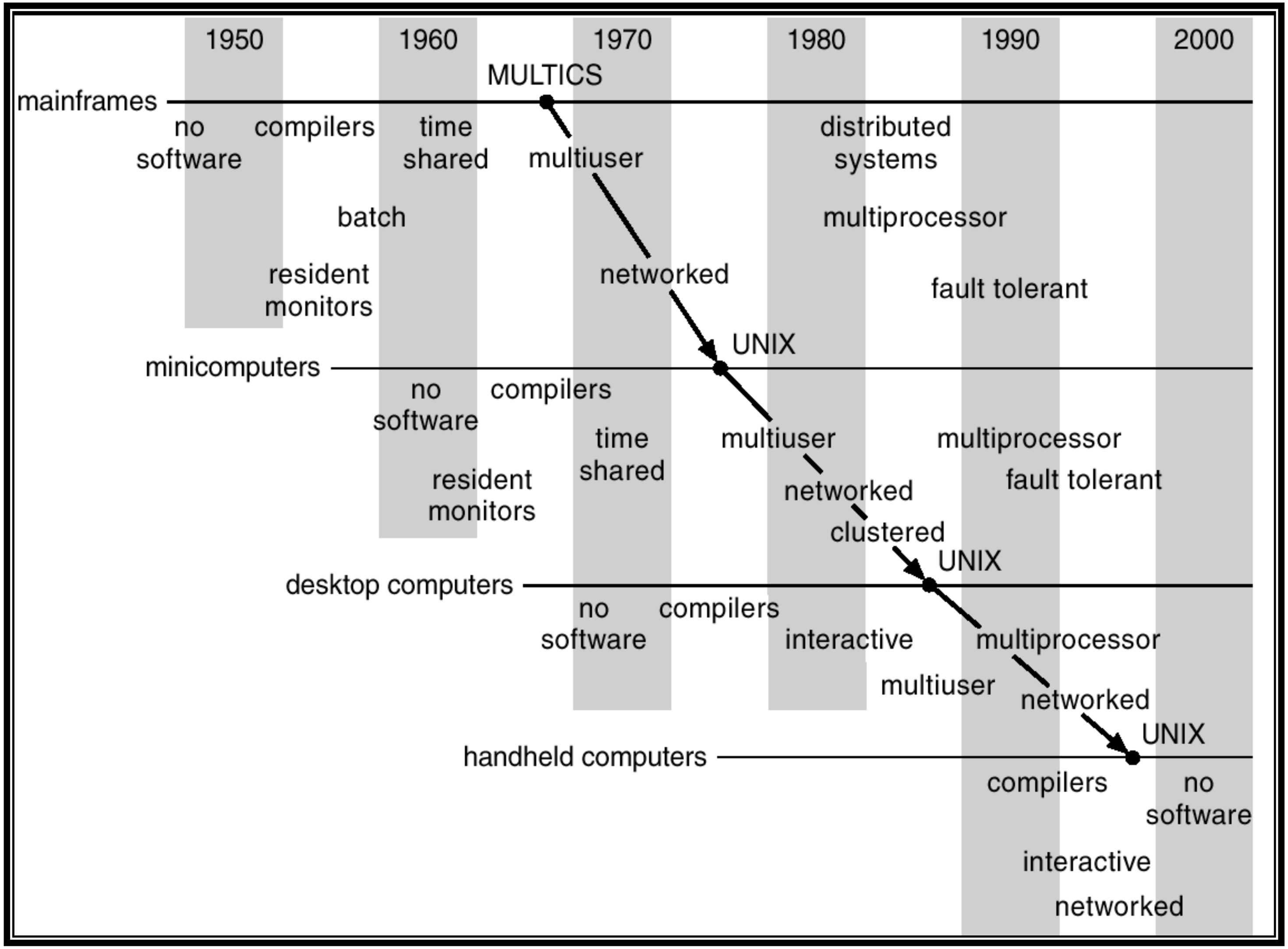
- The CPU is multiplexed among several jobs that are kept in memory and on disk (the CPU is allocated to a job only if the job is in memory).
- A job swapped in and out of memory to the disk.
- On-line communication between the user and the system is provided; when the operating system finishes the execution of one command, it seeks the next "control statement" from the user's keyboard.

Types of OS Structure

- **Multiprogramming** 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 at a time
  - 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

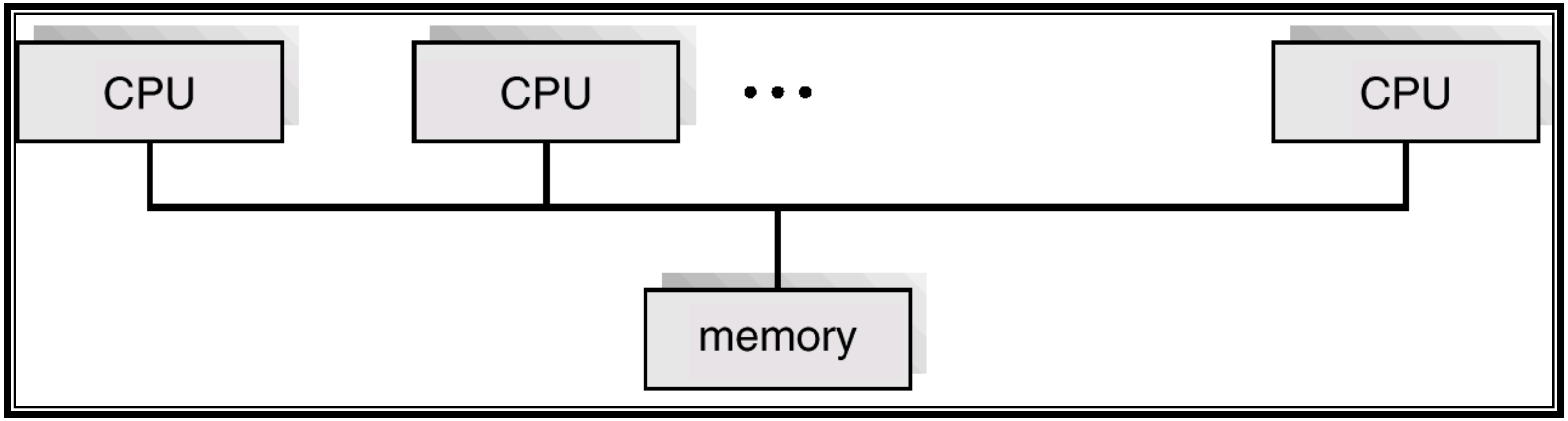
Migration of Operating-System Concepts and Features



Multiprocessor System

- Multiprocessor systems with more than on CPU in close communication also called as tightly coupled system.

- *Tightly coupled system* – processors share memory and a clock; communication usually takes place through the shared memory.



Symmetric Multiprocessing Architecture

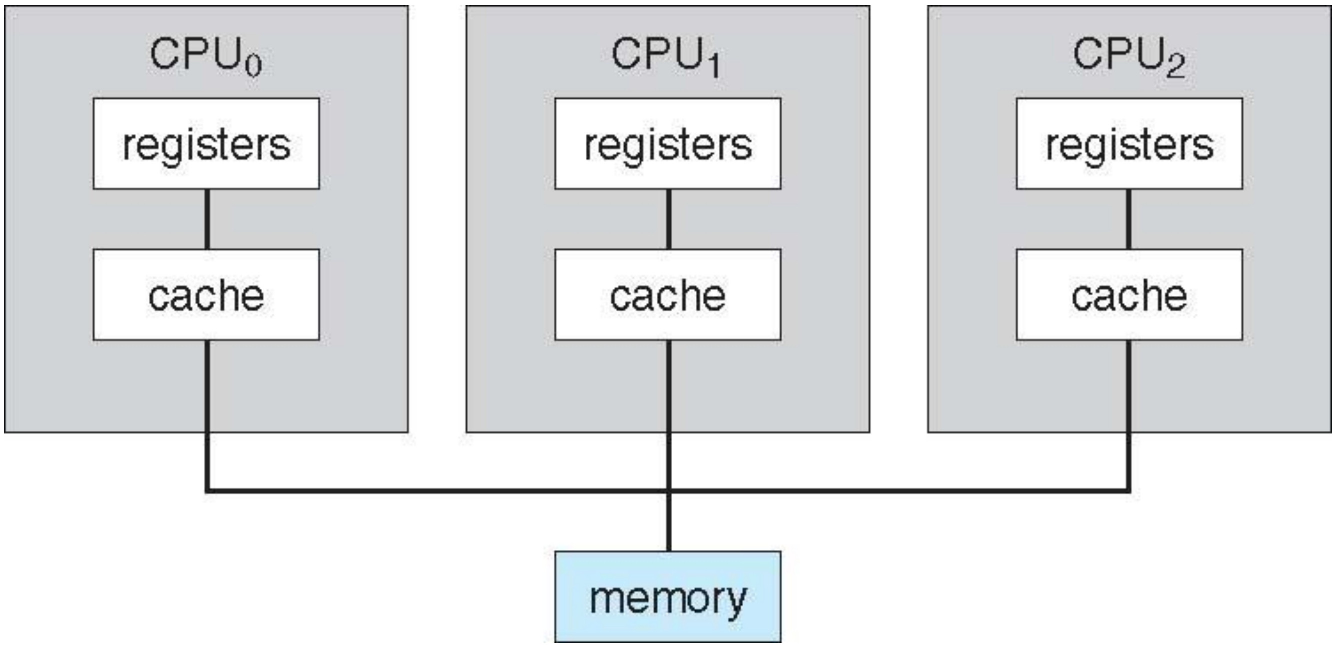


Diagram: Symmetric multiprocessing architecture with shared memory

Multiprocessing Architecture

- **Multiprocessors** systems growing in use and importance
  - Also known as **parallel systems**, **tightly-coupled systems**
  - Advantages include:

1. **Increased throughput**
   - *More work done in less time.*
   - *For N multiprocessor- Speedup ratio is not N, less than N, due to overhead in connecting the shared memory*
2. **Economy of scale**
   - Share peripherals, mass storage and power supplies
   - Saves money compared to multiple single processor systems
3. **Increased reliability – graceful degradation** or **fault tolerance**
   - Failure of one processor will not fail the system. However, it will degrade the performance of the system

Multiprocessor Systems (Cont.)

- *Symmetric multiprocessing (SMP)*
  - Each processor runs and identical copy of the operating system.
  - Many processes can run at once without performance deterioration.
  - Most modern operating systems support SMP

    Example- Windows, Linux

Must be Careful in I/O sending data to appropriate processor,

Load distribution must be equal: No overload on a particular processor.

- *Asymmetric multiprocessing*
  - Each processor is assigned a specific task; master processor schedules and allocate work to slave processors.
  - More common in extremely large systems

    Example- SunOS- Version 4

A Dual-Core Design

- *Multiple Computing Cores on a single chip*
  - On single chip communication is easier than multiple chips with different CPUs.
  - Uses less power being on a single chip.
  - Specially suited for web servers and databases.

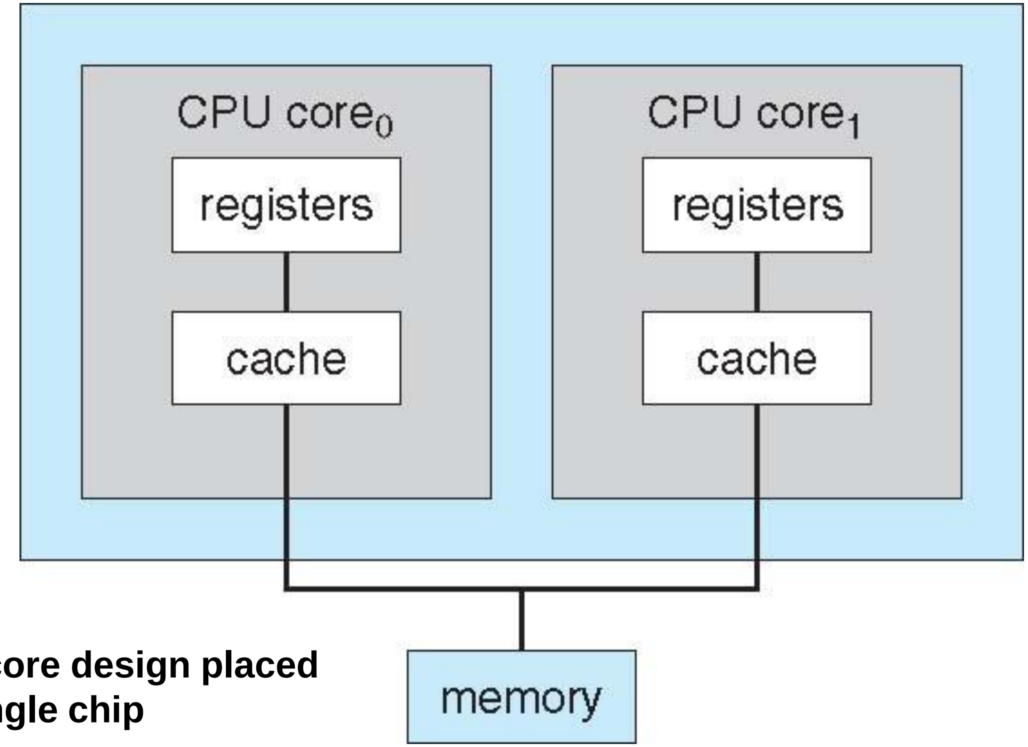


Diagram: A dual core design placed on a single chip

Real-Time OS

- Often used as a control device in a dedicated application such as controlling scientific experiments, medical imaging systems, industrial control systems, Space Shuttle, Satellite control, and some display systems (automobile, robotic applications, etc)
- Process must be complete within a well-defined fixed-time constraints or the system fails.
- Real-Time systems may be either *hard* or *soft* real-time.

Real-Time Systems (Cont.)

- **Hard real-time:**
  - Guarantees that the critical tasks to be completed on time. (Applications: Satellite launch, Fighter jets, Missiles, industrial control and industrial robots)
  - Secondary storage limited or absent, data stored in short term memory, or read-only memory (ROM)
  - Conflicts with time-sharing systems, two features cannot be mixed, virtual memory is almost never found on RTOS
- **Soft real-time**
  - Critical tasks gets priority over other tasks.
  - Limited utility/usability in industrial control of robotics
  - Useful in applications (multimedia, virtual reality, undersea exploration,

  planetary rovers). Requires advanced operating-system features.

Storage Structure

- **Main memory** – only storage media that the CPU can access directly
  - **Random access (re-writable)- semiconductor technology**
  - Typically **volatile,** usually too small to store all the programs and data permanently

  - **EEPROM-** Cannot be changed frequently, For example- Factory installed programs in smartphones
- **Secondary storage** – extension of main memory that provides large **nonvolatile** storage capacity

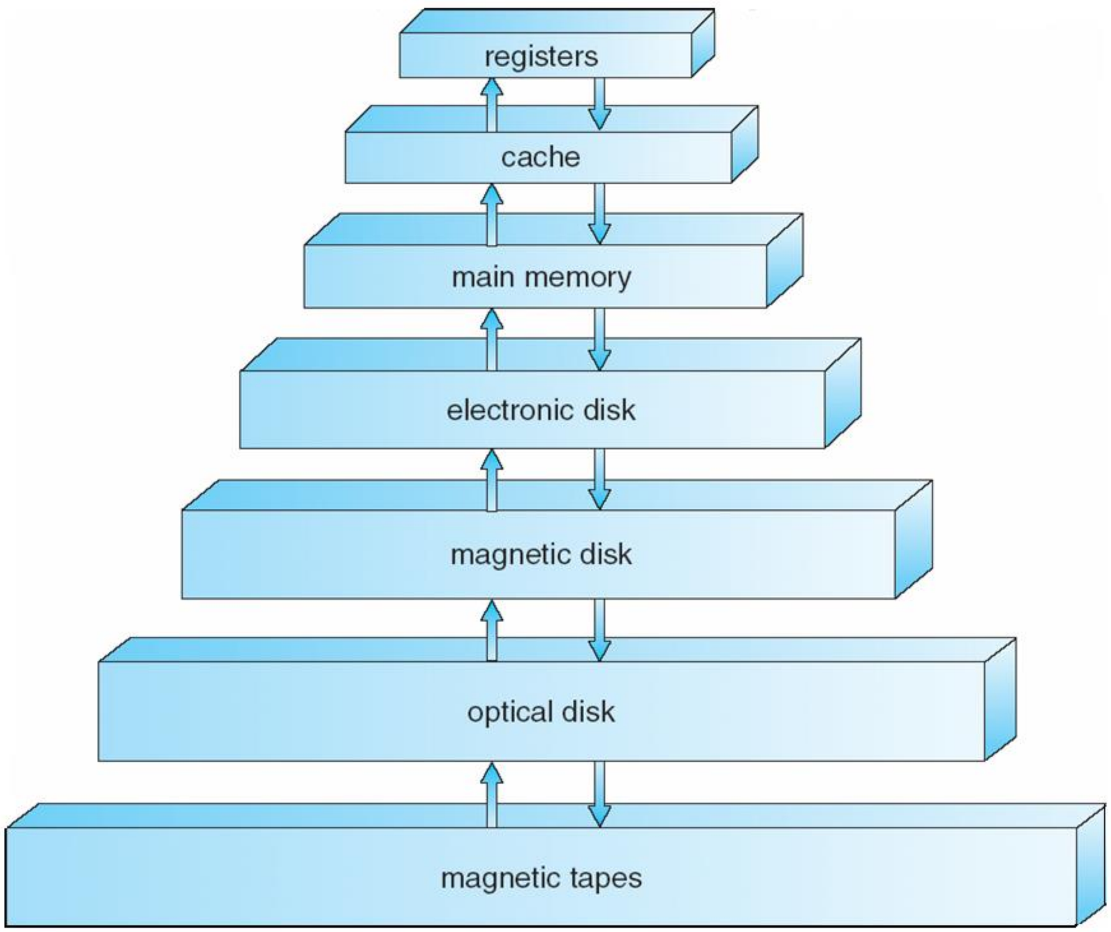
- **Magnetic disks** – rigid metal or glass platters covered with magnetic recording material
  - Disk surface is logically divided into **tracks**, which are subdivided into **sectors**
  - The **disk controller** determines the logical interaction between the device and the computer

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



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; and 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).

Memory Management

- All data in memory before and after processing
- All instructions in memory in order to execute
- Memory management determines what is in memory when
  - Optimizing CPU utilization and computer response to users
- Memory management activities done by OS
  - 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 dirs
    - 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

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
  - Selection of cache size and its replacement policy can greatly improve the performance of the system.

Can cache size be equal to main memory?

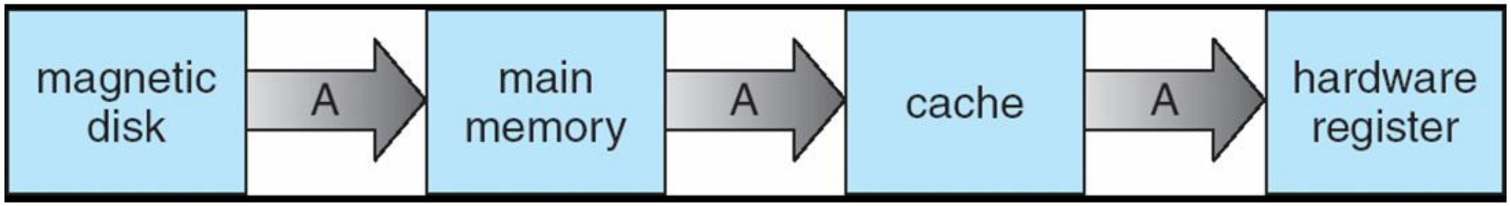
Performance of Various Levels of Storage

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

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000.000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

Migration of Integer A from Disk to Register

- Multitasking environments must be careful to use most recent value, if several processes trying to access integer A
  - Most recent value must be given/ available to each process.



- Multiprocessor environment must provide **cache coherency** in hardware such that all CPUs have the most recent value in their cache.

- **cache coherency-** Update to the value of one cache contents, must be immediately reflected/copied in all the other caches.

- Distributed environment situation even more complex
  - Several copies of the same files are placed on different machines

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 of data (input)
- Process termination requires reclaim of any reusable resources
  - Ex: Monitor, Printer
- Single-threaded process has one **program counter** specifying location of next instruction to execute
  - Process executes instructions sequentially, one at a time, until completion
- 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.

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

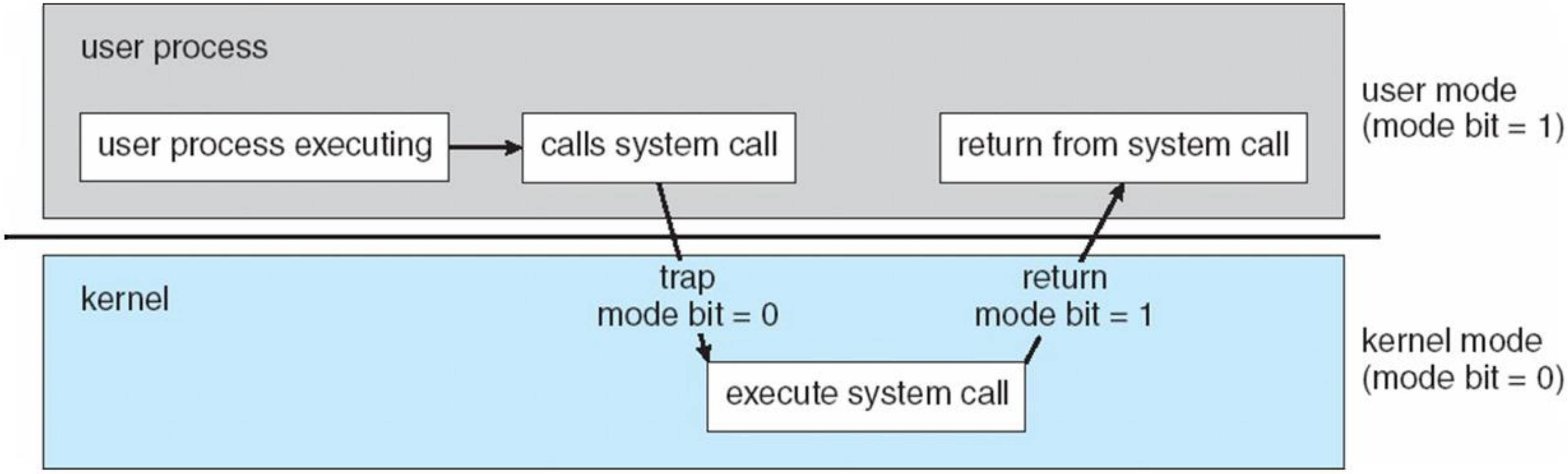
Operating-System Modes (Operations)

- OS is 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

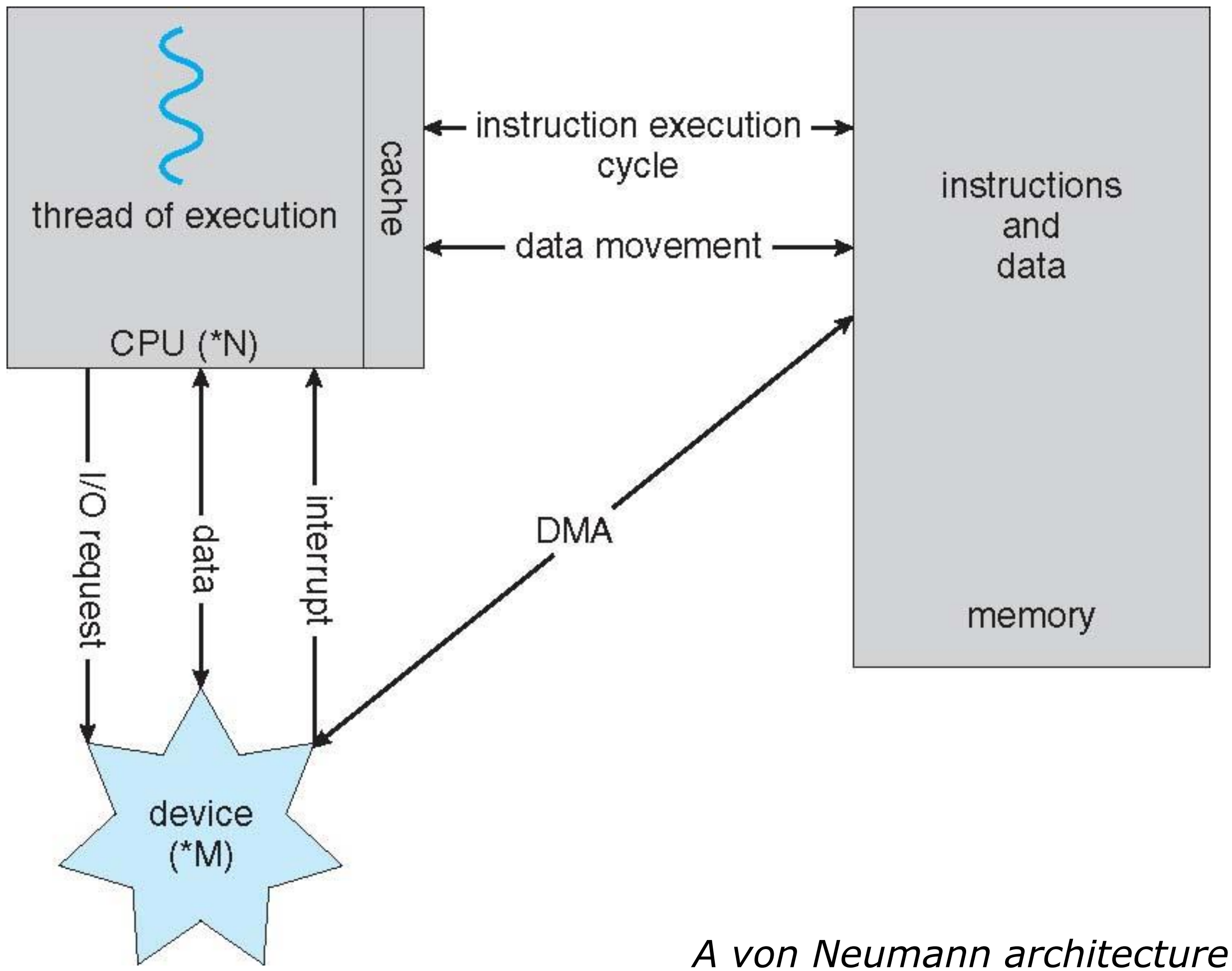
- **Dual-mode** operation allows OS to protect itself and other system components
  - **User mode** and **kernel mode**
  - **Mode bit** provided by hardware
    - Provides ability to distinguish when system is running user code or kernel code
    - Some instructions designated as **privileged**, only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

Transition from User to Kernel Mode

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



How a Modern Computer Works



A von Neumann architecture