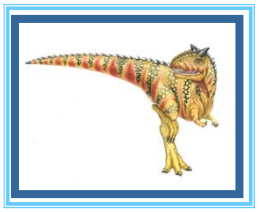
Chapter 1: Introduction



(slides selected/improved by R. Doemer, 01/03/11)

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

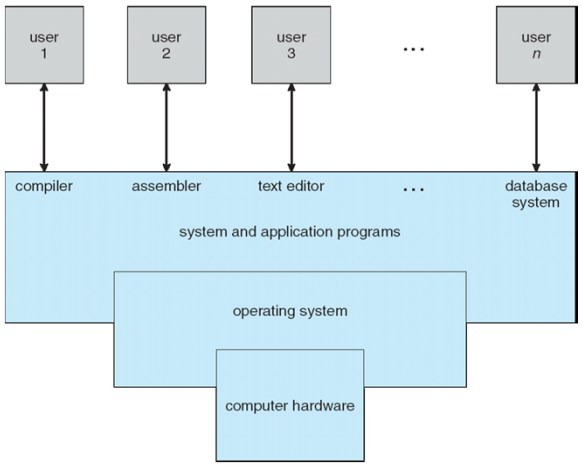
What is an Operating System?

- 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



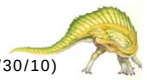
Operating System Definition

- 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 widely
- "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.

(slide modified by R. Doemer, 03/30/10)

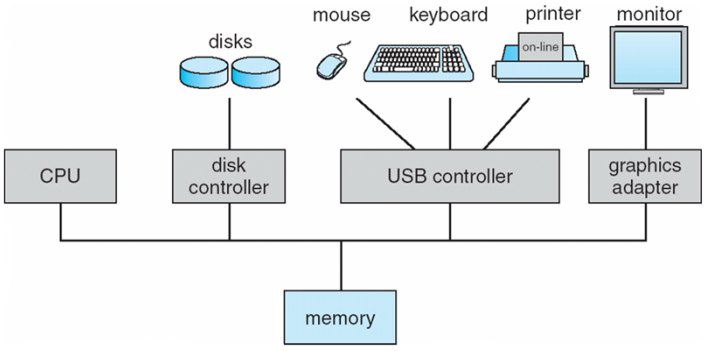


Computer Startup

- **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

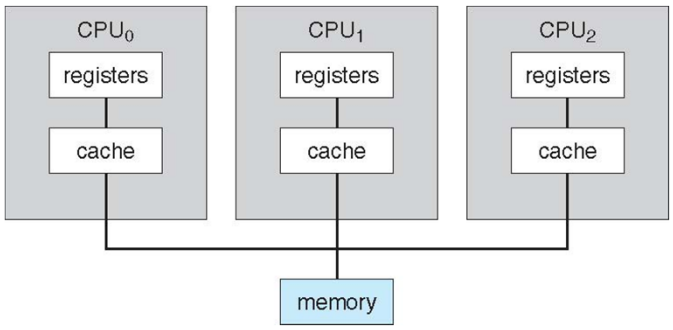
- Computer-system operation
  - One or more CPUs, device controllers connect through common bus providing access to shared memory
  - Concurrent execution of CPUs and devices competing for memory cycles



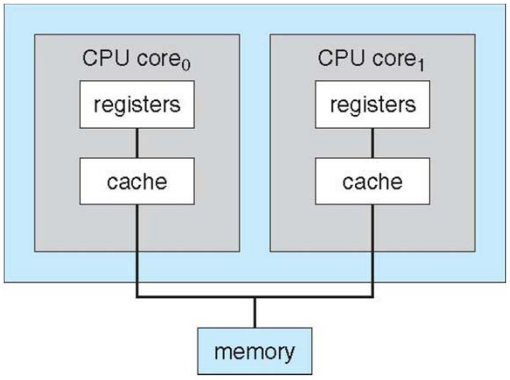
Computer-System Architecture

- Most systems use a single general-purpose processor (PDAs through mainframes)
  - 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
    2. Symmetric Multiprocessing

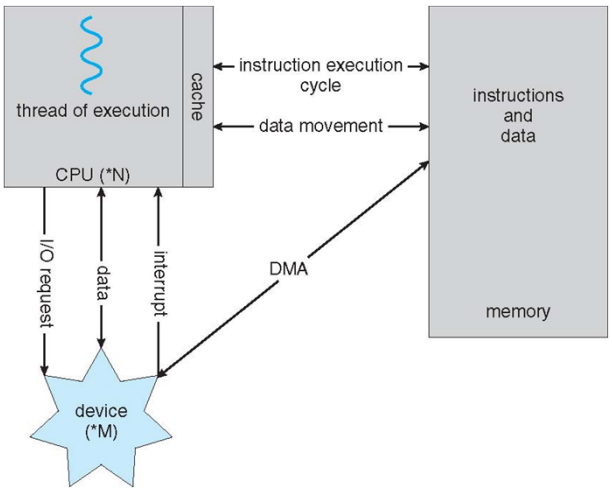
Symmetric Multiprocessing Architecture



A Dual-Core Design

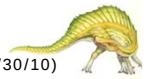


How a Modern Computer Works



Computer-System Operation

- I/O devices and the CPU 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 controller buffers
- I/O is from the device to the local buffer of controller
- Device controller informs CPU that it has finished its operation by raising an *interrupt*



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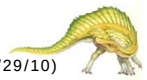
Common Functions of Interrupts

- 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*
- An operating system is **interrupt driven**
- Note:
  A *trap* is a software-generated interrupt caused either by an error or a user request (system-call)



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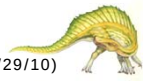
Interrupt Handling

- The operating system preserves the state of the CPU by storing registers and the program counter on the stack
- The OS then determines which type of interrupt has occurred by one of two schemes:
  - **polling**
  - **vectored interrupt system**
- Separate segments of code determine what action should be taken for each type of interrupt



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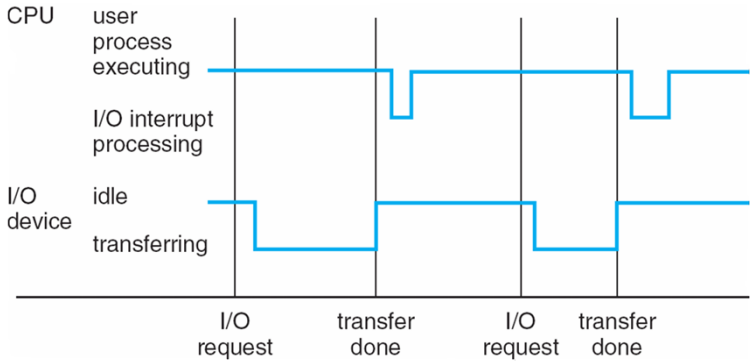
Interrupt Timeline

- Interrupt time line for a single process doing output
  - Process issues I/O request
  - I/O device signals “transfer done” via interrupt



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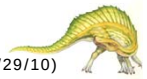
I/O Structure

- *Synchronous* I/O:
  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
- *Asynchronous* I/O:
  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



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Direct Memory Access Structure

- DMA: Direct Memory Access
- 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

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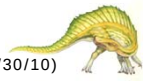
Operating-System Operations

- **Interrupt driven** (by software and 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
- **Timer** to prevent infinite loop / process hogging resources
  - Set interrupt after specific period
  - Timer decrements counter
  - When counter zero generate an interrupt
  - Set up before for scheduling process to regain control or terminate program that exceeds allotted time



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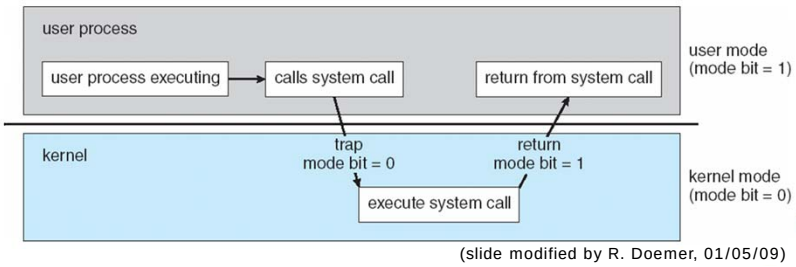
Operating-System Operations

- **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



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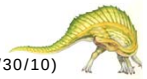
Storage Structure

- CPU registers
  - the only storage capability within the CPU core
- Main memory
  - the only large storage media that the CPU can access directly
- Secondary storage
  - 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



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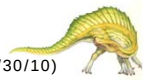
Storage Hierarchy

- Storage systems are organized in a hierarchy
- Storage systems vary in
  - Speed
  - Cost
  - Volatility
- **Caching** is often used between storage systems
  - transparently copying information into faster storage system (e.g. CPU cache holds most-recently used data from main memory)
  - main memory can be viewed as a *cache* for secondary storage



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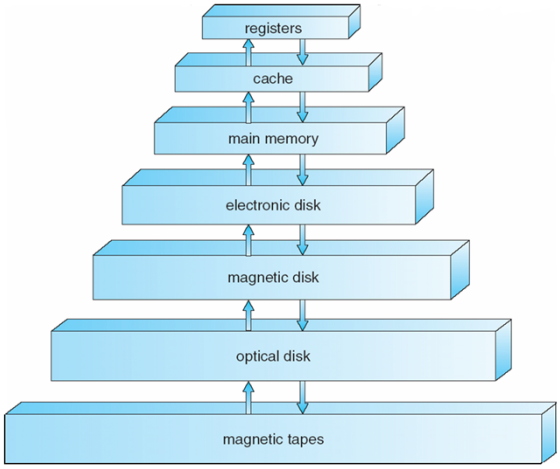
Storage-Device Hierarchy



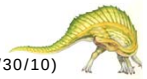
Performance of Various Levels of Storage

- 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

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) is checked first to determine if information is there
  - If it is, information is used directly from the cache (fast)
  - If not, data is used from actual storage *and* copied to cache for future use
- Cache is usually smaller (but more costly per byte!) than storage being cached
  - Cache management is an important design problem
  - Factors include *cache size* and *replacement policy*



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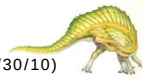
Storage Management

- 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

Operating System Structure

- **Multiprogramming** needed for efficiency
  - CPU and I/O devices underutilized by single user
  - Multiprogramming organizes jobs (code and data) so that 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)**
  - CPU switches jobs so frequently that users can interact with each job
  - **Response time** should be < 1 second
  - Each user has at least one program executing in memory ⇨ **process**
  - Several jobs ready to run at the same time ⇨ **CPU scheduling**
  - Not all processes fit in memory ⇨ **swapping**
  - Processes only partially in memory ⇨ **Virtual memory**



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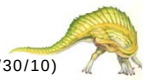
Process Management

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



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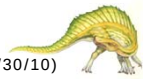
Process Management Activities

The operating system is responsible for

- 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



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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
  - 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

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

End of Chapter 1