CSE 325: Operating Systems
3rd Year Computer Engineering
Zagazig University

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LECTURE #1

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Course Info

Course website:

- http://www.aashahine.faculty.zu.edu.eg

Textbook:

- "Operating System Concepts", Silberschatz, Galvin, and Gagne, 9th Edition, 2013,
- http://codex.cs.yale.edu/avi/os-book/OS9

Course Info (Cont.)

Grading:

<table>
<tr><th>Course work</th><th colspan="2">Grade distribution</th></tr>
<tr><td>Participation</td><td>4pt</td><td rowspan="4">30</td></tr>
<tr><td>Homework</td><td>8pt</td></tr>
<tr><td>Programming Assignments</td><td>8pt</td></tr>
<tr><td>Midterm Exam</td><td>10pt</td></tr>
<tr><td>Final Exam</td><td colspan="2">70pt</td></tr>
<tr><td>Total Points</td><td colspan="2">100</td></tr>
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Topics Covered

Chapter 1: Introduction

Chapter 2: Operating System Structures

Chapter 3: Processes

Chapter 4: Threads

Chapter 5: Process Synchronization

Chapter 6: CPU Scheduling

Chapter 7: Deadlocks

Chapter 8: Main Memory

Chapter 9: Virtual Memory

Chapter 10: Mass-Storage Structure

Chapter 11: File-System Interface

Chapter 12: File-System Implementation

FATAL: Could not read from the boot medium! System halted.

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

Kernel Data Structures

Computing Environments

Open-Source Operating Systems

Objectives

To describe the basic organization of computer systems

To provide a grand tour of the major components of operating systems

To give an overview of the many types of computing environments

To explore several open-source operating systems

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:

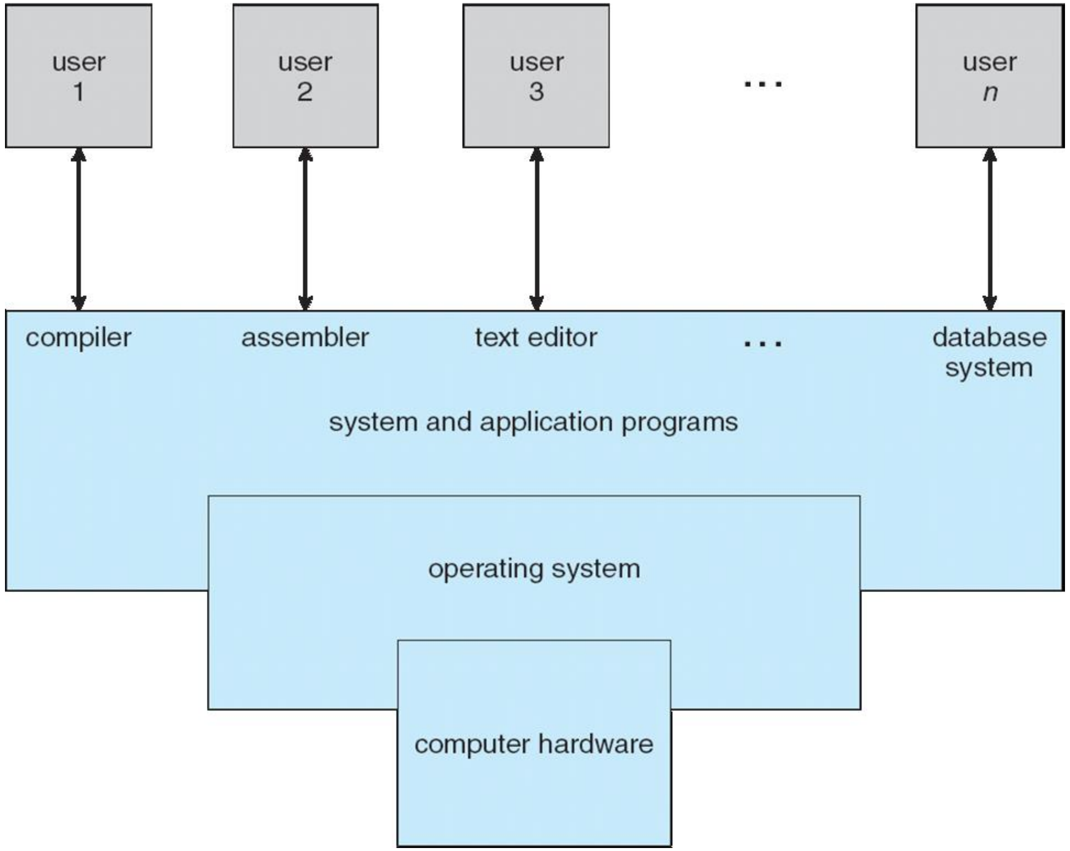
- Execute user programs and make solving user problems easier
- Make the computer system convenient to use
- Use the computer hardware in an efficient manner

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

- 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 a 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

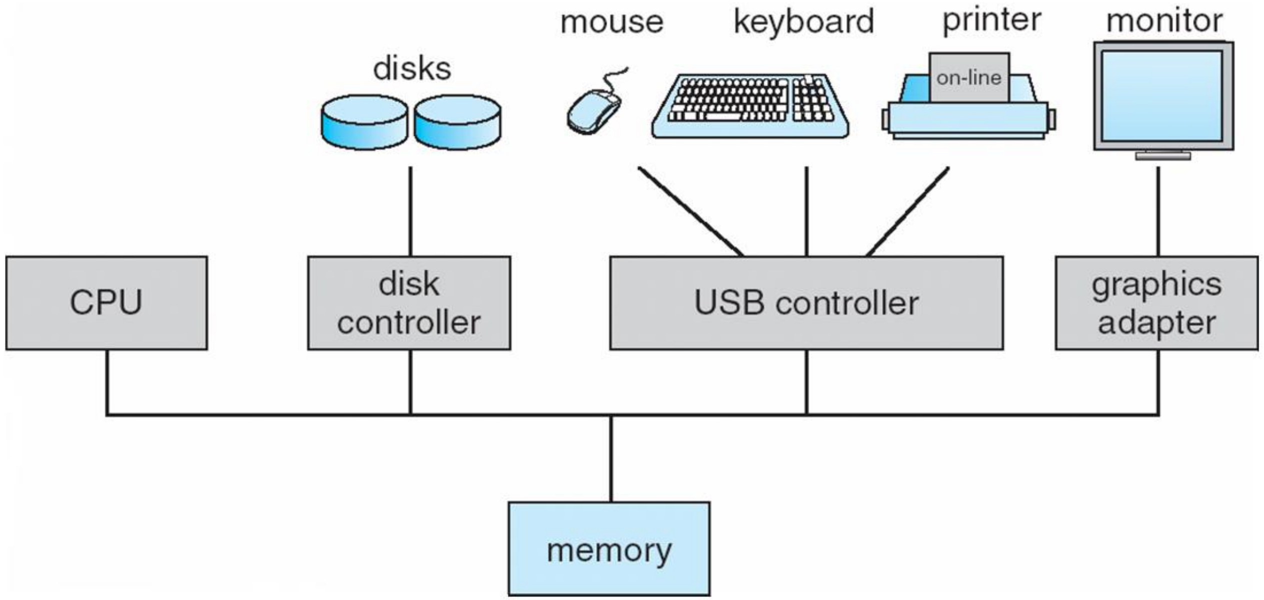
bootstrap program is loaded at power-up or reboot

- 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

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

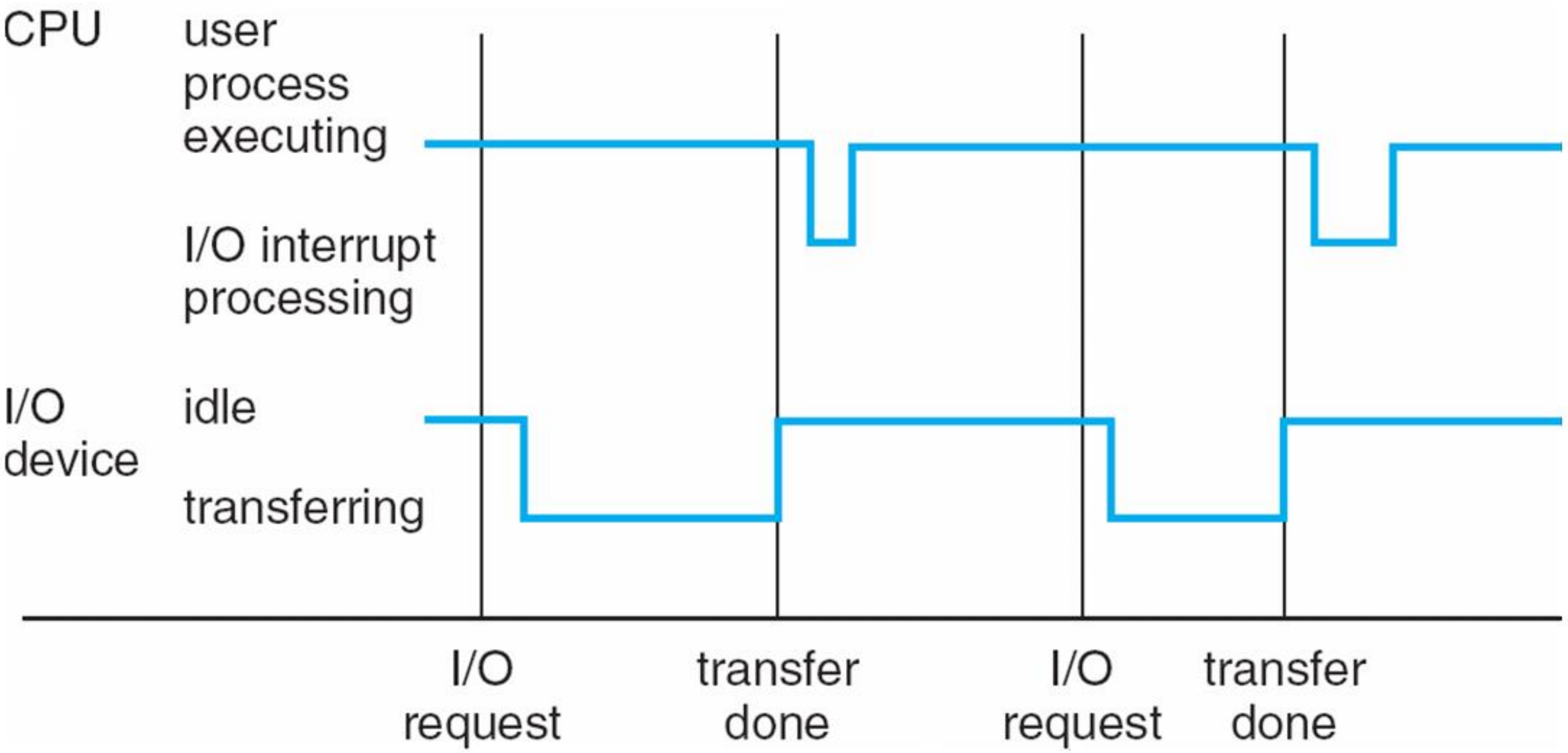
The operating system preserves the state of the CPU by storing registers and the program counter

Determines which type of interrupt has occurred:

- polling
- vectored interrupt system

Separate segments of code determine what action should be taken for each type of interrupt

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 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

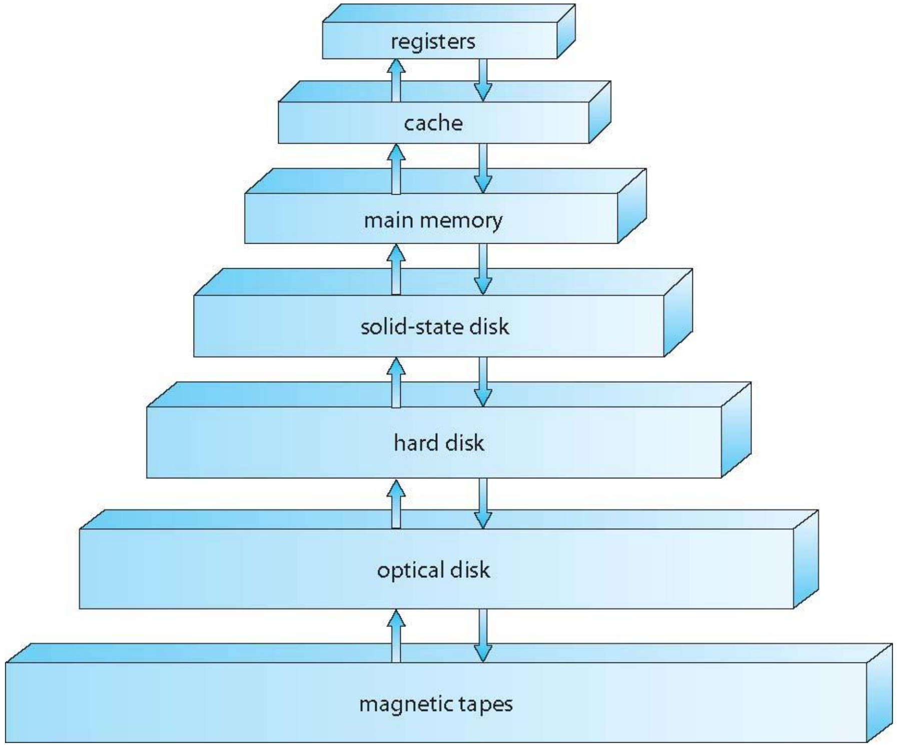
Storage Hierarchy

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

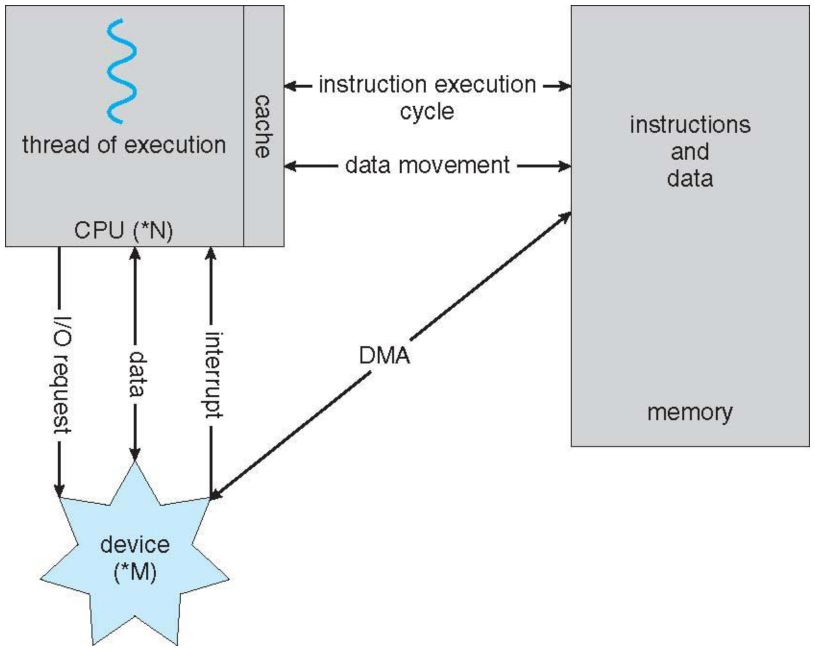
Direct Memory Access Structure

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

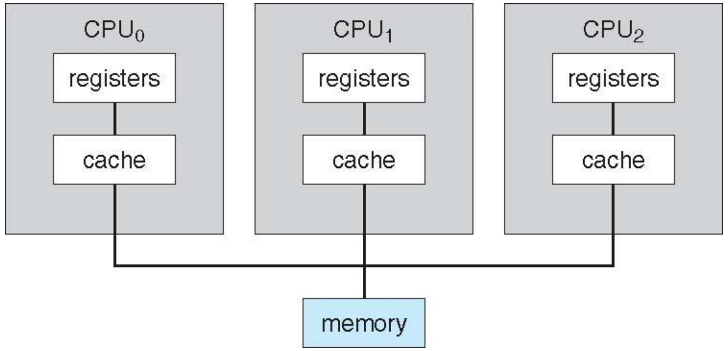
Most systems use a single general-purpose processor

- 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:
  - Increased throughput
  - Economy of scale
  - Increased reliability – graceful degradation or fault tolerance
- Two types:
  - Asymmetric Multiprocessing – each processor is assigned a specie task.
  - Symmetric Multiprocessing – each processor performs all tasks

Symmetric Multiprocessing Architecture

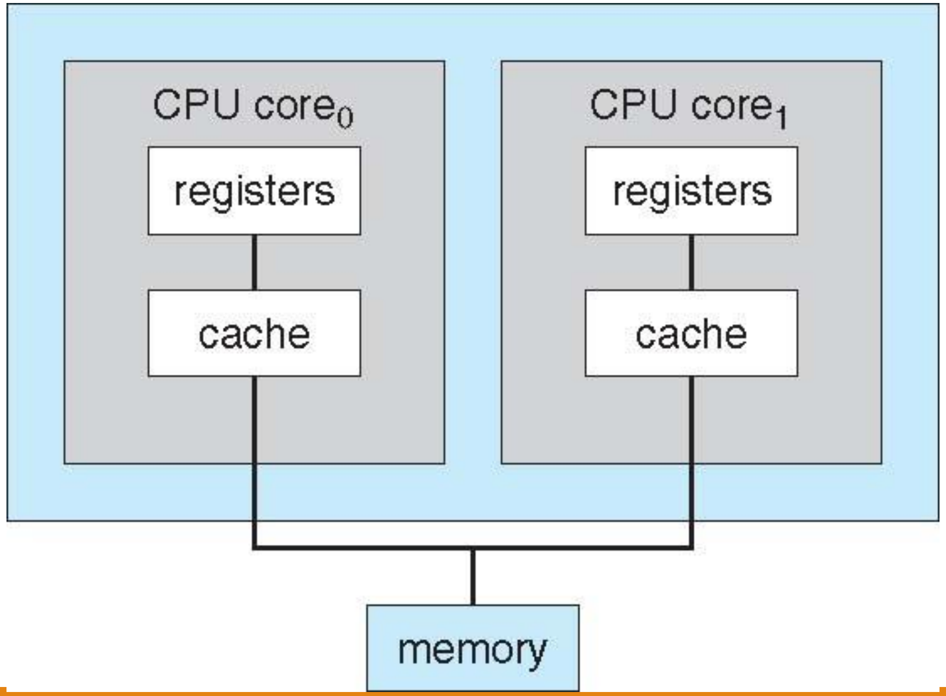


A Dual-Core Design

Multi-chip and multicore

Systems containing all chips

- Chassis containing multiple separate systems

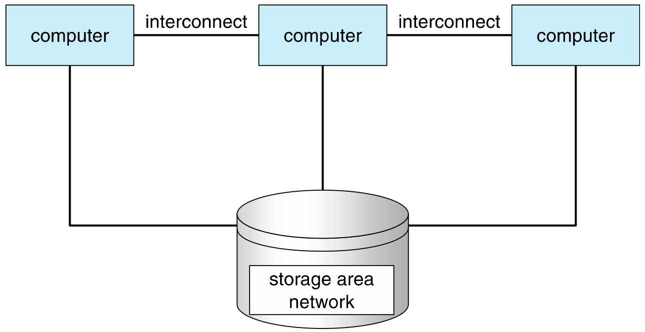


Clustered Systems

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

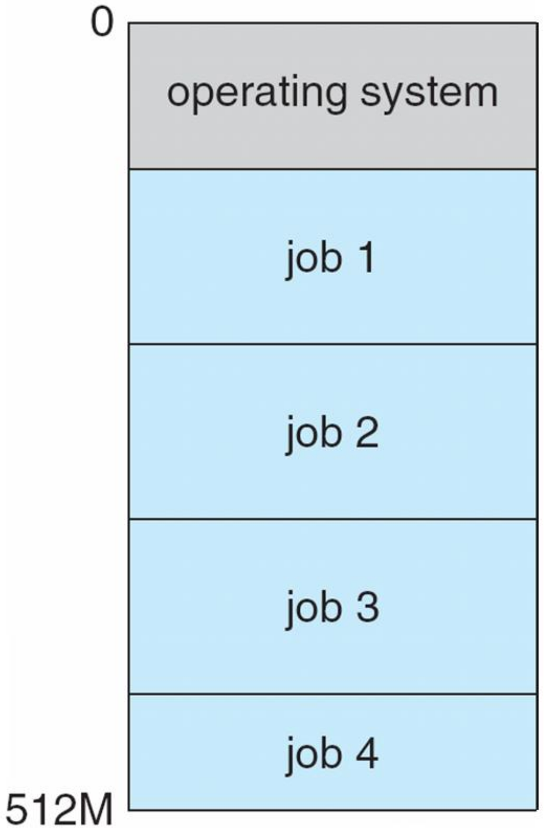
Multiprogramming (Batch system) needed for efficiency

- 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 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

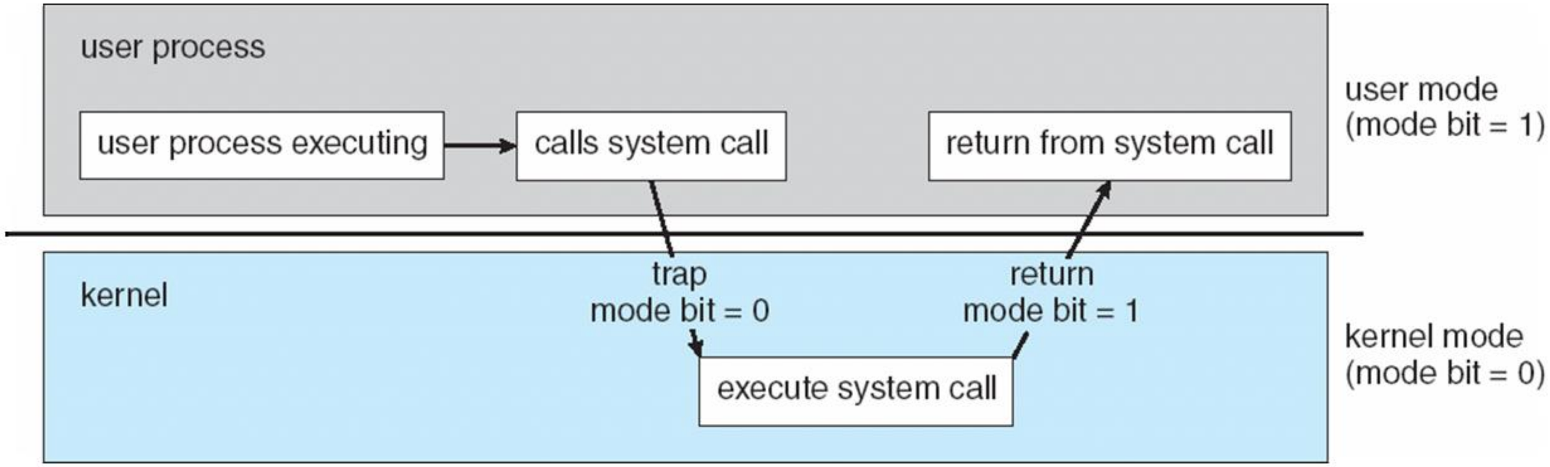
Increasingly CPUs support multi-mode operations

- 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



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

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

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

- 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

OS activities
- Free-space management
- Storage allocation
- Disk scheduling

Some storage need not be fast
- Tertiary storage includes optical storage, magnetic tape
- Still must be managed – by OS or applications
- Varies between WORM (write-once, read-many-times) and RW (read-write)

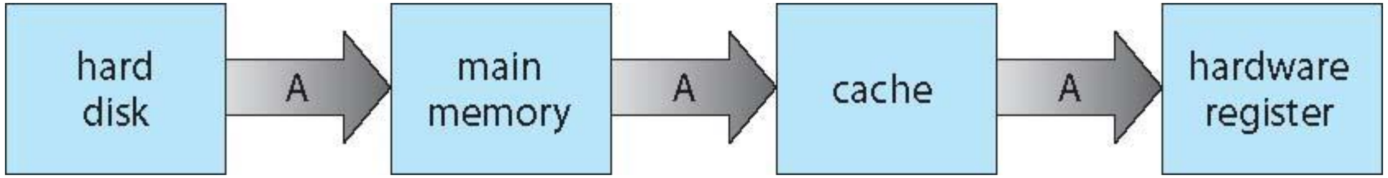
Performance of Various Levels of Storage

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

Movement between levels of storage hierarchy can be explicit or implicit

Migration of data “A” from Disk to Register

Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy



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

Distributed environment situation even more complex

- Several copies of a datum can exist
- Various solutions covered in Chapter 17

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

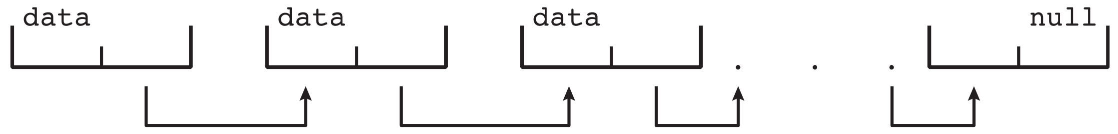
Systems generally first distinguish among users, to determine who can do what

- 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

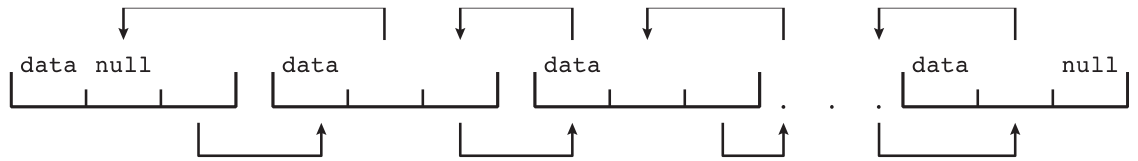
Kernel Data Structures

Many similar to standard programming data structures

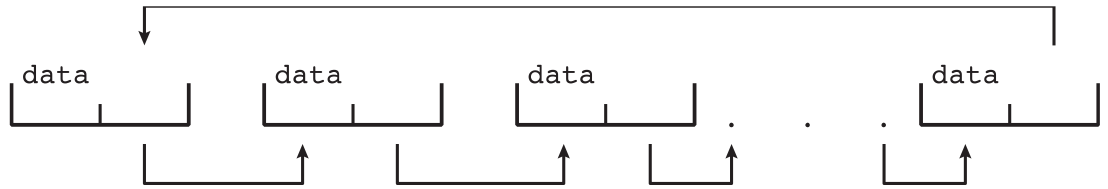
Singly linked list



Doubly linked list



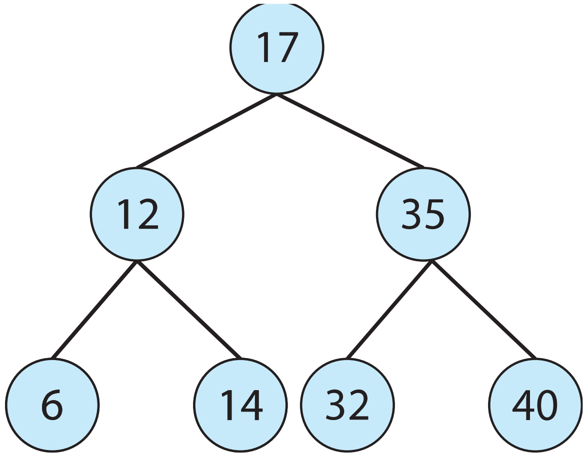
Circular linked list



Kernel Data Structures

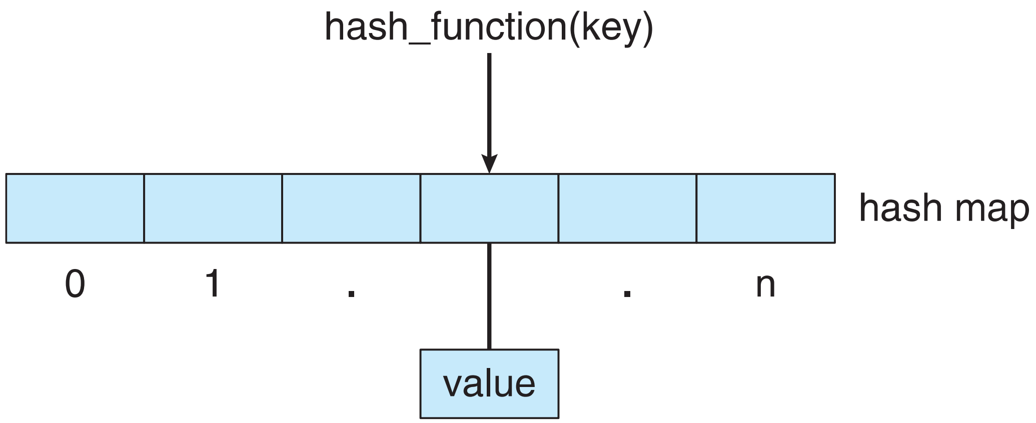
Binary search tree
left <= right

- Search performance is O(n)
- Balanced binary search tree is O(lg n)



Kernel Data Structures

Hash function can create a hash map



Bitmap – string of n binary digits representing the status of n items

Linux data structures defined in

include files <linux/list.h>, <linux/kfifo.h>, <linux/rbtree.h>

Computing Environments - Traditional

Stand-alone general purpose machines

But blurred as most systems interconnect with others (i.e., the Internet)

Portals provide web access to internal systems

Network computers (thin clients) are like Web terminals

Mobile computers interconnect via wireless networks

Networking becoming ubiquitous – even home systems use firewalls to protect home computers from Internet attacks

Computing Environments - Mobile

Handheld smartphones, tablets, etc

What is the functional difference between them and a “traditional” laptop?

Extra feature – more OS features (GPS, gyroscope)

Allows new types of apps like augmented reality

Use IEEE 802.11 wireless, or cellular data networks for connectivity

Leaders are Apple iOS and Google Android

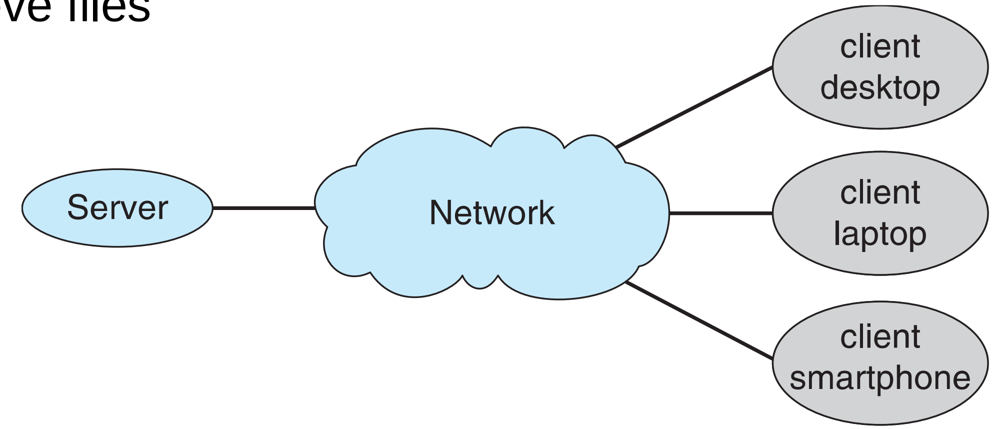
Computing Environments – Distributed

Distributed computiing

- Collection of separate, possibly heterogeneous, systems networked together
  - Network is a communications path, TCP/IP most common
    - Local Area Network (LAN)
    - Wide Area Network (WAN)
    - Metropolitan Area Network (MAN)
    - Personal Area Network (PAN)
- Network Operating System provides features between systems across network
  - Communication scheme allows systems to exchange messages
  - Illusion of a single system

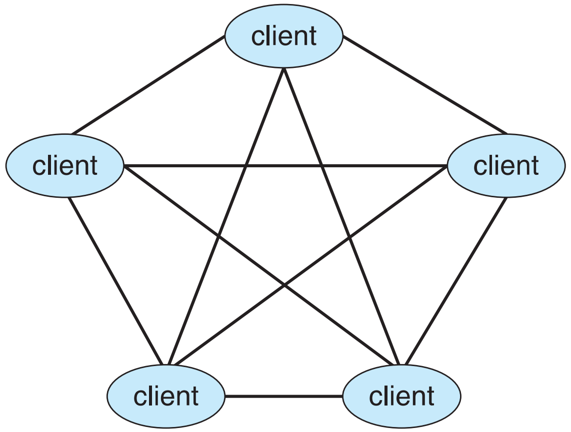
Computing Environments – Client-Server

- Client-Server Computing
  - Dumb terminals supplanted by smart PCs
  - Many systems now servers, responding to requests generated by clients`
    - Compute-server system provides an interface to client to request services (i.e., database)
    - File-server system provides interface for clients to store and retrieve files



Computing Environments - Peer-to-Peer

Another model of distributed system



P2P does not distinguish clients and servers

- Instead all nodes are considered peers
- May each act as client, server or both
- Node must join P2P network
  - Registers its service with central lookup service on network, or
  - Broadcast request for service and respond to requests for service via discovery protocol
- Examples include Napster and Gnutella, Voice over IP (VoIP) such as Skype

Computing Environments - Virtualization

Allows operating systems to run applications within other OSes
- Vast and growing industry

Emulation used when source CPU type different from target type (i.e. PowerPC to Intel x86)
- Generally slowest method
- When computer language not compiled to native code – Interpretation

Virtualization – OS natively compiled for CPU, running guest OSes also natively compiled
- Consider VMware running WinXP guests, each running applications, all on native WinXP host OS
- VMM (virtual machine Manager) provides virtualization services

Computing Environments - Virtualization

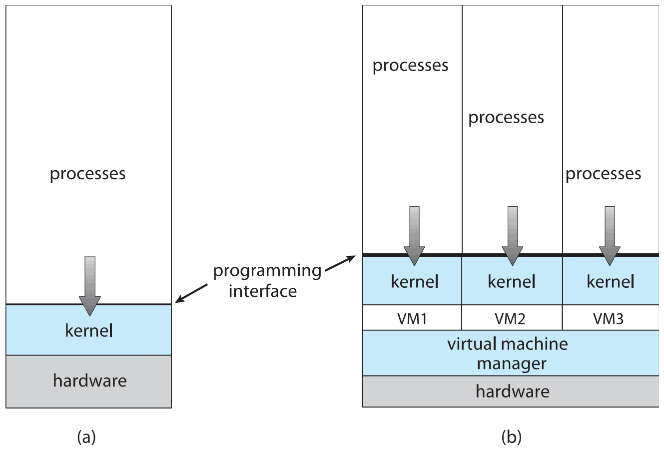
Use cases involve laptops and desktops running multiple OSes for exploration or compatibility

- Apple laptop running Mac OS X host, Windows as a guest
- Developing apps for multiple OSes without having multiple systems
- QA testing applications without having multiple systems
- Executing and managing compute environments within data centers

VMM can run natively, in which case they are also the host

- There is no general purpose host then (VMware ESX and Citrix XenServer)

Computing Environments - Virtualization



Computing Environments – Cloud Computing

Delivers computing, storage, even apps as a service across a network

Logical extension of virtualization because it uses virtualization as the base for it functionality.

- Amazon EC2 has thousands of servers, millions of virtual machines, petabytes of storage available across the Internet, pay based on usage

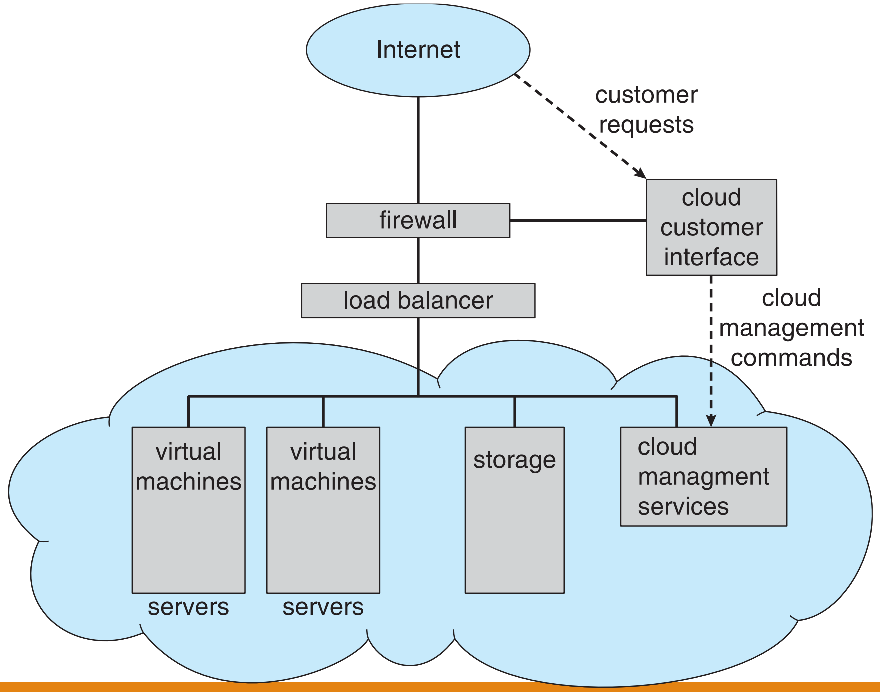
Many types

- Public cloud – available via Internet to anyone willing to pay
- Private cloud – run by a company for the company's own use
- Hybrid cloud – includes both public and private cloud components
- Software as a Service (SaaS) – one or more applications available via the Internet (i.e., word processor)
- Platform as a Service (PaaS) – software stack ready for application use via the Internet (i.e., a database server)
- Infrastructure as a Service (IaaS) – servers or storage available over Internet (i.e., storage available for backup use)

Computing Environments – Cloud Computing

Cloud computing environments composed of traditional OSes, plus VMMs, plus cloud management tools

- Internet connectivity requires security like firewalls
- Load balancers spread traffic across multiple applications



Computing Environments – Real-Time Embedded Systems

Real-time embedded systems most prevalent form of computers
- Vary considerable, special purpose, limited purpose OS, real-time OS
- Use expanding

Many other special computing environments as well
- Some have OSes, some perform tasks without an OS

Real-time OS has well-defined fixed time constraints
- Processing must be done within constraint
- Correct operation only if constraints met

Open-Source Operating Systems

Operating systems made available in source-code format rather than just binary closed-source

Counter to the copy protection and Digital Rights Management (DRM) movement

Started by Free Software Foundation (FSF), which has “copyleft” GNU Public License (GPL)

Examples include GNU/Linux and BSD UNIX (including core of Mac OS X), and many more

Can use VMM like VMware Player (Free on Windows), Virtualbox (open source and free on many platforms - http://www.virtualbox.com)

- Use to run guest operating systems for exploration

End of Chapter 1