Module 1 - Introduction to Operating Systems

Contents

Module 1:Introduction [9 Hrs] [Knowledge Level (1)]

Introduction to OS – Operating System Architecture & Operations – Operating System Services and components - Operating System computing environment – System Calls – Operating System Structures - Process Concept – Interprocess Communication.

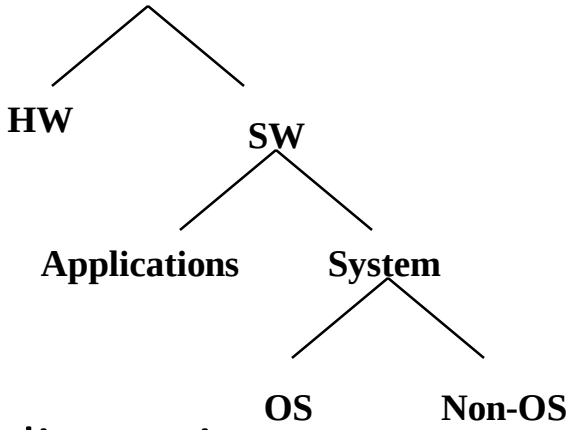
Course Outcome: Describe the fundamental concepts of Operating Systems.

What is Operating System ?

- An operating system is a program that manages a computer's hardware. It also provides a basis for application programs and acts as an intermediary between the computer user and the computer hardware.
- Operating system goals:
  - A program that controls the execution of application programs
  - Make the computer system convenient to use.
  - Use the computer hardware in an efficient manner.

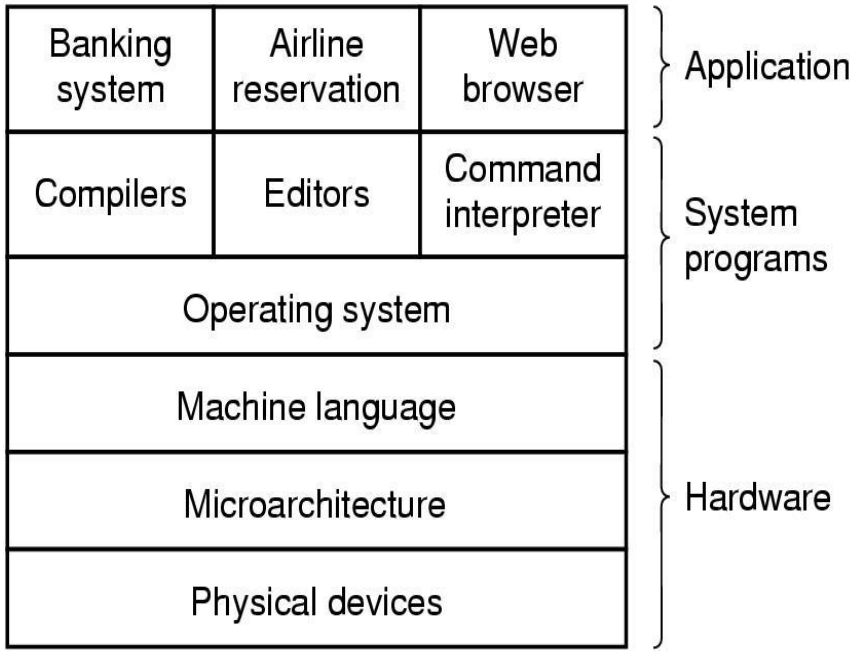
Where does the OS fit in?

- Basic Taxonomy



  - Software is differentiated according to its purpose
  - System software provides a general environment where programmers/developers can create applications and users can run applications

Introduction



- **A computer system consists of**
  - **hardware**
  - **system programs**
  - **application programs**

System Goals

- **Objectives of an OS**
  - **Convenience**
    - **An operating system makes a computer more convenient to use.**
  - **Efficiency**
    - **An operating system allows the computer system resources to be used in an efficient manner.**
  - **Ability to Evolve**
    - **Should permit effective development, testing, and introduction of new system features and functions without interfering with service.**

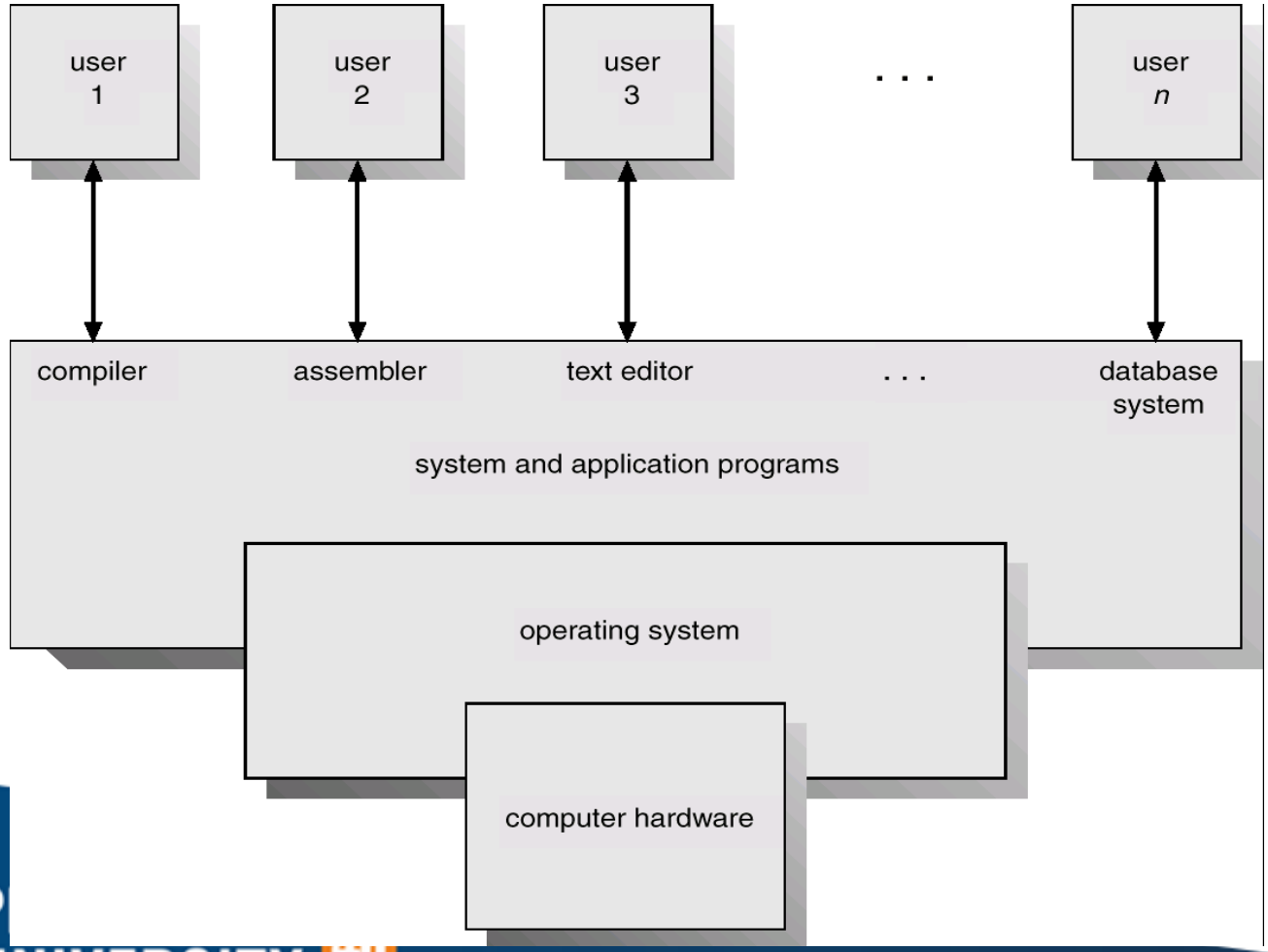
Two View points

- **User view**
  - User sits in front of PC
  - User sit at a terminal connected to a mainframe
- **System view**
  - Resource allocator
  - Control program

Abstract view of a computer system

1. Hardware – provides basic computing resources (CPU, memory, I/O devices).
2. Operating system – controls and coordinates the use of the hardware among the various application programs for the various users.
3. Applications programs – define the ways in which the system resources are used to solve the computing problems of the users (compilers, database systems, video games, business programs).
4. Users (people, machines, other computers).

Abstract View of System Components



Operating System Definitions

- Resource allocator – manages and allocates resources.
- Control program – controls the execution of user programs and operations of I/O devices .
- Kernel – the one program running at all times (all else being application programs).

Operating System as a resource manager

- It is actually a program that is executed by the processor to control the processor!
- Directs the processor in the use of system resources
- Directs the processor when executing other programs
- Processor stops executing the operating system in order to execute other programs and, then, gives the control back to the operating system

Operating System as a resource manager

- Memory management is decided by the operating system and memory management hardware in the processor.
- The operating system decides about the access of programs and files to I/O devices.
- In case of multiple processors, it decides for them all

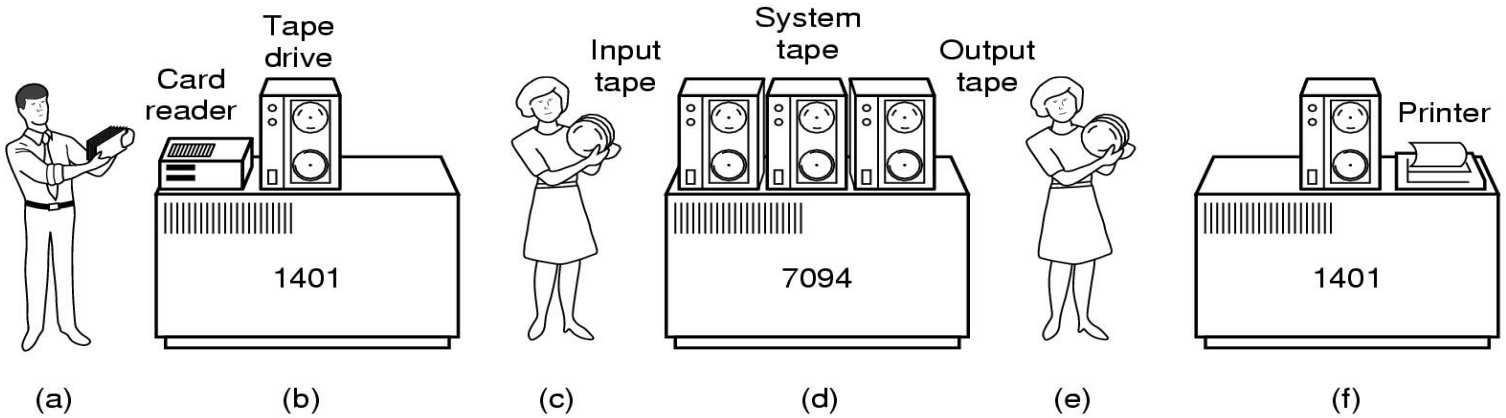
Operating system timeline

- First generation: 1945 – 1955
  - Vacuum tubes
  - Plug boards
- Second generation: 1955 – 1965
  - Transistors
  - Batch systems
- Third generation: 1965 – 1980
  - Integrated circuits
  - Multiprogramming
- Fourth generation: 1980 – present
  - Large scale integration
  - Personal computers
- Next generation: ???
  - Systems connected by high-speed networks?
  - Wide area resource management?

First generation: direct input

- Run one job at a time
  - Enter it into the computer (might require rewiring!)
  - Run it
  - Record the results
- Problem: lots of wasted computer time!
  - Computer was idle during first and last steps
  - Computers were ***very*** expensive!
- Goal: make better use of an expensive commodity: computer time

Second generation: batch systems



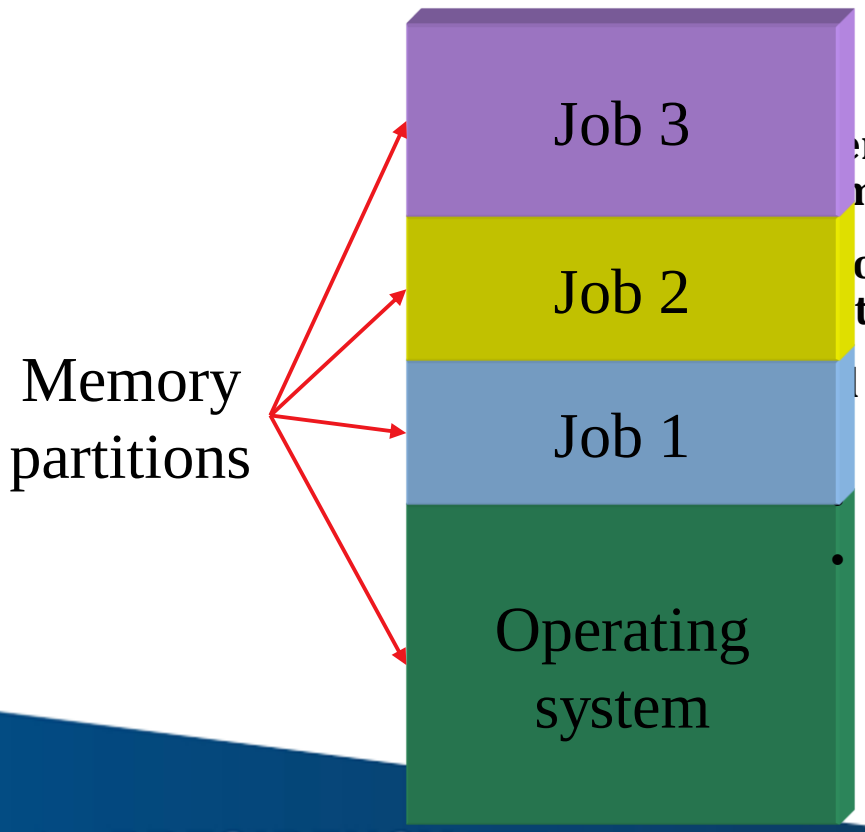
- Bring cards to 1401
- Read cards onto input tape
- Put input tape on 7094
- Perform the computation, writing results to output tape
- Put output tape on 1401, which prints output

- Advantages of batch systems
  - move much of the work of the operator to the computer
  - increased performance since it was possible for job to start as soon as the previous job finished
- Disadvantages
  - turn-around time can be large from user standpoint
  - more difficult to debug program
  - due to lack of protection scheme, one batch job can affect pending jobs (read too many cards, etc)
  - a job could corrupt the monitor, thus affecting pending jobs
  - a job could enter an infinite loop

Spooling

- Original batch systems used tape drives
- Later batch systems used disks for buffering
  - Operator read cards onto disk attached to the computer
  - Computer read jobs from disk
  - Computer wrote job results to disk
  - Operator directed that job results be printed from disk
- Disks enabled simultaneous peripheral operation on-line (spooling)
  - Computer overlapped I/O of one job with execution of another
  - Better utilization of the expensive CPU
  - Still only one job active at any given time

Third generation: multiprogramming



- **Multiple jobs in memory**
  - **Protected from one another**
  - **erating system protected n each job as well**
  - **ources (time, hardware) t between jobs**
  - **not interactive**
    - **User submits job**
    - **Computer runs it**
    - **User gets results minutes (hours, days) later**

Timesharing

- It's a logical extension of multiprogramming.
- The CPU executes multiple jobs by switching among them
- It allows many users to share the computer simultaneously
- It uses time scheduling and multiprogramming to provide each user with a small portion of a time shared computer.

Timesharing

- Its more complex than multiprogramming because jobs may have to be swapped in and out of main memory.
- Here it comes virtual memory

Desktop Systems

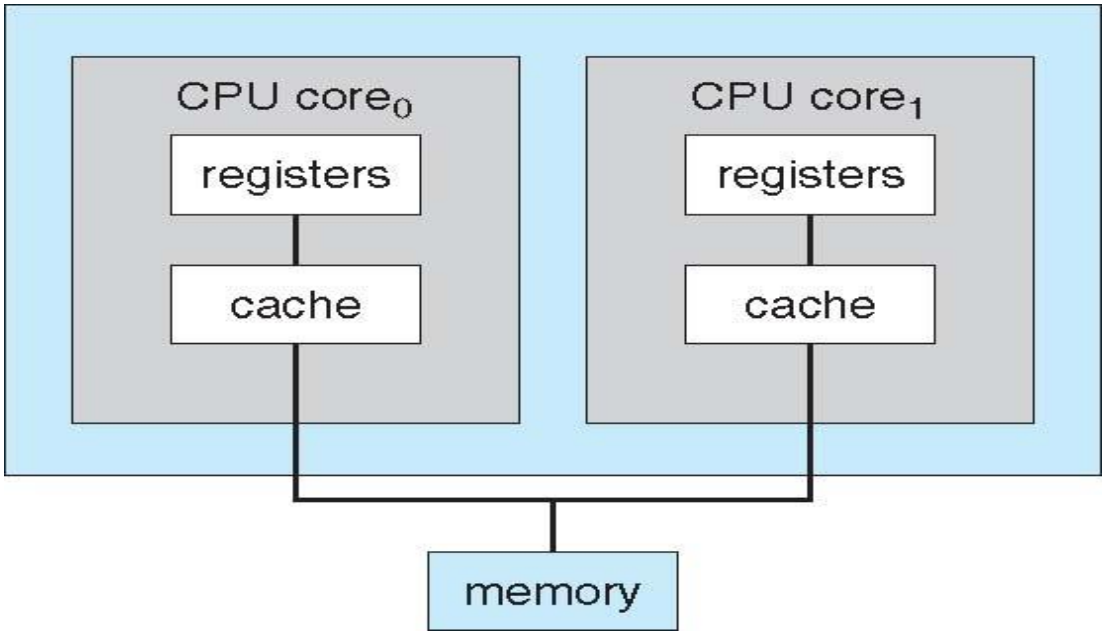
- *Personal computers* – computer system dedicated to a single user.
- I/O devices – keyboards, mice, display screens, small printers.
- User convenience and responsiveness.
- Can adopt technology developed for larger operating system' often individuals have sole use of computer and do not need advanced CPU utilization of protection features.
- May run several different types of operating systems (Windows, MacOS, UNIX, Linux)

Parallel Systems

- Multiprocessor systems with more than on CPU in close communication.
- *Tightly coupled system* – processors share memory and a clock; communication usually takes place through the shared memory.
- Advantages of parallel system:
  - Increased *throughput*
  - Economical
  - Increased reliability
    - graceful degradation
    - fail-soft systems

A Dual-Core Design

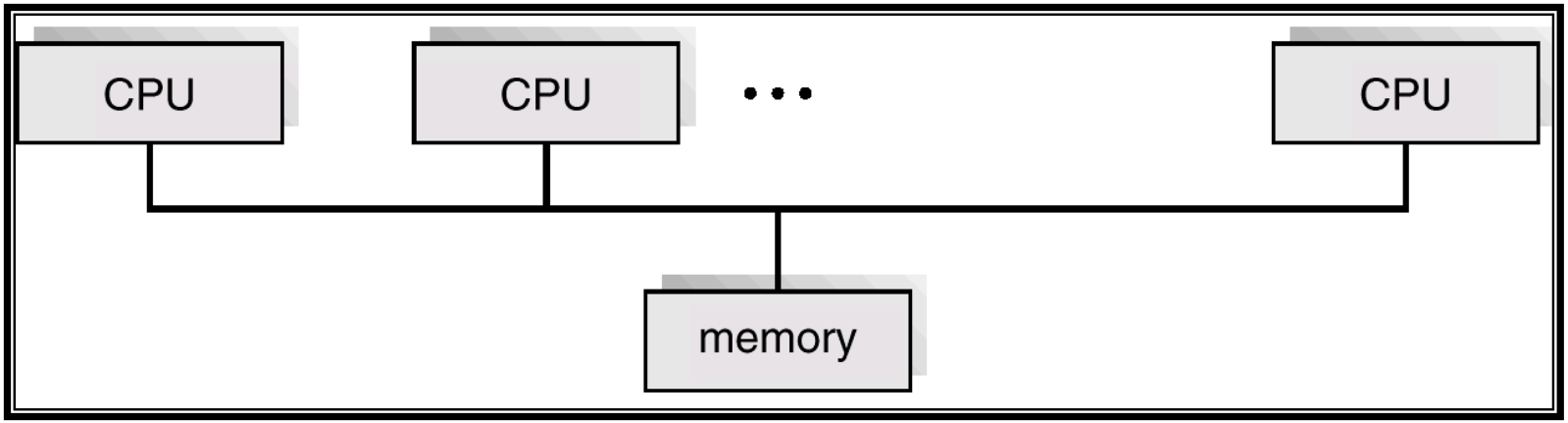
- Multi-chip and **multicore**
- Systems containing all chips
  - Chassis containing multiple separate systems



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

Symmetric Multiprocessing Architecture



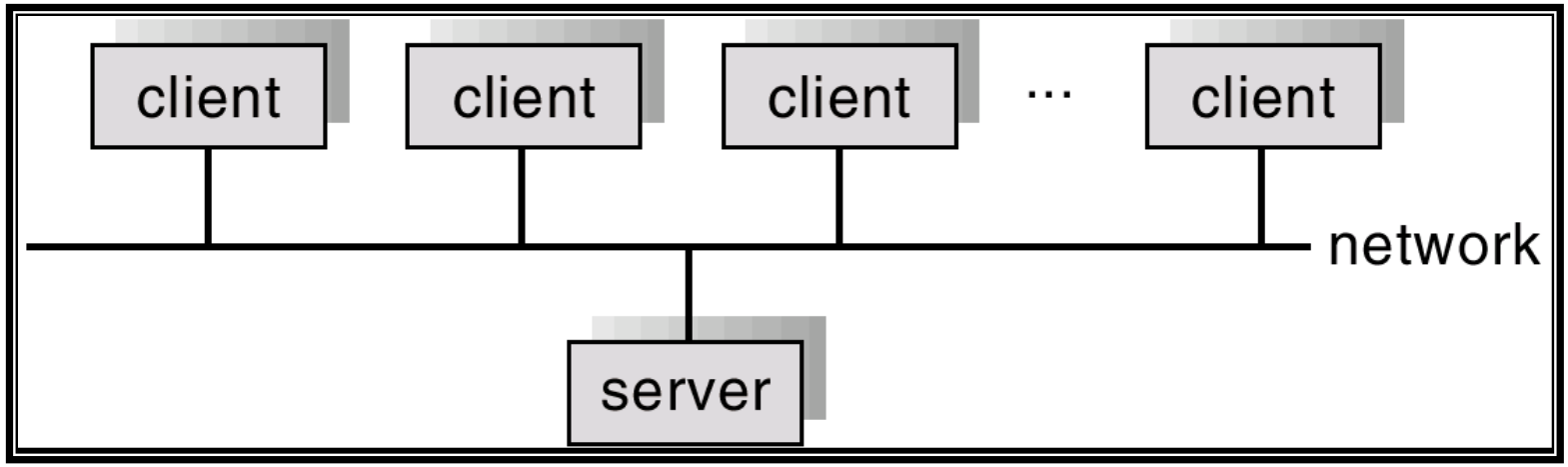
Distributed Systems

- Distribute the computation among several physical processors.
- *Loosely coupled system* – each processor has its own local memory; processors communicate with one another through various communications lines, such as high-speed buses or telephone lines.
- Advantages of distributed systems.
  - Resources Sharing
  - Computation speed up – load sharing
  - Reliability
  - Communications

Distributed Systems (cont)

- Requires networking infrastructure.
- Local area networks (LAN) or Wide area networks (WAN)
- May be either client-server or peer-to-peer systems.

General Structure of Client-Server



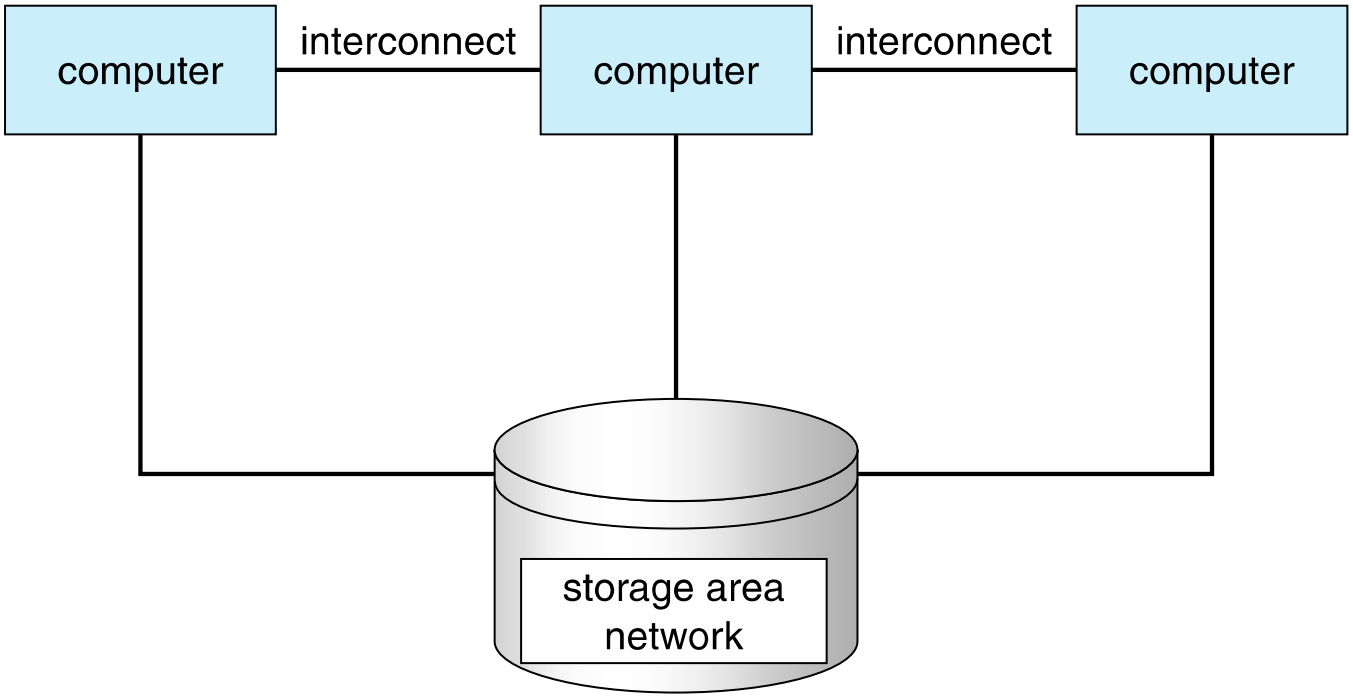
Handheld Systems

- Personal Digital Assistants (PDAs)
- Cellular telephones
- Issues:
  - Limited memory
  - Slow processors
  - Small display screens.

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**

Clustered Systems



Hardware Protection

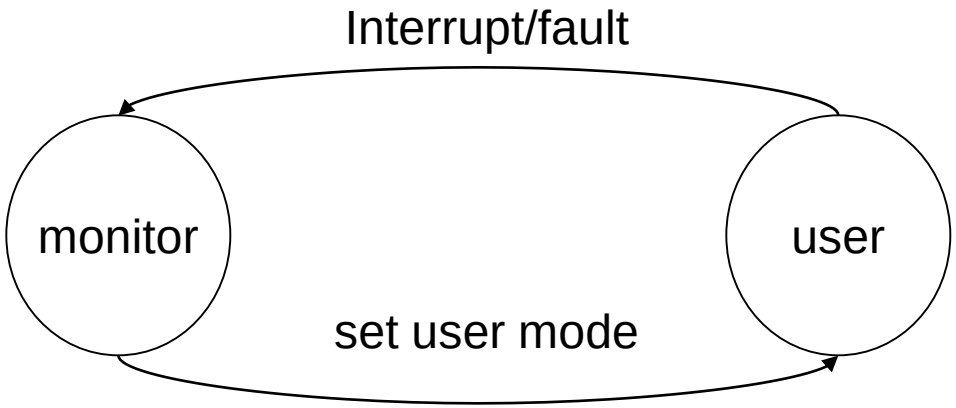
- Dual-Mode Operation
- I/O Protection
- Memory Protection
- CPU Protection

Dual-Mode Operation

- Sharing system resources requires operating system to ensure that an incorrect program cannot cause other programs to execute incorrectly.
- Provide hardware support to differentiate between at least two modes of operations.
  1. ***User mode*** – execution done on behalf of a user.
  2. ***Monitor mode*** (also *kernel mode* or *system mode*) – execution done on behalf of operating system.

Dual-Mode Operation (Cont.)

- ***Mode bit*** added to computer hardware to indicate the current mode: monitor (0) or user (1).
- When an interrupt or fault occurs hardware switches to monitor mode.

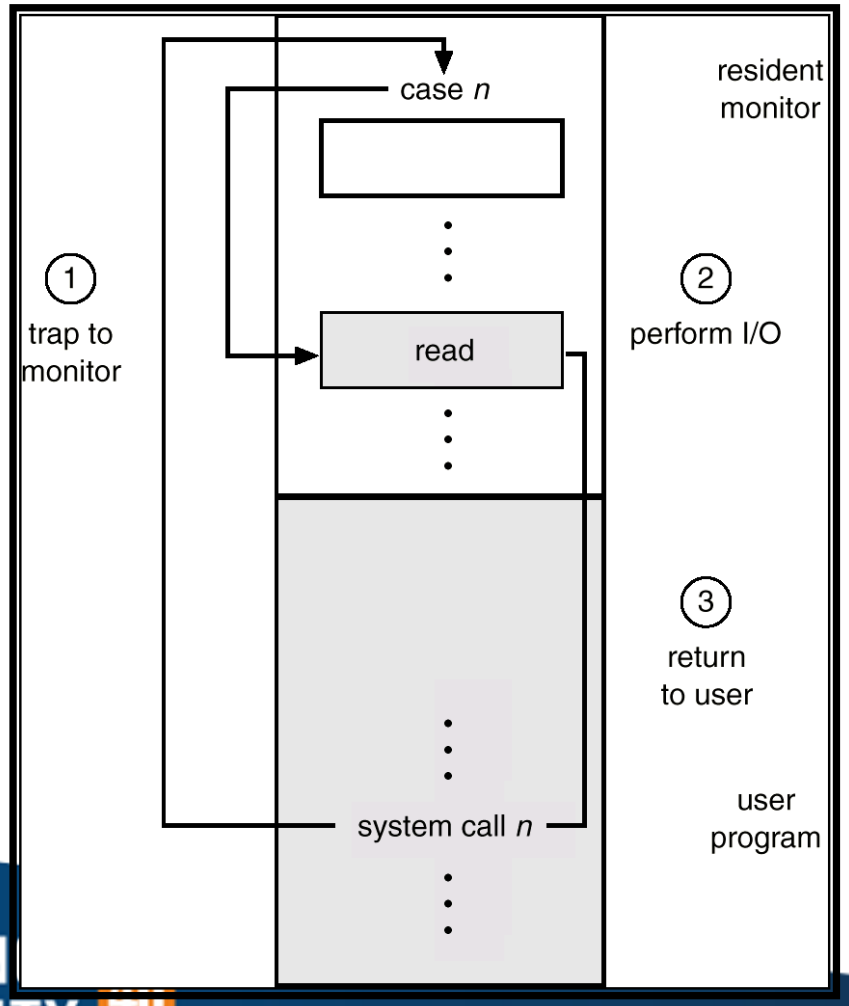


Privileged instructions can be issued only in monitor mode.

I/O Protection

- All I/O instructions are privileged instructions.
- Must ensure that a user program could never gain control of the computer in monitor mode (I.e., a user program that, as part of its execution, stores a new address in the interrupt vector).

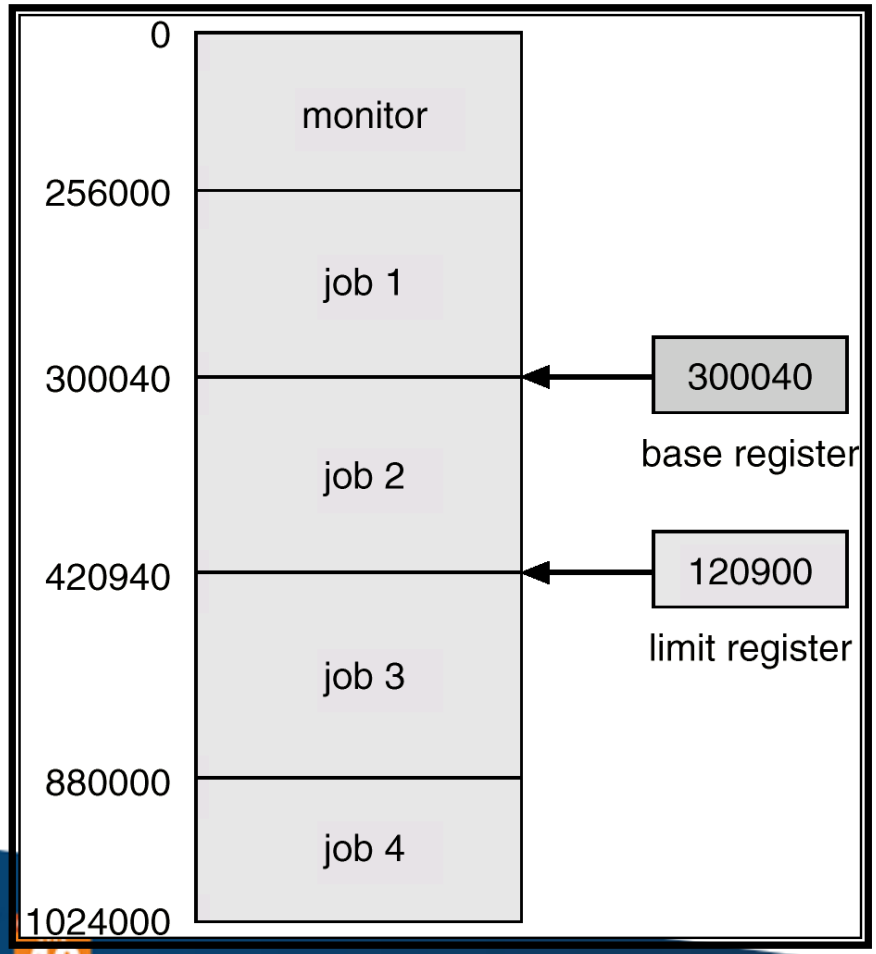
Use of A System Call to Perform I/O



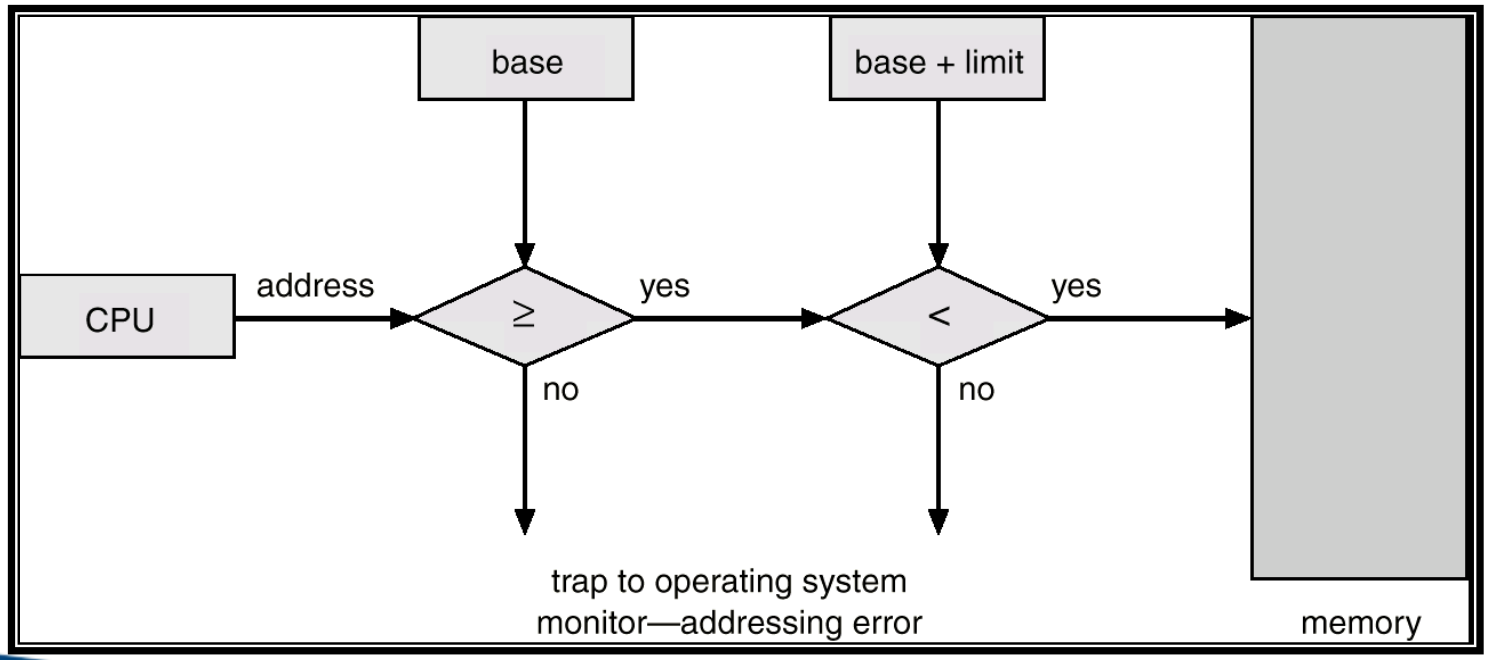
Memory Protection

- Must provide memory protection at least for the interrupt vector and the interrupt service routines.
- In order to have memory protection, add two registers that determine the range of legal addresses a program may access:
  - **Base register** – holds the smallest legal physical memory address.
  - **Limit register** – contains the size of the range
- Memory outside the defined range is protected.

Use of A Base and Limit Register



Hardware Address Protection



Hardware Protection

- When executing in monitor mode, the operating system has unrestricted access to both monitor and user's memory.
- The load instructions for the *base* and *limit* registers are privileged instructions.

CPU Protection

- *Timer* – interrupts computer after specified period to ensure operating system maintains control.
  - Timer is decremented every clock tick.
  - When timer reaches the value 0, an interrupt occurs.
- Timer commonly used to implement time sharing.
- Time also used to compute the current time.
- Load-timer is a privileged instruction.

Operating System Services

- **Program execution –** system capability to load a program into memory and to run it.
- **I/O operations –** since user programs cannot execute I/O operations directly, the operating system must provide some means to perform I/O.
- **File-system manipulation –** program capability to read, write, create, and delete files.
- **Communications –** exchange of information between processes executing either on the same computer or on different systems tied together by a network.
- **Error detection –** ensure correct computing by detecting errors in the CPU and memory hardware, in I/O devices, or in user programs.

Additional Operating System Functions

Additional functions exist not for helping the user, but rather for ensuring efficient system operations.

- Resource allocation – allocating resources to multiple users or multiple jobs running at the same time.
- Accounting – keep track of and record which users use how much and what kinds of computer resources for account billing or for accumulating usage statistics.
- Protection – ensuring that all access to system resources is controlled.

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)

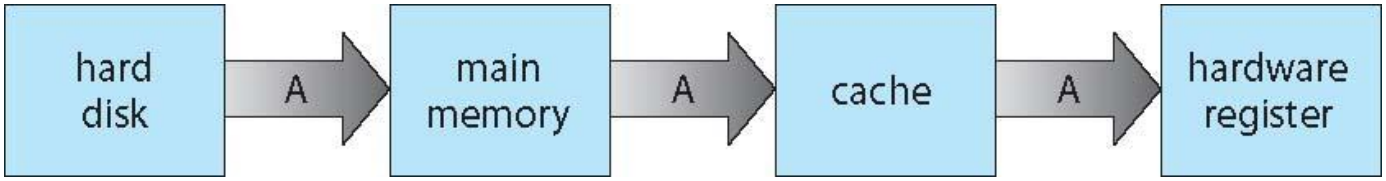
Performance of Various Levels of Storage

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

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

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

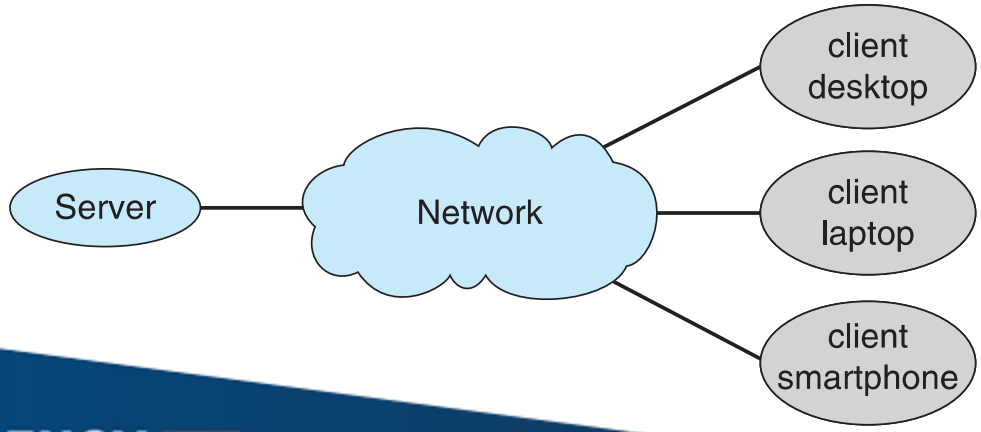
- Handheld smartphones, tablets, etc
- What is the functional difference between them and a “traditional” laptop?
- Extra feature – more OS features (GPS, gyroscope)
- Allows new types of apps like ***augmented reality***
- Use IEEE 802.11 wireless, or cellular data networks for connectivity
- Leaders are **Apple iOS** and **Google Android**

Computing Environments – Distributed

- Distributed computing
  - 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

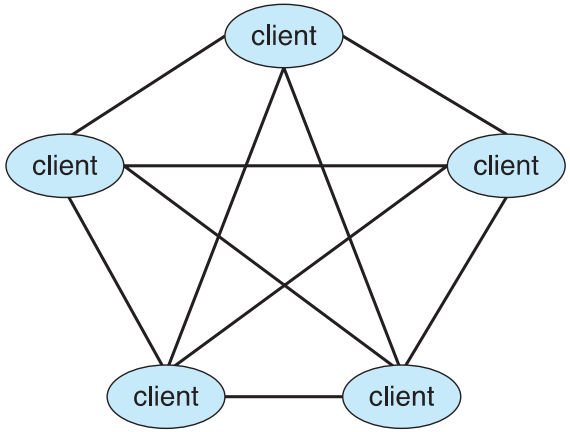
Computing Environments – Client-Server

- 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



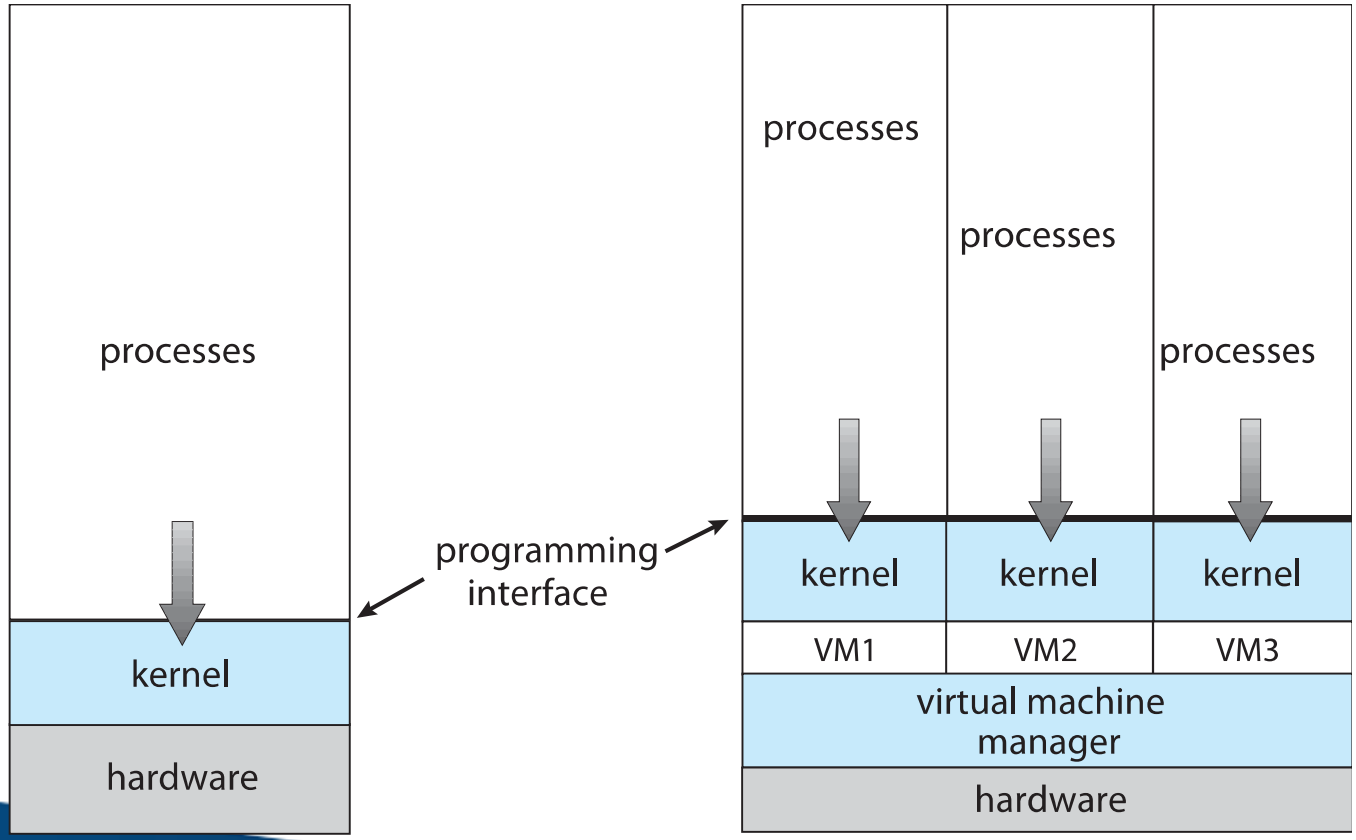
Computing Environments - Virtualization

- 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

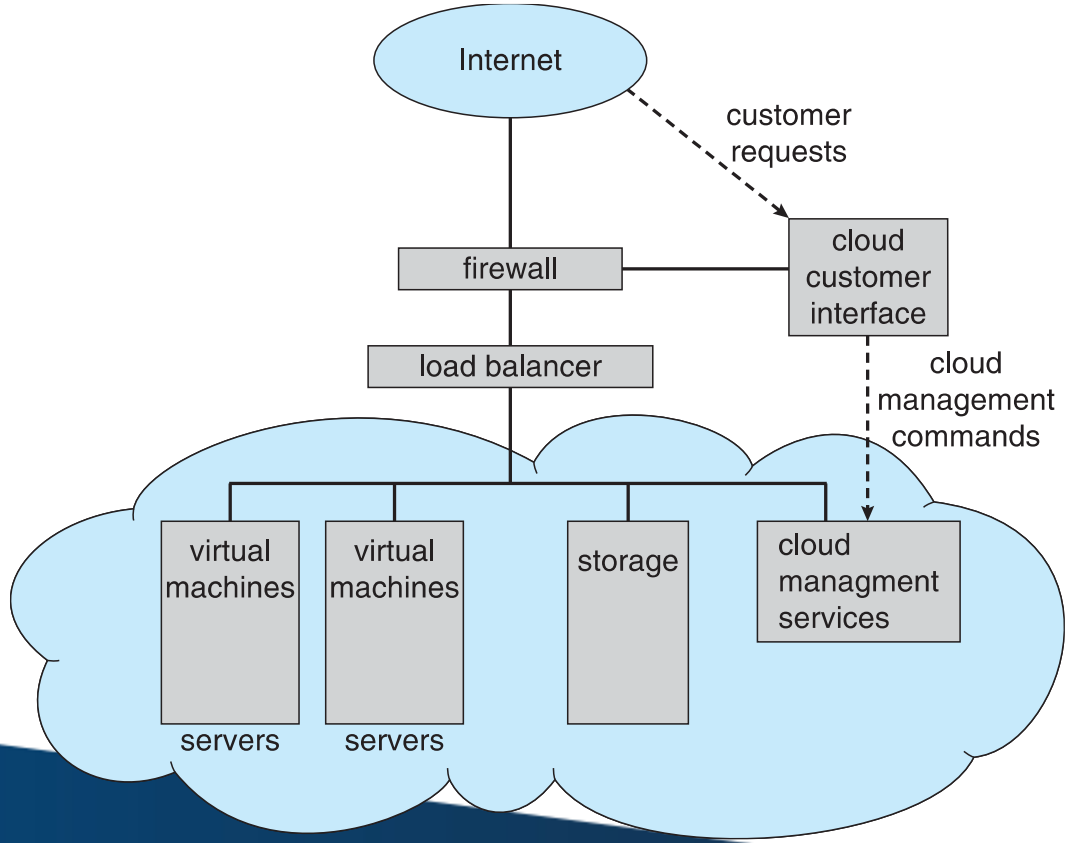


Computing Environments – Cloud Computing

- 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

Real-Time Systems (Cont.)

- **Hard real-time:**
  - **Secondary storage limited or absent, data stored in short term memory, or read-only memory (ROM)**
  - **Conflicts with time-sharing systems, not supported by general-purpose operating systems.**
- **Soft real-time**
  - **Limited utility in industrial control of robotics**
  - **Useful in applications (multimedia, virtual reality) requiring advanced operating-system features.**

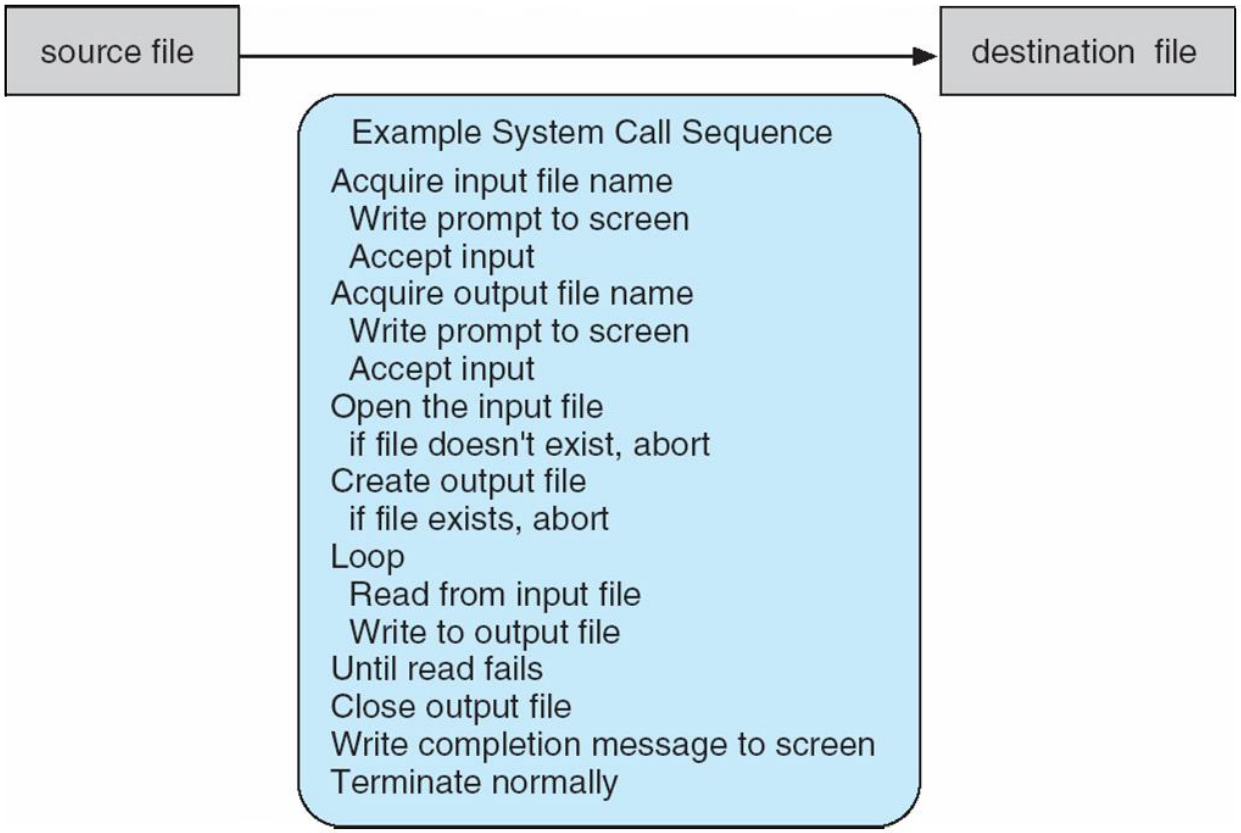
System Calls

- Programming interface to the services provided by the OS
- Typically written in a high-level language (C or C++)
- Mostly accessed by programs via a high-level **Application Programming Interface (API)** rather than direct system call use
- Three most common APIs are Win32 API for Windows, POSIX API for POSIX-based systems (including virtually all versions of UNIX, Linux, and Mac OS X), and Java API for the Java virtual machine (JVM)

Note that the system-call names used throughout this ppt are generic

Example of System Calls

- System call sequence to copy the contents of one file to another file



Example of Standard API

EXAMPLE OF STANDARD API

As an example of a standard API, consider the `read()` function that is available in UNIX and Linux systems. The API for this function is obtained from the `man` page by invoking the command

```
man read
```

on the command line. A description of this API appears below:

```
#include <unistd.h>

ssize_t    read(int fd, void *buf, size_t count)
```

return value — function name — parameters

A program that uses the `read()` function must include the `unistd.h` header file, as this file defines the `ssize_t` and `size_t` data types (among other things). The parameters passed to `read()` are as follows:

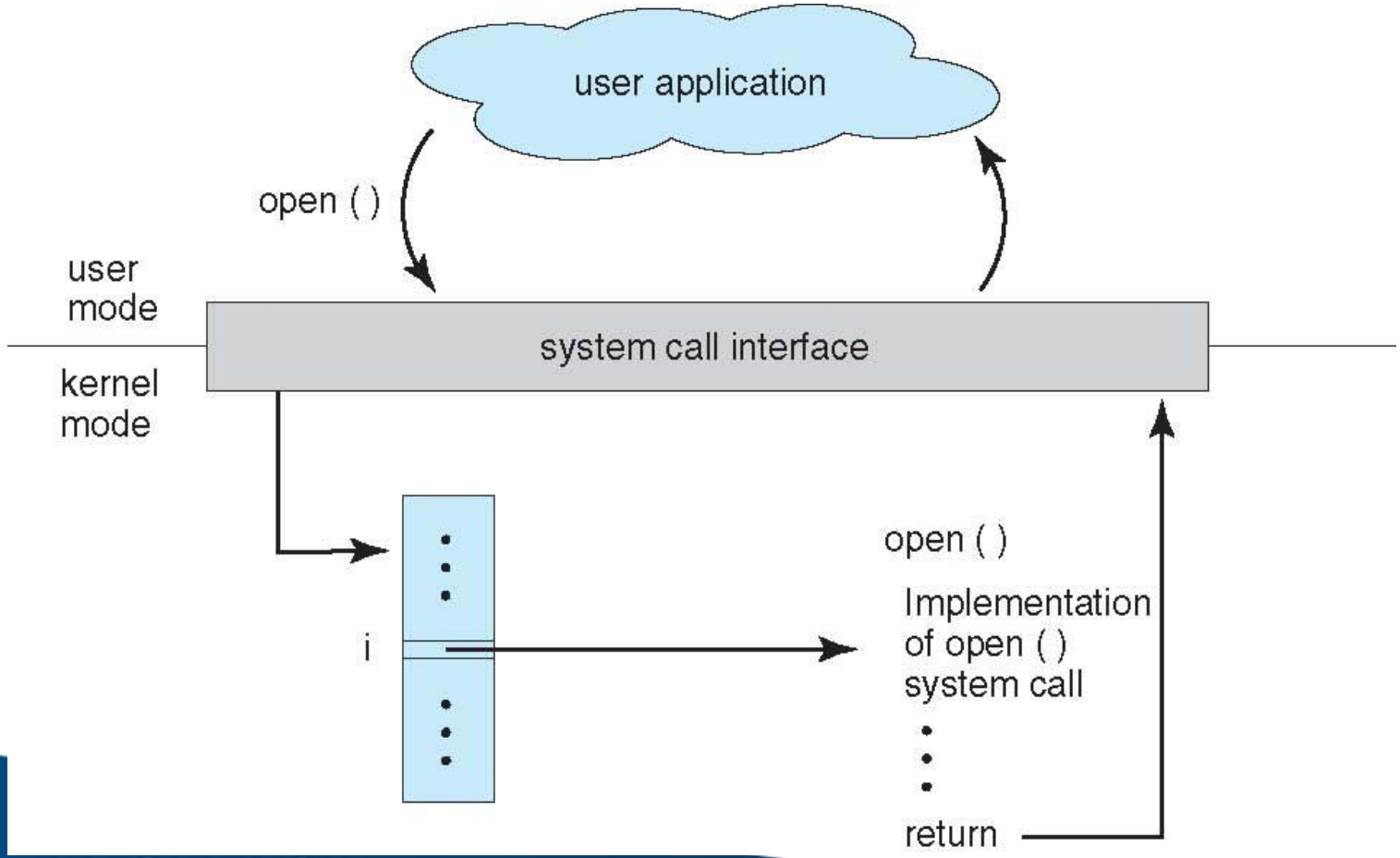
- `int fd`—the file descriptor to be read
- `void *buf`—a buffer where the data will be read into
- `size_t count`—the maximum number of bytes to be read into the buffer

On a successful read, the number of bytes read is returned. A return value of 0 indicates end of file. If an error occurs, `read()` returns −1.

System Call Implementation

- Typically, a number associated with each system call
  - **System-call interface** maintains a table indexed according to these numbers
- The system call interface invokes the intended system call in OS kernel and returns status of the system call and any return values
- The caller need know nothing about how the system call is implemented
  - Just needs to obey API and understand what OS will do as a result call
  - Most details of OS interface hidden from programmer by API
    - Managed by run-time support library (set of functions built into libraries included with compiler)

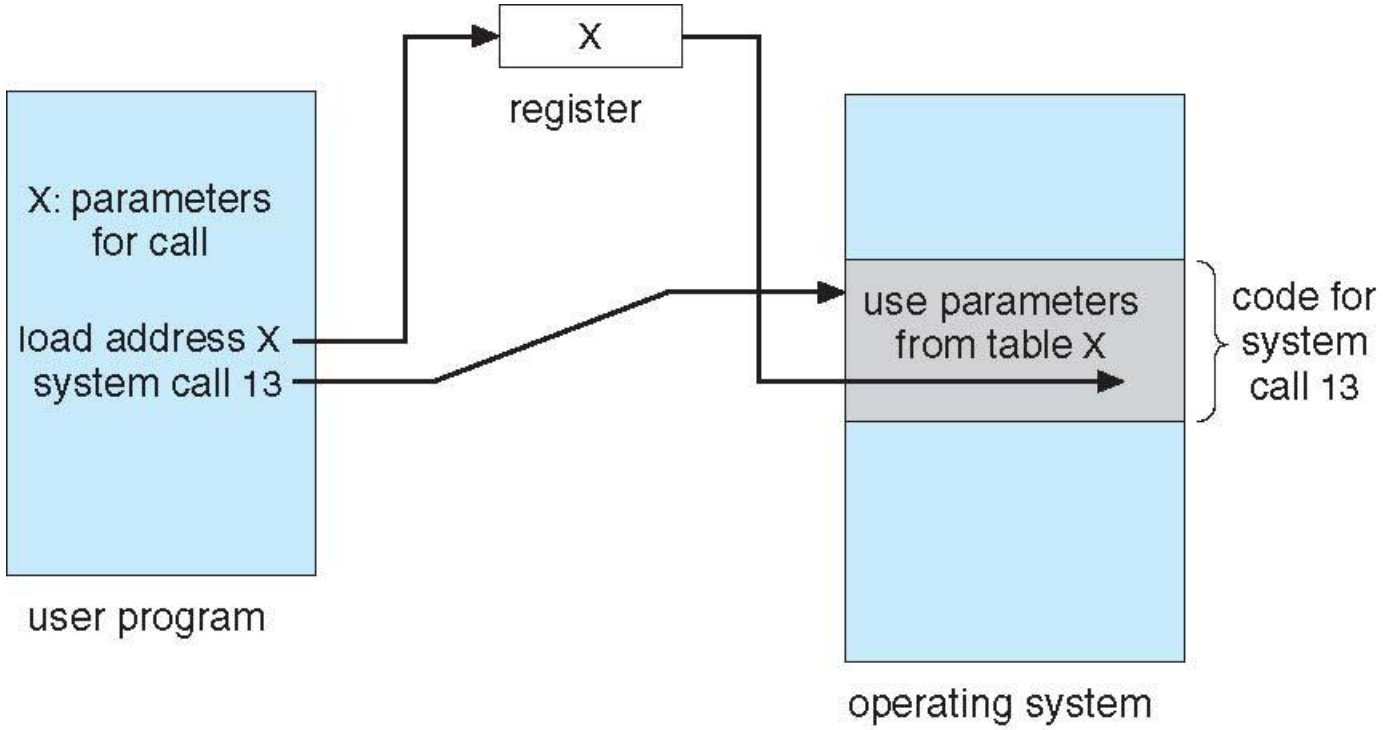
API – System Call – OS Relationship



System Call Parameter Passing

- Often, more information is required than simply identity of desired system call
  - Exact type and amount of information vary according to OS and call
- Three general methods used to pass parameters to the OS
  - Simplest: pass the parameters in registers
    - In some cases, may be more parameters than registers
  - Parameters stored in a block, or table, in memory, and address of block passed as a parameter in a register
    - This approach taken by Linux and Solaris
  - Parameters placed, or **pushed**, onto the **stack** by the program and **popped** off the stack by the operating system
  - Block and stack methods do not limit the number or length of parameters being passed

Parameter Passing via Table



Types of System Calls

- Process control
  - create process, terminate process
  - end, abort
  - load, execute
  - get process attributes, set process attributes
  - wait for time
  - wait event, signal event
  - allocate and free memory
  - Dump memory if error
  - **Debugger** for determining **bugs, single step** execution
  - **Locks** for managing access to shared data between processes

Types of System Calls

- File management
  - create file, delete file
  - open, close file
  - read, write, reposition
  - get and set file attributes
- Device management
  - request device, release device
  - read, write, reposition
  - get device attributes, set device attributes
  - logically attach or detach devices

Types of System Calls (Cont.)

- Information maintenance
  - get time or date, set time or date
  - get system data, set system data
  - get and set process, file, or device attributes
- Communications
  - create, delete communication connection
  - send, receive messages if **message passing model** to **host name** or **process name**
    - From **client** to **server**
  - **Shared-memory model** create and gain access to memory regions
  - transfer status information
  - attach and detach remote devices

Types of System Calls (Cont.)

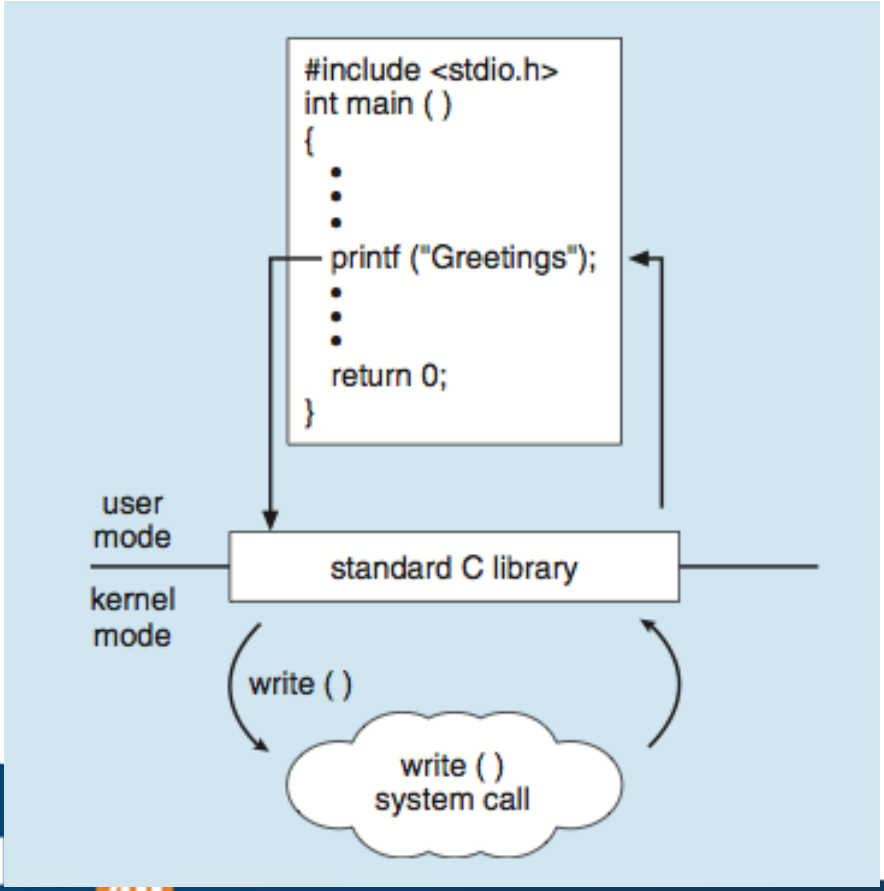
- Protection
  - Control access to resources
  - Get and set permissions
  - Allow and deny user access

Examples of Windows and Unix System Calls

	Windows	Unix
Process Control	CreateProcess() ExitProcess() WaitForSingleObject()	fork() exit() wait()
File Manipulation	CreateFile() ReadFile() WriteFile() CloseHandle()	open() read() write() close()
Device Manipulation	SetConsoleMode() ReadConsole() WriteConsole()	ioctl() read() write()
Information Maintenance	GetCurrentProcessID() SetTimer() Sleep()	getpid() alarm() sleep()
Communication	CreatePipe() CreateFileMapping() MapViewOfFile()	pipe() shmget() mmap()
Protection	SetFileSecurity() InitlializeSecurityDescriptor() SetSecurityDescriptorGroup()	chmod() umask() chown()

Standard C Library Example

- C program invoking printf() library call, which calls write() system call

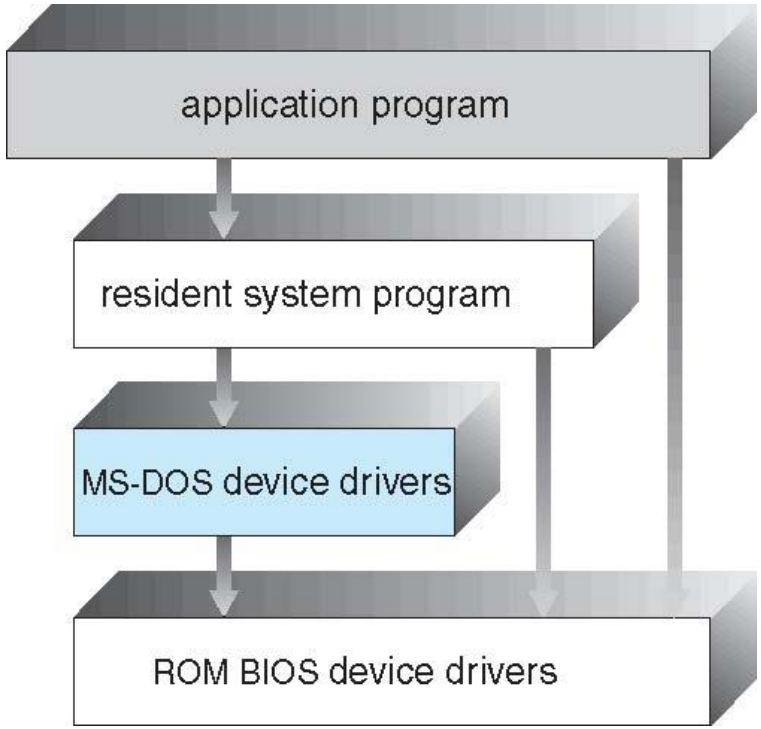


Operating System Structure

- General-purpose OS is very large program
- Various ways to structure ones
  - Simple structure – MS-DOS
  - More complex -- UNIX
  - Layered – an abstrcation
  - Microkernel -Mach

Simple Structure -- MS-DOS

- MS-DOS – written to provide the most functionality in the least space
  - Not divided into modules
  - Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated



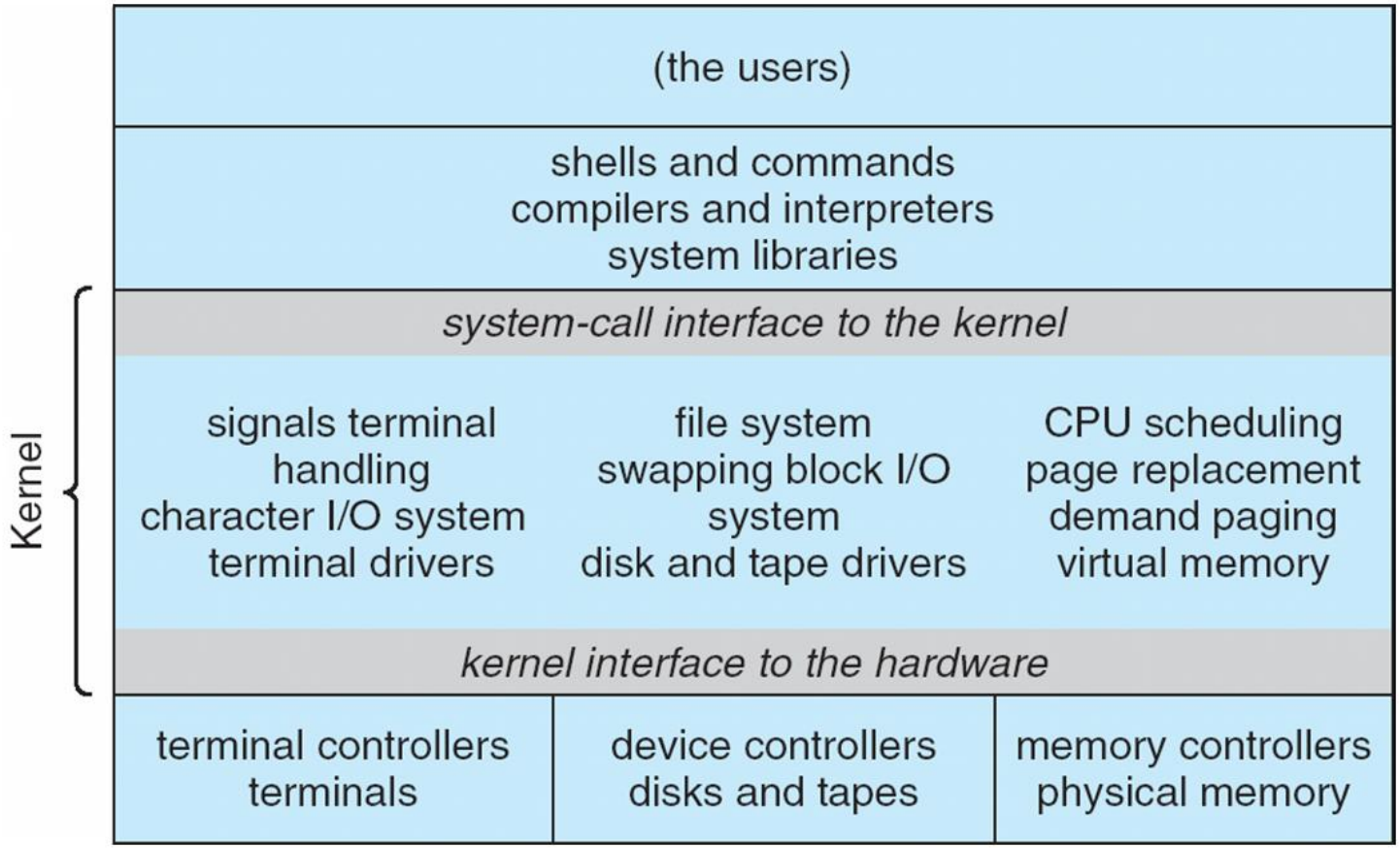
Non Simple Structure -- UNIX

UNIX – limited by hardware functionality, the original UNIX operating system had limited structuring. The UNIX OS consists of two separable parts

- Systems programs
- The kernel
  - Consists of everything below the system-call interface and above the physical hardware
  - Provides the file system, CPU scheduling, memory management, and other operating-system functions; a large number of functions for one level

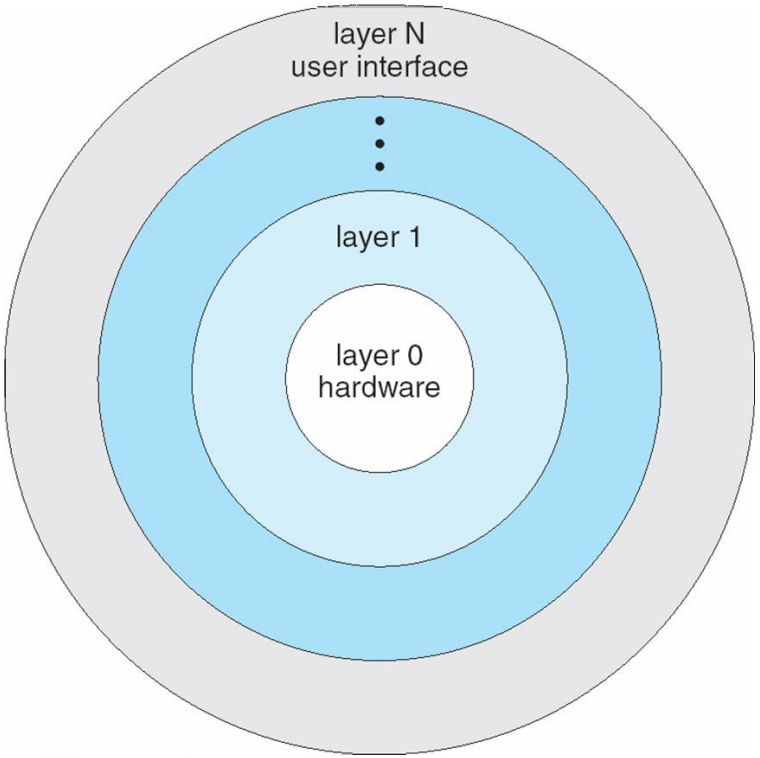
Traditional UNIX System Structure

Beyond simple but not fully layered



Layered Approach

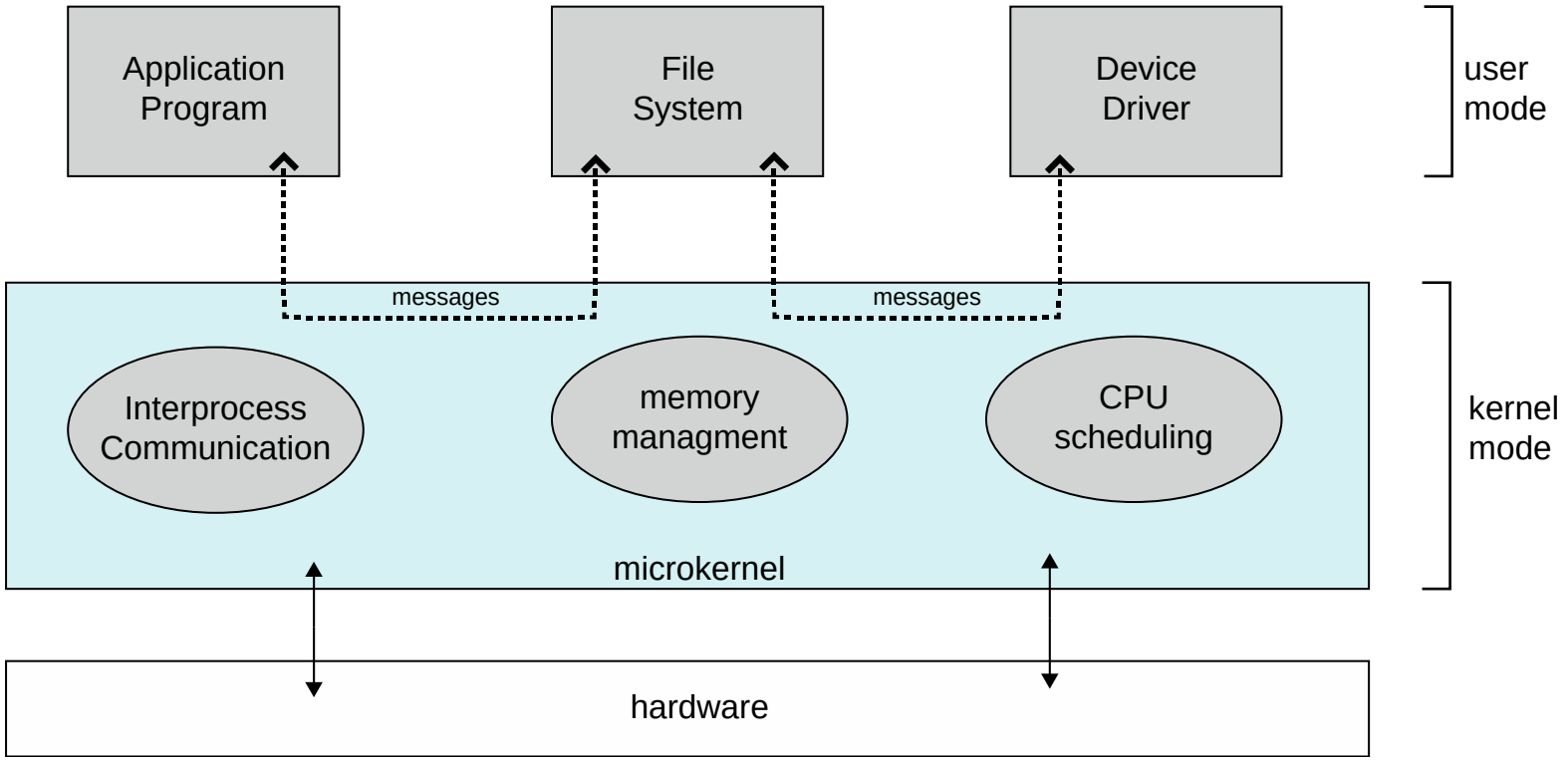
- The operating system is divided into a number of layers (levels), each built on top of lower layers. The bottom layer (layer 0), is the hardware; the highest (layer N) is the user interface.
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers



Microkernel System Structure

- Moves as much from the kernel into user space
- **Mach** example of **microkernel**
  - Mac OS X kernel (**Darwin**) partly based on Mach
- Communication takes place between user modules using **message passing**
- Benefits:
  - Easier to extend a microkernel
  - Easier to port the operating system to new architectures
  - More reliable (less code is running in kernel mode)
  - More secure
- Detriments:
  - Performance overhead of user space to kernel space communication

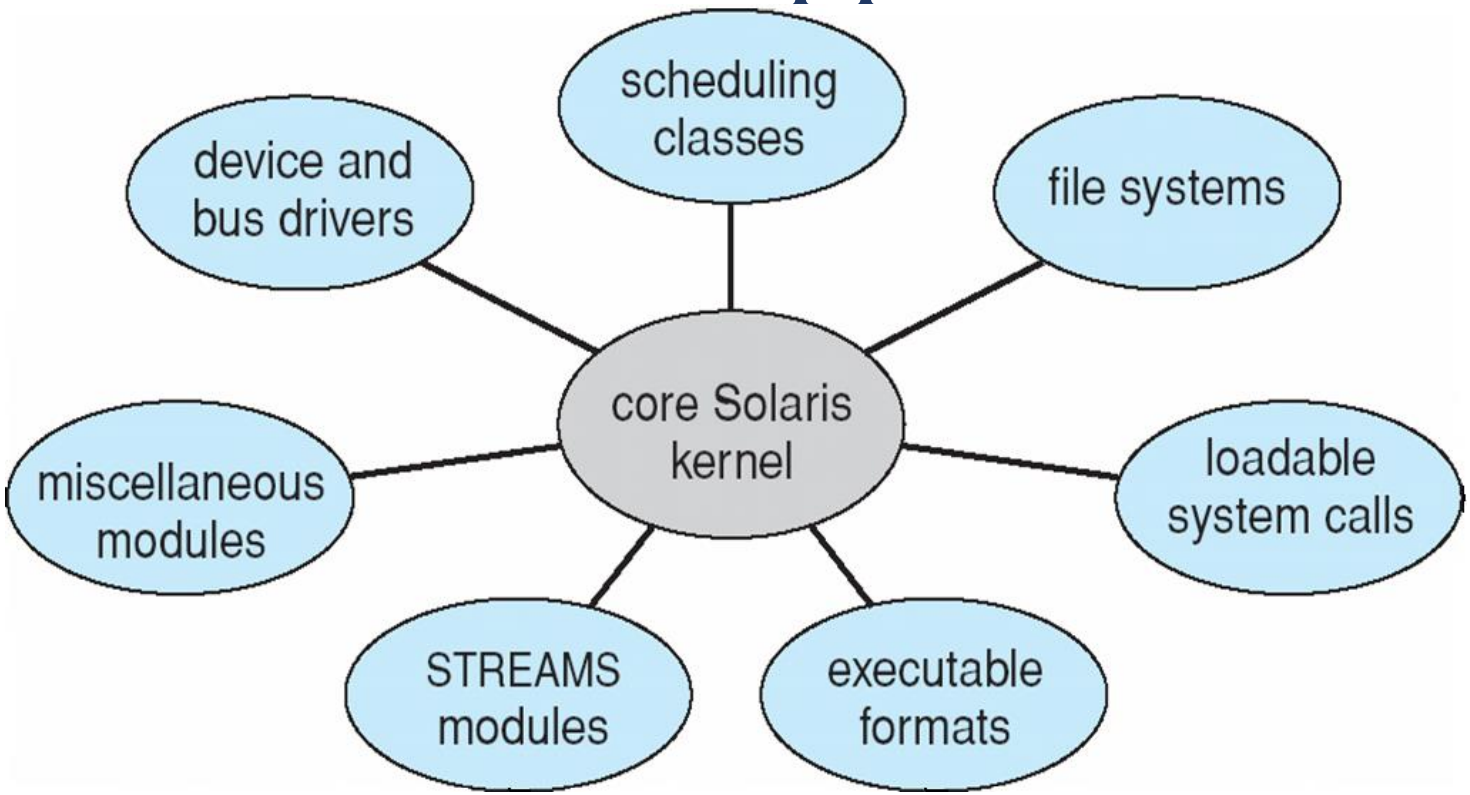
Microkernel System Structure



Modules

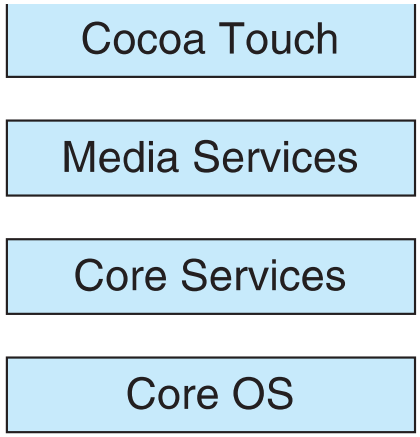
- Many modern operating systems implement **loadable kernel modules**
  - Uses object-oriented approach
  - Each core component is separate
  - Each talks to the others over known interfaces
  - Each is loadable as needed within the kernel
- Overall, similar to layers but with more flexible
  - Linux, Solaris, etc

Solaris Modular Approach



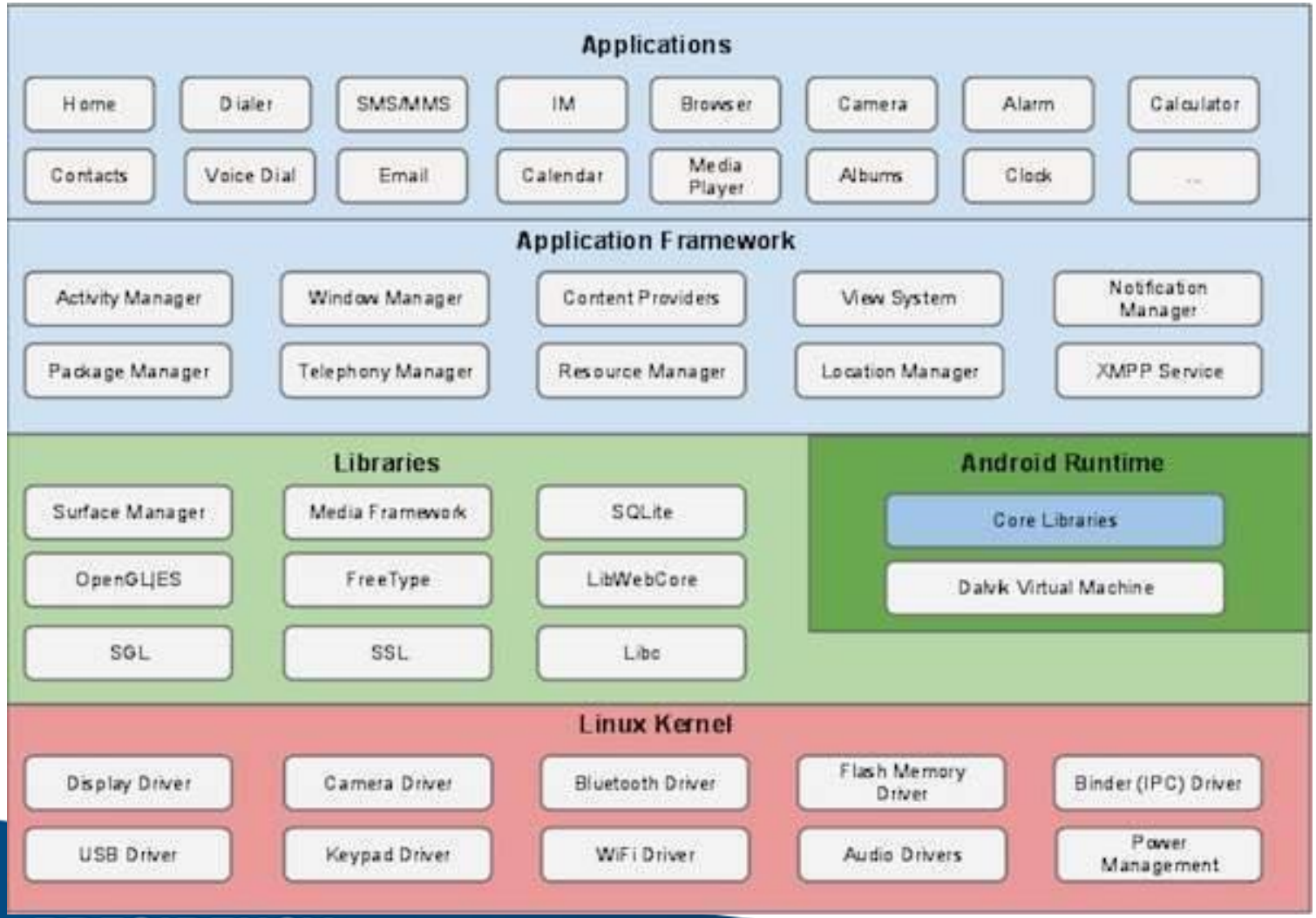
iOS

- Apple mobile OS for ***iPhone***, ***iPad***
  - Structured on Mac OS X, added functionality
  - Does not run OS X applications natively
    - Also runs on different CPU architecture (ARM vs. Intel)
  - **Cocoa Touch** Objective-C API for developing apps
  - **Media services** layer for graphics, audio, video
  - **Core services** provides cloud computing, databases
  - Core operating system, based on Mac OS X kernel



Android

- Developed by Open Handset Alliance (mostly Google)
  - Open Source
- Similar stack to IOS
- Based on Linux kernel but modified
  - Provides process, memory, device-driver management
  - Adds power management
- Runtime environment includes core set of libraries and Dalvik virtual machine
  - Apps developed in Java plus Android API
    - Java class files compiled to Java bytecode then translated to executable than runs in Dalvik VM
- Libraries include frameworks for web browser (webkit), database (SQLite), multimedia, smaller libc


Applications
Home
Dialer
SMS/MMS
IM
Browser
Camera
Alarm
Calculator
Contacts
Voice Dial
Email
Calendar
Media Player
Albums
Clock
...
Application Framework
Activity Manager
Window Manager
Content Providers
View System
Notification Manager
Package Manager
Telephony Manager
Resource Manager
Location Manager
XMPP Service
Libraries
Surface Manager
Media Framework
SQLite
OpenGL|ES
FreeType
LibWebCore
SGL
SSL
Libc
Android Runtime
Core Libraries
Dalvik Virtual Machine
Linux Kernel
Display Driver
Camera Driver
Bluetooth Driver
Flash Memory Driver
Binder (IPC) Driver
USB Driver
Keypad Driver
WiFi Driver
Audio Drivers
Power Management

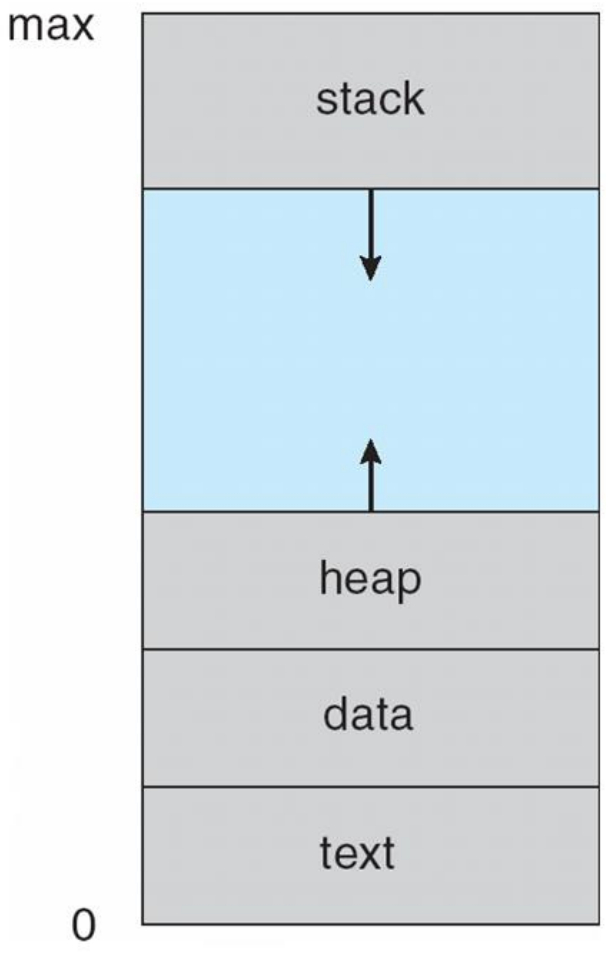
Process Concept

- An operating system executes a variety of programs:
  - Batch system – **jobs**
  - Time-shared systems – **user programs** or **tasks**
- **Process** – a program in execution; process execution must progress in sequential fashion
- Multiple parts
  - The program code, also called **text section**
  - Current activity including **program counter**, processor registers
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Data section** containing global variables
  - **Heap** containing memory dynamically allocated during run time

Process Concept (Cont.)

- Program is ***passive*** entity stored on disk (**executable file**), process is ***active***
  - Program becomes process when executable file loaded into memory
- Execution of program started via GUI mouse clicks, command line entry of its name, etc
- One program can be several processes
  - Consider multiple users executing the same program

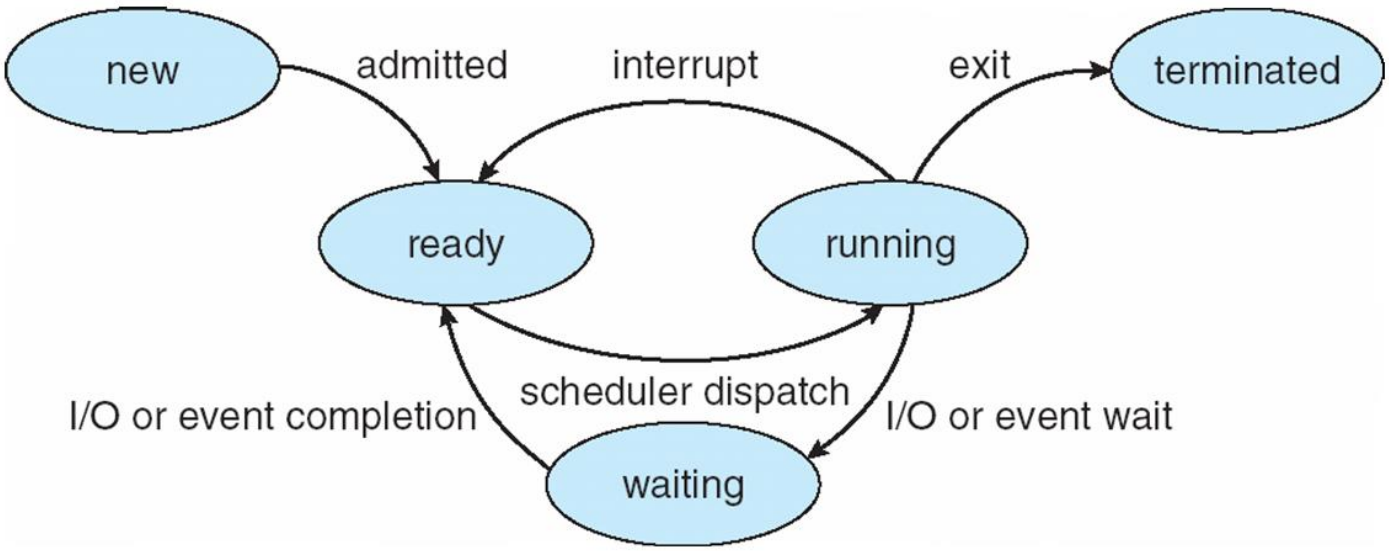
Process in Memory



Process State

- As a process executes, it changes **state**
  - **new**: The process is being created
  - **running**: Instructions are being executed
  - **waiting**: The process is waiting for some event to occur
  - **ready**: The process is waiting to be assigned to a processor
  - **terminated**: The process has finished execution

Diagram of Process State

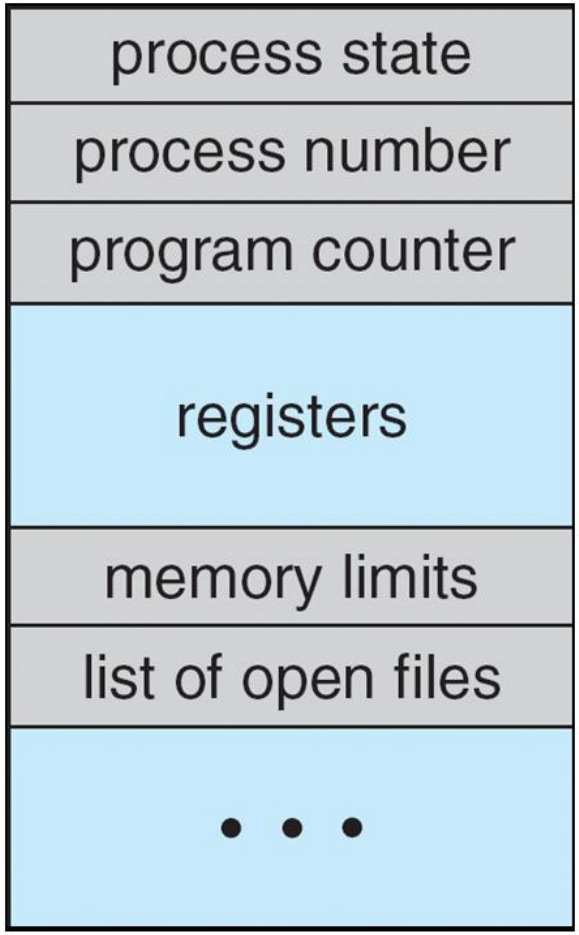


Process Control Block (PCB)

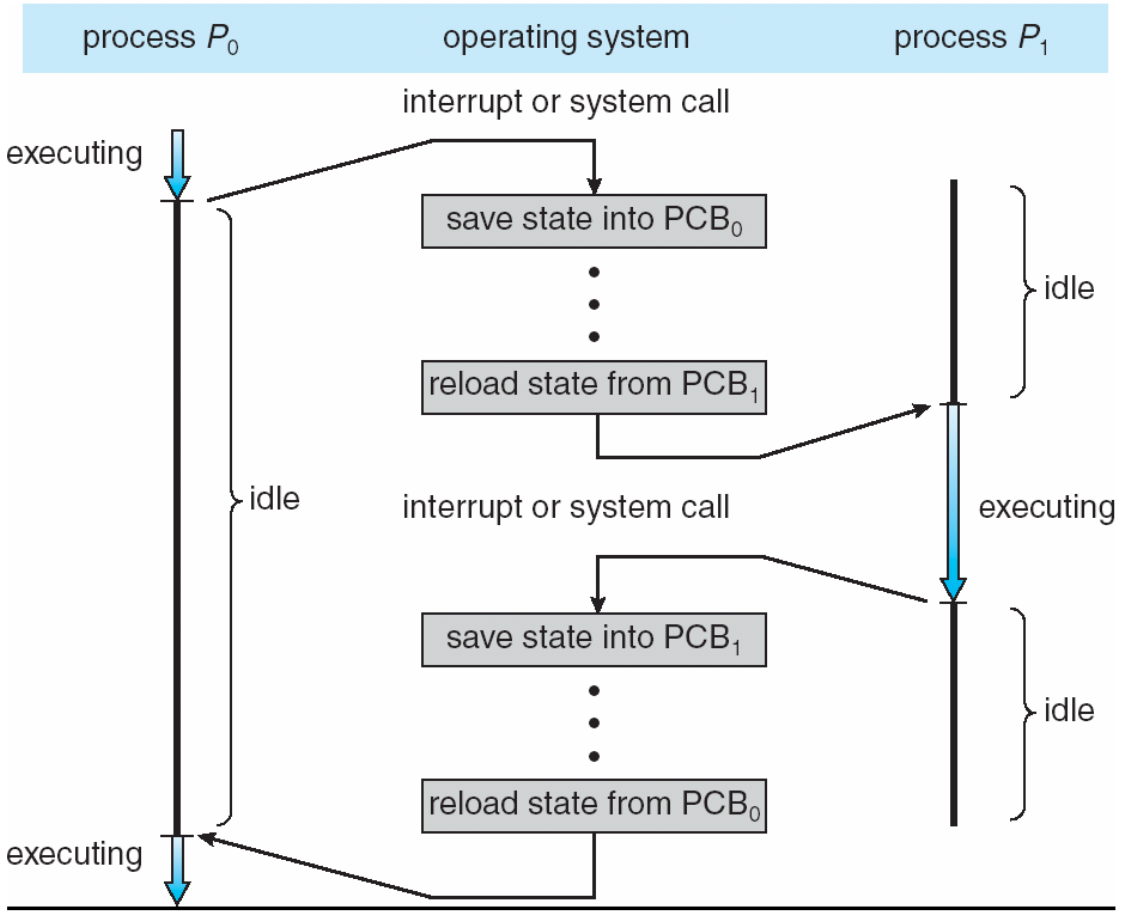
Information associated with each process

(also called **task control block**)

- Process state – running, waiting, etc
- Program counter – location of instruction to next execute
- CPU registers – contents of all process-centric registers
- CPU scheduling information- priorities, scheduling queue pointers
- Memory-management information – memory allocated to the process
- Accounting information – CPU used, clock time elapsed since start, time limits
- I/O status information – I/O devices allocated to process, list of open files



CPU Switch From Process to Process



Context Switch

- When CPU switches to another process, the system must **save the state** of the old process and load the **saved state** for the new process via a **context switch**
- **Context** of a process represented in the PCB
- Context-switch time is overhead; the system does no useful work while switching
  - The more complex the OS and the PCB ➔ the longer the context switch
- Time dependent on hardware support
  - Some hardware provides multiple sets of registers per CPU ➔ multiple contexts loaded at once

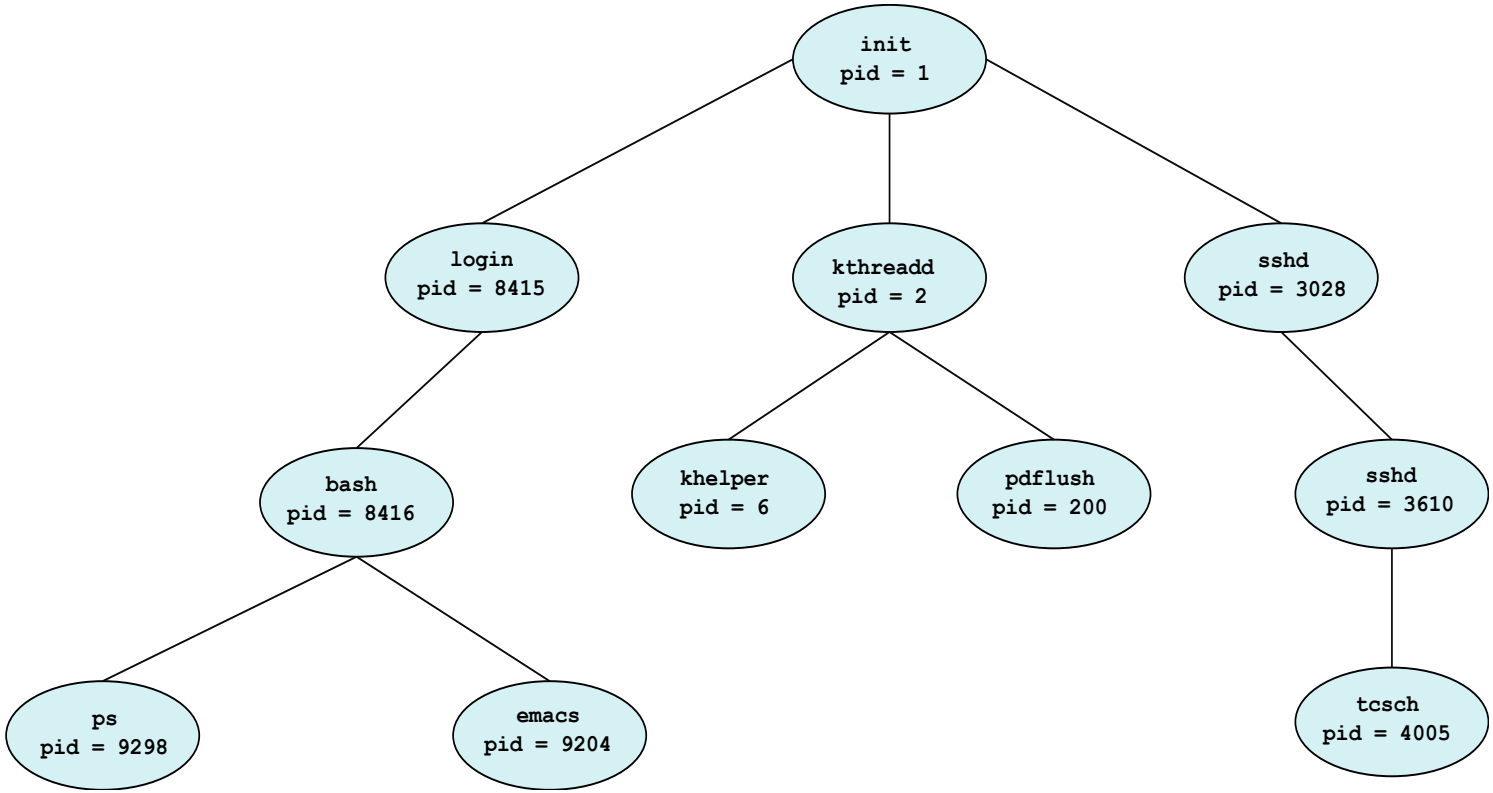
Operations on Processes

- System must provide mechanisms for:
  - process creation,
  - process termination,
  - and so on as detailed next

Process Creation

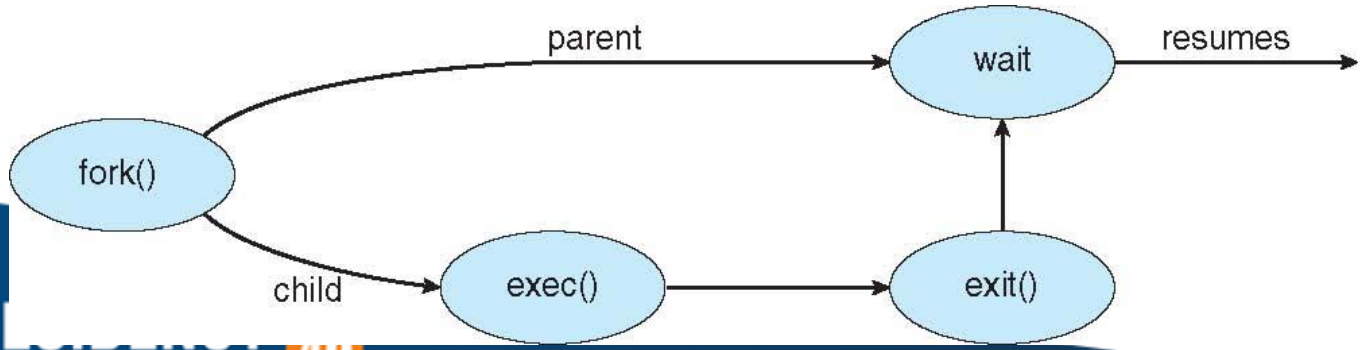
- **Parent** process create **children** processes, which, in turn create other processes, forming a **tree** of processes
- Generally, process identified and managed via a **process identifier** (**pid**)
- Resource sharing options
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources
- Execution options
  - Parent and children execute concurrently
  - Parent waits until children terminate

A Tree of Processes in Linux



Process Creation (Cont.)

- Address space
  - Child duplicate of parent
  - Child has a program loaded into it
- UNIX examples
  - **`fork()`** system call creates new process
  - **`exec()`** system call used after a **`fork()`** to replace the process' memory space with a new program



Process Termination

- Process executes last statement and then asks the operating system to delete it using the **exit()** system call.
  - Returns status data from child to parent (via **wait()**)
  - Process' resources are deallocated by operating system
- Parent may terminate the execution of children processes using the **abort()** system call. Some reasons for doing so:
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - The parent is exiting and the operating systems does not allow a child to continue if its parent terminates

Process Termination

- Some operating systems do not allow child to exists if its parent has terminated. If a process terminates, then all its children must also be terminated.
  - **cascading termination.** All children, grandchildren, etc. are terminated.
  - The termination is initiated by the operating system.
- The parent process may wait for termination of a child process by using the **wait()**system call**.** The call returns status information and the pid of the terminated process

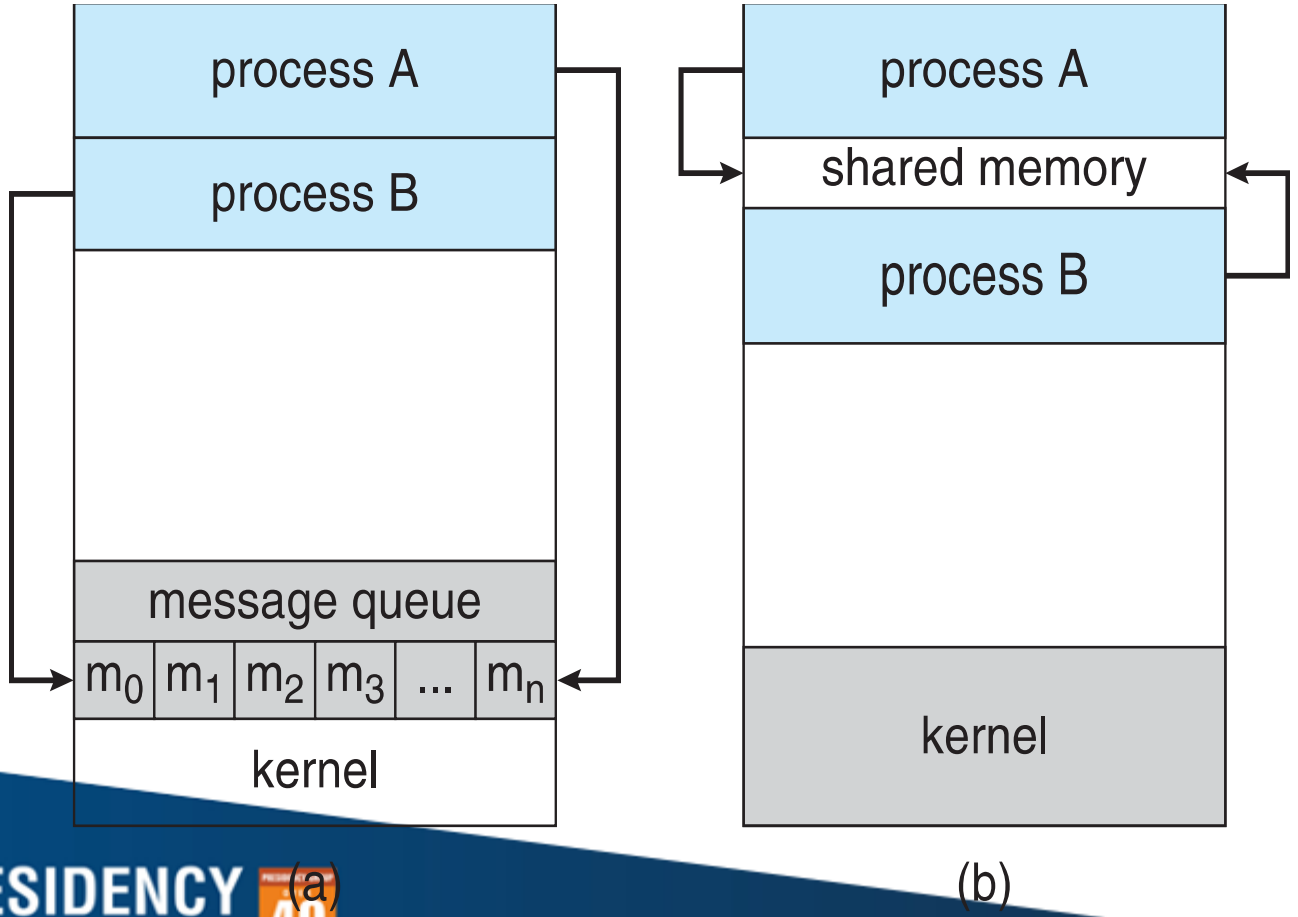
  pid = wait(&status);
- If no parent waiting (did not invoke **wait()**) process is a **zombie**
- If parent terminated without invoking **wait** , process is an **orphan**

Interprocess Communication

- Processes within a system may be ***independent*** or ***cooperating***
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **interprocess communication** (**IPC**)
- Two models of IPC
  - **Shared memory**
  - **Message passing**

Communications Models

(a) Message passing. (b) shared memory.



Interprocess Communication – Shared Memory

- An area of memory shared among the processes that wish to communicate
- The communication is under the control of the users processes not the operating system.
- Major issues is to provide mechanism that will allow the user processes to synchronize their actions when they access shared memory.

Producer-Consumer Problem

- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process
  - **unbounded-buffer** places no practical limit on the size of the buffer
  - **bounded-buffer** assumes that there is a fixed buffer size

Bounded-Buffer – Shared-Memory Solution

- Shared data

```
#define BUFFER_SIZE 10
typedef struct {
   . . .
} item;

item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

- Solution is correct, but can only use BUFFER_SIZE-1 elements

Bounded-Buffer – Producer

```
item next_produced;
while (true) {
        /* produce an item in next produced */
        while (((in + 1) % BUFFER_SIZE) == out)
                ; /* do nothing */
        buffer[in] = next_produced;
        in = (in + 1) % BUFFER_SIZE;
}
```

Bounded Buffer – Consumer

```
item next_consumed;

while (true) {
        while (in == out)
                ; /* do nothing */
        next_consumed = buffer[out];

        out = (out + 1) % BUFFER_SIZE;


        /* consume the item in next consumed */

}
```

Interprocess Communication – Message Passing

- Mechanism for processes to communicate and to synchronize their actions
- Message system – processes communicate with each other without resorting to shared variables
- IPC facility provides two operations:
  - **`send`**(*message*)
  - **`receive`**(*message*)
- The *message* size is either fixed or variable

Message Passing (Cont.)

- If processes *P* and *Q* wish to communicate, they need to:
  - Establish a ***communication link*** between them
  - Exchange messages via send/receive

- Implementation of communication link
  - Direct or indirect
  - Synchronous or asynchronous
  - Automatic or explicit buffering

Direct Communication

- Processes must name each other explicitly:
  - **`send`** (*P, message*) – send a message to process P
  - **`receive`**(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link
  - The link may be unidirectional, but is usually bi-directional

Indirect Communication

- Messages are directed and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes
  - Each pair of processes may share several communication links
  - Link may be unidirectional or bi-directional

Indirect Communication

- Operations
  - create a new mailbox (port)
  - send and receive messages through mailbox
  - destroy a mailbox
- Primitives are defined as:

  `send`(*A, message*) – send a message to mailbox A

  `receive`(*A, message*) – receive a message from mailbox A

Indirect Communication

- Mailbox sharing
  - P_1, P_2, and P_3 share mailbox A
  - P_1, sends; P_2 and P_3 receive
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes
  - Allow only one process at a time to execute a receive operation
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

Synchronization

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** -- the sender is blocked until the message is received
  - **Blocking receive** -- the receiver is blocked until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** -- the sender sends the message and continue
  - **Non-blocking receive** -- the receiver receives:
    - A valid message, or
    - Null message
  - Different combinations possible
    - If both send and receive are blocking, we have a **rendezvous**

Buffering

- Queue of messages attached to the link.
- implemented in one of three ways
  1. Zero capacity – no messages are queued on a link.
     Sender must wait for receiver (rendezvous)
  2. Bounded capacity – finite length of *n* messages
     Sender must wait if link full
  3. Unbounded capacity – infinite length
     Sender never waits