Operating Systems: CSE 3204

Chapter One

Introduction to Operating System and its Structures

(Materials partly taken from Operating System Concepts by Silberschatz, Galvin and Gagne, 2005 – 7th Edition, chapter 1-2)

Lecture 1: Introduction to Operating Systems

Contents

- What operating systems do
- Computer system structure
- Computer system organization
- Operating system operations
- Computing environments
- Operating system-views
- **Reading Assignments**

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.
  - It's a **resource allocator** →Manages all resources
    - Decides between conflicting requests for efficient and fair resource use
  - It's a **control program**
    - Controls the execution of programs to prevent errors and improper use of the computer

Operating System Definition (Contd.)

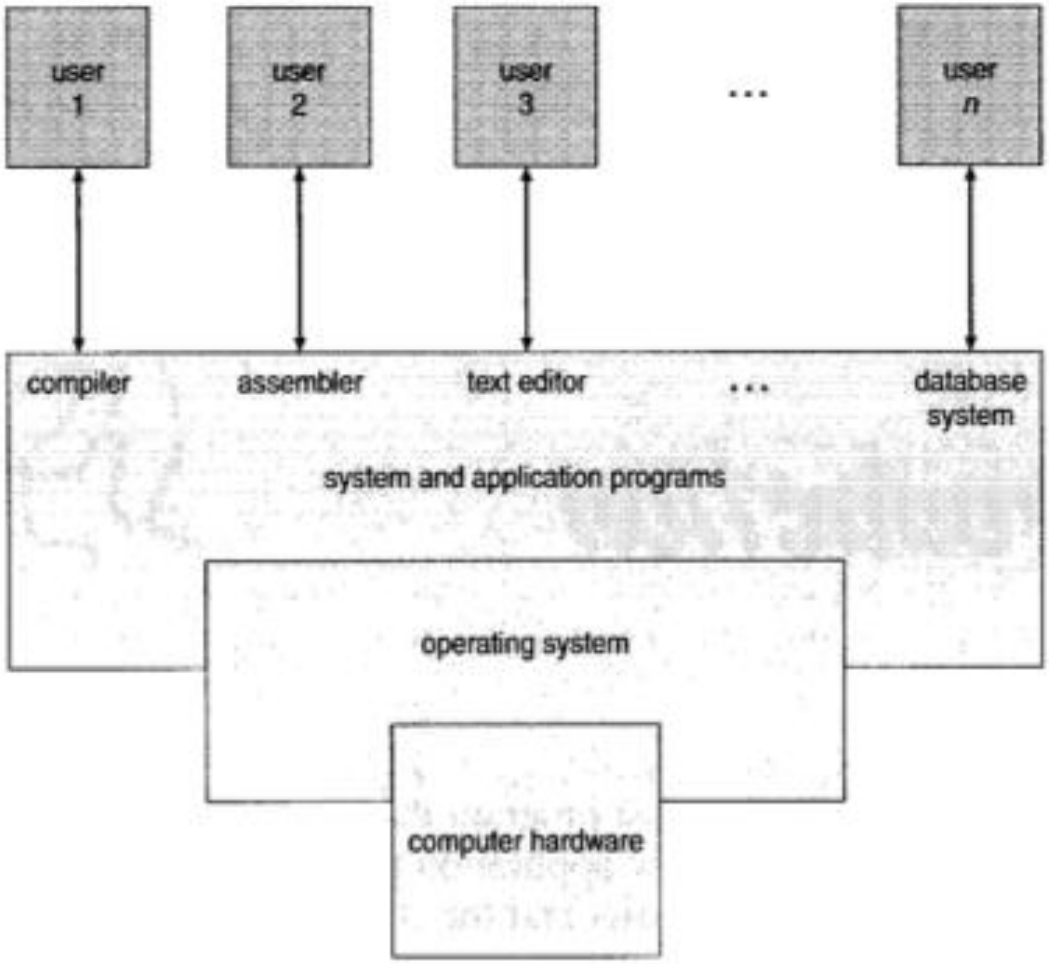
- Operating system is the first layer of software loaded into the computer working memory.
  - An interface between the user, the computer software and the hardware resources.
- It provides a software platform on top of which other program can run.

- "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 System structure

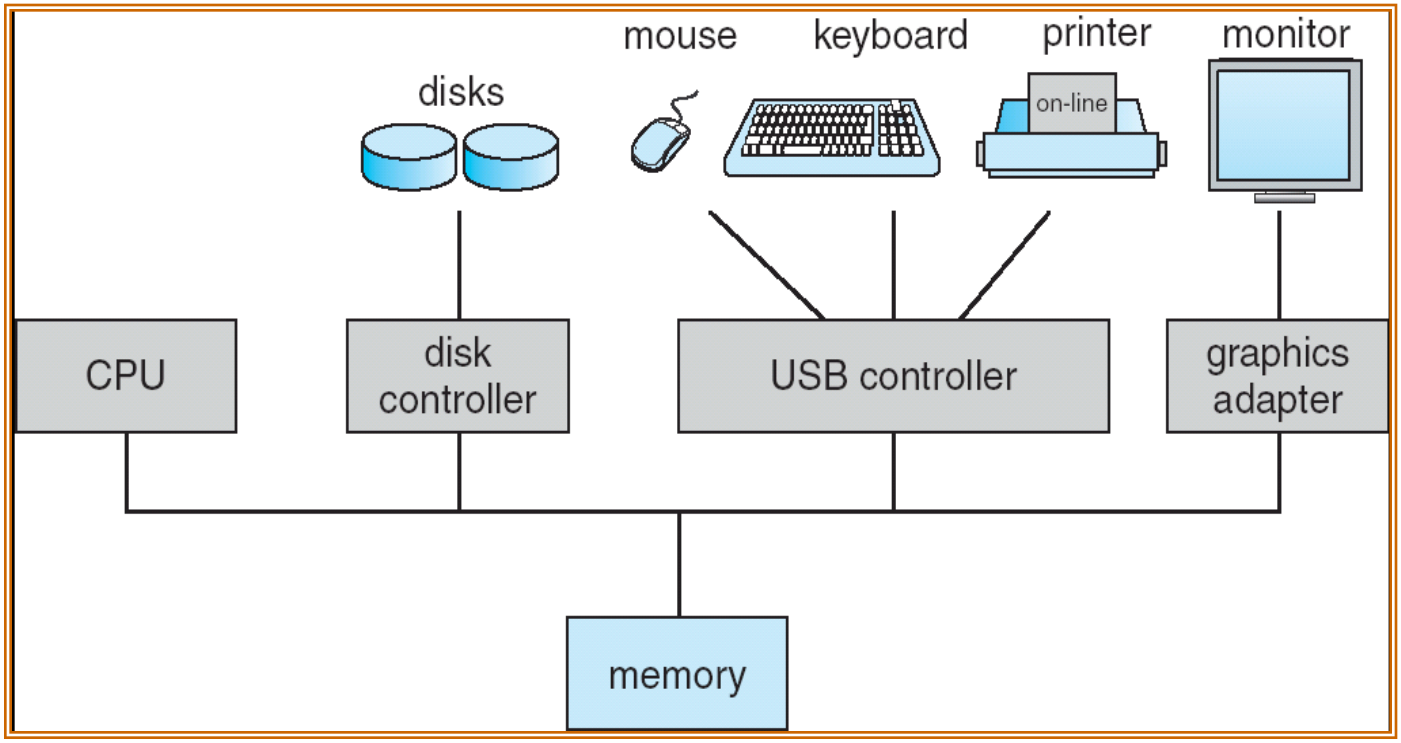
Components of a computer:

- **User**
  - machine/person /computer
- **Application programs**
  - a special software used to solve particular problems of users
- **Operating system**
  - Controls and coordinates use of hardware among various users and applications
- **Computer hardware**
  - I/O device, Memory, CPU



Computer System Organization

- 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*.

Computer Startup

- **bootstrap program** is loaded at power-up or reboot
  - Typically stored in ROM or EEPROM (Electronic Erasable Programmable Read Only Memory), generally known as **firmware,** within the computer hardware
  - Initializes all aspects of the system
  - Loads operating system kernel and starts execution

Interrupts

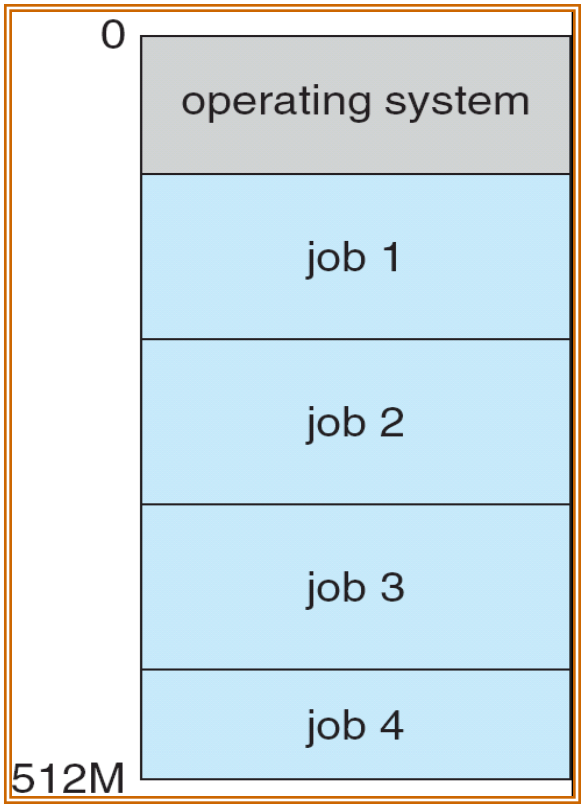
- An interruption of the normal sequence of execution
- Improves processing efficiency
- Allows the processor to execute other instructions while an I/O operation is in progress
- A suspension of a process caused by an event external to that process and performed in such a way that the process can be resumed
- **Interrupt Handler:**
  - A program that determines nature of the interrupt and performs whatever actions are needed
  - Control is transferred to this program
  - Generally part of the operating system

Common Functions of Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the *interrupt vector*, which contains the addresses of all the service routines.
- Interrupt architecture must save the address of the interrupted instruction.
- Incoming interrupts are *disabled* while another interrupt is being processed to prevent a *lost interrupt*.
- A ***trap*** is a software-generated interrupt caused either by an error or a user request.
- An operating system is *interrupt* driven.

Operating System Structure

- **Multiprogramming** is needed for efficiency
  - A single user cannot keep CPU and I/O devices busy at all times
  - Multiprogramming increases CPU utilization by organizing 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



Memory Layout for multiprogramed system

Operating System Structure (contd.)

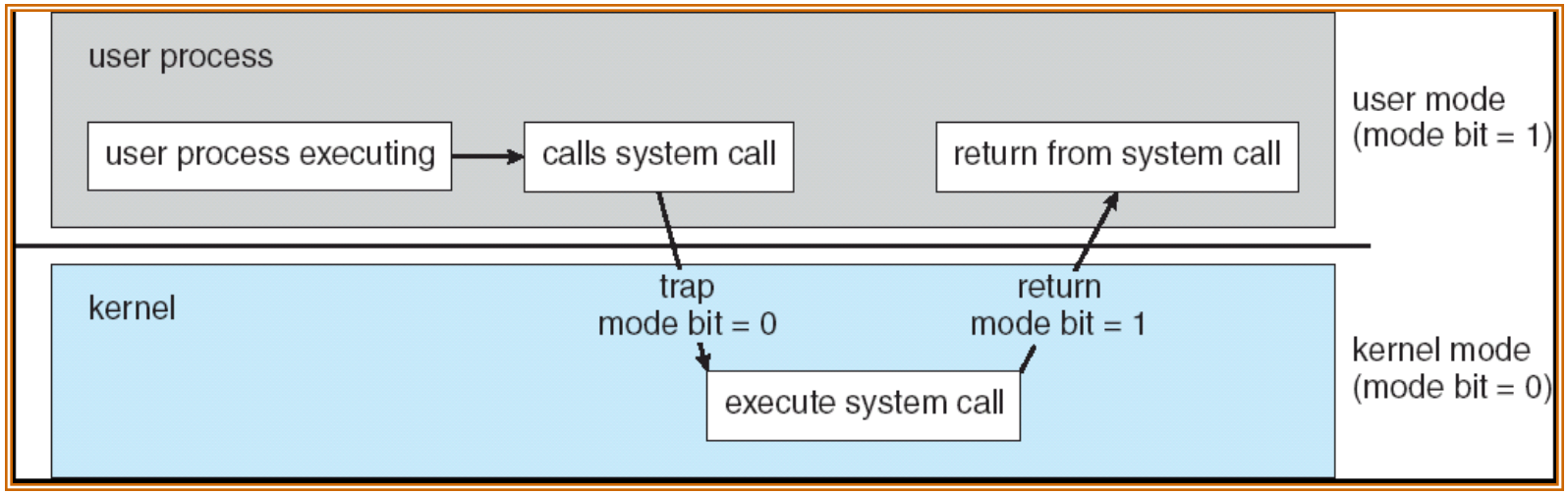
- **Timesharing (multitasking)** is a logical extension of multiprogramming in which CPU executes jobs by switching among them
  - The switch occurs so frequently that users can interact with each job while it is running, creating an **interactive** computing
  - The user gives instruction to the operating system or the program running using an input device and waits for immediate result on an output device
    - Therefore, the **response time** should be < 1 second
  - Since the time a command/action takes in such systems is short, little CPU time is needed for each user
    - This allows many users to share the computer simultaneously
  - 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

Operating-System Operations

- Interrupt driven by hardware
- Software (program) 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
- In order to ensure an appropriate execution of operating system code and user defined code, most systems provide a hardware support
- **Dual-mode** operation allows OS to protect itself and other system components
  - **User mode:** execution done on behalf of a user.
  - **Monitor mode (also kernel mode or system mode) :** execution done on behalf of operating system.
- **Mode bit** added to computer hardware to indicate the current mode: monitor (0) or user (1).
    - Some instructions designated as **privileged** are only executable in kernel mode
    - System call changes mode to kernel, return from call resets it to user mode

Transition from User to Kernel Mode

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



Computing Environments

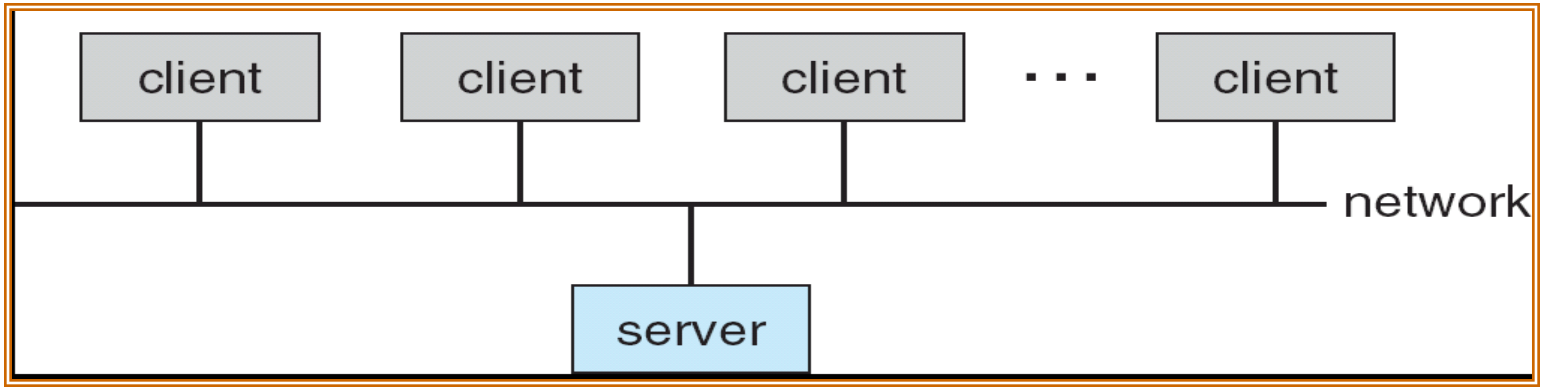
- **Computing Environment** is a collection of computer hardware, software, machines and networks that support the processing and interaction of electronic information to solve different computational problems.
- There are four basic environment
  - Traditional
  - Client Server
  - Peer-to-Peer (P2P)
  - Web-based

Computing Environments (contd.)

- **Traditional**
  - Office environment
    - PCs connected to a network, terminals attached to mainframe or minicomputers providing batch and timesharing
    - Now portals allowing networked and remote systems access to same resources
  - Home networks
    - Used to be single system, then modems
    - Now firewalled, networked

Computing Environments (Cont.)

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



Peer-to-Peer Environment

- Another model of distributed system
- P2P does not distinguish clients and servers
  - Instead all nodes are considered peers
  - Each node may 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*

Web Based Environment

- The Web has become ubiquitous
- PCs most prevalent devices
- More devices becoming networked to allow web access
- New category of devices to manage web traffic among similar servers: **load balancers**
- Use of operating systems like Windows 95, client-side, have evolved into Linux and Windows XP, which can be clients and servers

Special Purpose Systems

Real-time embedded systems

•These systems have fixed time constraint, so that their operations should be finished with in that time

•Embedded computers are commonly found everywhere (at home, in industries, manufacturing robots, care engines, etc)

•They monitor and control devices and usually they have no or little user interface

•Systems that control scientific experiments, industry processes, home appliances etc are real-time systems

Multi-media systems

• Handles multimedia data (video, audio) in addition to conventional data (text files, programs, spreadsheets etc

Hand-held

• Includes personal digital assistants (PDAs) like pocket PCs and palm PCs and cellular telephones

•They use special-purpose embedded operating systems

Operating-System View

There are several points to view Operating Systems:

- Functional view (what it does)
- Components view (Designers view)
- Services view (Users/Programmers view)
- Structure view (How it is implemented)

Functional view (What it does)

- Program execution and handling
  - Starting programs, managing their execution and communicating their results.
- I/O operations
  - Mechanisms for initiating and managing I/O
- File-system Management
  - Creating, maintaining and manipulating files
- Communications
  - Between processes of the same user
    - Such as sending result of input request to a user program
  - Between different users

Functional view (…)

- Exception detection and handling
  - Protection related issues
  - Safety in the case of power failures via backups.
  - Detecting undesirable state such as printers out of paper.
- Resource allocation
  - Includes processor and I/O scheduling, memory management
- Accounting
  - To track users usage of resources for billing and statistical reasons
- Protection
  - Maintaining integrity of user's data
  - Integrity checks to keep out unauthorized users
  - Maintaining logs of incorrect attempts

Component view: Processes

- A process is
  - 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*.
  - Dynamic entity created by the execution of the program.
- Processes may play different roles
  - User processes
  - OS (system) processes
- A single process can swap other processes
  - A computation requires typically many processes
    - Shell, one or more user processes, one or more system processes

Component view: Process management

- **Operations:**
  - Creation and termination
  - Suspension and resumption
    - Due to interrupts, context switches
  - Synchronizing processes
    - Making sure that a process that is waiting on an I/O waits till it is completed and does not wait forever, i.e., wakes-up soon after an I/O process terminates.
  - Communication
    - Between two processes enabling them to cooperate.
  - Deadlock detection and avoidance.

Component view: Storage management

- Managing main memory
  - Allocating main memory to active processes
    - Maintaining a map of allocated vs. free memory
  - De-allocating currently used memory to make a room for other processes.
- Managing secondary storage
  - Managing the free sectors/tracks on the disk
  - Allocating this storage to programs
  - Scheduling access requests to the disk

Component view: I/O Management

- Devices
  - Device drivers
  - Accepting an I/O request and invoking appropriate device driver
  - Buffering, caching, spooling
- Files
  - Non-volatile representation of users/system programs and data.
  - **File systems**
    - A file is a collection of related information defined by its creator.
    - Support logical organization of data that the user might want to see
    - Map data onto the physical storage devices and orchestrate their access and update.
  - **Operations**
    - Creation, manipulation and deletion of files and directories
    - Moving files from primary to secondary storage while maintaining structure.
    - Interaction with the memory manager
    - Backup and protection

Component view: Networking

- Support to communication in a distributed system
  - FTP
  - http
  - Network file system

Component view: Protection

- Controlling the access of programs, processes, or users to the resources defined by the computer system.

Services view

1. **Command Interpreters**
   - User interface between users and the kernel
2. **System calls**
   - Programming interface to the services provided by the OS
   - Typically written in high level language like C or C++
   - Mostly accessed by programs via a high-level **Application Program 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)
3. **System programs**

- System programs provide convenient environment for program execution and development.

Services View (contd.)

System programs (contd.)

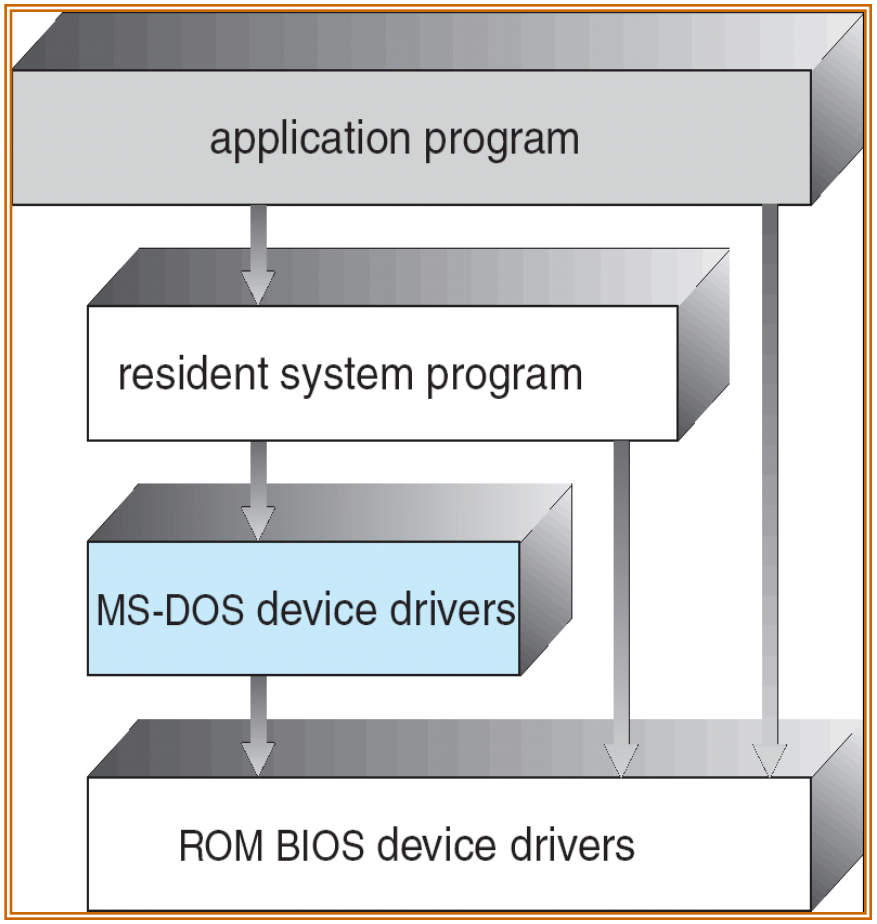
- Some are user interfaces to system calls; some are more complex.
- Each **system call** is usually supported by a system program.
- **They can be divided into:**
  - File manipulation
  - Status information
  - File modification
  - Programming language support
  - Program loading and execution
  - Communications
  - Application programs

Shell: an OS interface

- Program that sits on the kernel as an interface between users and the kernel.
- It is a command interpretor and also has programming capability of its own
- Interactive access to the OS system calls
  - copy from File to File
- Contains a simple programming language
- Popularized by UNIX
  - Before UNIX: JCL, OS CLs (command languages)
  - Bourne shell, C shell (csh), Korn shell (ksh), Bourne-again shell (bash), etc.

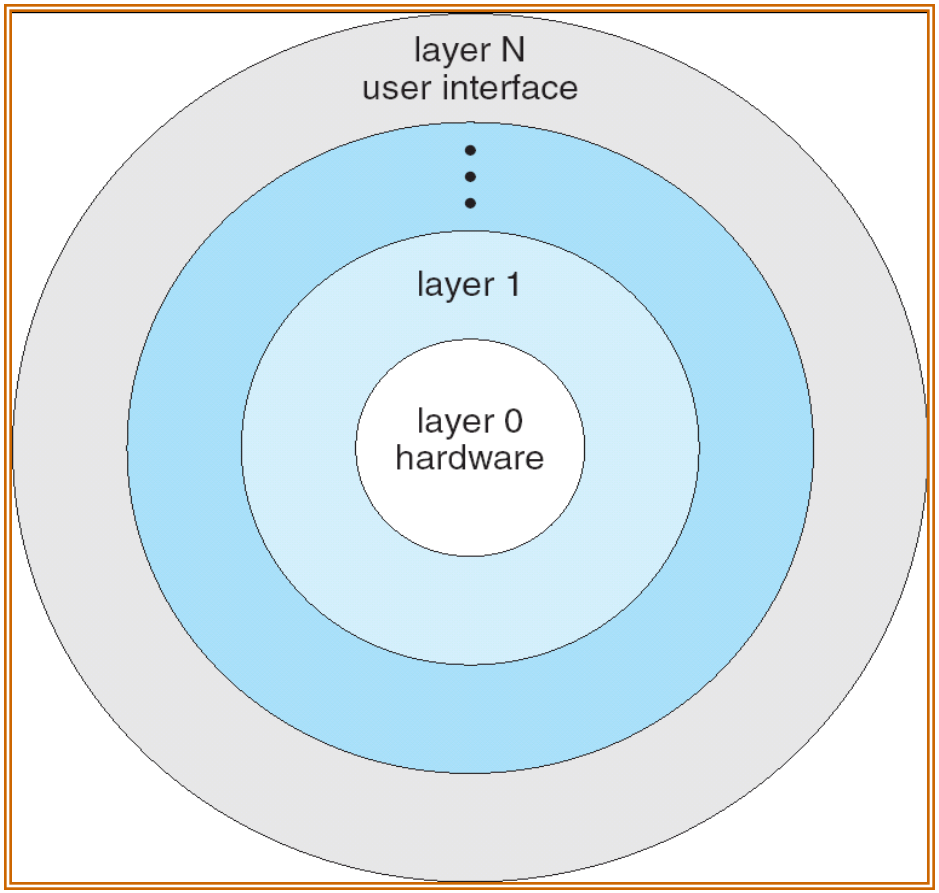
Structure View: Simple Structure

- 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
  - MSDOS is vulnerable to errant (or malicious) programs



Structure View: 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.

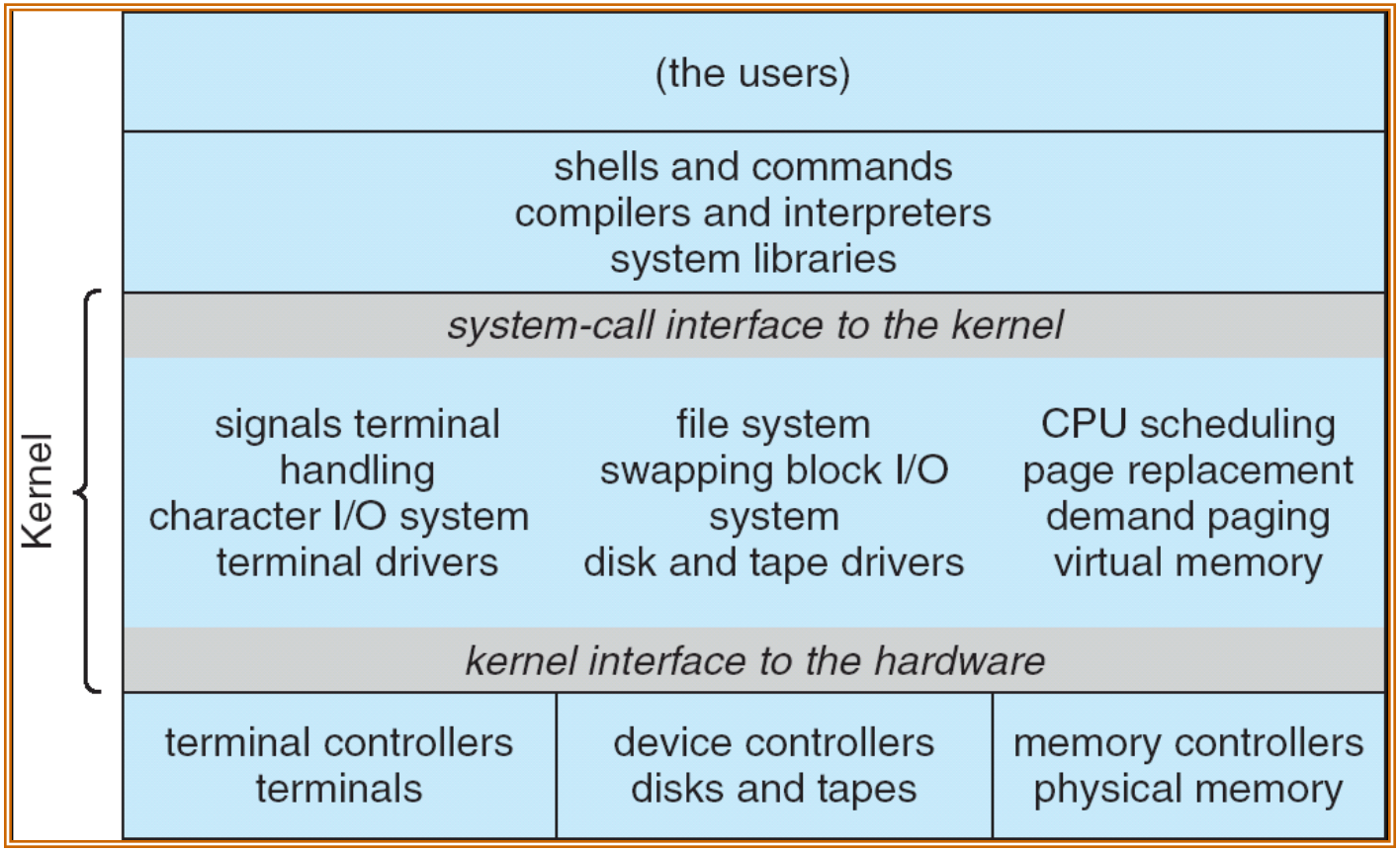


- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers

Structure View: Layered Approach

- 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

Structure View: Layered Approach

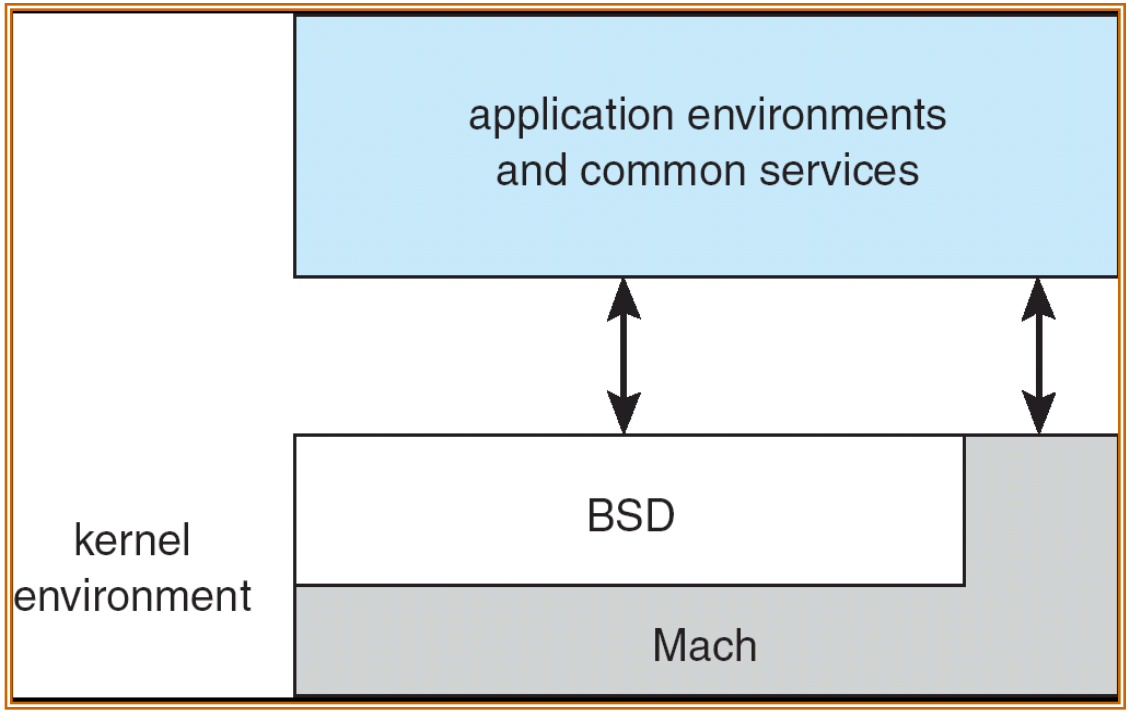


UNIX System Structure

Structure View: Microkernel

- Moves as much from the kernel into "*user*" space
- 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

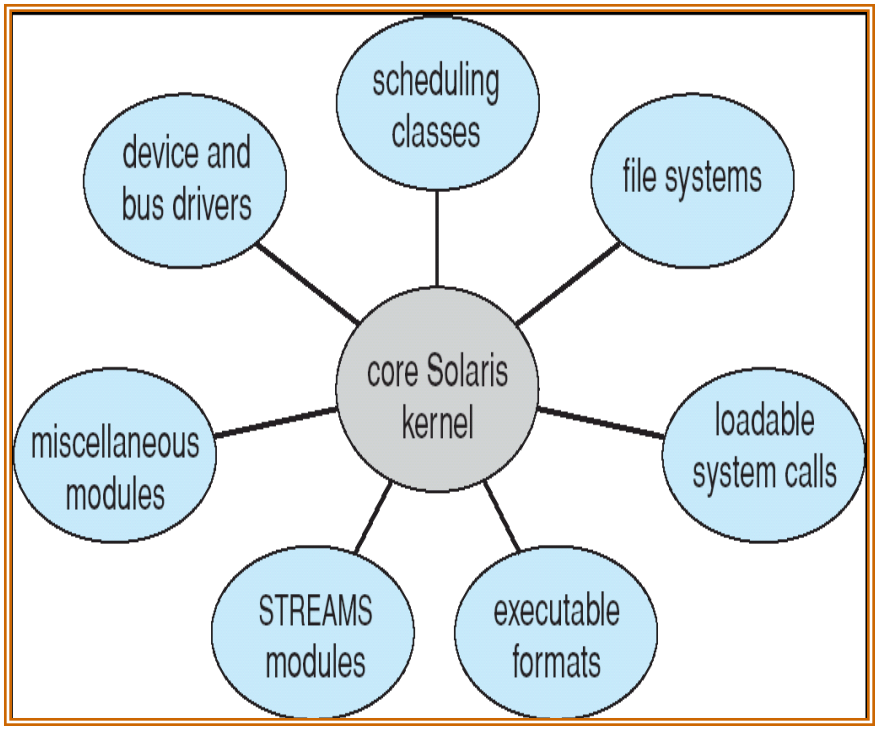
Structure View: Microkernel (contd.)



Mac OS X Structure

Structure View: Modules

- Most modern operating systems implement 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 nature

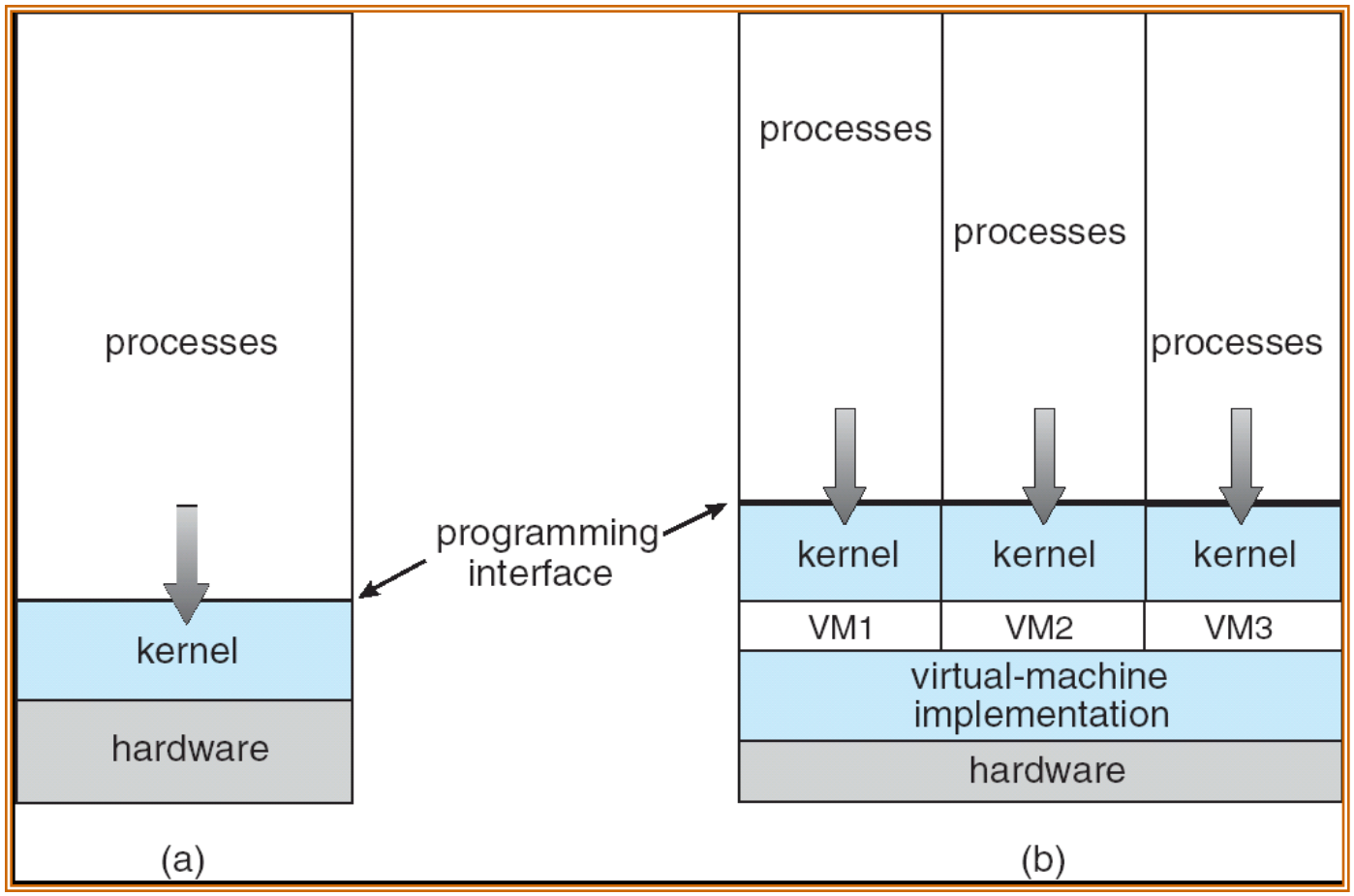


Solaris Modular Approach

Structure View: Virtual Machines

- A **virtual machine** takes the layered approach to its logical conclusion. It treats hardware and the operating system kernel as though they were all hardware
- A virtual machine provides an interface *identical* to the underlying bare hardware
- The operating system creates the illusion of multiple processes, each executing on its own processor with its own (virtual) memory
- The resources of the physical computer are shared to create the virtual machines
  - CPU scheduling can create the appearance that users have their own processor
  - Spooling and a file system can provide virtual card readers and virtual line printers
  - A normal user time-sharing terminal serves as the virtual machine operator's console

Structure View: Virtual Machines (contd.)



(a) Non virtual machine (b) virtual machine

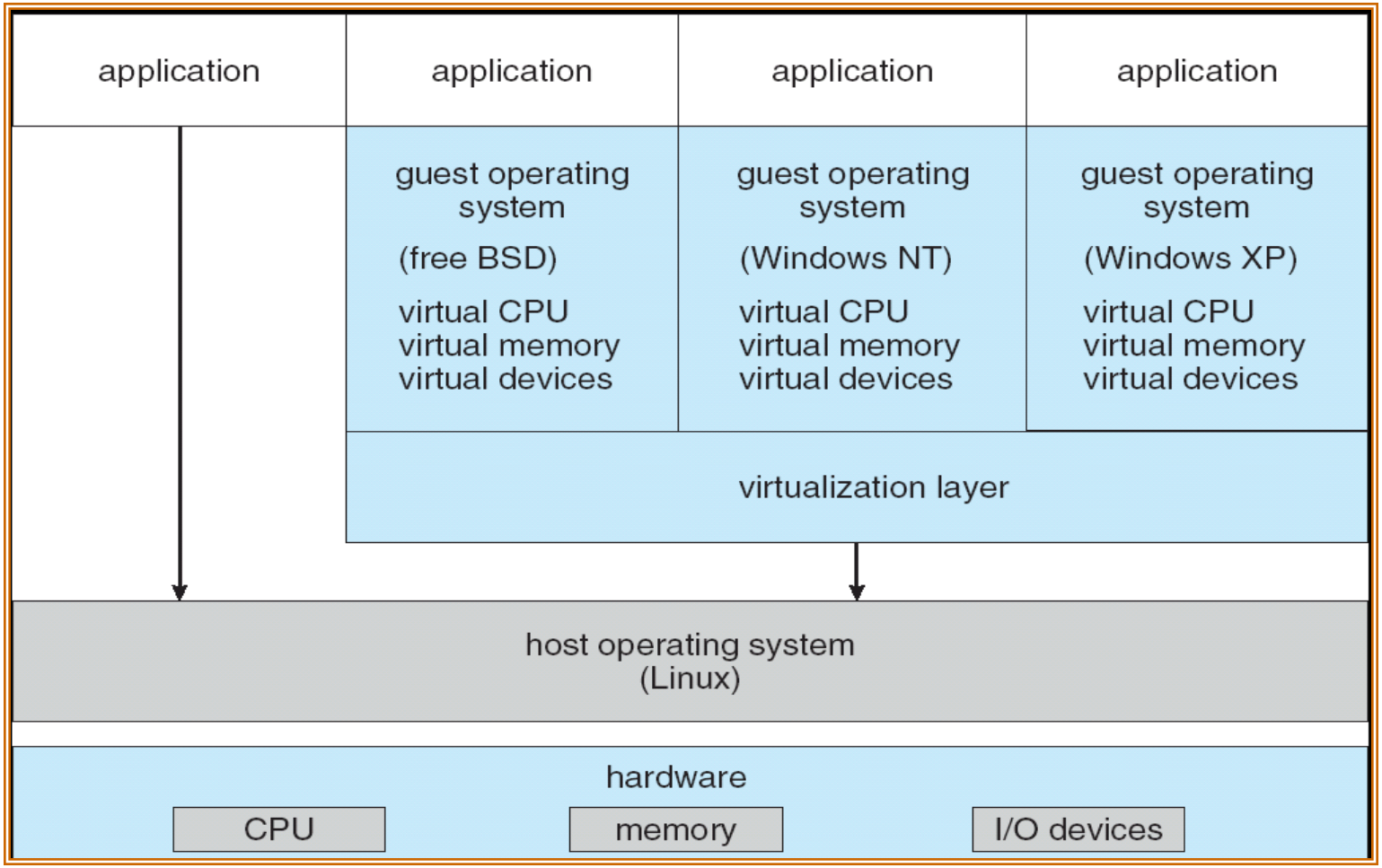
Structure View: Virtual Machines (contd.)

- The virtual-machine concept provides complete protection of system resources since each virtual machine is isolated from all other virtual machines. This isolation, however, permits no direct sharing of resources.

- A virtual-machine system is a perfect vehicle for operating-systems research and development. System development is done on the virtual machine, instead of on a physical machine and so does not disrupt normal system operation.

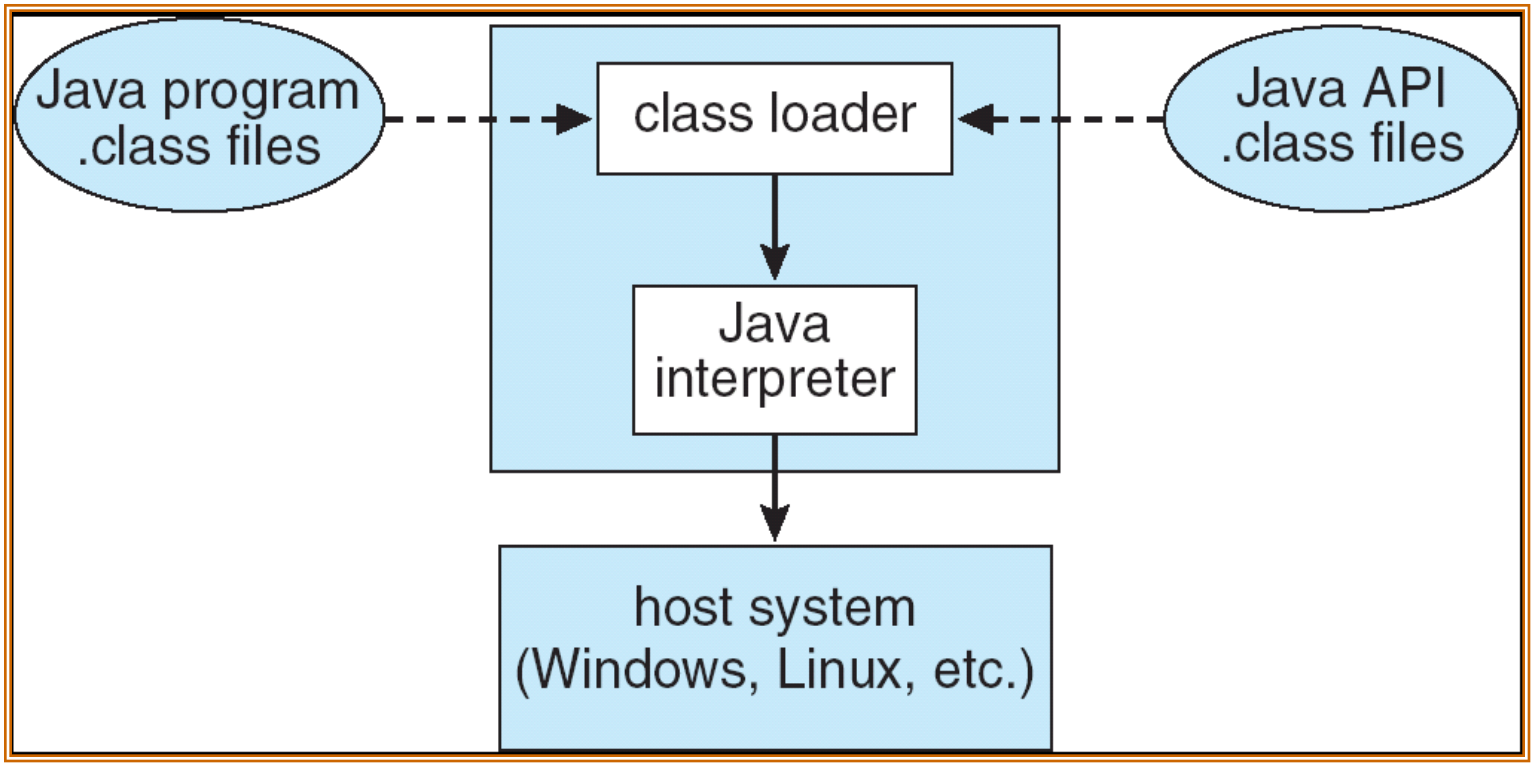
- The virtual machine concept is difficult to implement due to the effort required to provide an *exact* duplicate to the underlying machine

Structure View: Virtual Machines (contd.)



VMware Architecture

The Java Virtual Machine



Reading Assignments

1. As discussed in today's lecture, OS can be viewed from different perspectives. Read more about the functional and service views.
2. What are the uses of system calls and system programs. Identify their different types
3. What is cache memory? Discuss its advantages?
4. Operating system provides helpful services to users which are categorized in to two groups:
    - User interface, program execution, I/O operation, File-system Manipulation, Communications, Error detection
    - Resource Allocation, Accounting, Protection and Security

    Study the functions each of the services in the two categories
5. Read about the following operating systems and list out the major characteristics of each:
    - Serial processing
    - Simple batch systems
    - Multiprogrammed batch systems
    - Timesharing systems

Recommended Websites

- The Operating System Resource Center: A useful collection of documents and papers on a wide range of operating system topics.
- Review of Operating Systems: A comprehensive review of commercial, free, research and hobby operating systems.
- Operating System Technical Comparison: Includes a substantial amount of information on a variety of operating systems.
- ACM Special Interest Group on Operating Systems: Information on SIGOPS publications and conferences.
- IEEE Technical Committee on Operating Systems and Application Environments: Includes an online newsletter and links to other sites.
- The comp. os. research FAQ: Lengthy and worthwhile FAQ covering operating system design issues.