2 Operating System Structures

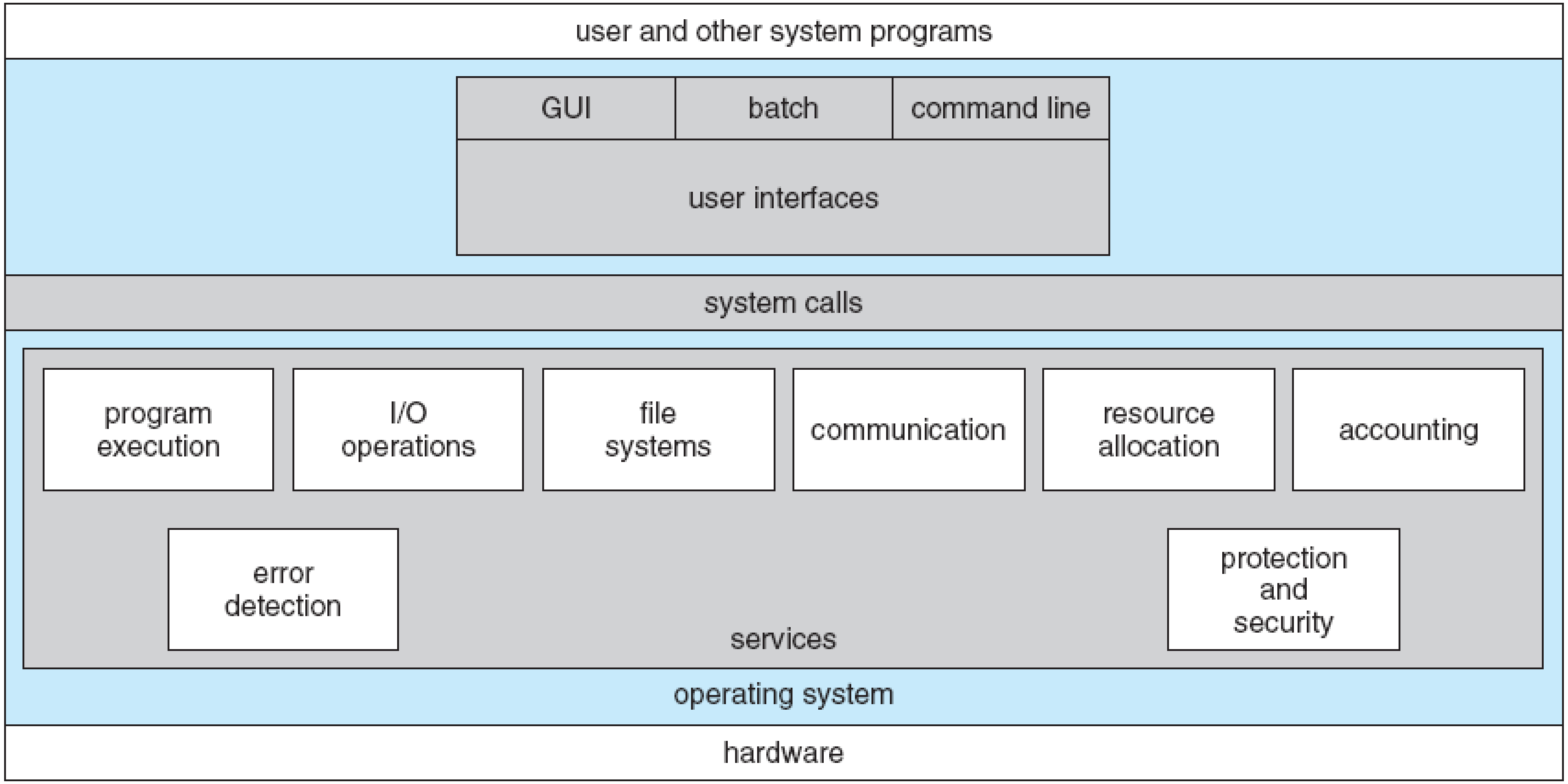
Contents

- Operating System Services
- User Operating System Interface
- System Calls
- Operating System Design and Implementation
- Operating System Structure

Objectives

- To describe the services an operating system provides to users, processes, and other systems
- To discuss the various ways of structuring an operating system
- To explain how operating systems are installed and customized and how they boot

Operating System Services - 1/2

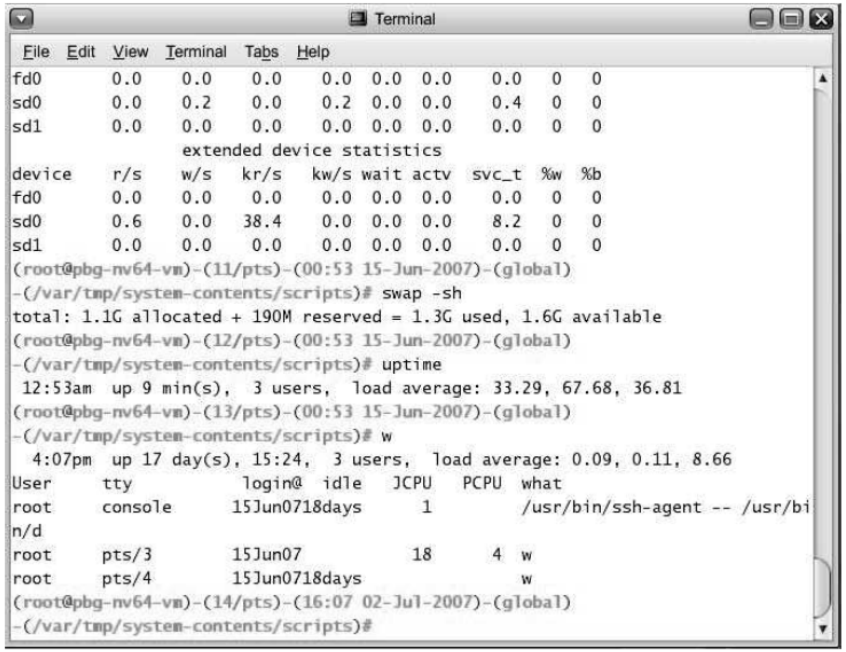


Operating System Services - 2/2

- One set of operating-system services provides functions that are helpful to the user
  - User interface : Command-Line (CLI), Graphics User Interface (GUI), Batch, …
  - Program execution
  - I/O operations
  - File-system manipulation
  - Communications
  - Error detection
- Another set of OS functions exists for ensuring the efficient operation of the system itself via resource sharing
  - Resource allocation
  - Accounting
  - Protection and security

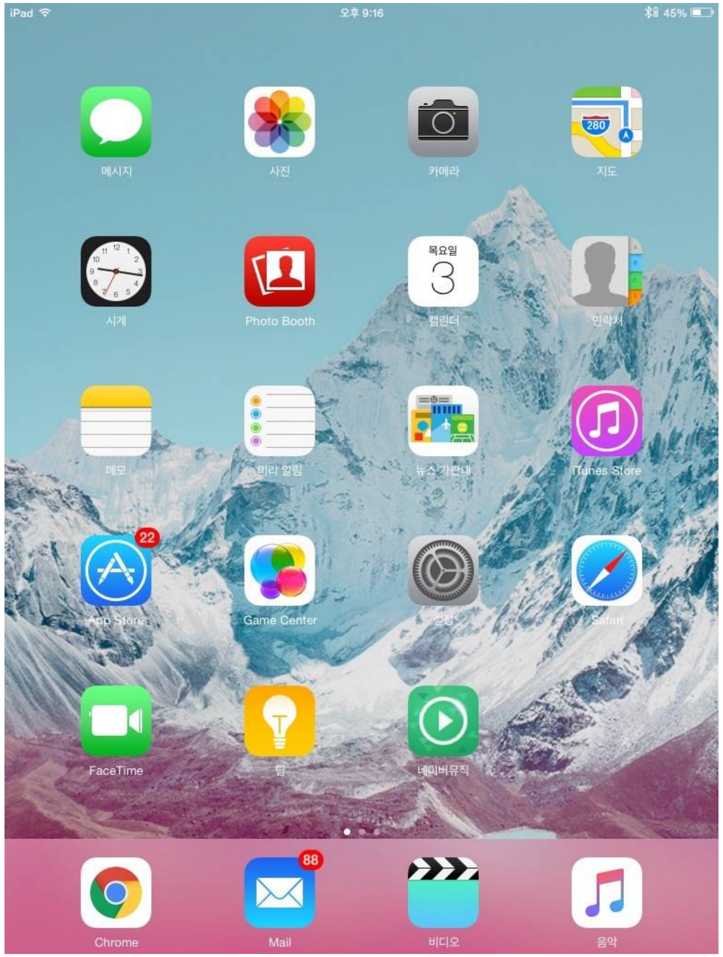
User Operating System Interface - CLI

- CLI allows direct command entry
  - Sometimes implemented in kernel, sometimes by systems program
  - Sometimes multiple flavors implemented ; shells
  - Primarily fetches a command from user and executes it



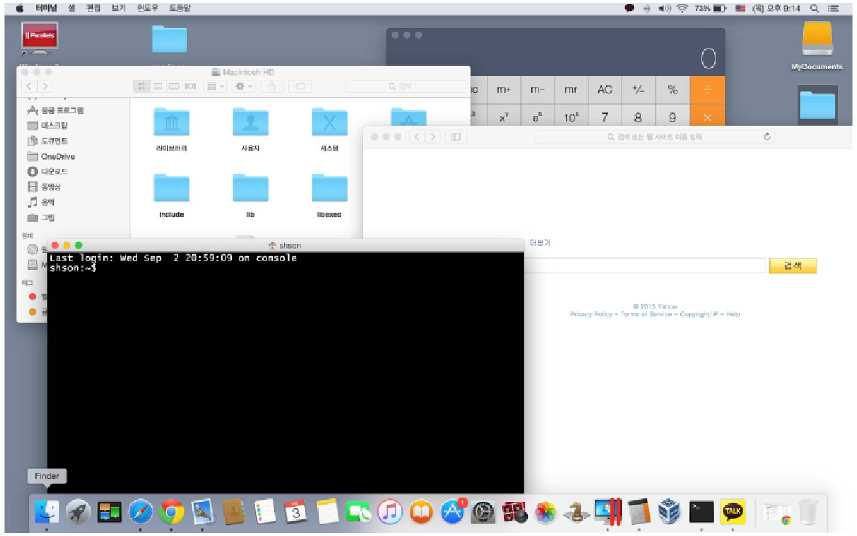
User Operating System Interface - GUI

- User-friendly desktop metaphor interface
  - Usually mouse, keyboard, and monitor
  - Icons represent files, programs, actions, etc
  - Various mouse buttons over objects in the interface cause various actions (provide information, options, execute function, open directory (known as a folder)
  - Invented at Xerox PARC



User Operating System Interface

- Many systems now include both CLI and GUI interfaces
  - Microsoft Windows is GUI with CLI “command” shell
  - Apple Mac OS X as “Aqua” GUI interface with UNIX kernel underneath and shells available
  - Solaris is CLI with optional GUI interfaces (Java Desktop, KDE)

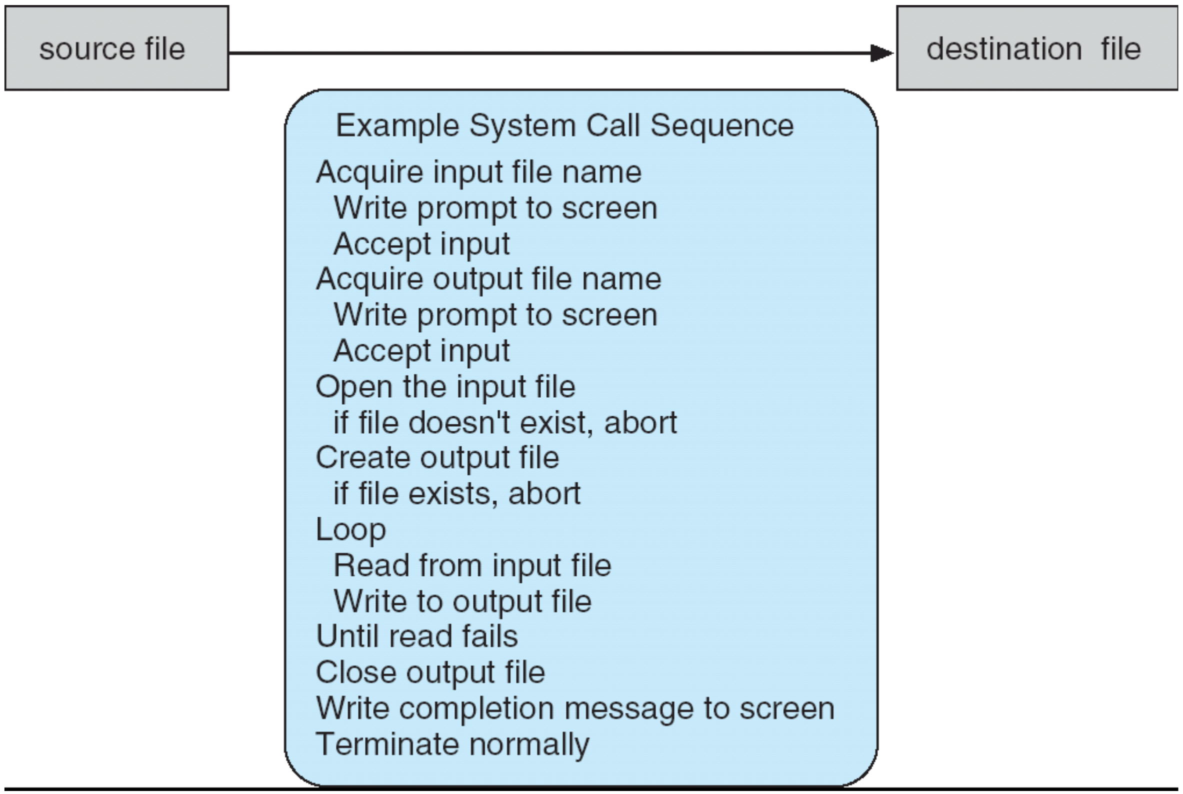


System Calls

- 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 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)
- Why use APIs rather than system calls?

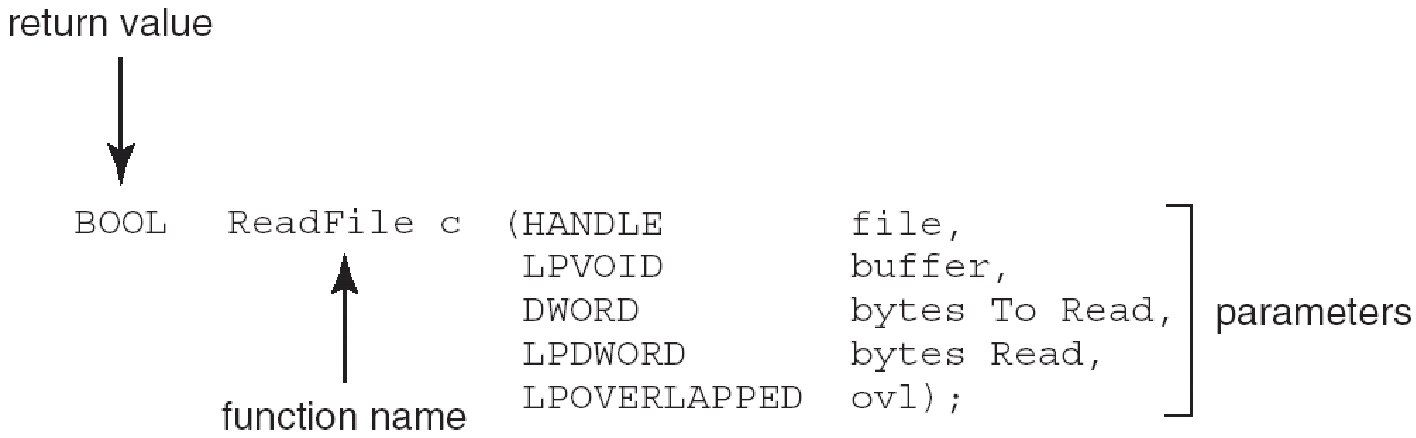
Example of System Calls

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



Example of Standard API

- Consider the ReadFile() function in the Win32 API - a function for reading from a file



- A description of the parameters passed to ReadFile()
  - HANDLE file—the file to be read
  - LPVOID buffer—a buffer where the data will be read into and written from
  - DWORD bytesToRead—the number of bytes to be read into the buffer
  - LPDWORD bytesRead—the number of bytes read during the last read
  - LPOVERLAPPED ovl—indicates if overlapped I/O is being used

Example of Standard API

- Consider the `read()` function in the POSIX API of UNIX/Linux system - a function for reading from a file

```
#include <unistd.h>

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

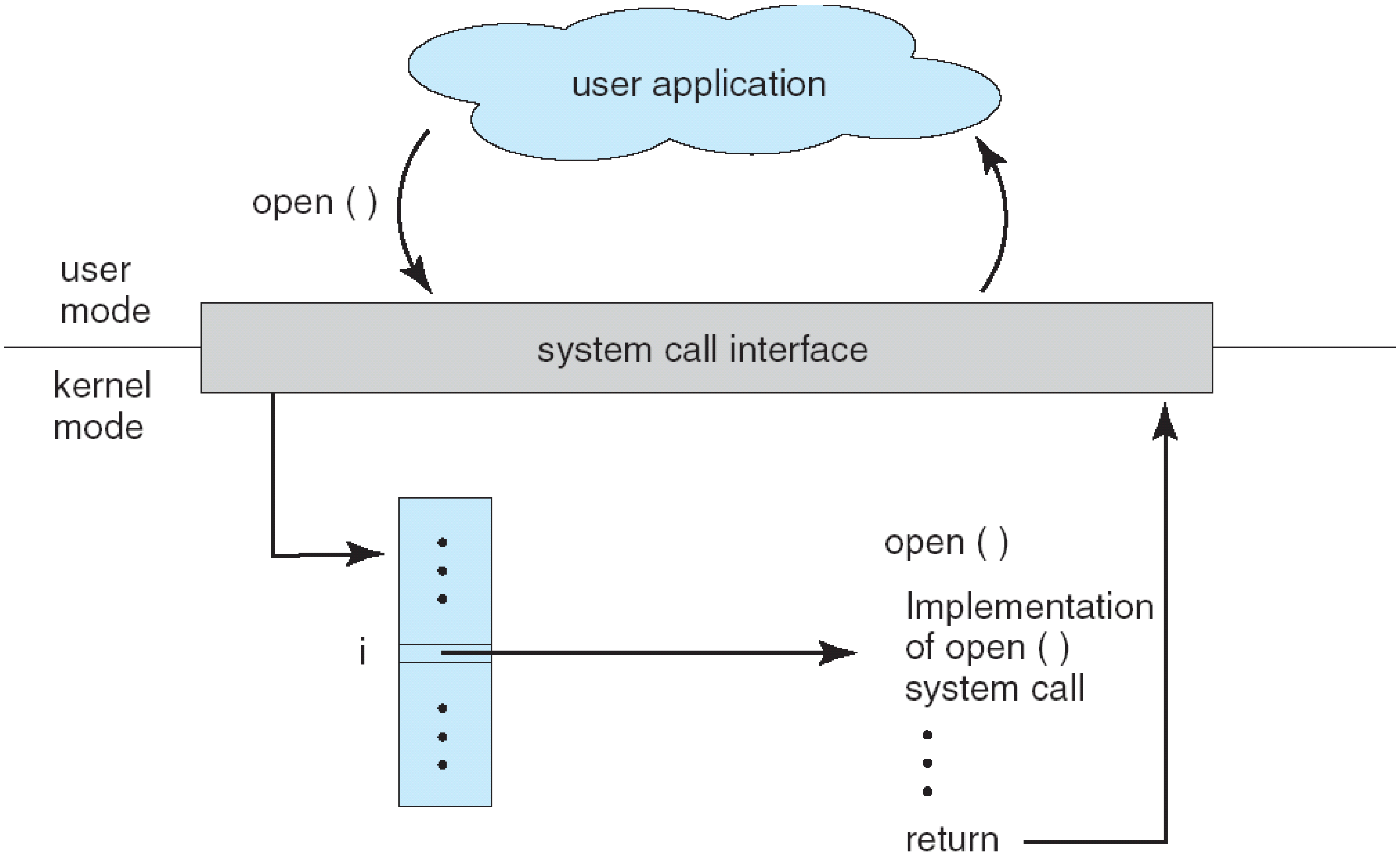
return value | function name | parameters

- A description of the parameters passed to `read()`
  - `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

System Call Implementation

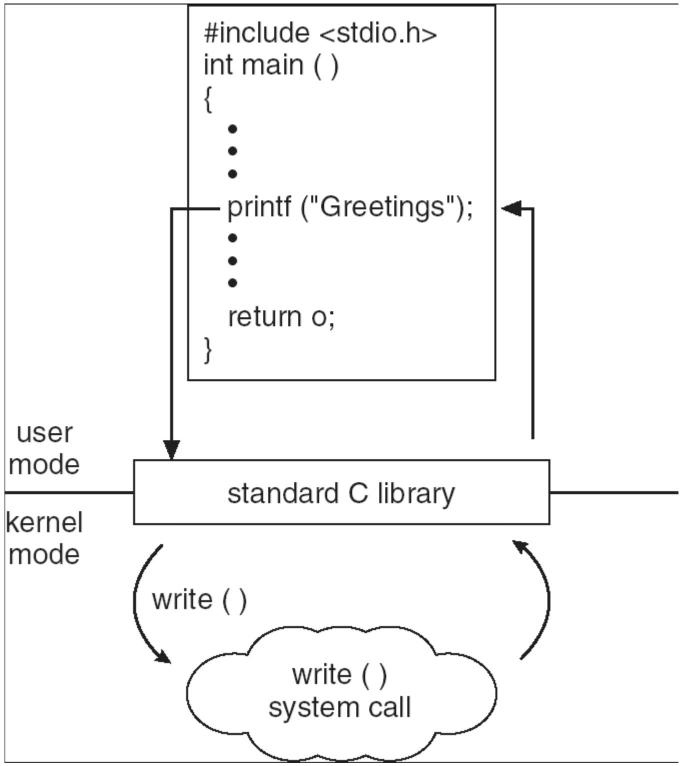
- Typically, a number associated with each system call
  - System-call interface maintains a table indexed according to these numbers
- The system call interface invokes intended system call in OS kernel and returns status of the system call and any return values
- The caller need know nothing about 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



Standard C Library Example

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



Operating System Operations

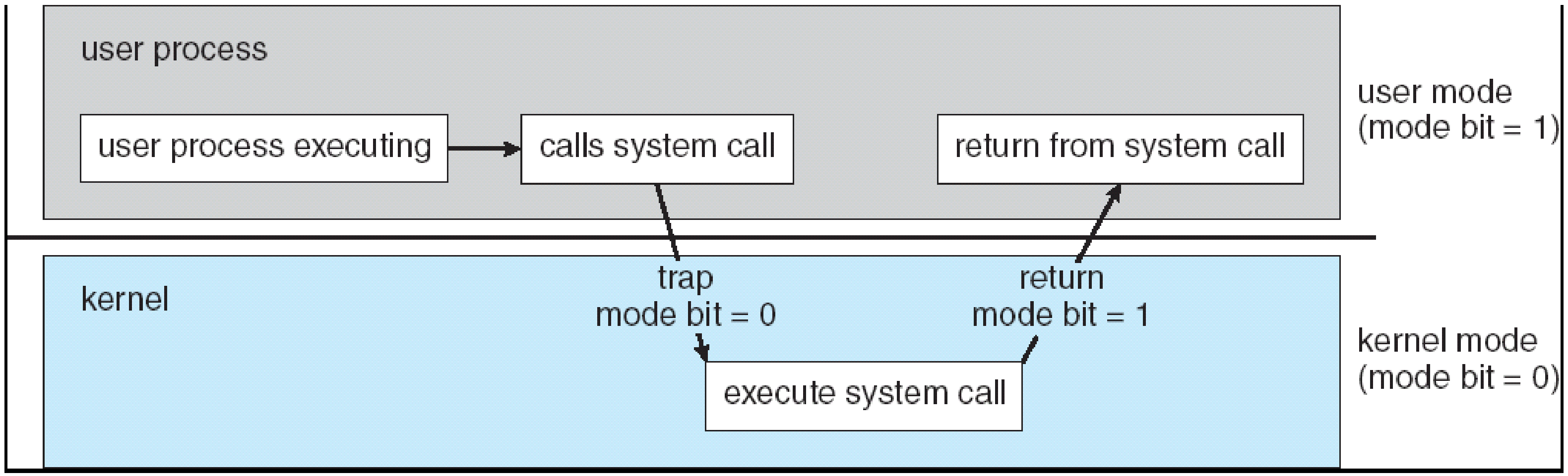
- Interrupt driven by hardware

- Software error or request creates **exception** or **trap**
  - Division by zero, request for operating system service
- Other process problems include infinite loop, processes modifying each other or the operating system

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

Transition from User to Kernel Mode

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



Operating System Design and Implementation - 1/2

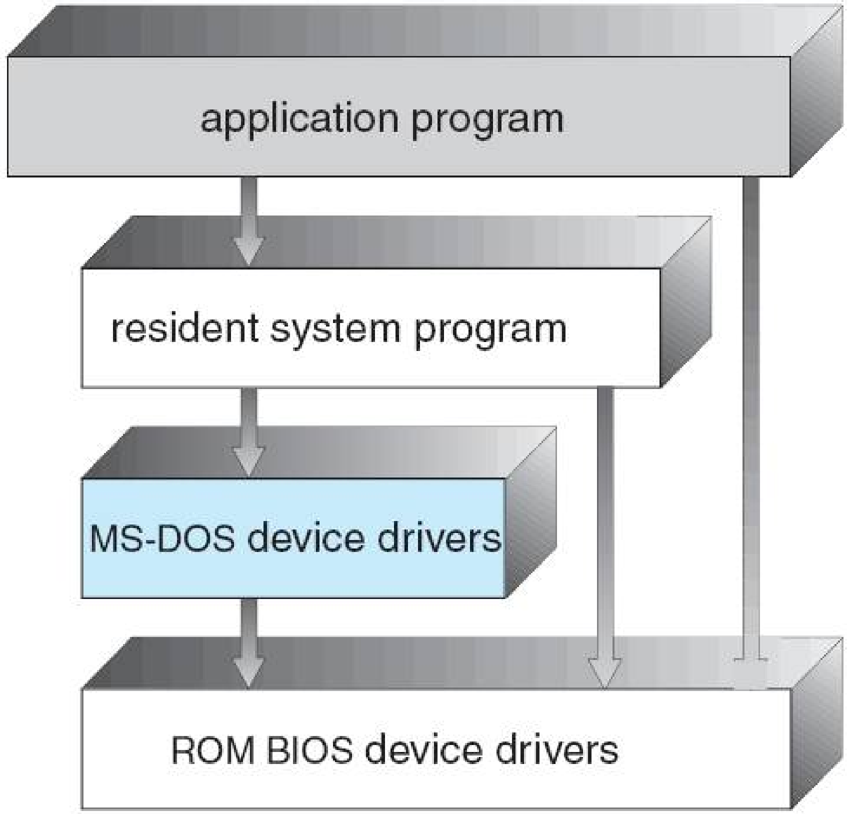
- Design and Implementation of OS not "solvable", but some approaches have proven successful
- Internal structure of different Operating Systems can vary widely
- Start by defining goals and specifications
- Affected by choice of hardware, type of system
- User goals and System goals
  - User goals – operating system should be convenient to use, easy to learn, reliable, safe, and fast
  - System goals – operating system should be easy to design, implement, and maintain, as well as flexible, reliable, error-free, and efficient

Operating System Design and Implementation - 2/2

- Important principle to separate
  - Policy: What will be done?
  - Mechanism: How to do it?
- Mechanisms determine how to do something, policies decide what will be done
- The separation of policy from mechanism is a very important principle, it allows maximum flexibility if policy decisions are to be changed later

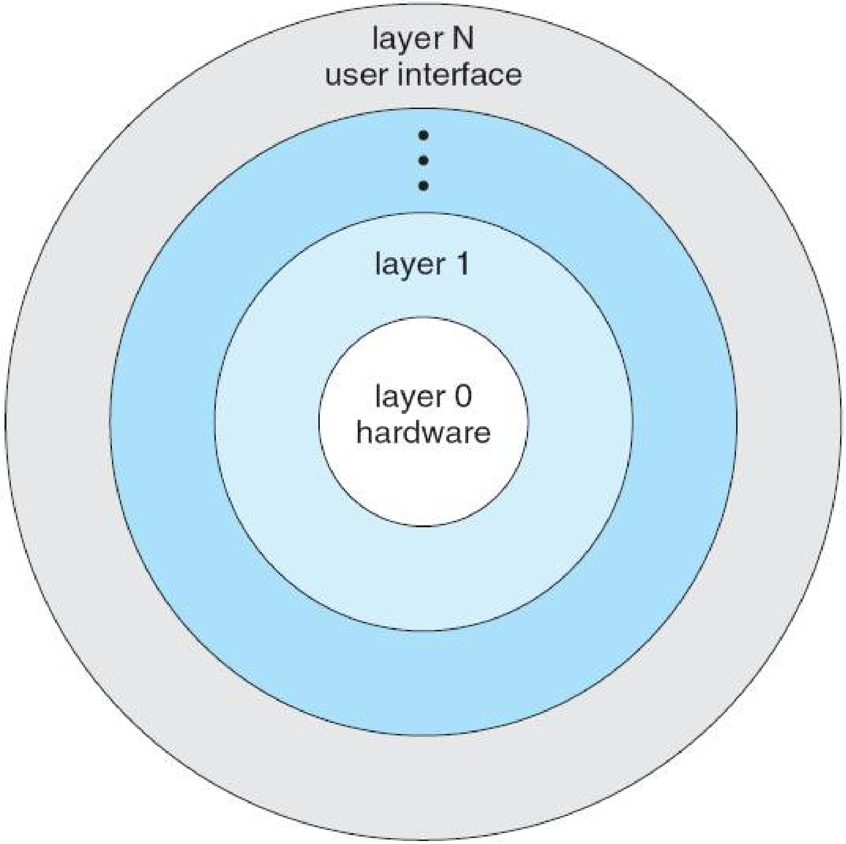
Simple Structure

- 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



Layered Approach

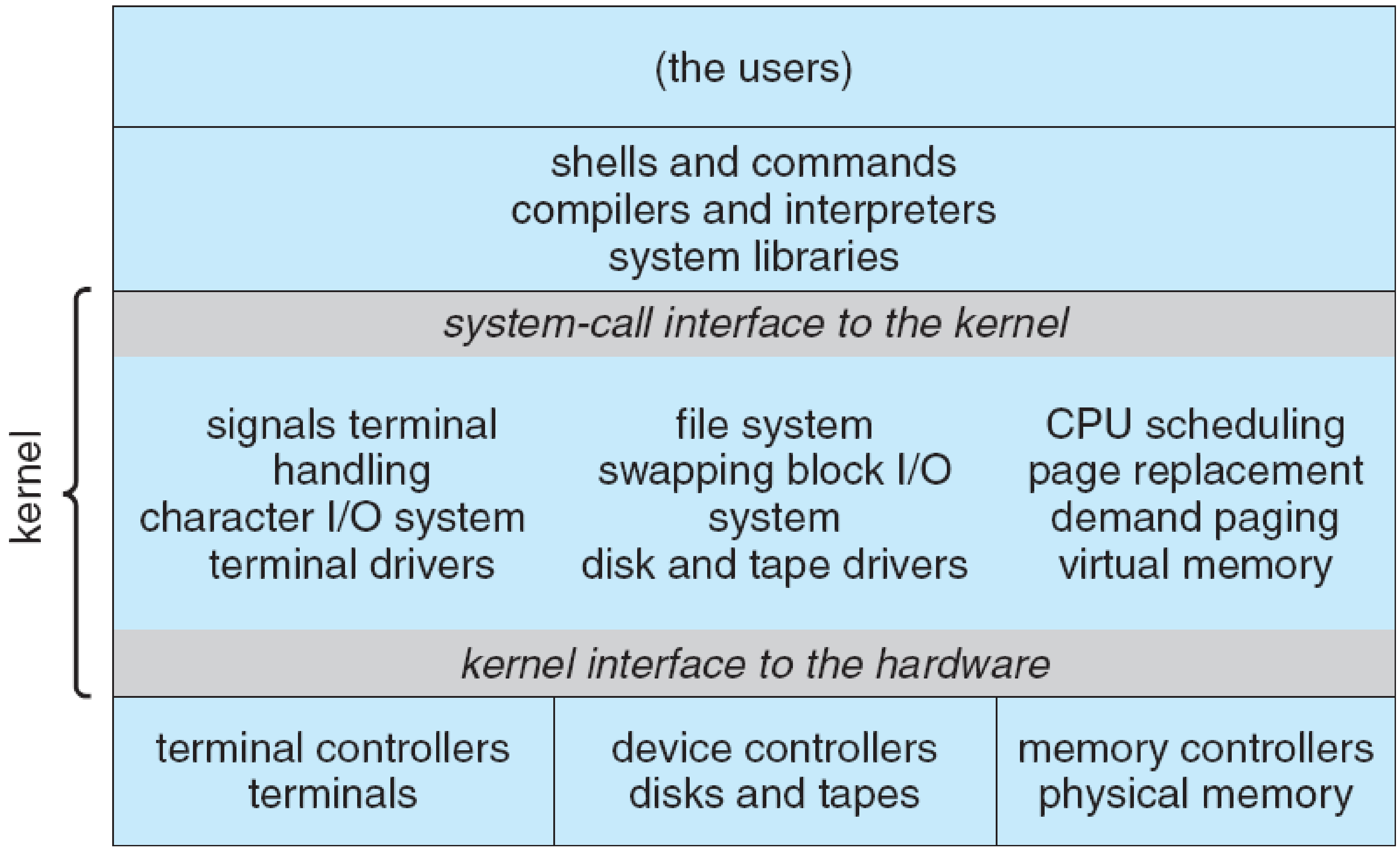
- The operating system is divided into a number of layers (levels), each built on top of lower layers. The bottom layer (layer 0), is the hardware; the highest (layer N) is the user interface.
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level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



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

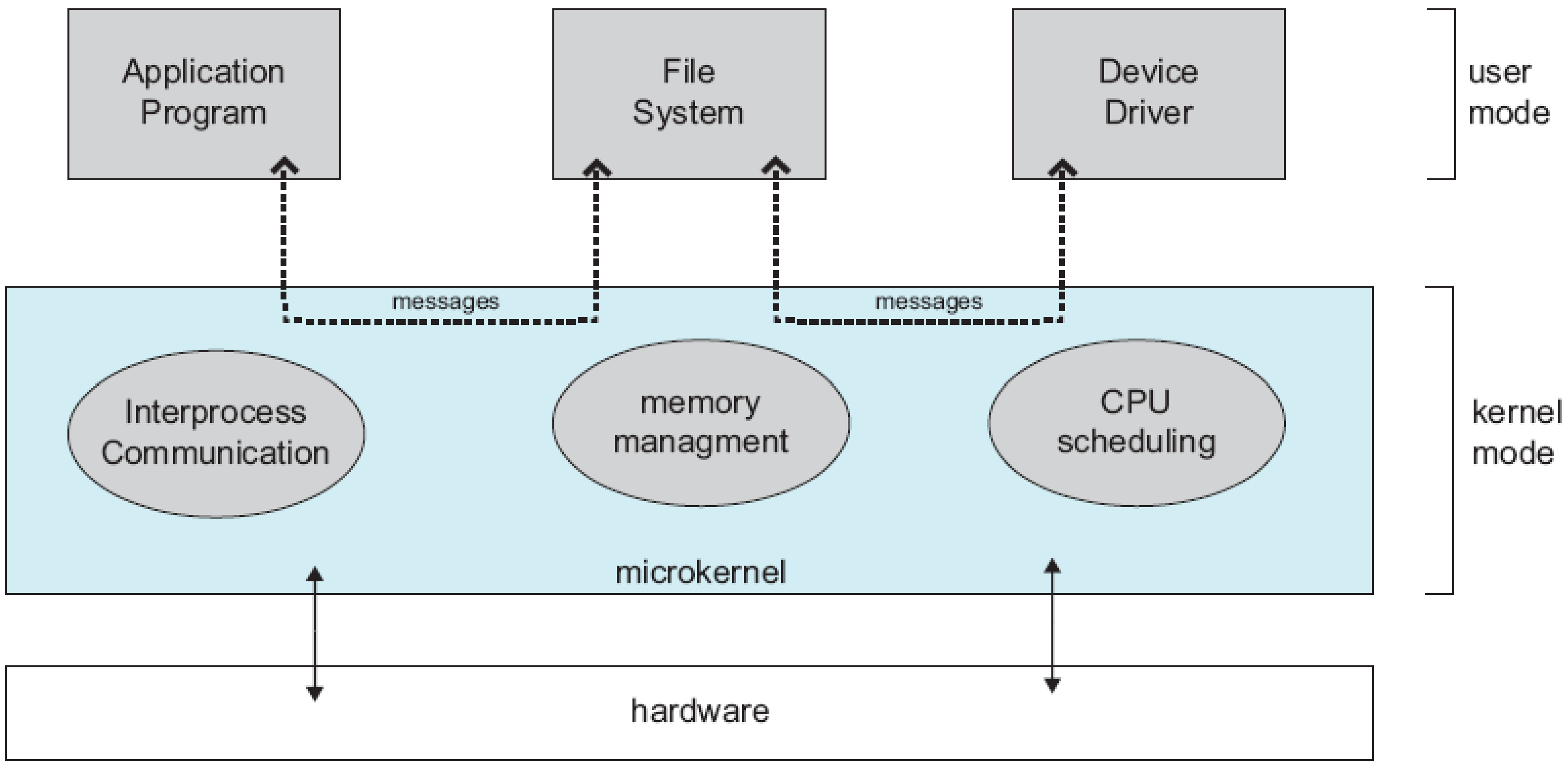
UNIX System Structure



Microkernel System Structure

- 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

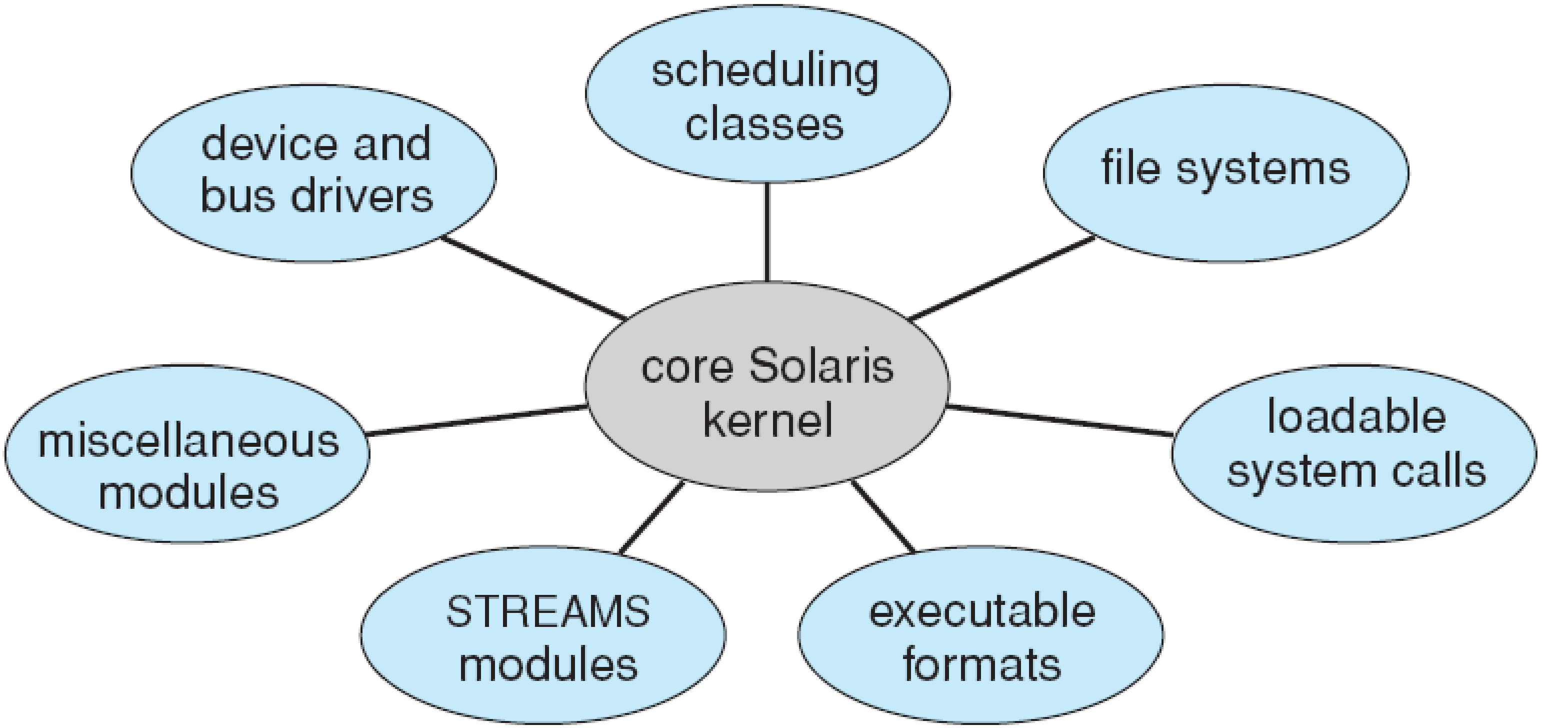
Architecture of a Typical Microkernel



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

Solaris Modular Approach



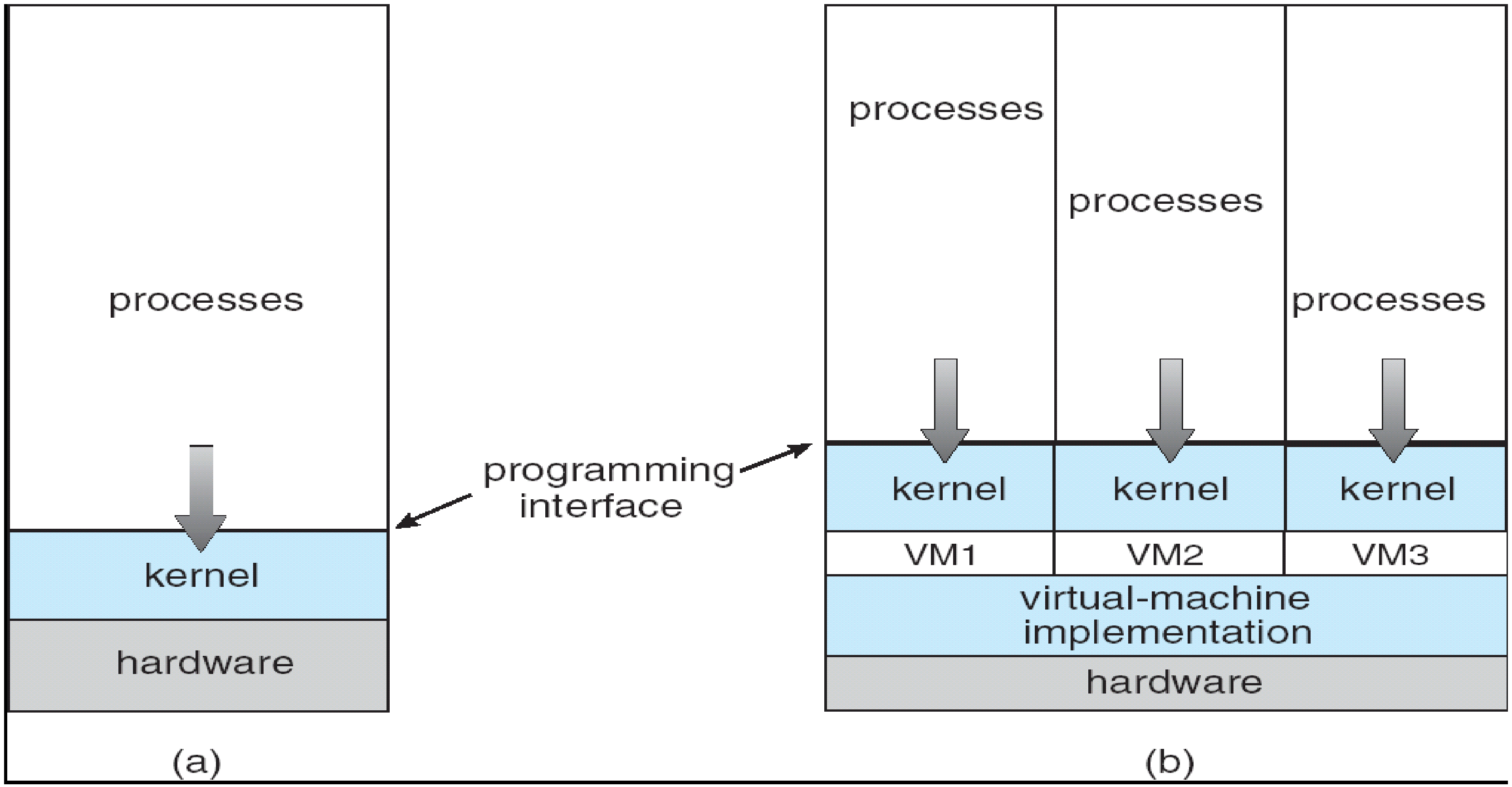
Virtual Machines - 1/4

- 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

Virtual Machines - 2/4

- 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

Virtual Machines - 3/4



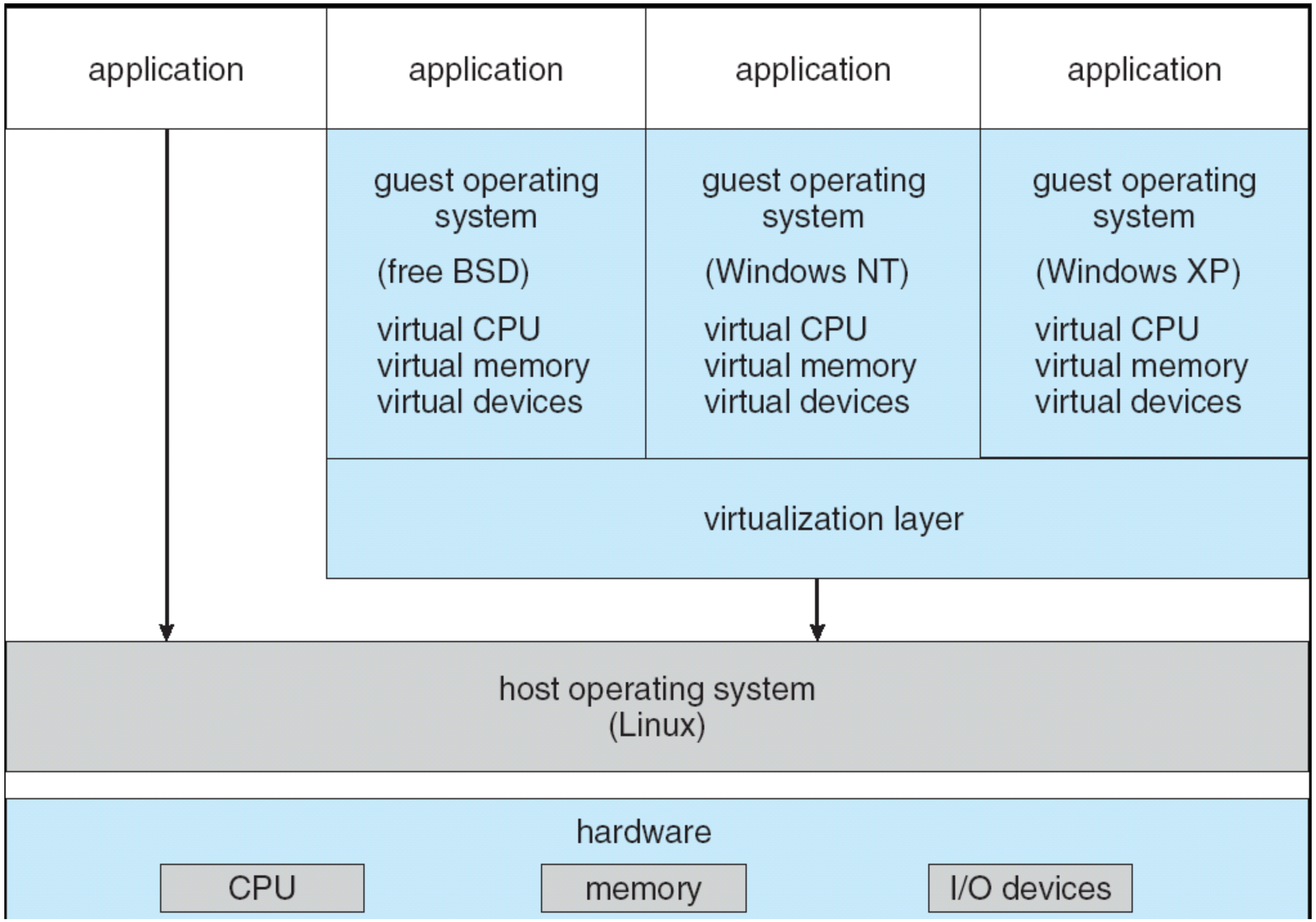
Non-virtual Machine

Virtual Machine

Virtual Machines - 4/4

- 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

VMware Architecture



The Java Virtual Machine