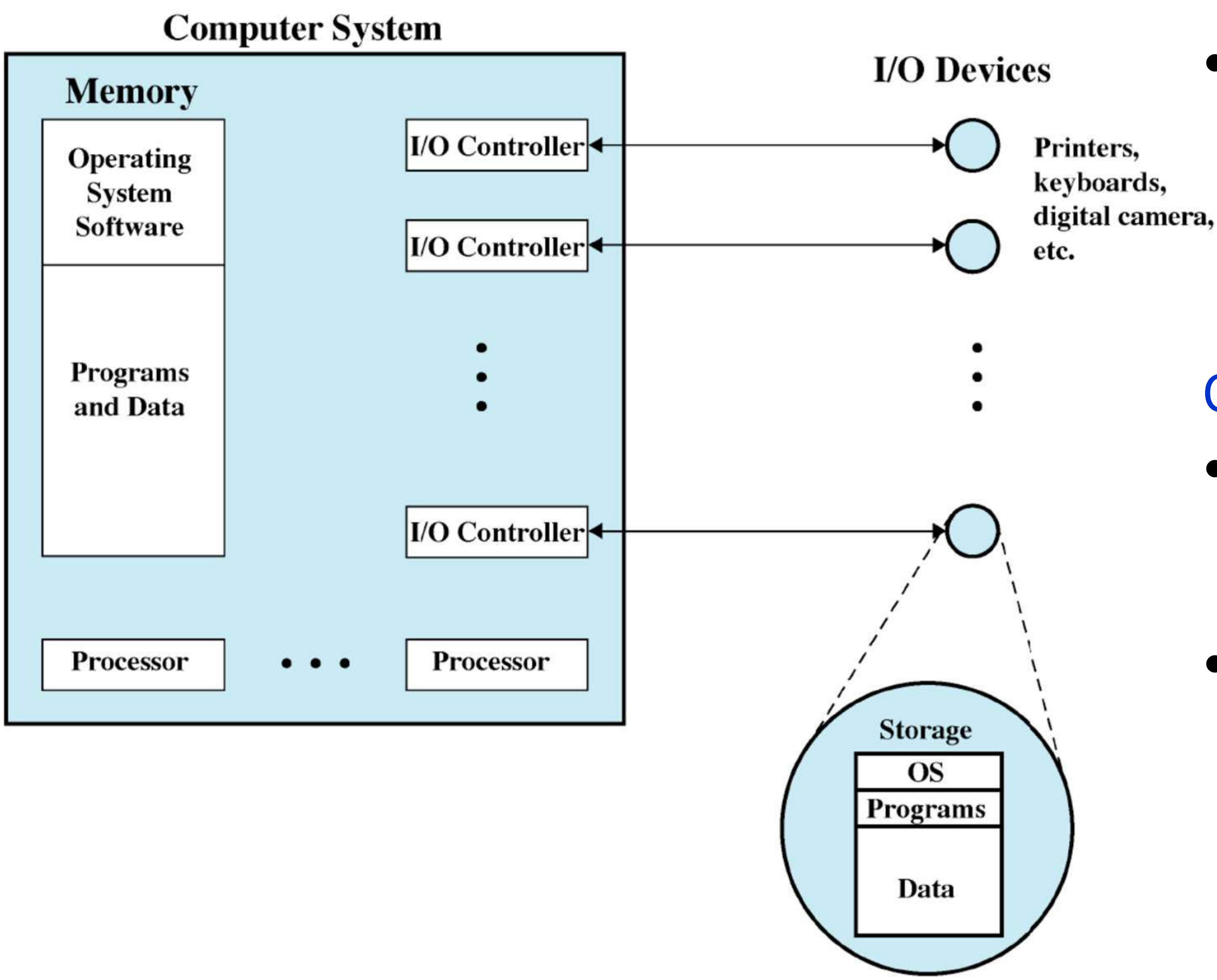
Operating Systems

1. Introduction

Operating System Services

Operating System: … It is a Program …



- Relinquishes control of the processor to execute other programs

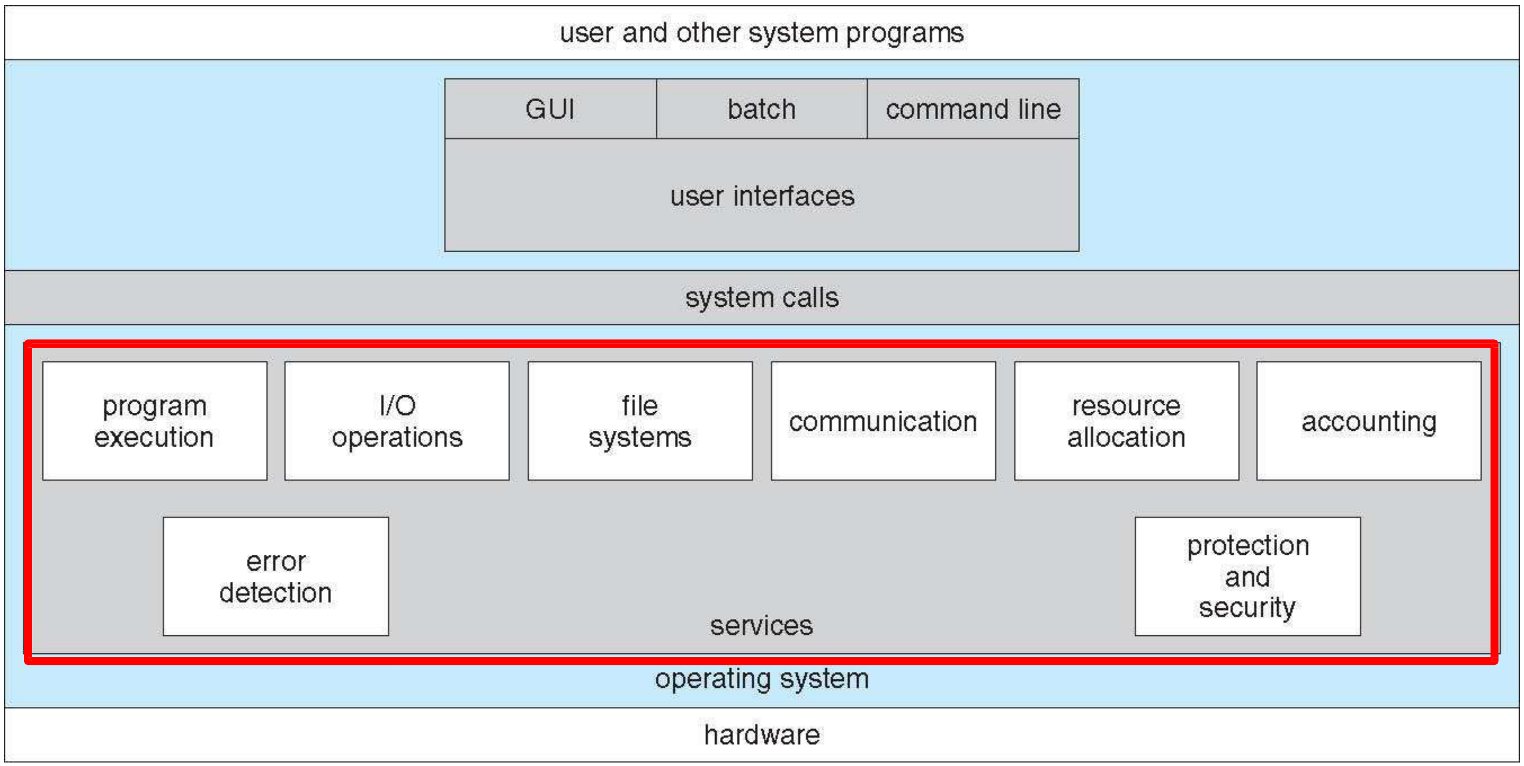
OS Kernel

- (Roughly) Portion of OS that is in main memory
- Contains most-frequently used functions

Operating System in Action

- OS is a program, just like any other program
- On computer start, bootstrap program is loaded from ROM
- Boot program activates OS kernel (permanent system process)
  - Shell (is not kernel): Program to let the user initiate processes
- Boot program
  - Examine/check machine configuration, e.g.,
    - ➢ Number of CPUs
    - ➢ How much memory
    - ➢ Number and type of HW devices
  - Build configuration structure describing the HW
  - Locates and Loads the OS
  - The control transfers to the OS

Operating System Services



Operating System Services – Helper

- User interface
  - Command line
    - ➢ Shell provides command line interface

```
cat file1 file2 file3 | sort > text.txt &
Create two processes cat, sort and links input/output
```

  - Graphical user interface
  - Batch interface
    - ➢ Commands are entered into files and those files are executed

- Program execution
  - Load program into memory and run it
  - End execution either normally or abnormally

Operating System Services – Helper

- I/O operations
  - User programs cannot control I/O device directly
  - Operating system must provide some means to control I/O
- File system manipulation
  - Program's capability to read, write, create or delete files or directories
  - Permission management to allow or deny access to files or directories
- Communication
  - Exchange of information between processes
  - Processes may be executing on different computers via network
  - Communication on same computer via shared memory or message passing

Operating System Services – Helper

- Error detection
  - OS needs to be constantly aware of possible errors
  - May occur in CPU & memory hardware, in I/O device, in user program
  - OS takes corrective actions to ensure correct computing
  - Debugging facilities to the application programmers

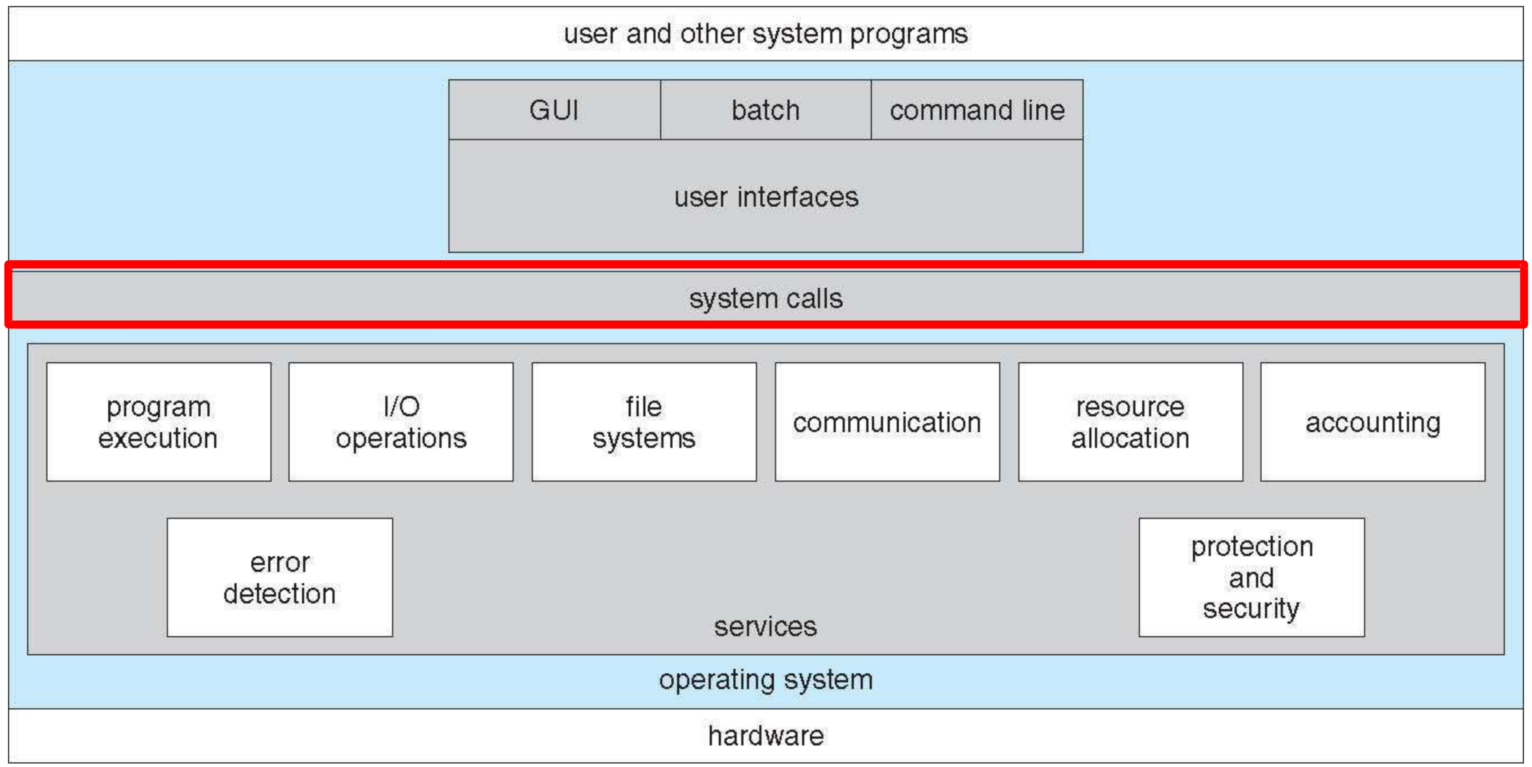
Operating System Services – Efficient Operations

- Resource allocation
  - Resource allocation to concurrently running jobs
  - Resources such as CPU cycles, main memory, file storage etc.

- Accounting
  - Track usage of computer resources
  - For billing or simply for accumulating usage statistics

- Protection and security
  - Protect access to system resources is controlled
  - Security from the outsiders, e.g., user authentication

System Calls

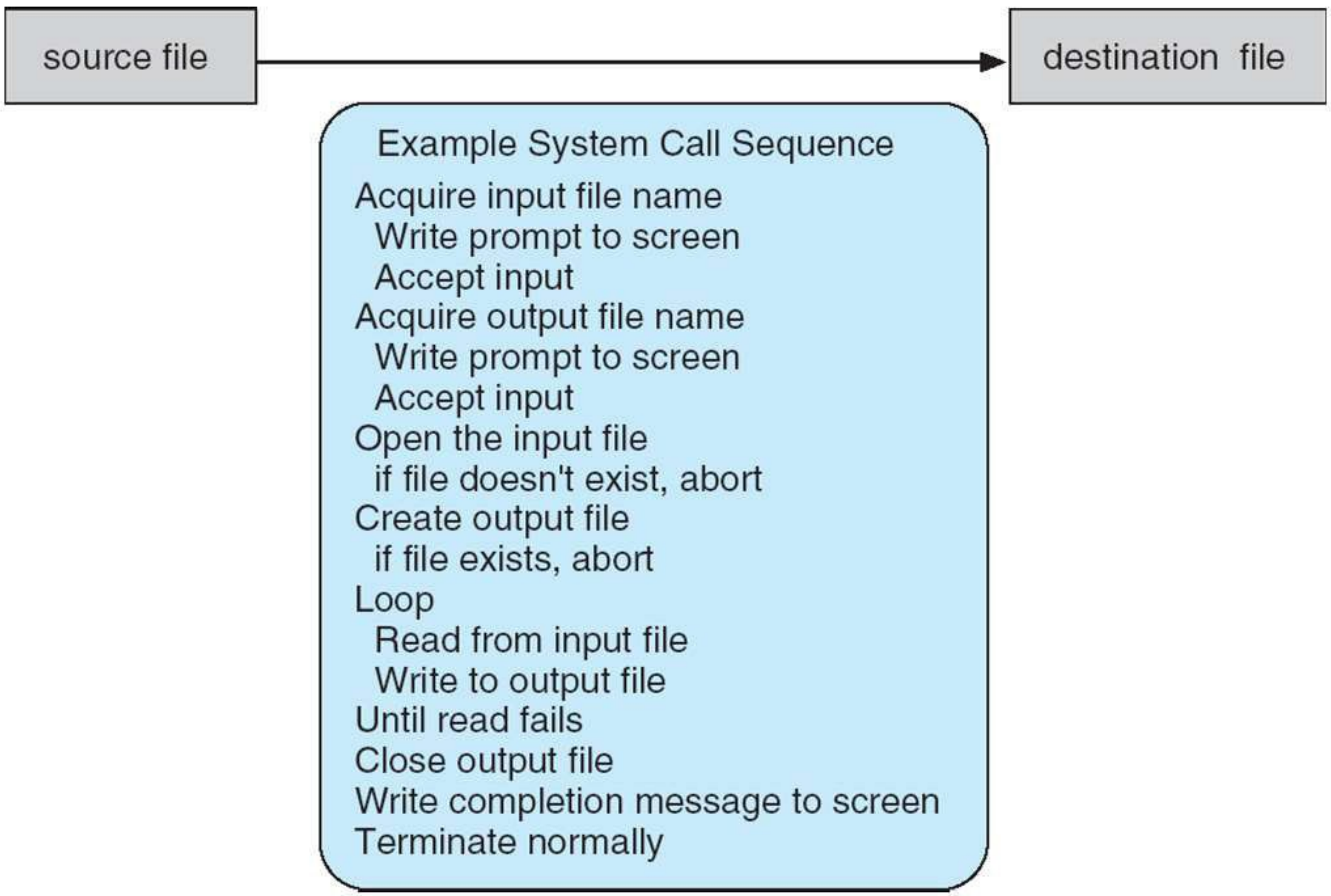


System Calls

- 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
  - Win32 API for Windows
  - POSIX API for POSIX-based systems
    - Virtually all versions of UNIX, Linux, and Mac OS (X)
  - Java API for the Java virtual machine (JVM)
- Why use APIs rather than system calls?

System Call – Example

- Copy the contents of one file to another file



Win32 API Example

- Consider the `ReadFile()` function in the Win32 API

return value

```
BOOL  ReadFile  (HANDLE        file,
                 LPVOID        buffer,
                 DWORD         bytes To Read,
                 LPDWORD       bytes Read,
                 LPOVERLAPPED  ovl);
```

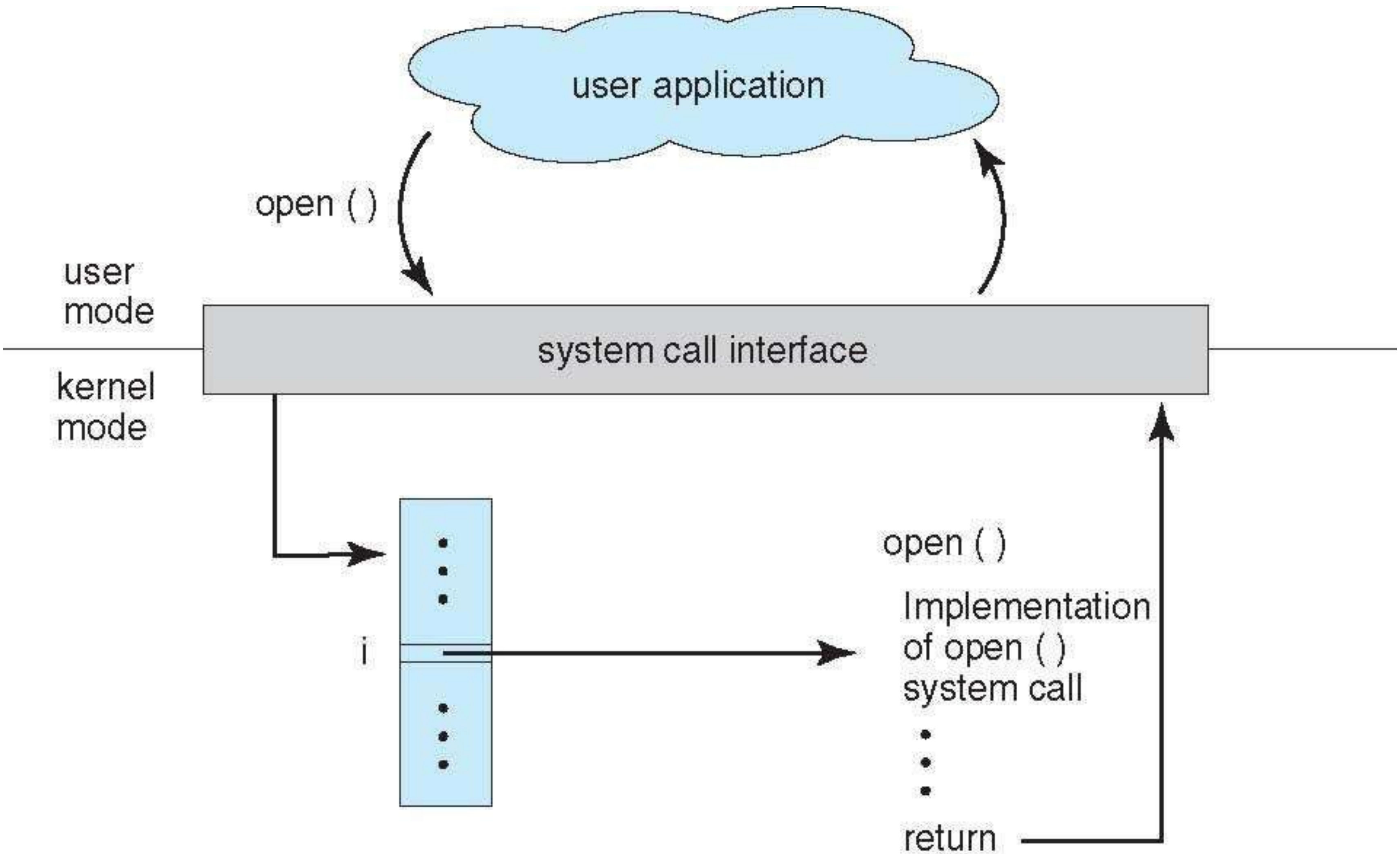
function name

parameters

A description of the parameters passed to `ReadFile()`

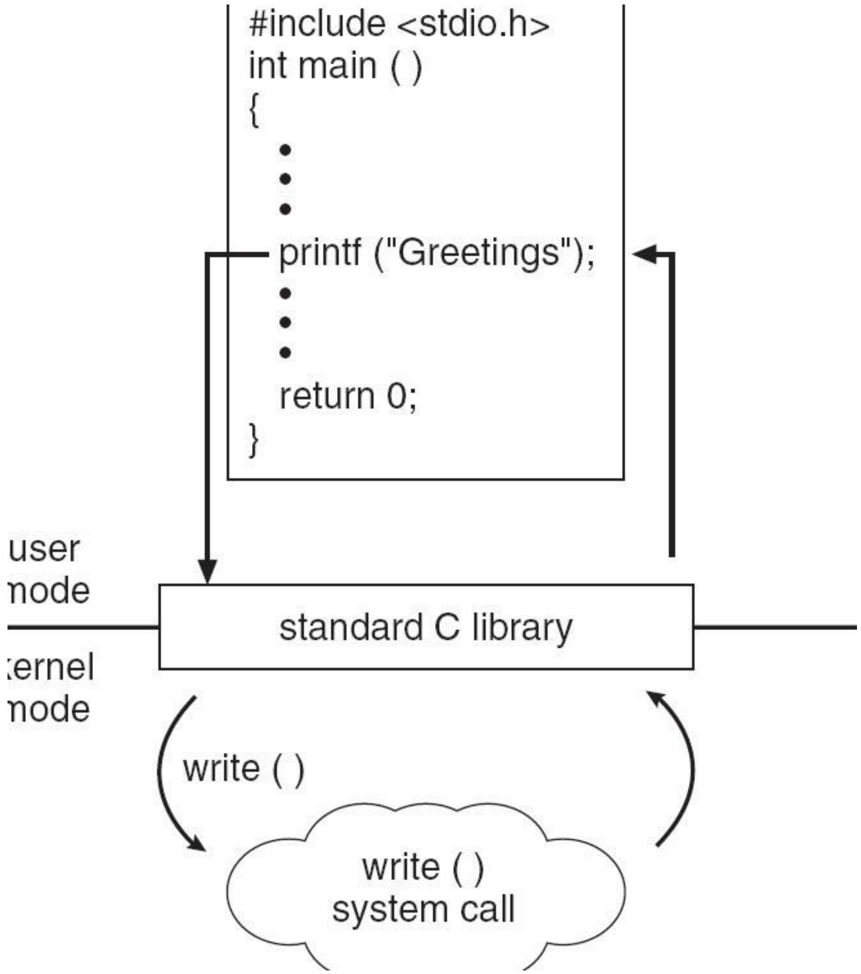
- `HANDLE file`: File to be read
- `LPVOID buffer`: Where the data will be read into and written from
- `DWORD bytesToRead`: Number of bytes to be read into the buffer
- `LPDWORD bytesRead`: Number of bytes read during the last read
- `LPOVERLAPPED ovl`: Indicates if overlapped I/O is being used

API and System Call Relationship

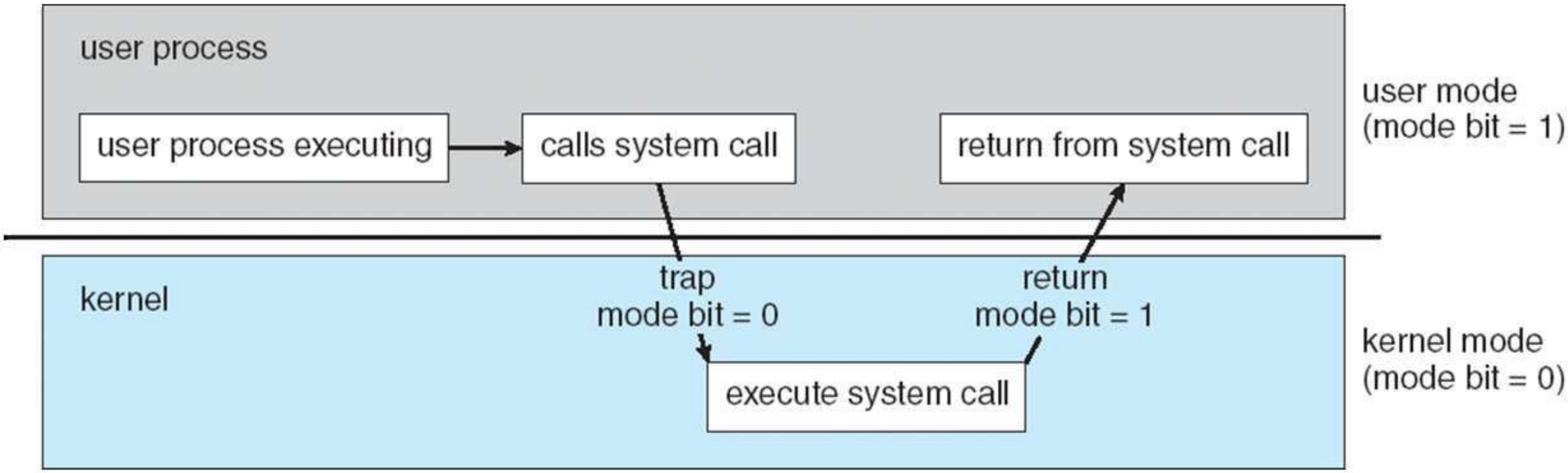


Standard C Library Example

- Program invoke `printf()` library function, which calls `write()` system call



Transition From User to Kernel Mode

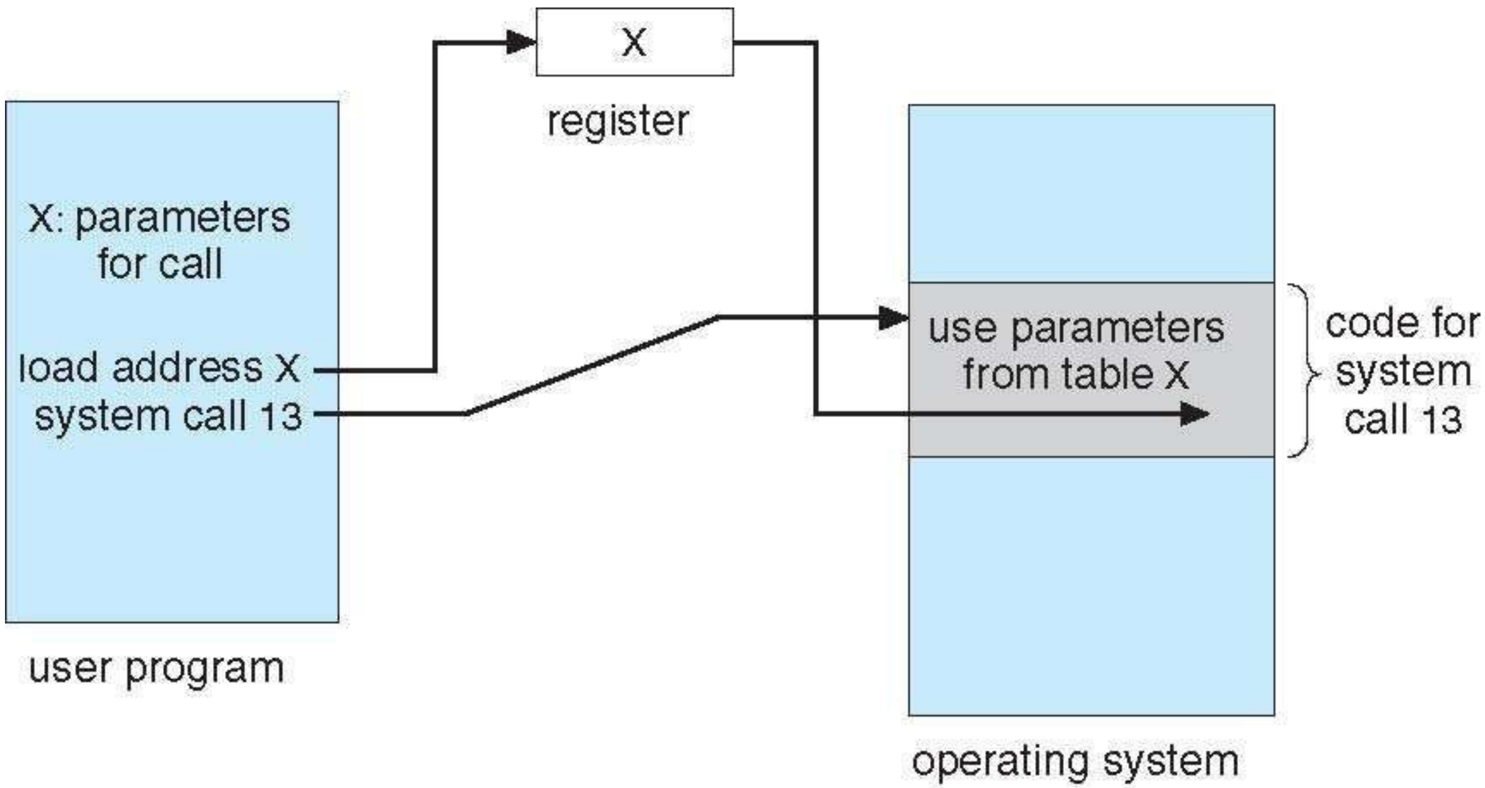


System Call – Parameter Passing

Three general methods used to pass parameters to the OS

- 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
  - End, abort
  - Load, execute
  - Create process, terminate process
  - Get process attributes, set process attributes
  - Wait for time
  - Wait event, signal event
  - Allocate and free memory

- File management
  - create file, delete file
  - open, close file
  - read, write, reposition
  - get and set file attributes

Types of System Calls

- Device management
  - Request device, release device
  - Read, write, reposition
  - Get device attributes, set device attributes
  - Logically attach or detach devices
- 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
  - Transfer status information
  - Attach and detach remote devices

Windows and Unix System Calls – Example

	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()`

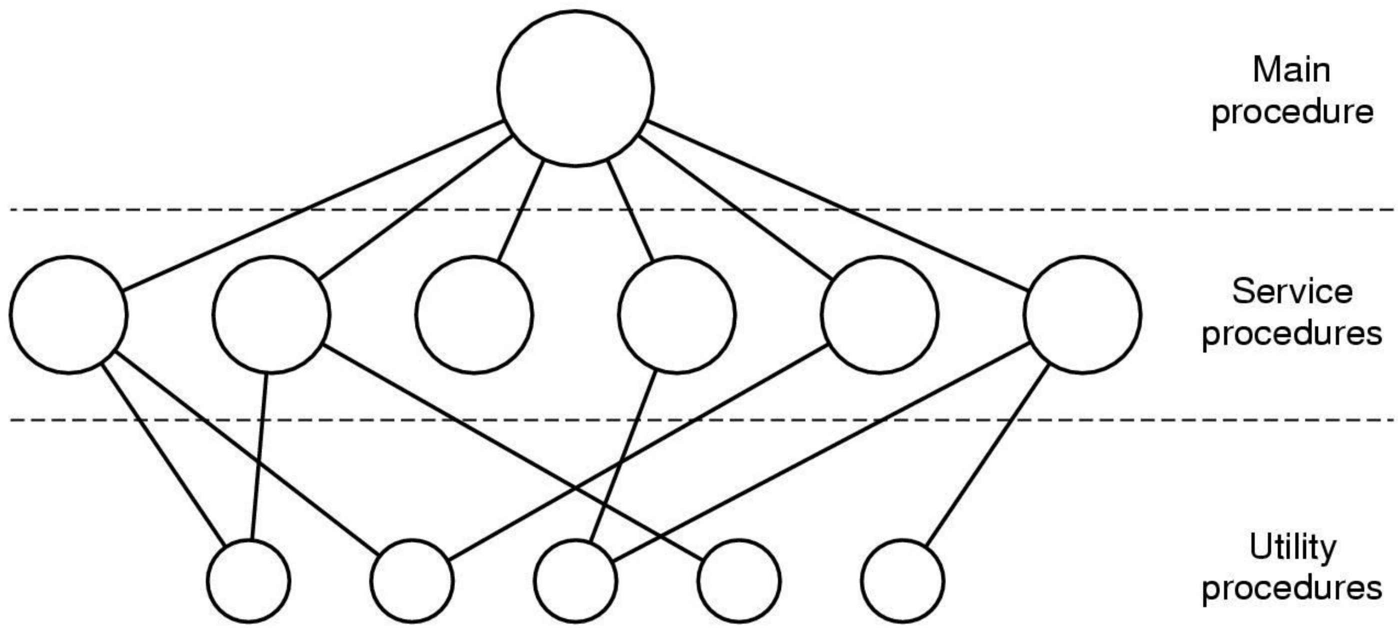
Communication	`CreatePipe()`
	`CreateFileMapping()`
	`MapViewOfFile()`
		`pipe()`
		`shmget()`
		`mmap()`

Protection	`SetFileSecurity()`
	`InitlializeSecurityDescriptor()`
	`SetSecurityDescriptorGroup()`
		`chmod()`
		`umask()`
		`chown()`

Operating System Structure

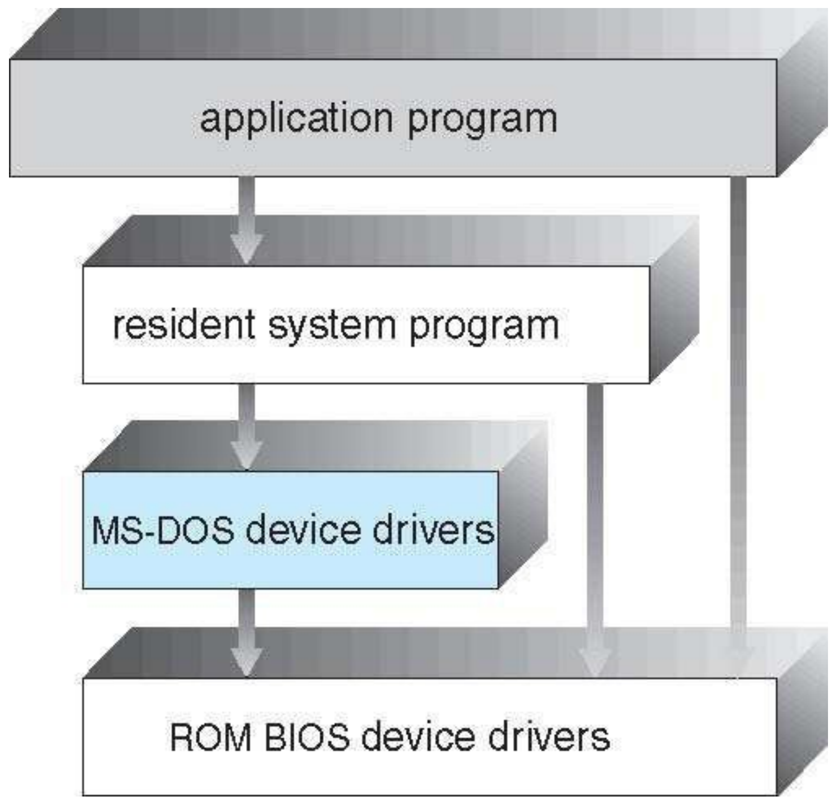
Monolithic Systems

- Most operating systems have relied on a monolithic structure
  - OS is written as a collection of procedures
  - Each procedure can call any other procedure
  - Issues: difficult to implement and maintain



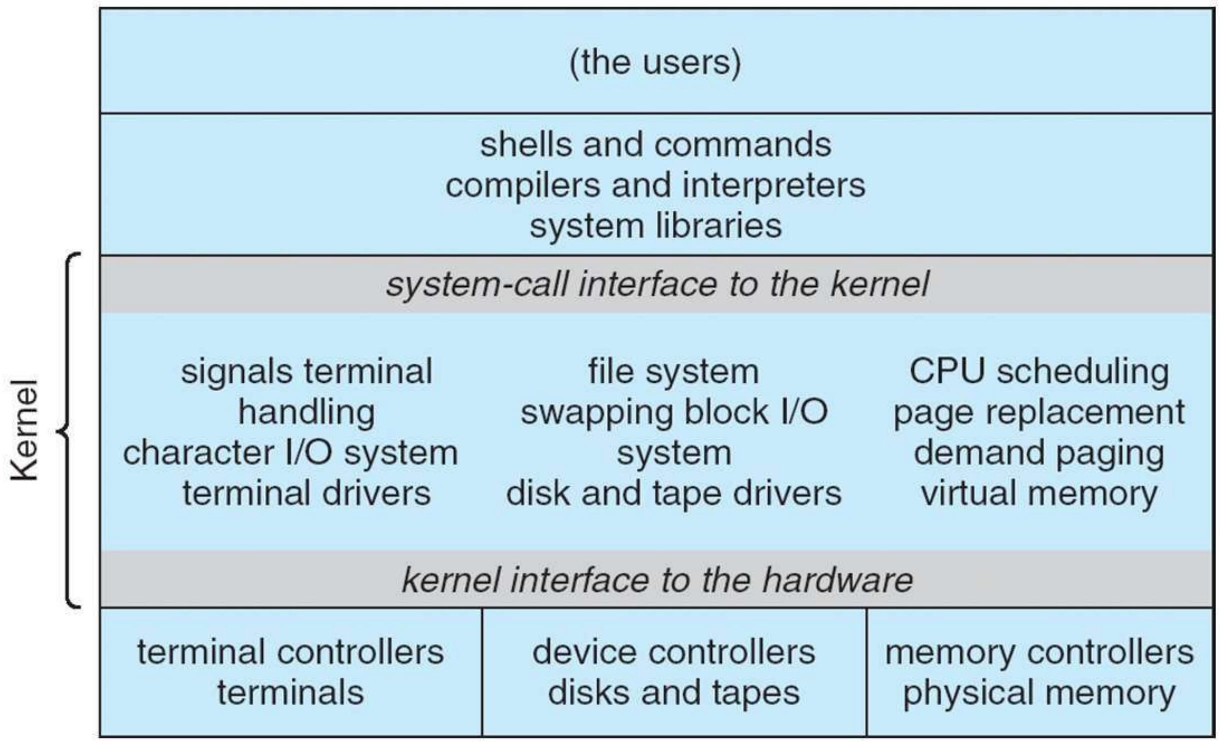
MS-DOS

- 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



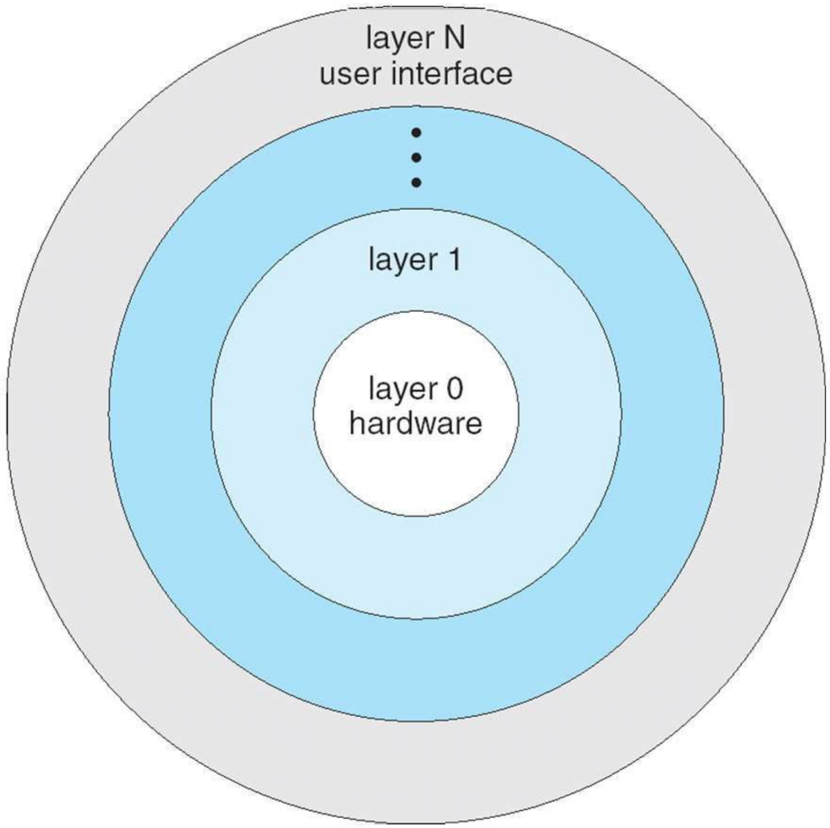
UNIX

- Traditional UNIX OS consists of two separable parts
  - Systems programs
  - Kernel
- Kernel consists of everything below the system-call interface and above the physical hardware

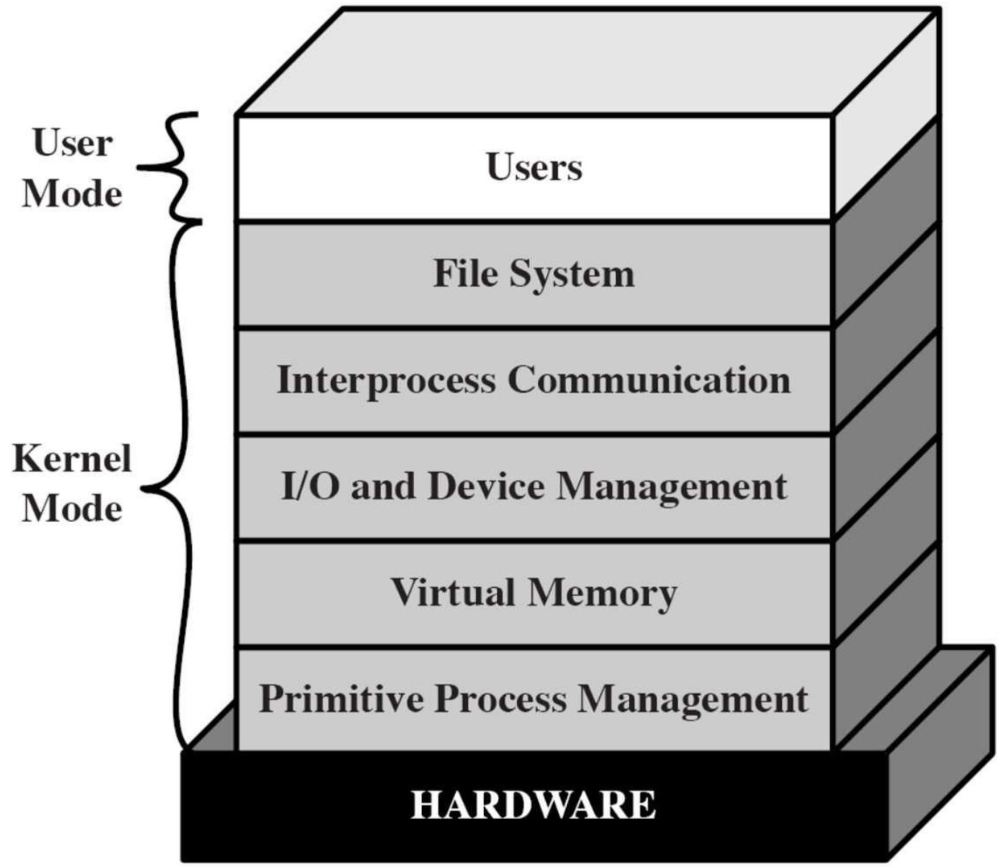


Layered Approach

- Break operating system into pieces
- Each layer interacts only with its lower layer
- Benefits
  - Allows to built modular systems
  - Can exchange each layer
  - Facilitates testing
    - Look at each layer separately
- Drawback
  - Difficult to define appropriate layers
  - Sometimes contradictory needs
  - Tends to be less efficient



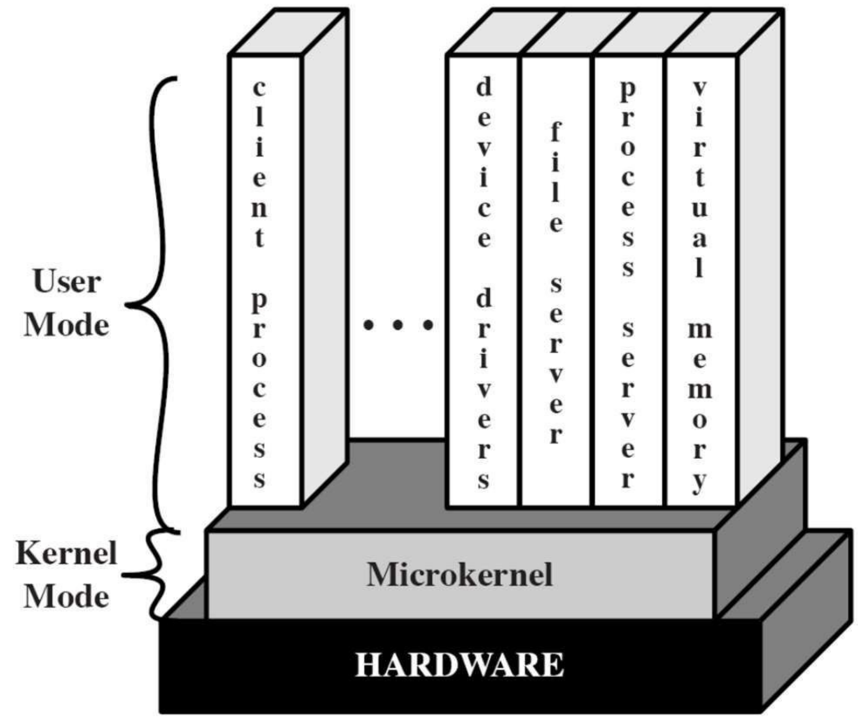
Layered Approach – Example



Microkernel

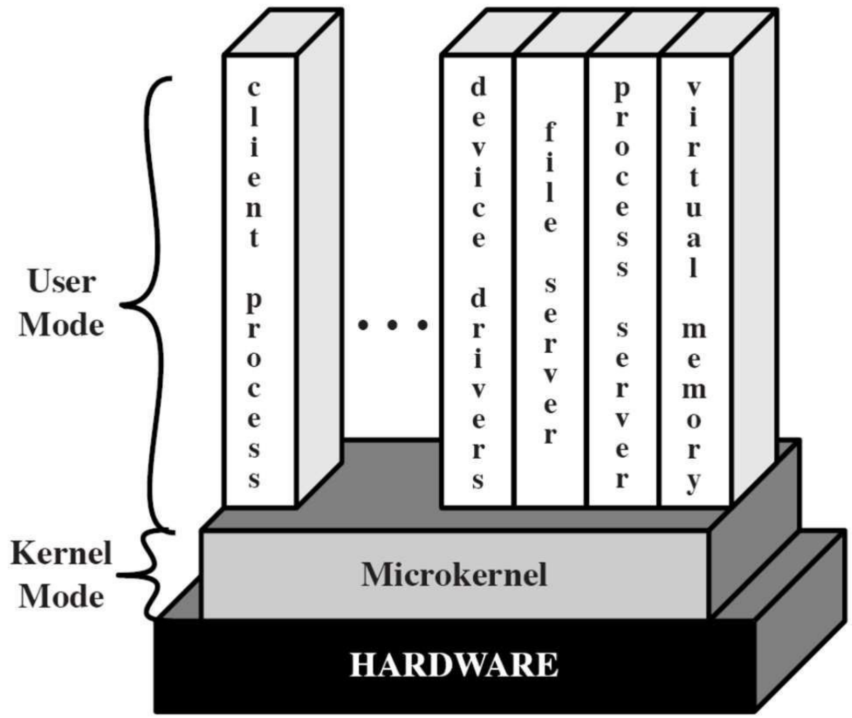
- Small OS core – contains only essential OS functions
  - Low-level memory management
  - Process scheduling
  - Communication facility

- Many services traditionally included in the OS kernel are now external subsystems
  - Device drivers, file systems, virtual memory manager, windowing system, security services
  - Run in user mode

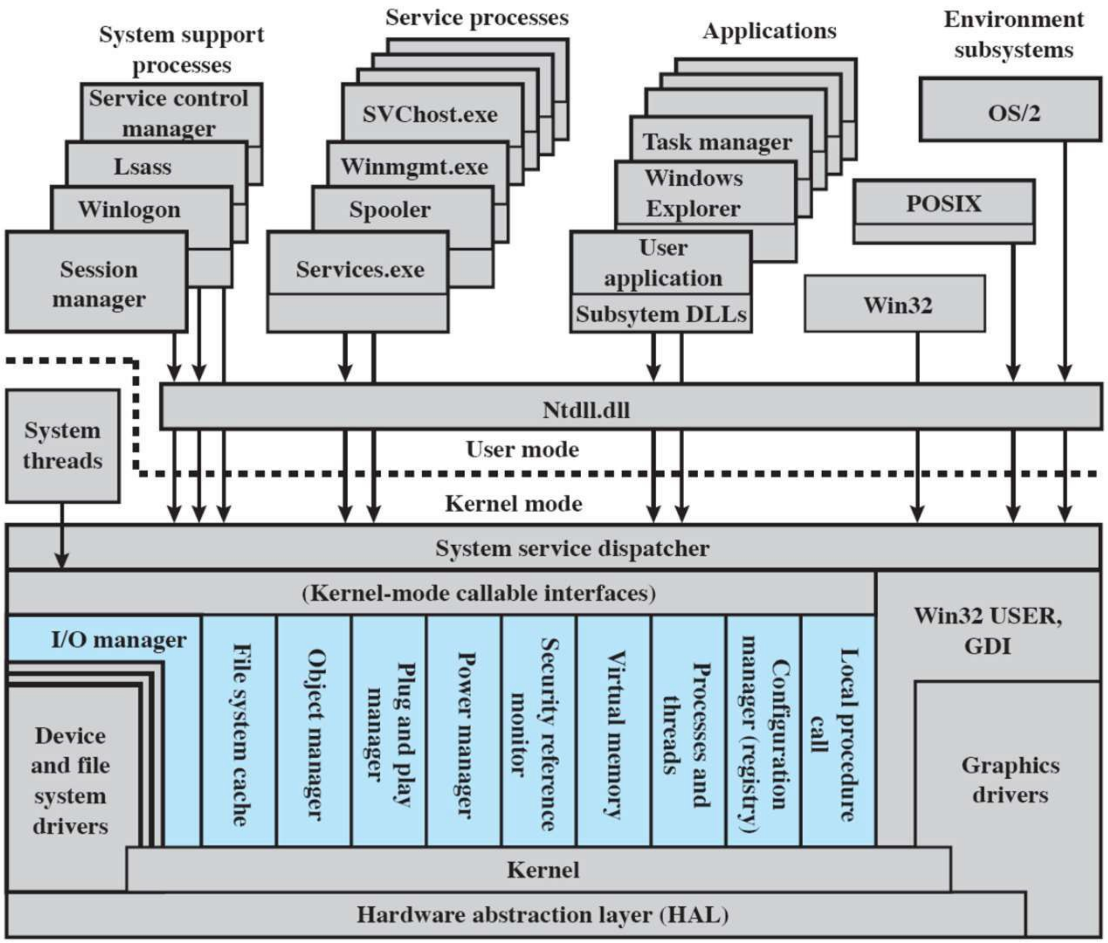


Microkernel

- Corresponds to client/server model
  - 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



Windows 2000



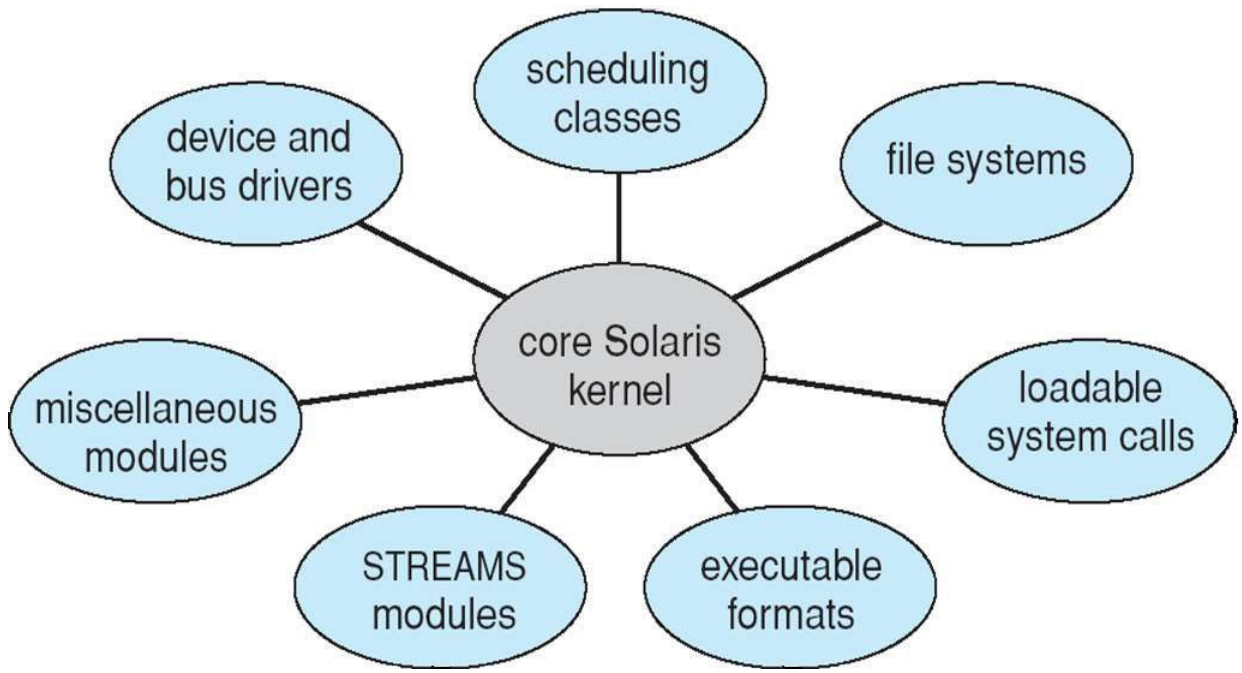
Lsass = local security authentication server
POSIX = portable operating system interface
GDI = graphics device interface
DLL = dynamic link libraries

Colored area indicates Executive

- Client/Server computing
- Modified microkernel architecture
  - Not a pure microkernel: many system functions outside of the microkernel run in kernel mode
  - Modules can be removed, upgraded, or replaced without rewriting the entire system

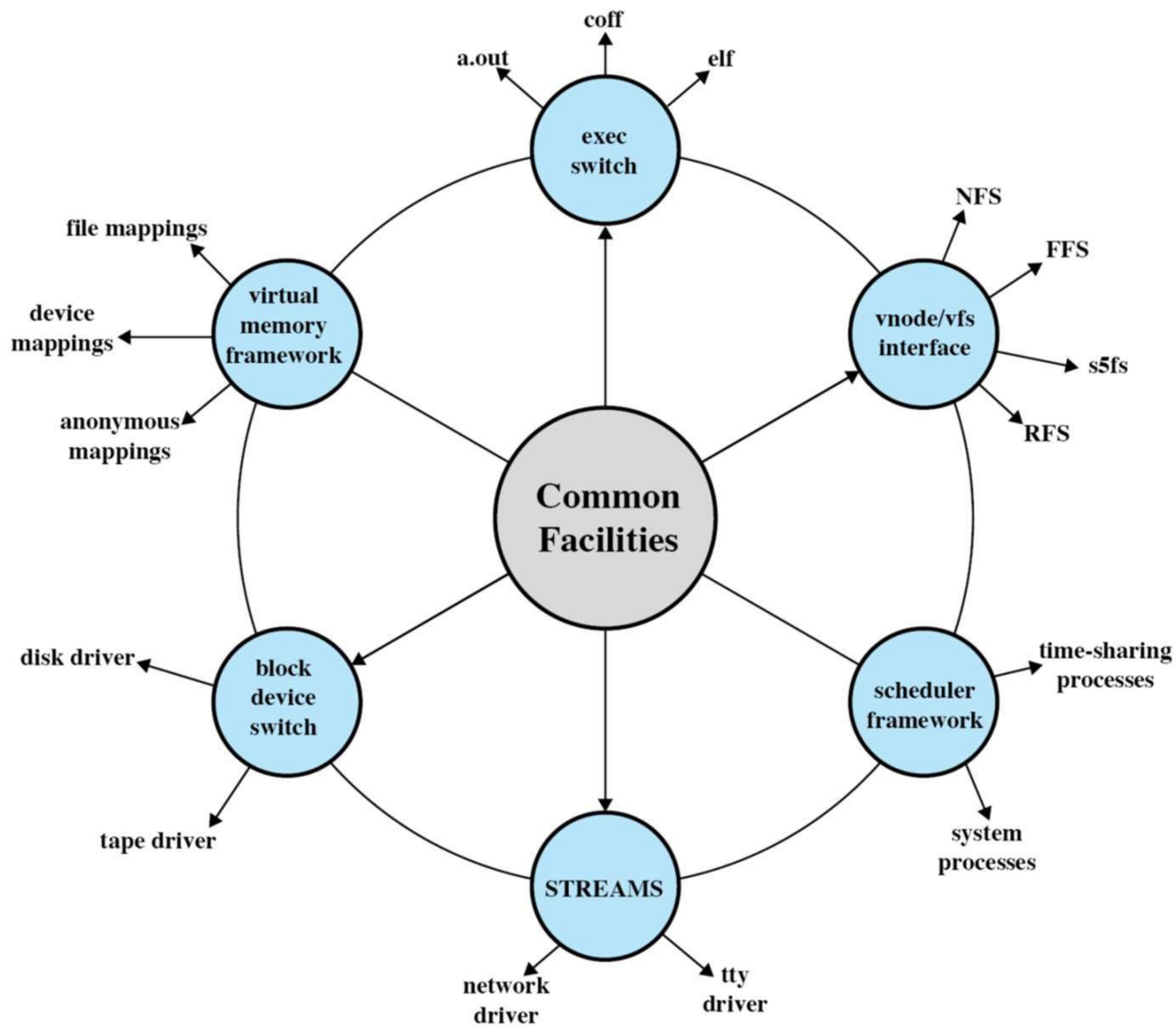
Modules

- Most modern operating systems implement kernel modules
  - 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



Modular Approach in Modern UNIX Instances

- Kernel set of core facilities
- Modules can be dynamically linked during run time
- Modern Unix approaches, e.g., Solaris follow a modular organization



Virtual Machines

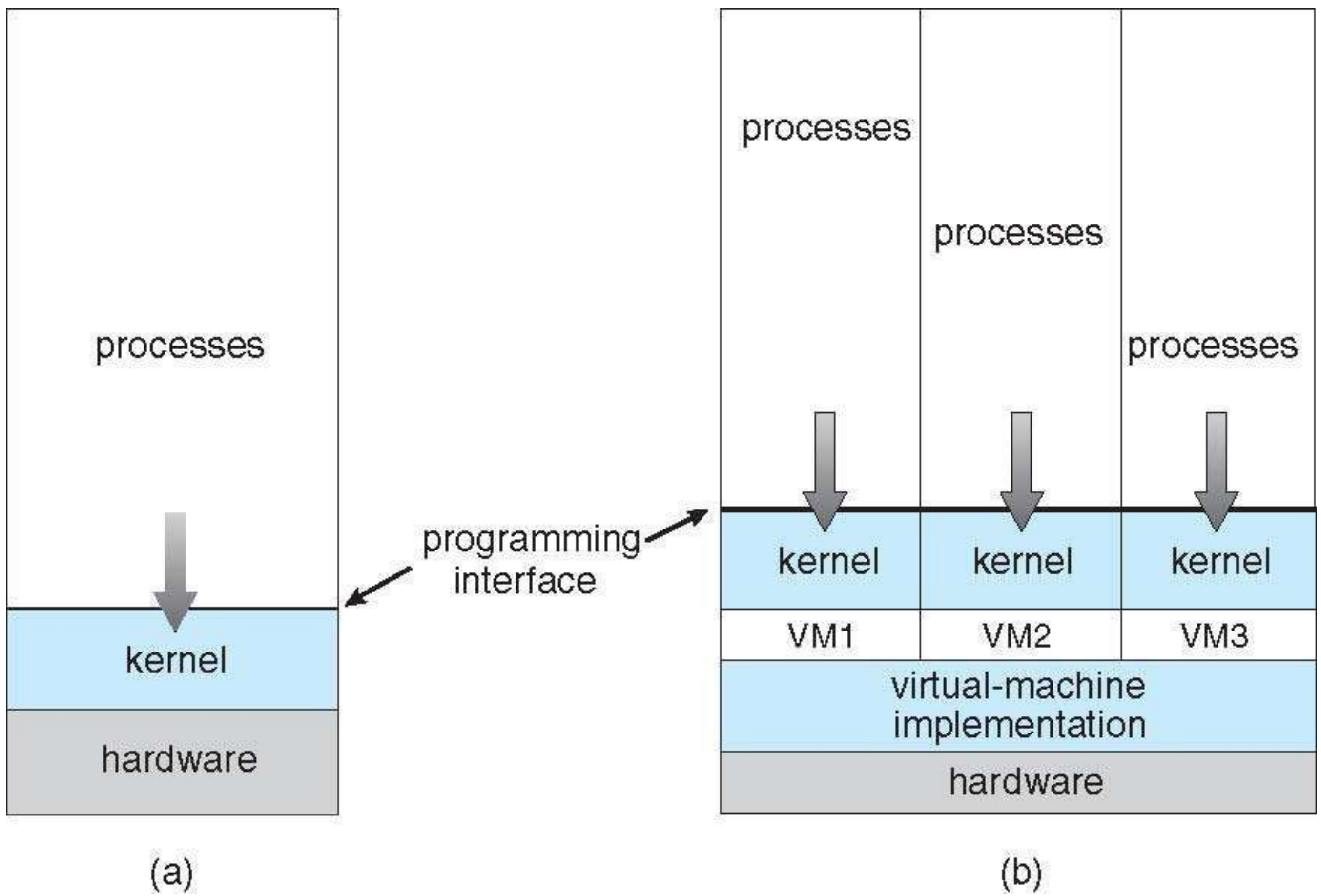
- Abstract the hardware of a single computer into several different execution environment
  - CPU, memory, disk drives, network interface cards and so forth

- Creates the illusion that each execution environment is running its own private computer

- A virtual machine provides interface identical to underlying bare hardware
  - I.e., all devices, interrupts, memory, page tables, etc.

- Virtual Machine Operating System creates illusion of multiple processors
  - Each capable of executing independently
  - No sharing, except via network protocols

Virtual Machines



(a) Non-virtual machine (b) Virtual machine

Java Virtual Machine

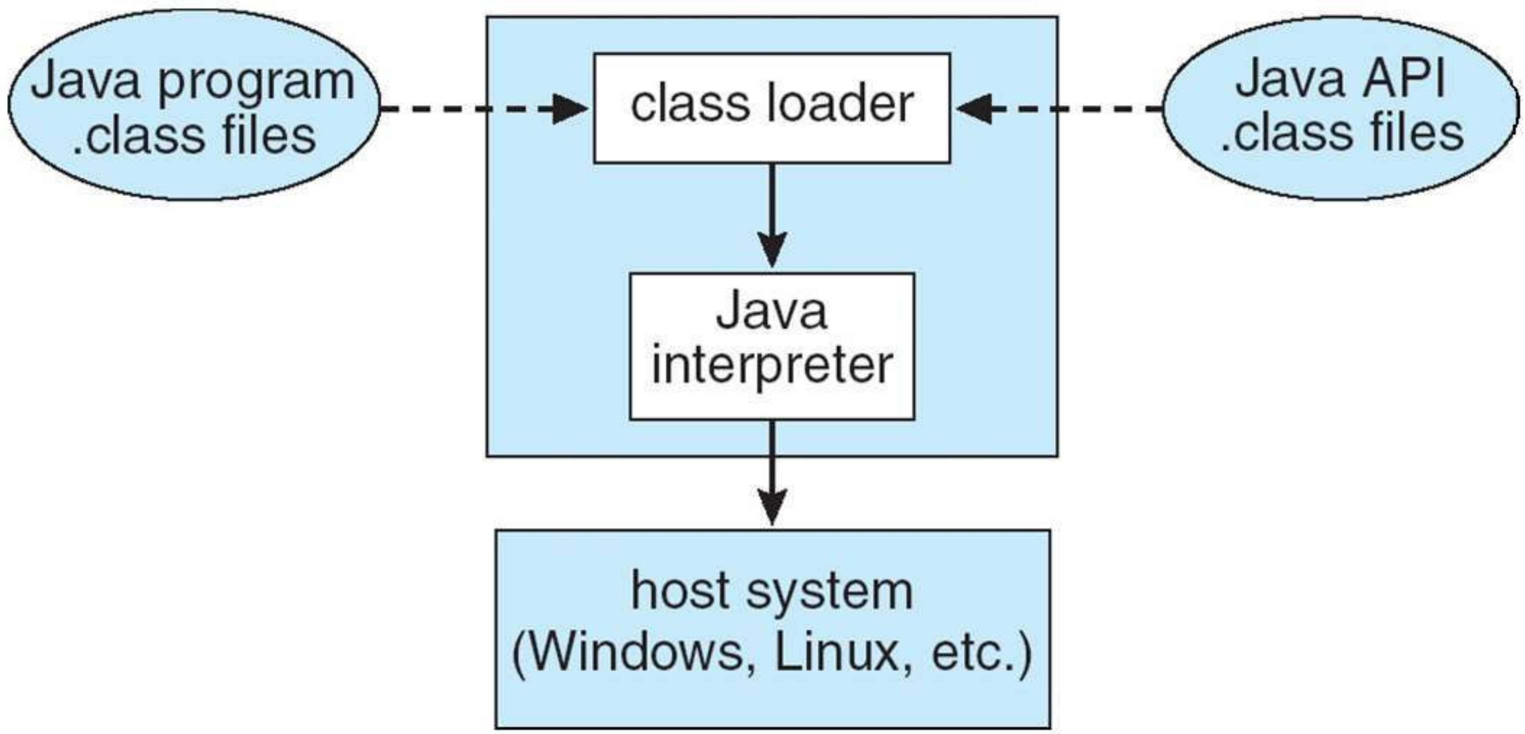
- Compiled Java programs are platform-neutral byte-codes
  - Executed by a Java Virtual Machine (JVM)

- JVM consists of
  - Class loader
  - Class verifier
  - Runtime interpreter

- Class verifier checks
  - .class file is valid Java byte code
  - Does not overflow or underflow the stack
  - Byte code does not perform illegal memory access

- Just-In-Time (JIT) compilers increase performance

Java Virtual Machine



Any Question So Far?