Operating System Concepts

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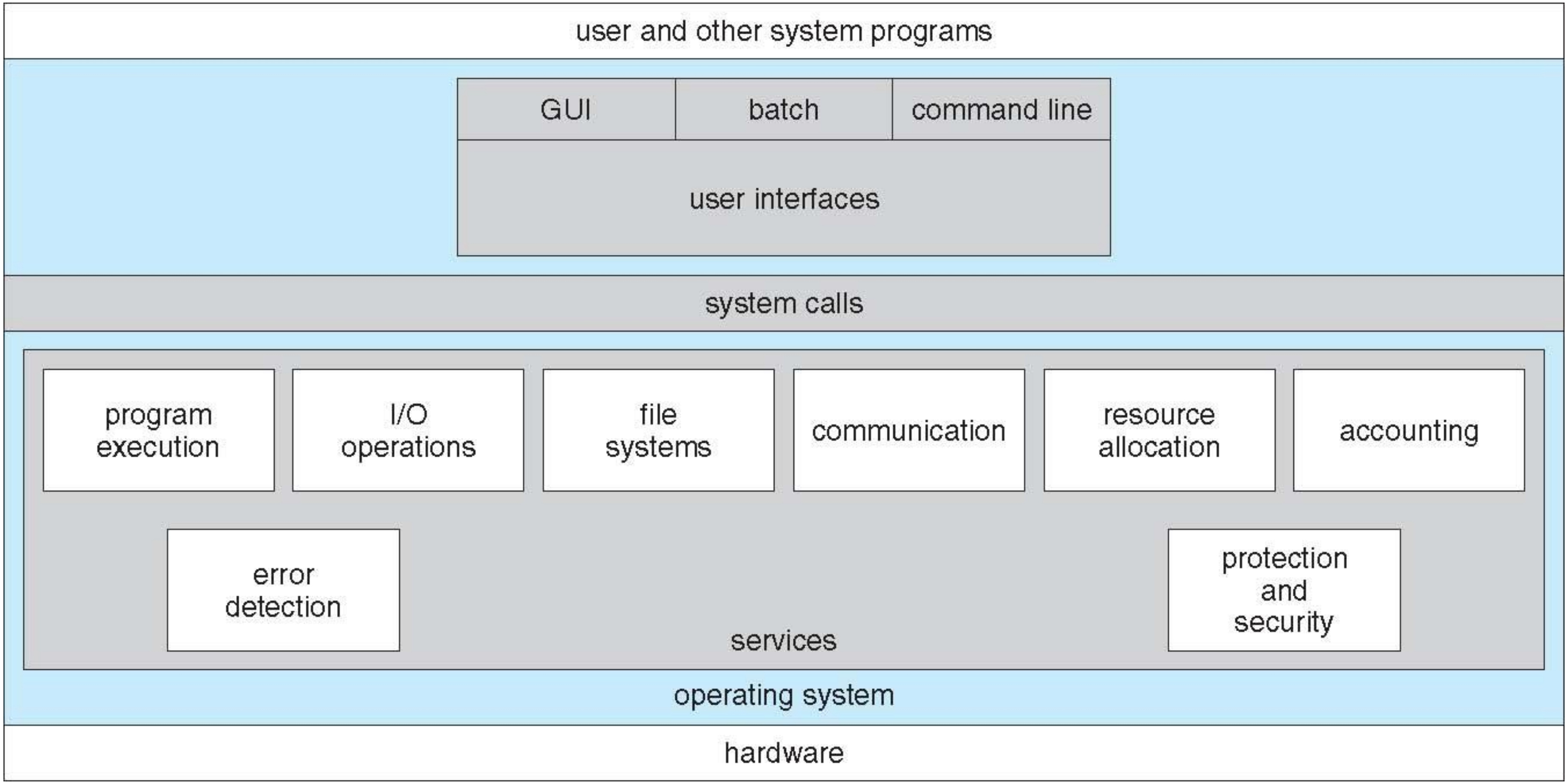
Contents

Chapter 2.
System Structures

A View of Operating System Services



Operation-System Services (1/3)

- User Interface (UI)
  - Command line Interface, batch interface, graphical user interface (GUI), etc.
  - Interface between the user and the operating system
  - Friendly UI’s
    - Command-line-based interfaces or mused-based window-and-menu interface
  - For example, UNIX shell and command.com in MS-DOS
- Program Execution
  - Loading, running, terminating, etc.

Operation-System Services (2/3)

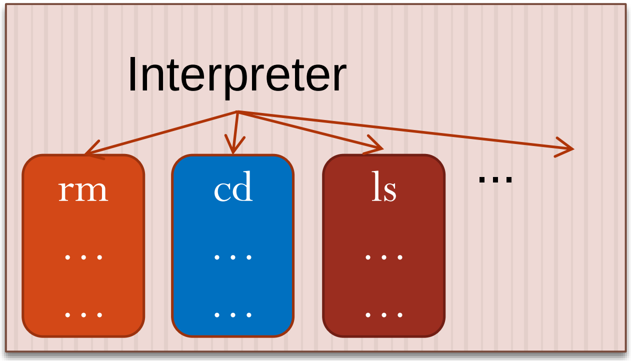
- I/O Operations
  - General/special operations for devices
    - Efficiency & protection
- File-System Manipulation
  - Read, write, create, delete, etc.
  - File and Directory Management
  - Permission Management
- Communications
  - Intra-processor or inter-processor communication
    - Shared memory or message passing

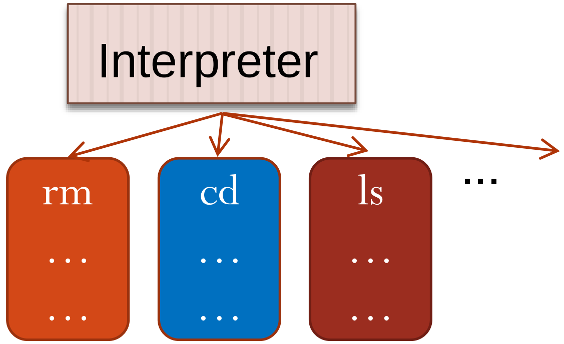
Operation-System Services (3/3)

- Error Detection
  - Possible errors from CPU, memory, devices, user programs
    → Ensure correct & consistent computing
- Resource Allocation
  - Multiple users might use some shared resources
  - Resource management has to be efficiency
- Accounting
  - Statistics or accounting
- Protection and Security
  - Ensure that all access to system resources is controlled
  - Enforce that all requests are authenticated

User OS Interface—Command Interpreter

- Two Approaches to Implement a Command-Line Interpreter (CLI):
  - Contain codes to execute commands
    - Fast but the interpreter tends to be big
    - Painful in revision
  - Implement commands as system programs→ Search programs which correspond to the commands (UNIX)
    - Using parameter passing
    - Being slow
    - Inconsistent interpretation of parameters

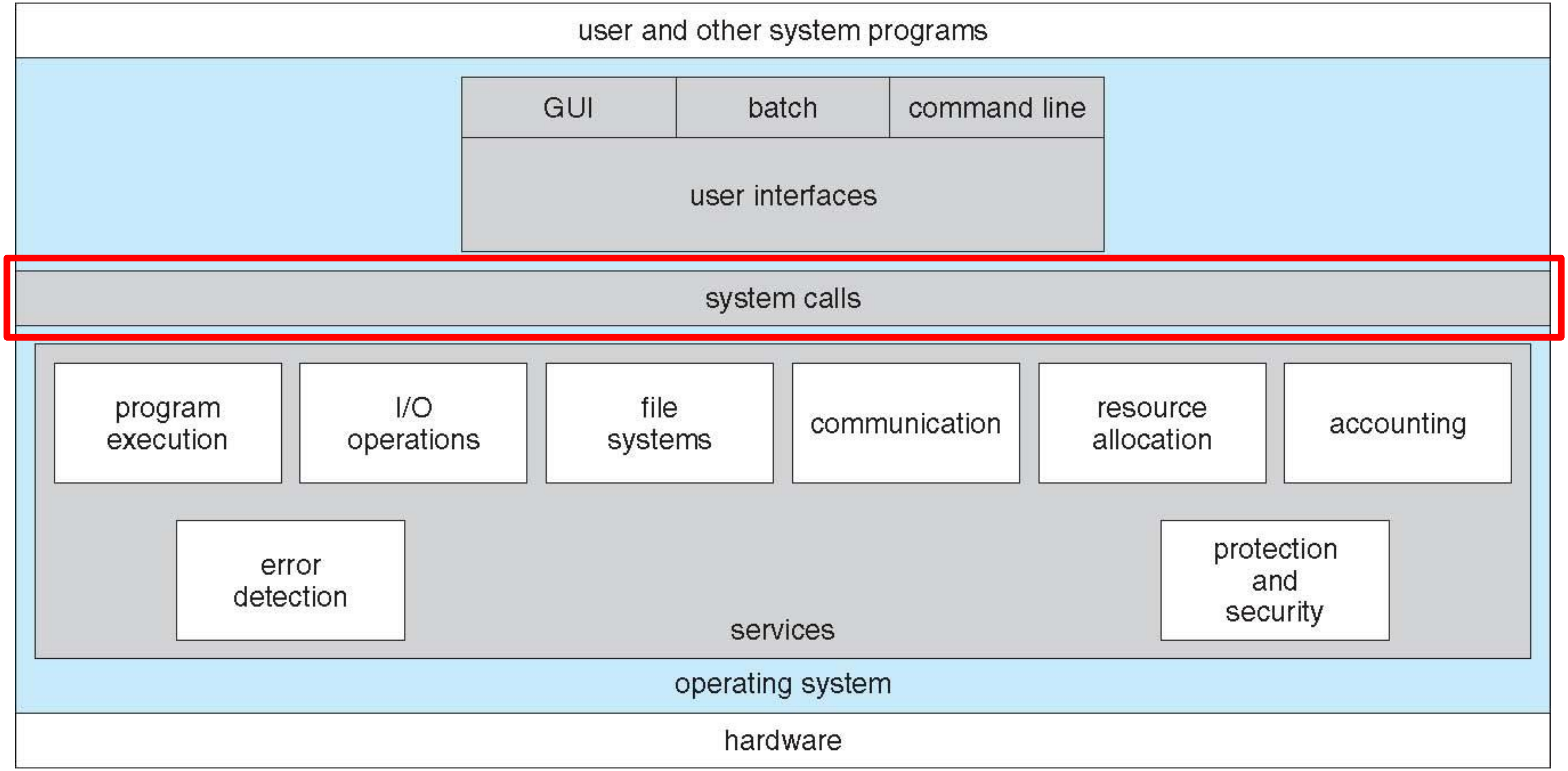




User OS Interface— GUI

- Components
  - Screen, icons, folders, pointer, etc.
- History
  - Xerox PARC research facility (1970’s)
  - Mouse– 1968
  - Mac OS– 1980’s
  - Windows 1.0~ 10
- Trends
  - Mixture of GUI and command-line interfaces
  - Multimedia, intelligence, etc.

System Calls in an OS



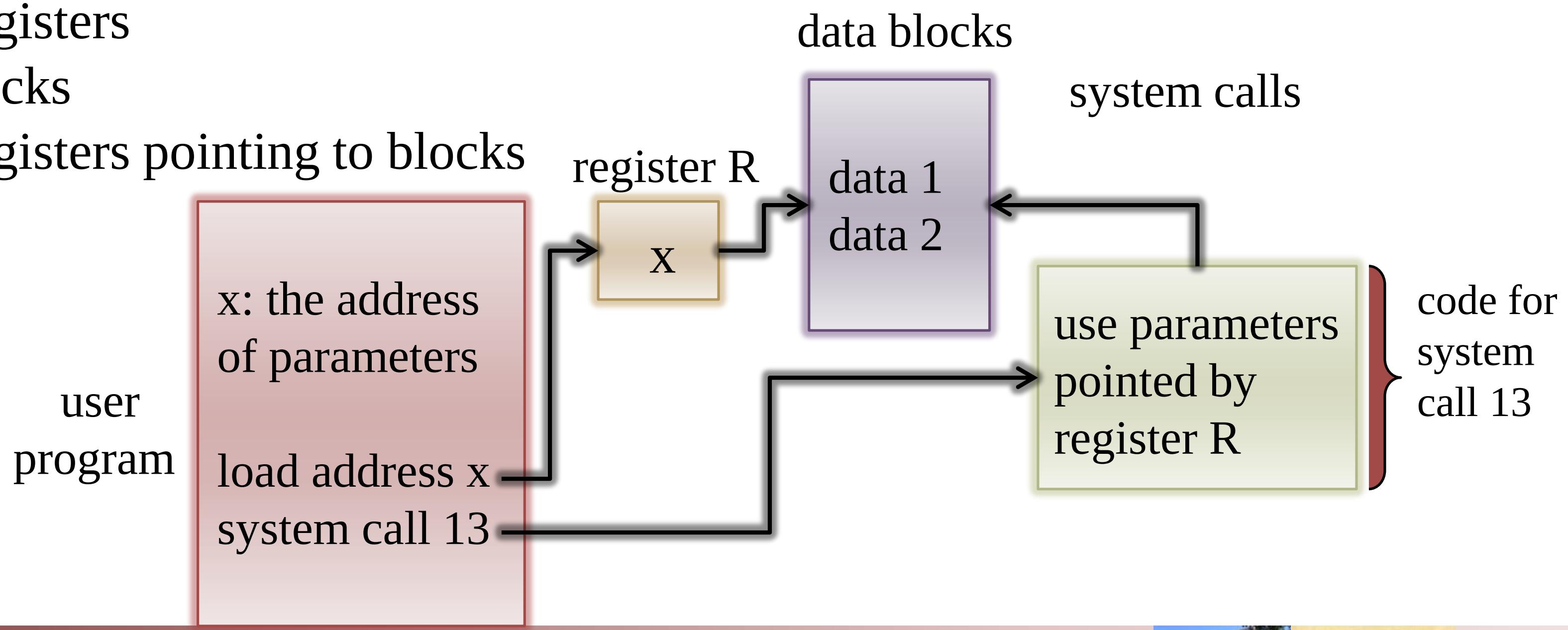
System Calls (1/2)

- System Calls
  - Interface between user processes and the OS
- Application Programming Interface (API)
  - Most details of OS interface hidden from programmer by API
  - Examples:
    - Win32 API for Windows
    - POSIX* API for POSIX-based systems including UNIX, Linux, and Mac OS X
  - Benefits (API vs System Calls)
    - Good portability, Ease of use, and Better functionality

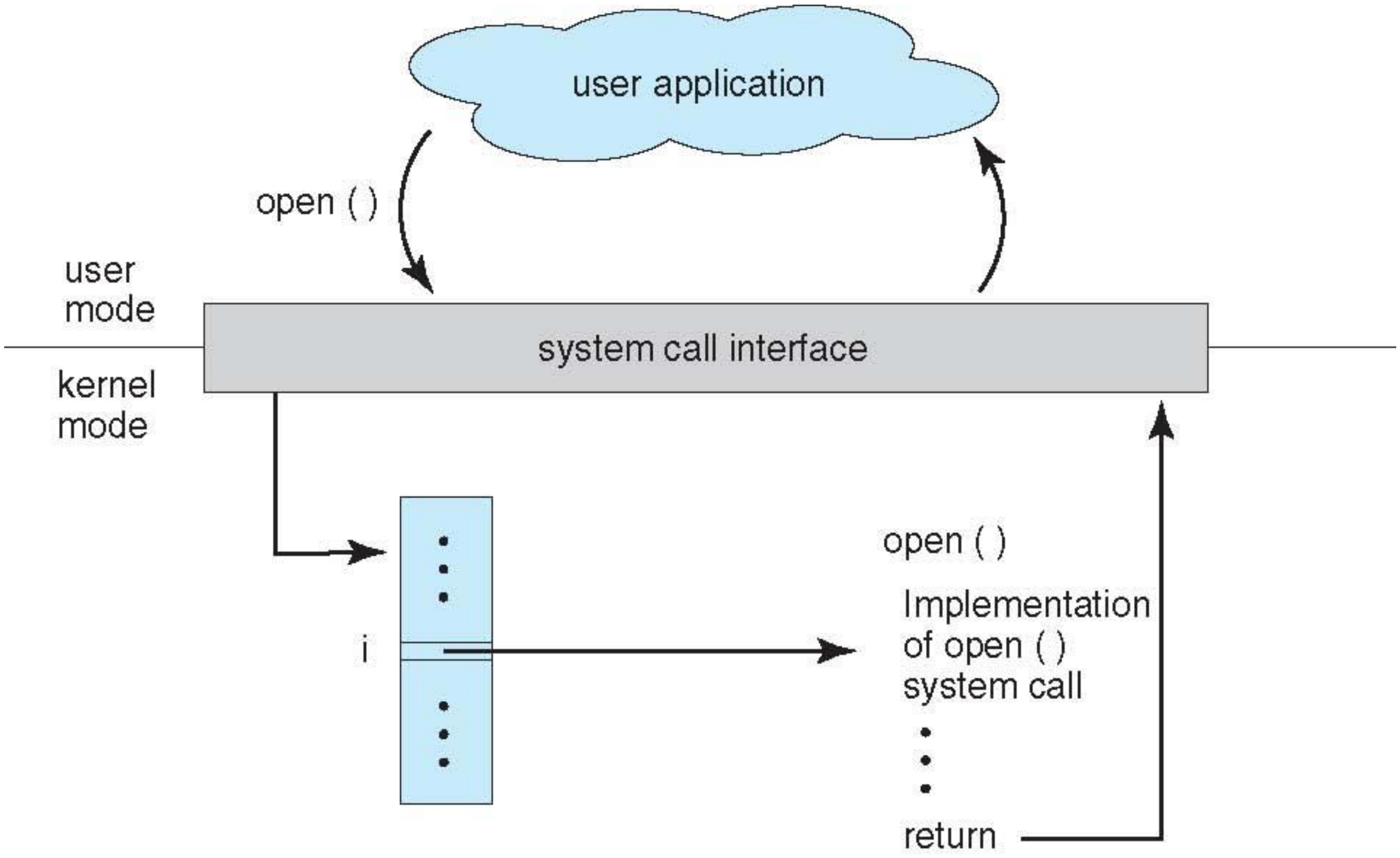
*POSIX: Portable Operating System Interface

System Calls (2/2)

- Triggering a System Call
  - Use a special instruction supported by the hardware
    - For Intel x86, it is “int 0x80”
  - Provide the type and parameters of the system call
- Parameter Passing
  - Registers
  - Stacks
  - Registers pointing to blocks

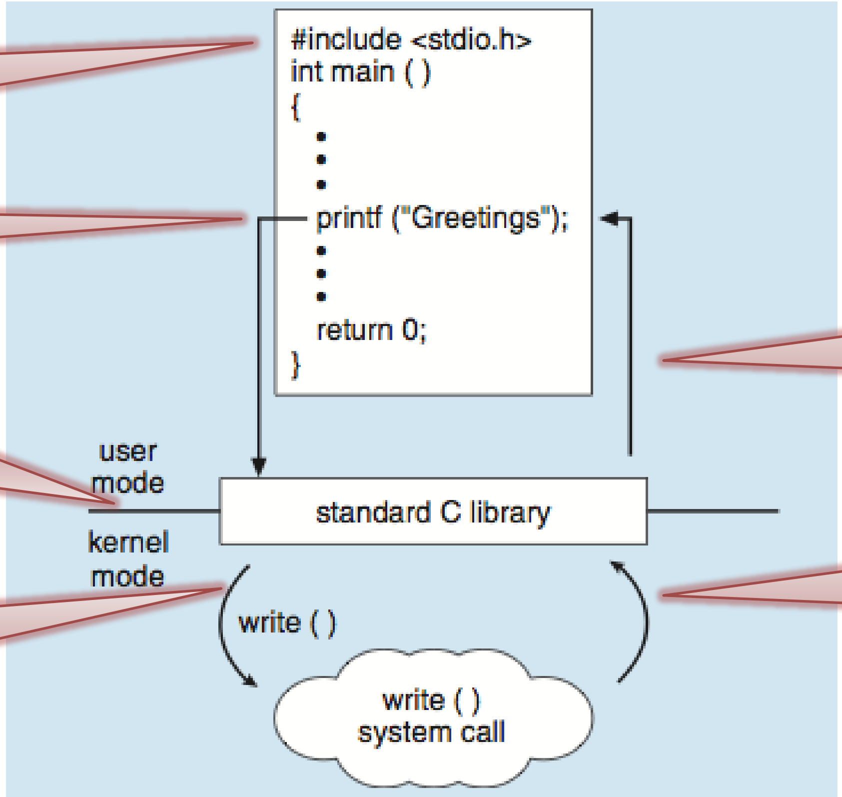


Relationship of System Call and OS



API, System Call and OS

- A C program can invoke printf() in the library (API)
- In the API implementation, printf() calls write() system call



Include a header file of the API (glibc in Linux)

Call a function of the API

The function printf() calls a system call write()

Change into kernel mode and run write()

Return from API call

Return from system call

Types of System Calls

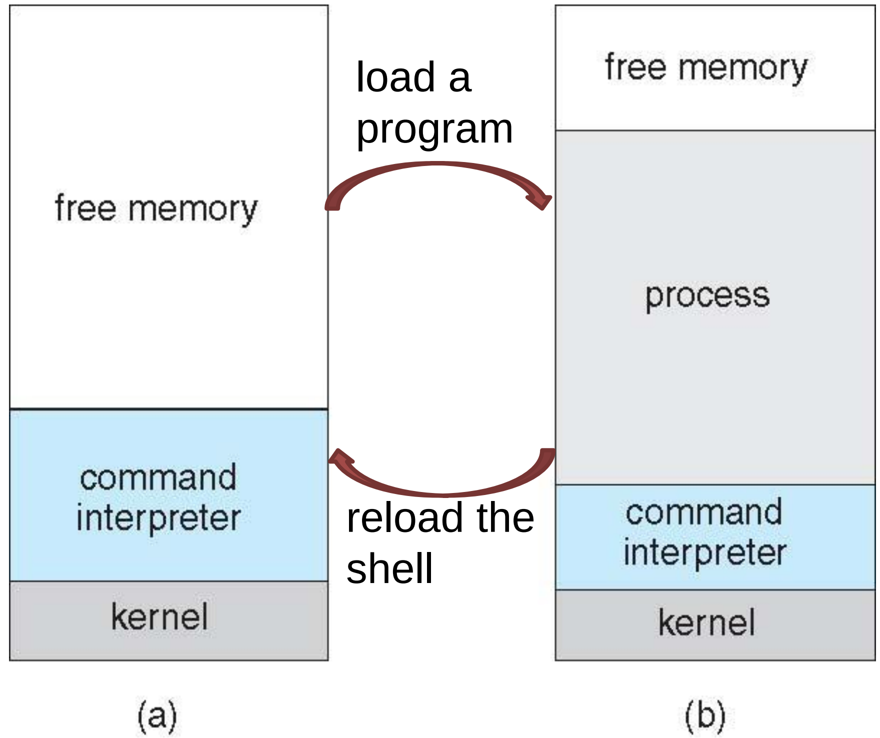
- Process Control
- File Management
- Device Management
- Information Maintenance
- Communications
- Protection

System Calls— Process Control (1/3)

- Load and execute
  - Have to return the control
- End (normal exit) or abort (abnormal)
  - Error level or no
  - Interactive, batch, GUI-supported systems
- Creation and/or termination of other processes
  - To support the techniques of multiprogramming and timesharing mentioned in Chapter 1
- Get process attributes, set process attributes
- Wait for time, wait event, signal event
- Allocate and free memory

System Calls— Process Control (2/3)

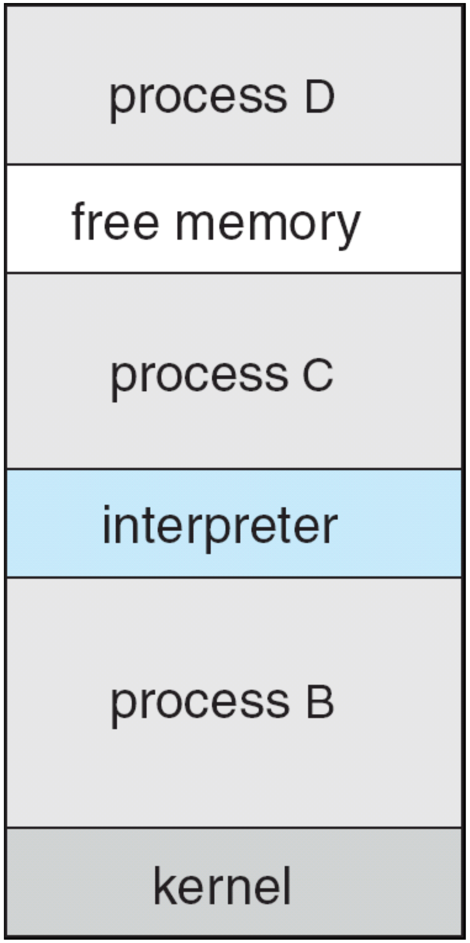
- Example: MS-DOS
  - Single-tasking
  - Shell is invoked when system is booted
  - Single memory space
  - Loads program into memory, overwriting all but the kernel
  - Program exit → shell reloaded



(a) At system startup (b) running a program

System Calls— Process Control (3/3)

- Example: FreeBSD
  - Multitasking
  - OS invokes user's choice of shell
  - Shell executes fork() system call to create process
  - OS loads program into process
  - Shell waits for process to terminate or continues with user commands
  - Process exits with return code
    - with code of 0 → no error
    - with code > 0 → error code



System Calls— File Management

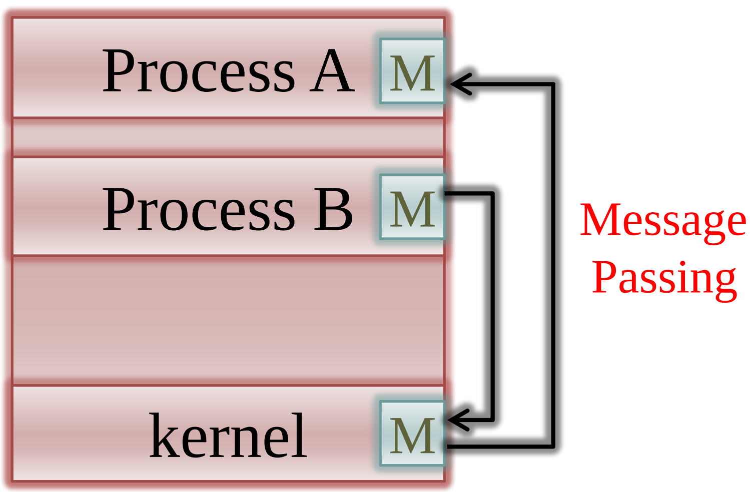
- Create and delete
- Open and close
- Read, write, and reposition (e.g., rewinding)
- Get or set attributes of files
- Operations for directories

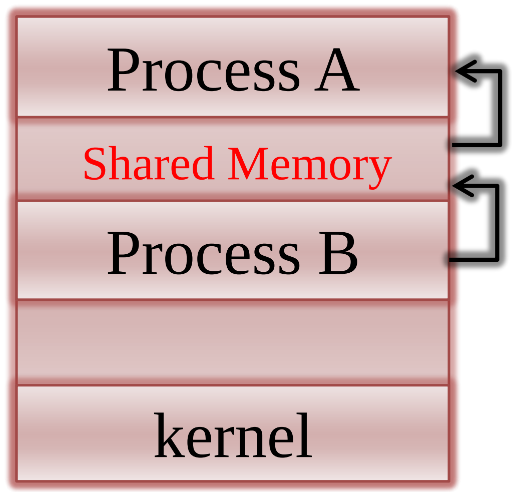
System Calls—Device Management

- Request device, release device
- Read, write, reposition
- Get device attributes, set device attributes
- Logically attach or detach devices

System Calls— Communications

- Message Passing
  - Open, close, accept connections
  - No access conflict and easy implementation
- Shared Memory
  - Memory mapping and process synchronization
  - Short latency and high throughput





System Calls— Information Maintenance and Protection

- Information Maintenance
  - Get time or date, set time or date
  - Get system data, set system data
- Protection
  - Control access to resources
  - Get and set permissions
  - Allow and deny user access

System Programs

- Goal:
  - Provide a convenient environment for program development and execution
- Types
  - File Management, e.g., rm
  - Status information, e.g., date
  - File Modifications, e.g., editors
  - Program Loading and Executions, e.g., loader
  - Programming Language Supports, e.g., compilers
  - Communications, e.g., telnet

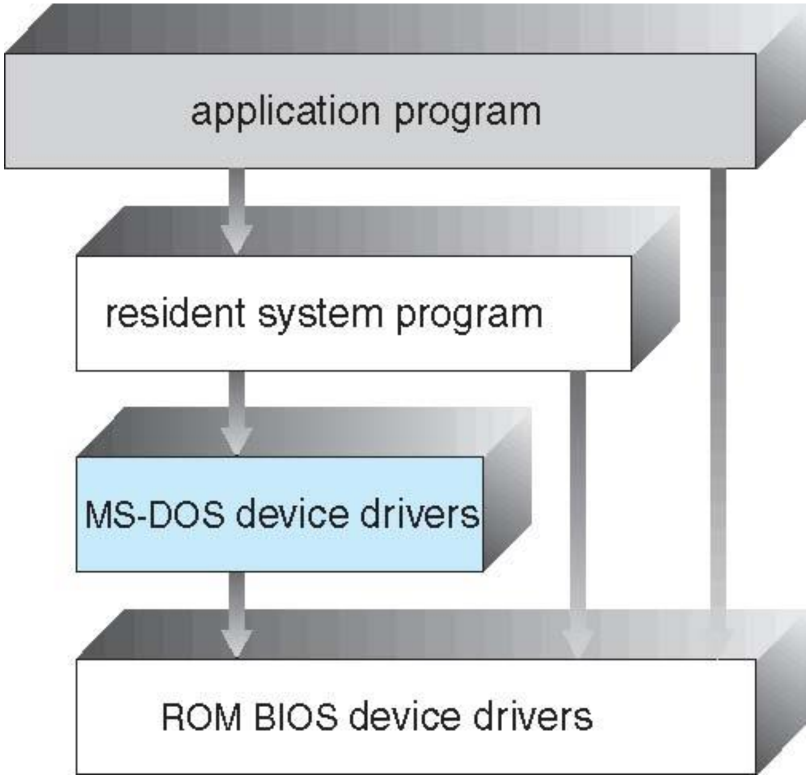
Policies and Approaches of OS Implementation

Operating System Design and Implementation

- Design Goals and Specifications
  - User goals: ease of use, short latency
  - System goals: reliable, high utilization
- Separation of Policy and Mechanism
  - Policy: What will be done
  - Mechanism：How to do things
- OS Implementation in High-Level Languages
  - Advantages:
    - Being easy to understand and debug
    - Being written fast, more compact, and portable
  - Disadvantages:
    - Less efficient
    - Larger size

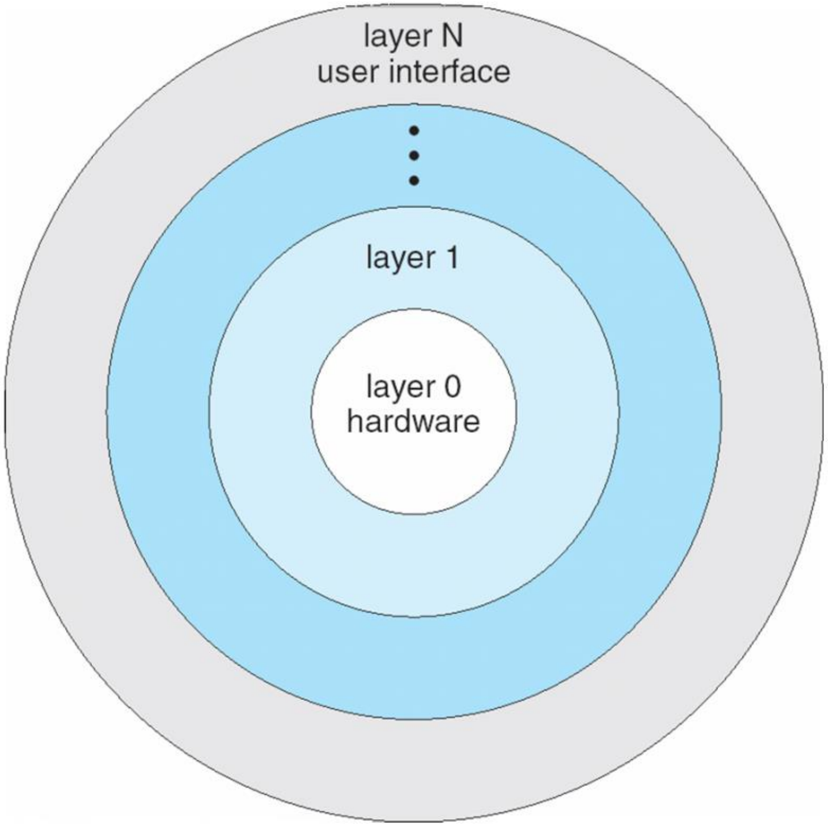
Operating System Structure—MS-DOS

- Not divided into modules
- Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated



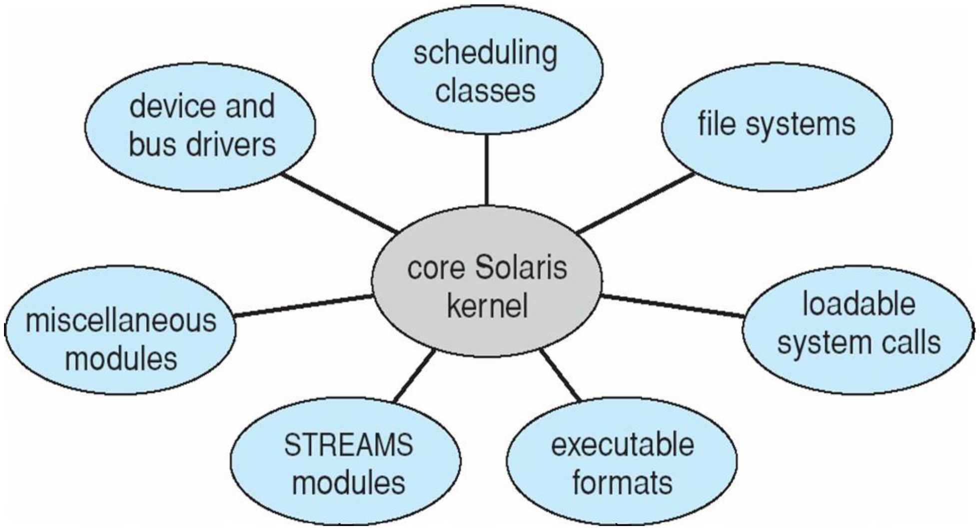
Operating System Structure—Layered Approach

- Advantage: Modularity
  →Debugging & Verification
- Difficulty: Appropriate layer definitions, less efficiency due to overheads
- A Layer Definition Example:
  - L5 User programs
  - L4 I/O buffering
  - L3 Operator-console device driver
  - L2 Memory management
  - L1 CPU scheduling
  - L0 Hardware



OS Structure— Modules

- Most modern operating systems implement loadable kernel modules
  - Uses object-oriented approach
  - Each core component is separate
- Solaris Modular Approach



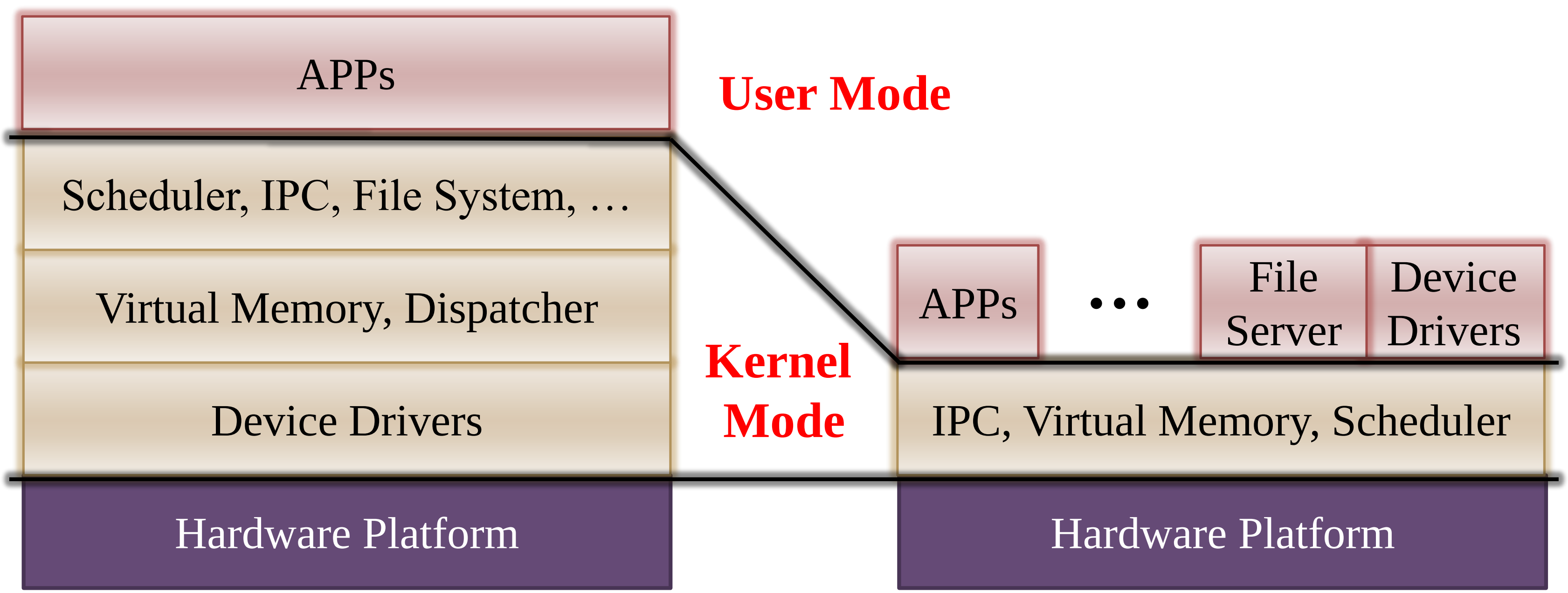
OS Structure— Microkernels

- The concept of microkernels was proposed in CMU in mid 1980s (Mach)
  - Moving all nonessential components from the kernel to the user or system programs
- Benefits
  - Ease of OS service extensions → portability, reliability, security
- Examples
  - Tru64 UNIX (Mach kernel), MacOS X (Darwin kernel), L4 Microkernel

Monolithic Kernel and Microkernel

Monolithic Kernel

Microkernel

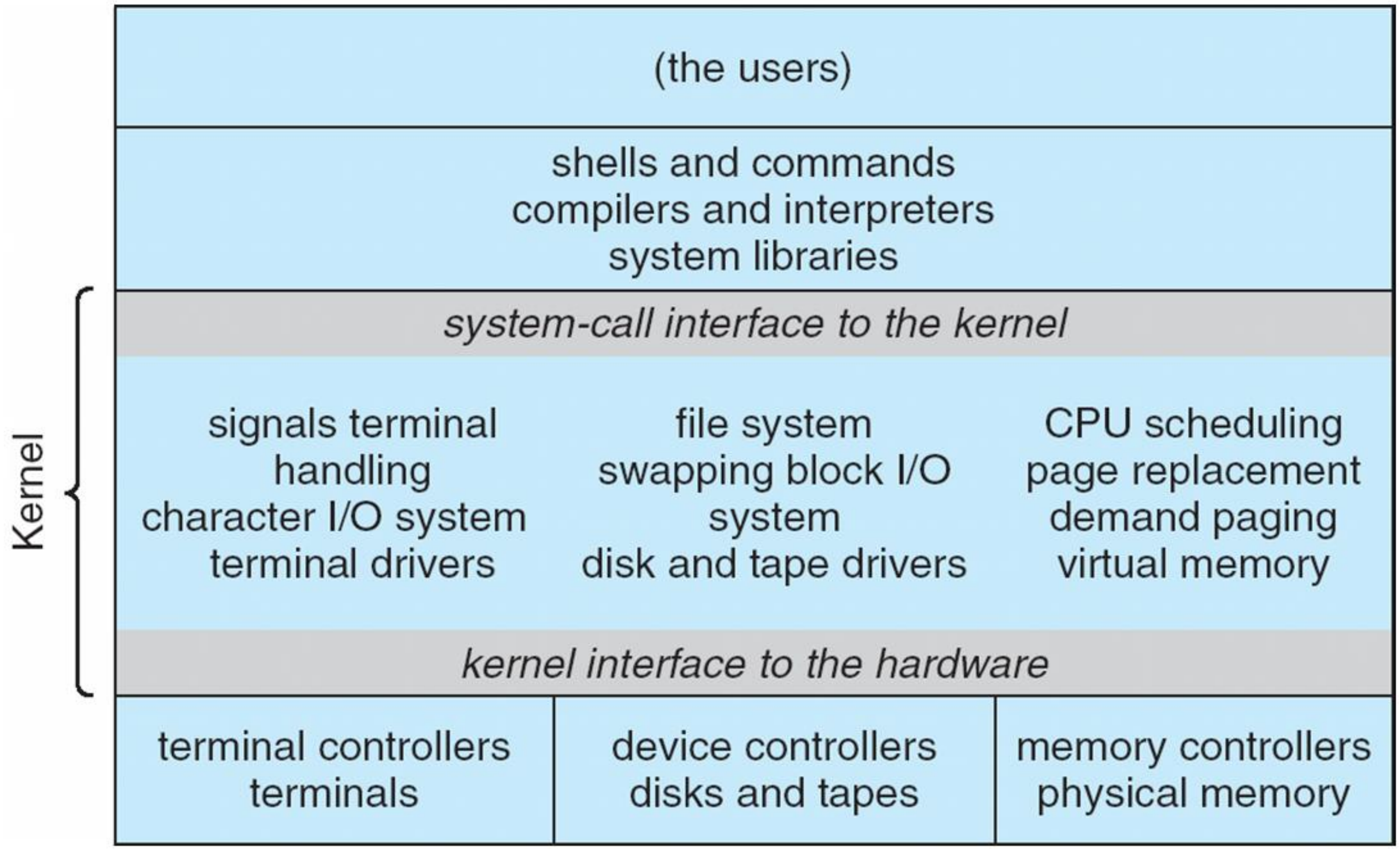


Hybrid Systems

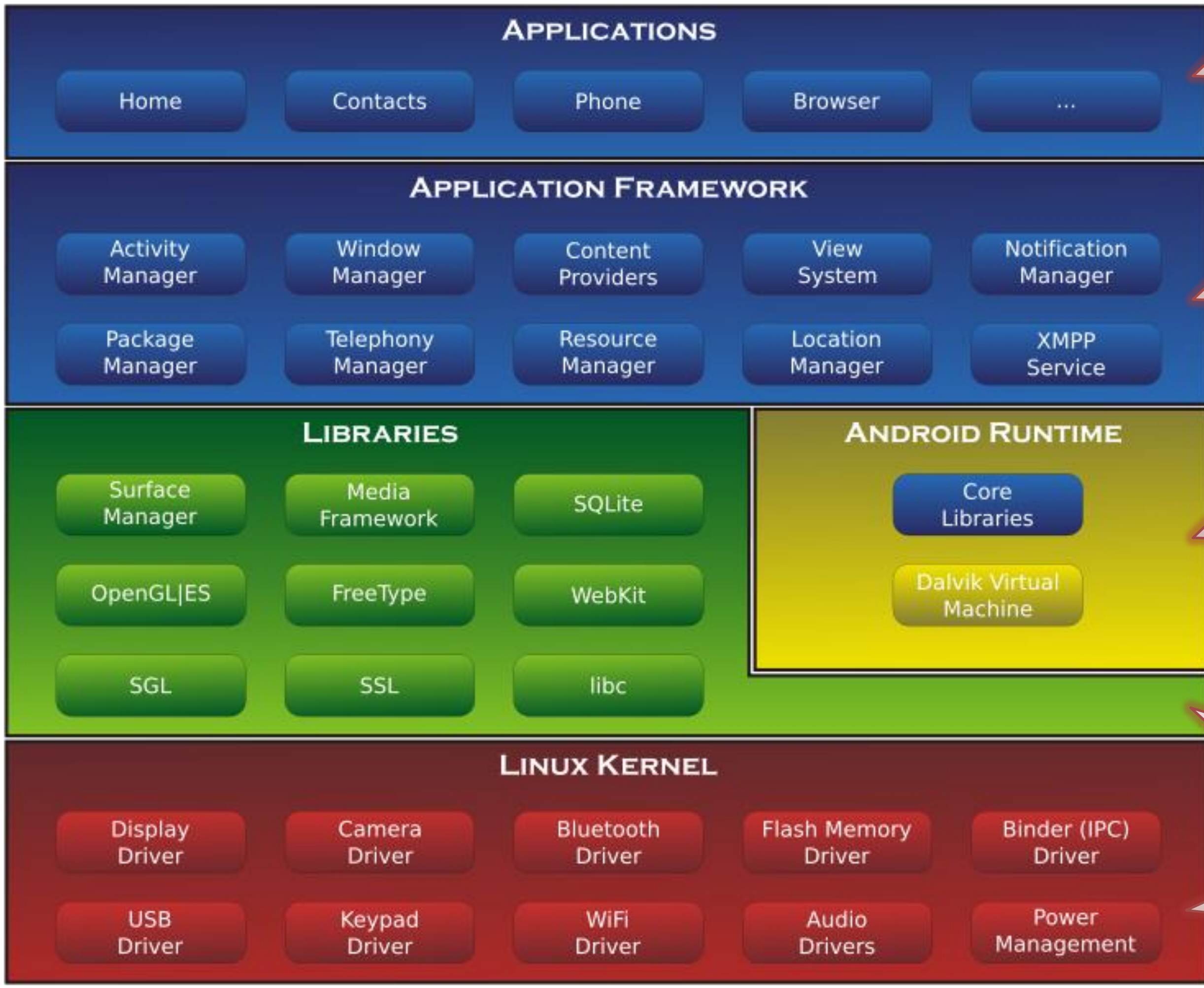
- Most modern operating systems actually use more than one model for their implementations
- Hybrid combines multiple approaches to address performance, security, usability needs
  - Linux and Solaris kernels in kernel address space, so monolithic, plus modular for dynamic loading of functionality
  - Windows mostly monolithic, plus microkernel for different subsystem personalities
  - Apple Mac OS X is based on a microkernel and also hybrid, layered, Aqua UI plus Cocoa programming environment

Traditional UNIX System Structure

- Beyond simple but not fully layered



OS Structure— Android



Include a Java-like API for user applications

Define frequently used function packages

Run each program on a Dalvik virtual machine

Provide useful libraries

Use the Linux kernel

Source: http://en.wikipedia.org/wiki/Android_(operating_system)

OS Structure— iOS

- Apple mobile OS for iPhone, iPad
  - Structured on Mac OS X, added functionality
  - Also runs on different CPU architecture (ARM vs. Intel)
  - Media services layer for graphics, audio, video
  - Cocoa Touch Objective-C and Swift APIs for developing apps

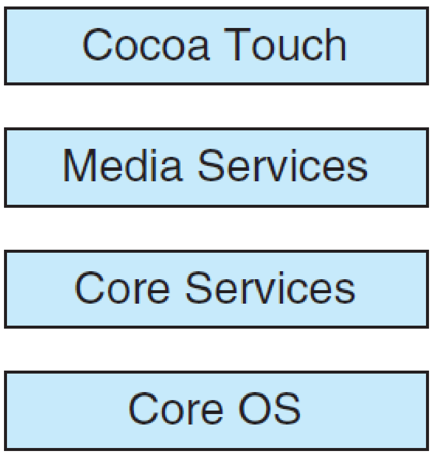


Figure 2.17 Architecture of Apple's iOS.

Operating System Debugging

- Debugging
  - An activity in finding and fixing errors or bugs, including performance problem, that exist in hardware or software
- Terminologies
  - Profiling– A procedure to understand the statistical trends
  - Performance tuning– A procedure that seeks to improve performance by removing bottlenecks
  - Crash– A kernel failure
  - Core dump– A capture of the memory of a process or OS

Operating System Generation

- Operating systems are designed to run on any of a class of machines; the system must be configured for each specific computer site
- SYSGEN program obtains information concerning the specific configuration of the hardware system
  - Used to build system-specific compiled kernel
  - Can generate more efficient code than one general kernel

Ease of modification

Good performance and smaller size

No recompilation & completely table-driven

Linking of modules for selected OS

Recompilation of a modified source code

System Boot

- When power is initialized on a system, execution starts at a fixed memory location
  - Firmware ROM is used to hold initial boot code
- Operating systems must be made available to hardware so hardware can start it
  - Small piece of code– bootstrap loader, stored in ROM or EEPROM locates the kernel, loads it into memory, and starts it
  - Sometimes two-step process where boot block at fixed location loaded by ROM code, which loads bootstrap loader from disk
- Common bootstrap loader, GRUB, allows selection of kernel from multiple disks, versions, kernel options