



Operating System Concepts

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Syllabus

- ▶ **Lecturer:** Che-Wei Chang (張哲維)
- ▶ **Lecture Hours:** Wednesday 9:10 am – 12:00 pm
- ▶ **Office Hours:** Thursday 4:00 pm – 5:30 pm
- ▶ **Classroom:** B0105R
- ▶ **Textbook:** Silberschatz, Galvin, and Gagne, “Operating System Principles,” 9th Edition, John Wiley & Sons
- ▶ **Website:** <https://icechewei.github.io/webpage/teaching.html>
- ▶ **Grading:**
 - Quiz and Attendance: 20%
 - Homework and Project: 40%
 - Midterm: 20%
 - Final: 20%



Teaching Assistants


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Rules

- ▶ Closed Book Examinations
 - All books and papers should be collected into your backpacks
- ▶ Some Quizzes
 - The announcement is not always provided
- ▶ No Grade Adjustment
 - Some bonus might be provided in the project and exams

Contents

- 
1. Introduction
 2. System Structures
 3. Process Concept
 4. Multithreaded Programming
 5. Process Scheduling
 6. Synchronization
 7. Deadlocks
 8. Memory-Management Strategies
 9. Virtual-Memory Management
 10. File System
 11. Implementing File Systems
 12. Secondary-Storage Systems





Chapter 1 . Introduction

Objectives

- ▶ To describe the basic organization of computer systems
- ▶ To provide a grand tour of the major components of operating systems
- ▶ To give an overview of the many types of computing environments
- ▶ To explore several open-source operating systems





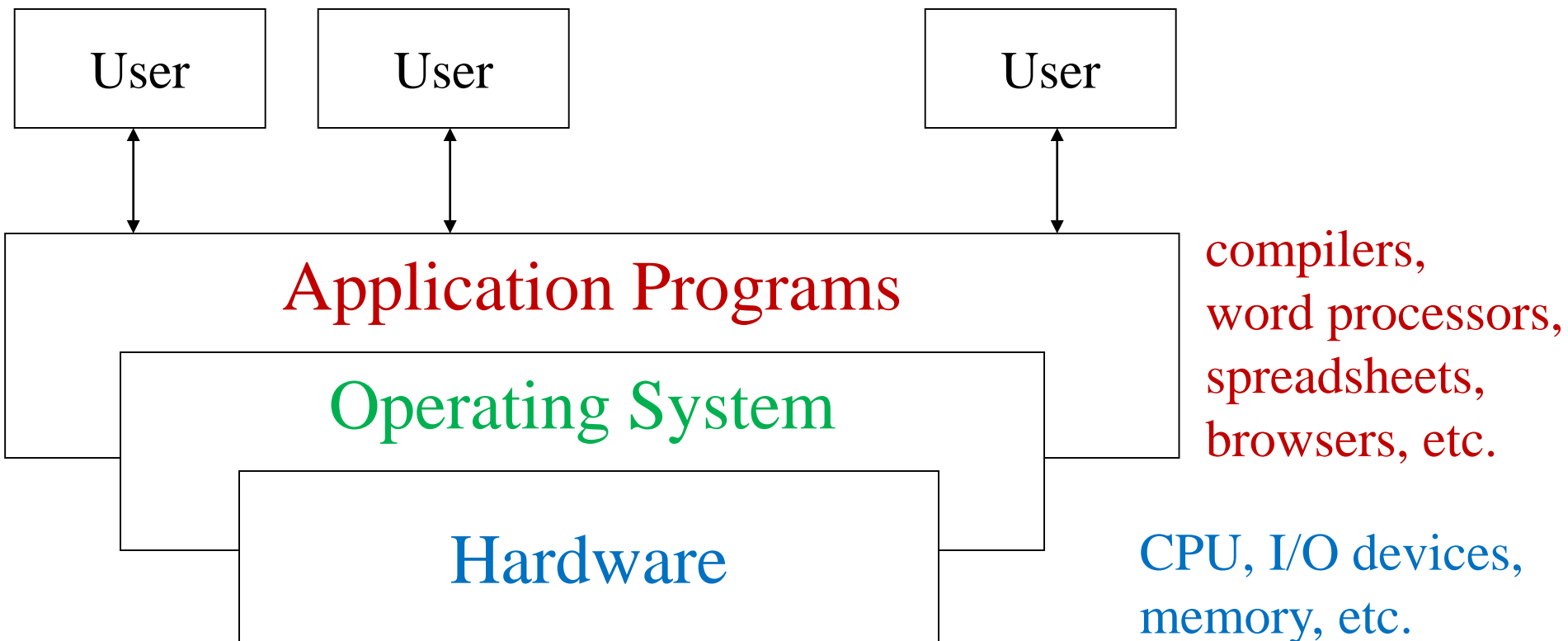
Overview

Introduction

- ▶ What is an Operating System?
 - A basis for application programs
 - An intermediary between users and hardware
- ▶ Amazing Variety
 - Super computers, enterprise servers, personal computers (PCs), handheld computers, embedded systems, wearable devices
 - Convenient vs Efficient



Computer System Components



- ▶ OS – a government/environment provider



User View

- ▶ The user view of the computer varies by the interface being used
- ▶ Examples:
 - Personal computer → Ease of use
 - Mainframe or minicomputer → maximization of resource utilization
 - Efficiency and fair share
 - Handheld computer → individual usability
 - Embedded computer without user view → run without user intervention



System View

- ▶ A Resource Allocator
 - CPU time, Memory Space, File Storage, I/O Devices, Shared Code, Data Structures, and more
- ▶ A Control Program
 - Control execution of user programs
 - Prevent errors and misuse
- ▶ OS Definition – US Department of Justice against Microsoft in 1998 (Netscape Navigator)
 - The stuff shipped by vendors as an OS
 - Internet Explorer → No
 - Microsoft Windows → Yes
 - Run at all time



System Goals

- ▶ Two Conflicting Goals:
 - Convenient for the user
 - Efficient operation of the computer system
- ▶ We should
 - recognize the influences of operating systems and computer architecture on each other
 - and learn why and how OS's are by tracing their evolution and predicting what they will become
 - Cray-2: a super computer in 1985 with 3.9 GFLOPS
 - GFLOPS: Giga FLoating-point Operations Per Second
 - Ryzen 9 3950X : an AMD desktop processor in 2019 (Q4) with 170.56 GFLOPS

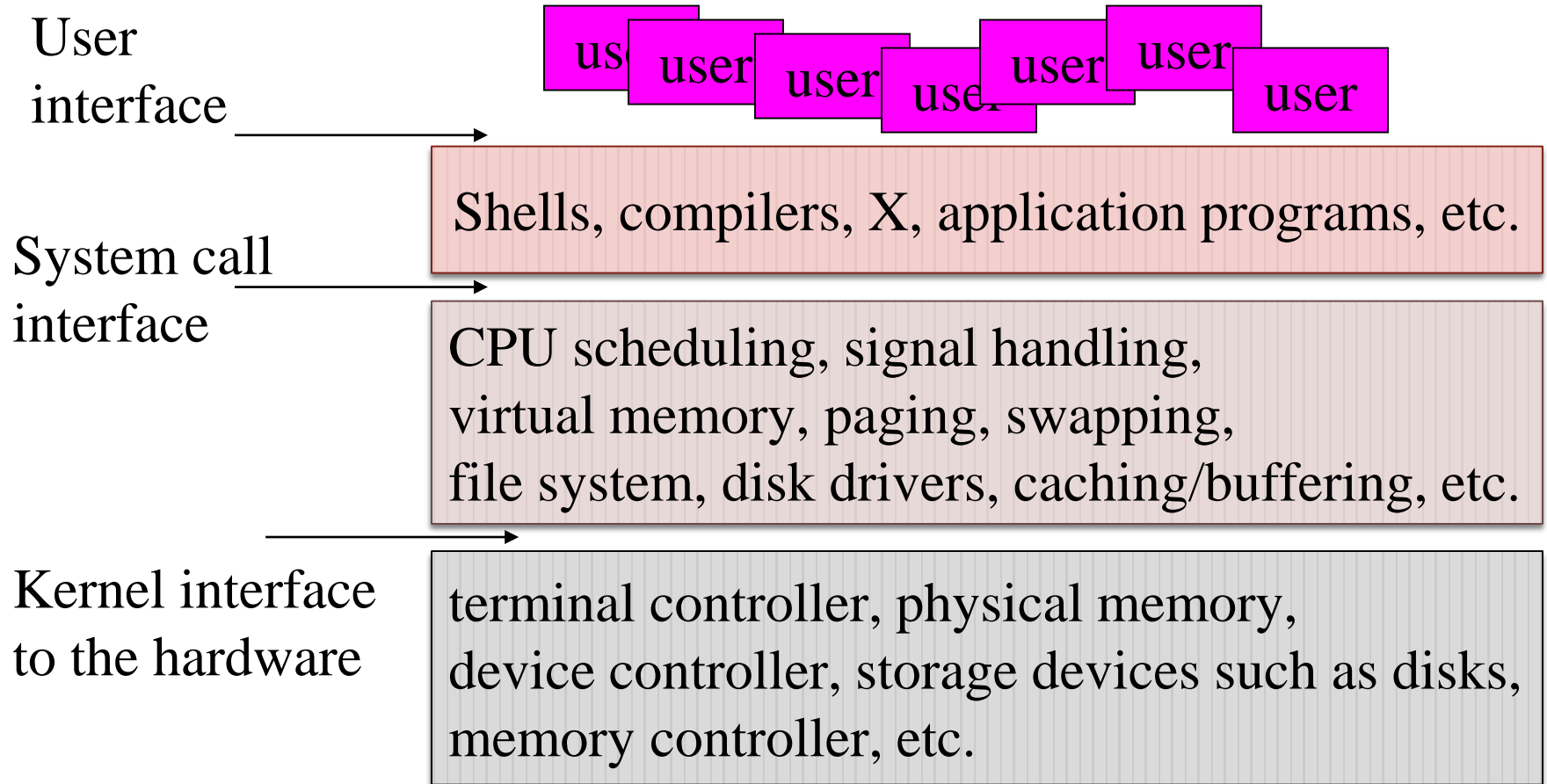
Source:

<https://en.wikipedia.org/wiki/Supercomputer>

https://setiathome.berkeley.edu/cpu_list.php



UNIX Architecture



UNIX



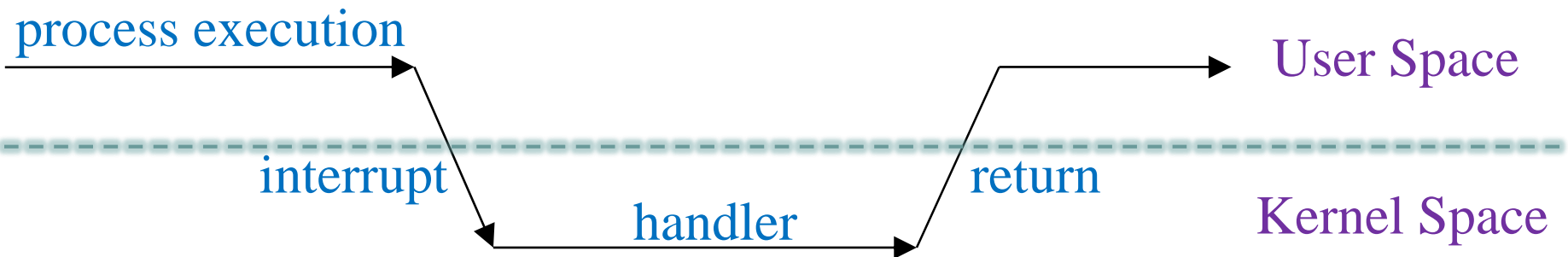
Computer Startup

- ▶ **Bootstrap program** is loaded at power-up or reboot
 - Typically stored in ROM or EPROM, generally known as firmware
 - Initializes all aspects of system
 - Loads operating system kernel and starts execution
 - BIOS: basic input output system
 - UEFI: unified extensible firmware interface
- ▶ **Operating system** runs initial program to initialize system processes, e.g., various daemons, login processes, after the kernel has been bootstrapped



Interrupt

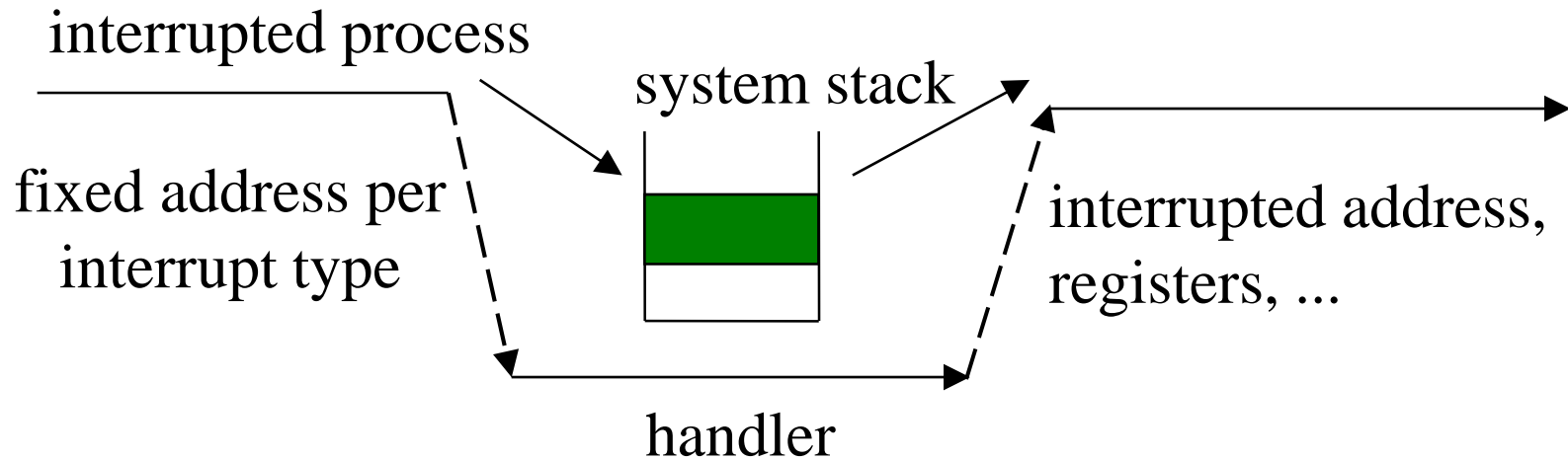
- ▶ **Hardware interrupts**: services requests of I/O devices
- ▶ **Software interrupts**: signals, invalid memory access, division by zero, **system calls**, etc



- ▶ Procedures: generic handler or interrupt vector (MS-DOS, UNIX)



Interrupt Handling Procedure (1 / 2)



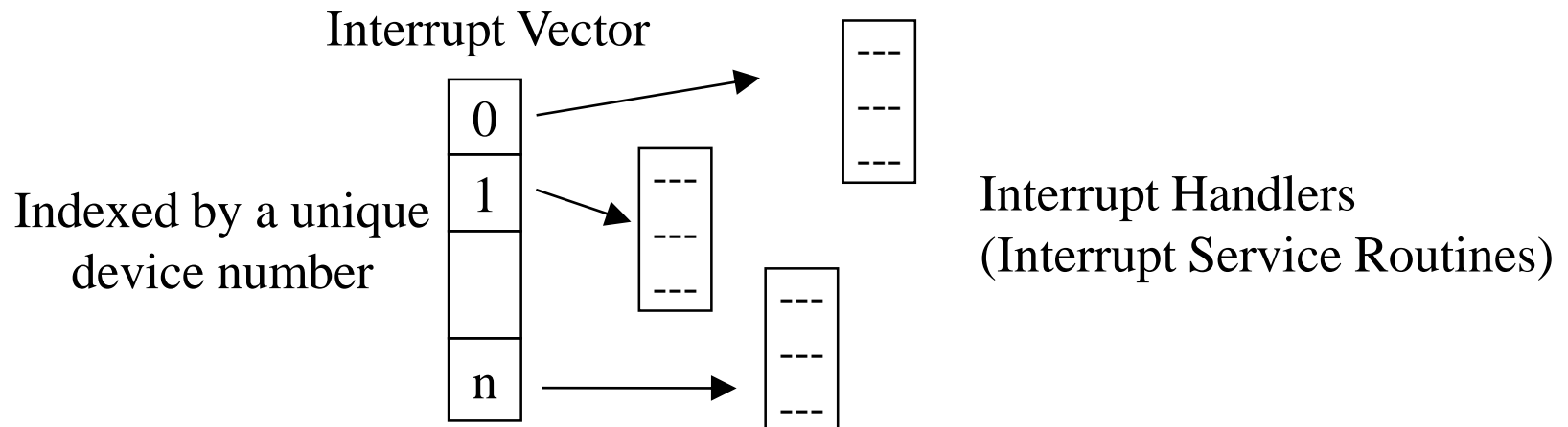
- ▶ Saving of the address of the interrupted instruction
 - By fixed locations or stacks
- ▶ Interrupt disabling or enabling issues
 - Might lose some interrupts?
 - ➔ prioritized interrupts masking



Interrupt Handling Procedure (2/2)

► Interrupt Handling

- Save interrupt information
- OS determine the interrupt type
- Call the corresponding handlers
- Return to the interrupted job by the restoring important information (e.g., saved return address and program counter)

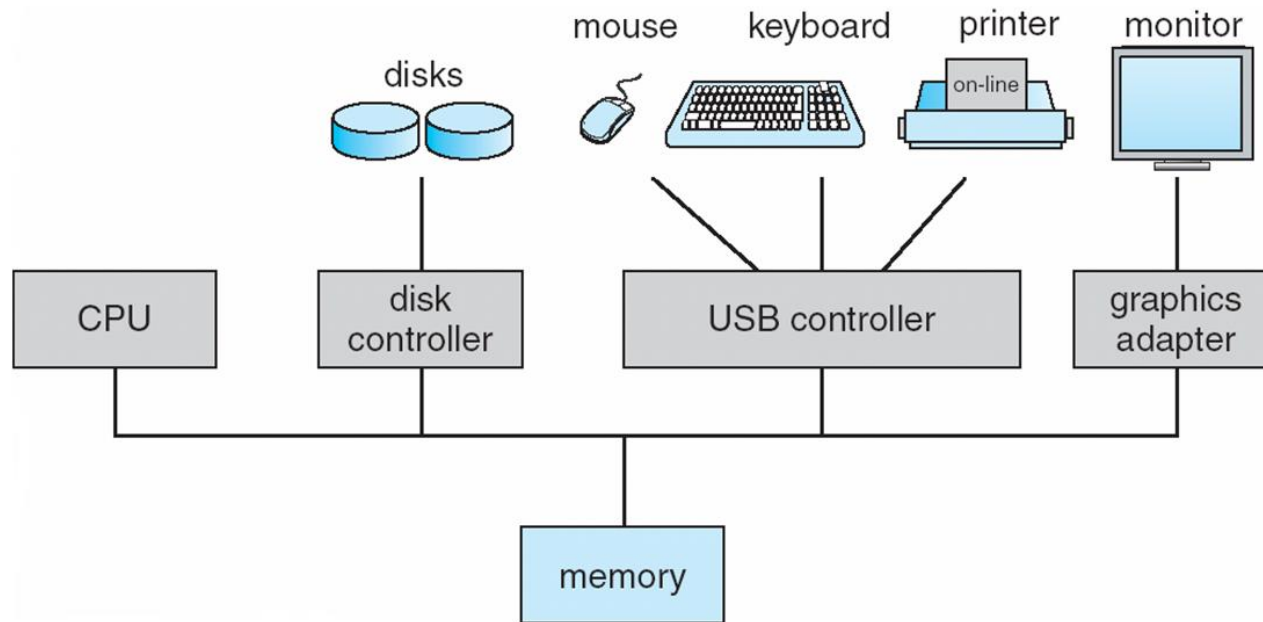




Computer Systems

Computer System Organization

- ▶ One or more CPUs for computing
- ▶ Memory and storage devices for keeping data
- ▶ Peripheral devices for I/O operations



Computer Processors

- ▶ Some systems use a single general-purpose processor
 - Most systems have special-purpose processors as well
- ▶ Multiprocessors systems are growing in use and importance
 - Tightly coupled: have more than one processor in close communication sharing computer bus, clock, and sometimes memory and peripheral devices
 - Loosely coupled: otherwise



Multiprocessor Systems

- ▶ Symmetric Multiprocessing
 - Each processor runs an identical copy of the OS
 - All processors are the same in user and system views
- ▶ Asymmetric Multiprocessing
 - Master-and-slave framework
 - Commonly seen in extremely large systems
 - Hardware and software make a difference



Parallel Systems

- ▶ Tightly-coupled multiprocessor systems are also known as parallel systems
- ▶ Advantages:
 - Increased throughput
 - Economy of scale
 - Increased reliability– graceful degradation and fault tolerance
- ▶ Trends
 - Multiple cores over single chip
 - Cores in a chip can even share cache
 - Hyper-threading processors
 - More than one programs can be executed on a core



Clustered Systems

- ▶ Loosely-coupled multiprocessor systems are also known as clustered systems
 - Computers which share storage and are closely linked via LAN networking
 - Processors do not share memory or a clock
- ▶ Advantages:
 - High availability
 - Performance improvement
- ▶ Some clusters are for high-performance computing
 - Applications must be written to use parallelization
- ▶ Some clusters have distributed lock manager
 - Conflicting operations must be avoided



Memory Management

- ▶ Memory: a large array of words or bytes, where each has its own address
- ▶ OS must keep several programs in memory to improve CPU utilization and user response time
- ▶ Management algorithms depend on the hardware support
- ▶ Services
 - Memory usage and availability
 - Decision of memory assignment
 - Memory allocation and deallocation



Secondary Storage Management

- ▶ Goal:
 - On-line storage medium for programs & data
 - Backup of main memory
- ▶ Services for Disk Management
 - Free-space management
 - Storage allocation, e.g., continuous allocation
 - Read/write request scheduling, e.g., first-come-first-serve



Tertiary Storage Management

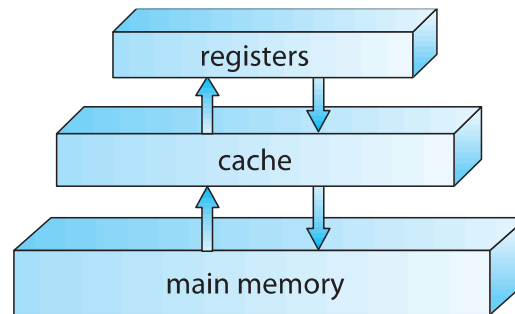
- ▶ Goals:
 - Backups of disk data, seldom-used data, and long-term archival storage
- ▶ Examples:
 - Magnetic tape drives and their tapes, CD & DVD drives and platters
- ▶ Services – OS Supports or Applications' Duty
 - Device mounting and unmounting
 - Exclusive allocation and freeing
 - Data transfers from tertiary devices to secondary storage devices



Storage-Device Hierarchy

Primary Storage

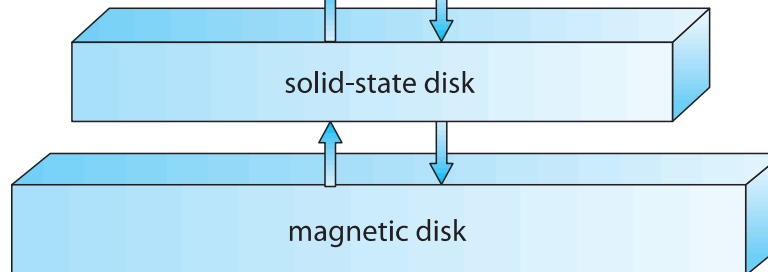
- volatile storage



- Access time: a cycle
- Access time: several cycles
- Access time: many cycles

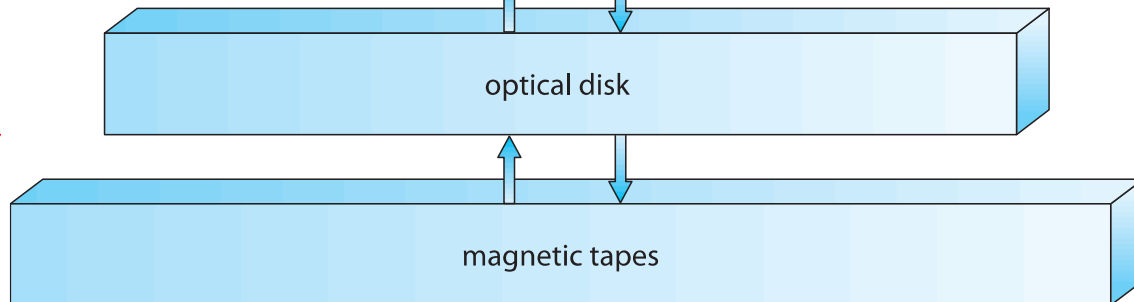
Secondary Storage

- nonvolatile storage



Tertiary Storage

- removable media



I/O Devices

- ▶ Device drivers are used by OS to drive the device controllers
- ▶ Character Devices
 - Sequential access
 - Examples might include printers, scanners, sound boards
 - The same device may have both block and character oriented interfaces
- ▶ Block Devices
 - Block size is from 512B to 4KB
 - For example, disks are commonly implemented as block devices

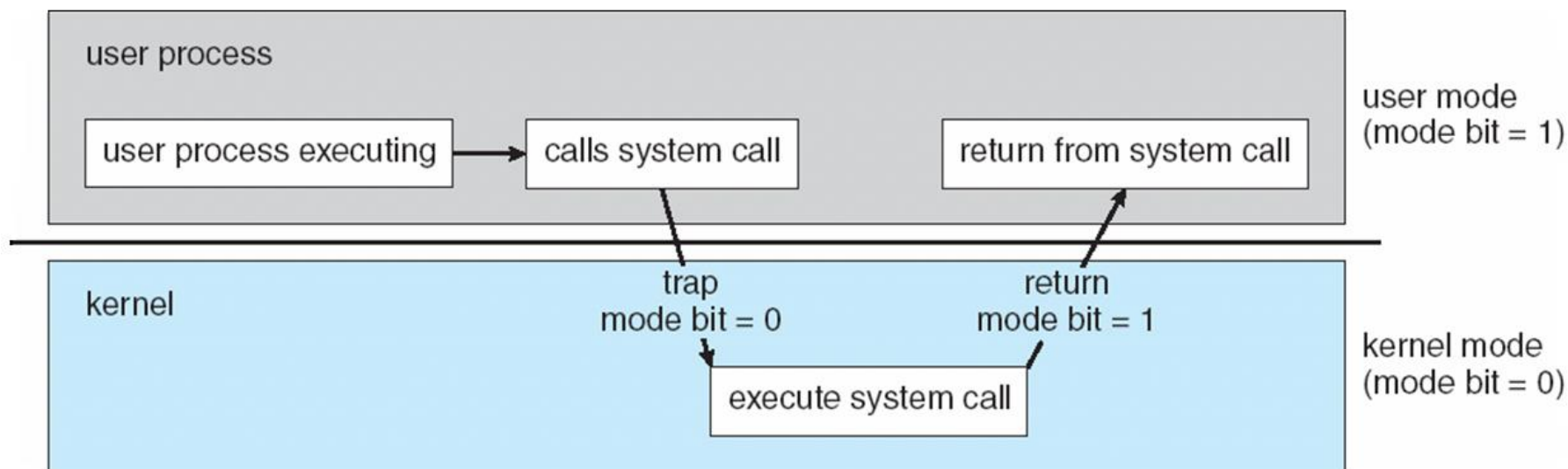


Hardware Protection

- ▶ 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 the current mode to kernel mode, return from call resets it to user mode
- ▶ Increasingly CPUs support multi-mode operations
 - For example, virtual machine manager (VMM) mode



Transition Between User and Kernel Modes





Operating-System Operations

Process Management

- ▶ **A process is a program in execution**
 - A program is a passive entity
 - A process is an active entity
- ▶ Process needs resources to accomplish its task
 - CPU, memory, I/O, files
 - Initialization data
- ▶ Process termination requires to reclaim any reusable resources
- ▶ Typically system has many processes, some users, some operating system running concurrently on one or more CPUs



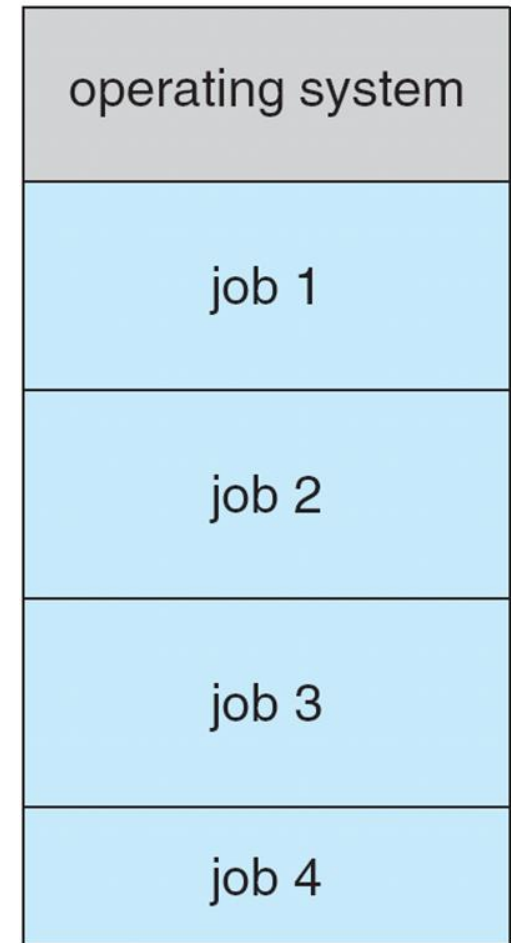
Process Management Activities

- ▶ 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



Multiprogramming

- ▶ Multiprogramming is needed for efficiency
 - Single user cannot keep CPU and I/O devices busy at all times
 - Multiprogramming organizes jobs (code and data) so CPU always has one to execute
 - A subset of total jobs in system is kept in memory via **job scheduling**
 - One job selected and run via **CPU scheduling**
 - When a job has to wait (for I/O for example), OS switches to another job



Timesharing

- ▶ Timesharing (multitasking) is a logical extension of multiprogramming
 - CPU switches jobs so frequently
 - Users can interact with each job while it is running
 - Timesharing creates interactive computing
- ▶ Each user has at least one program executing in memory
 - A program executing in memory → a process is created
- ▶ If several processes ready to run at the same time
 - Pick a process to run on CPU → CPU scheduling
- ▶ If processes don't fit in memory,
 - Swapper moves them in and out of memory → job scheduling
- ▶ Virtual memory allows execution of processes not completely in memory



Caching (1 / 2)

▶ Caching

- Information is copied to a faster storage system on a temporary basis
- Assumption: Data or binaries will be used again soon
 - Programmable registers, instruction cache, etc.

▶ Cache Management

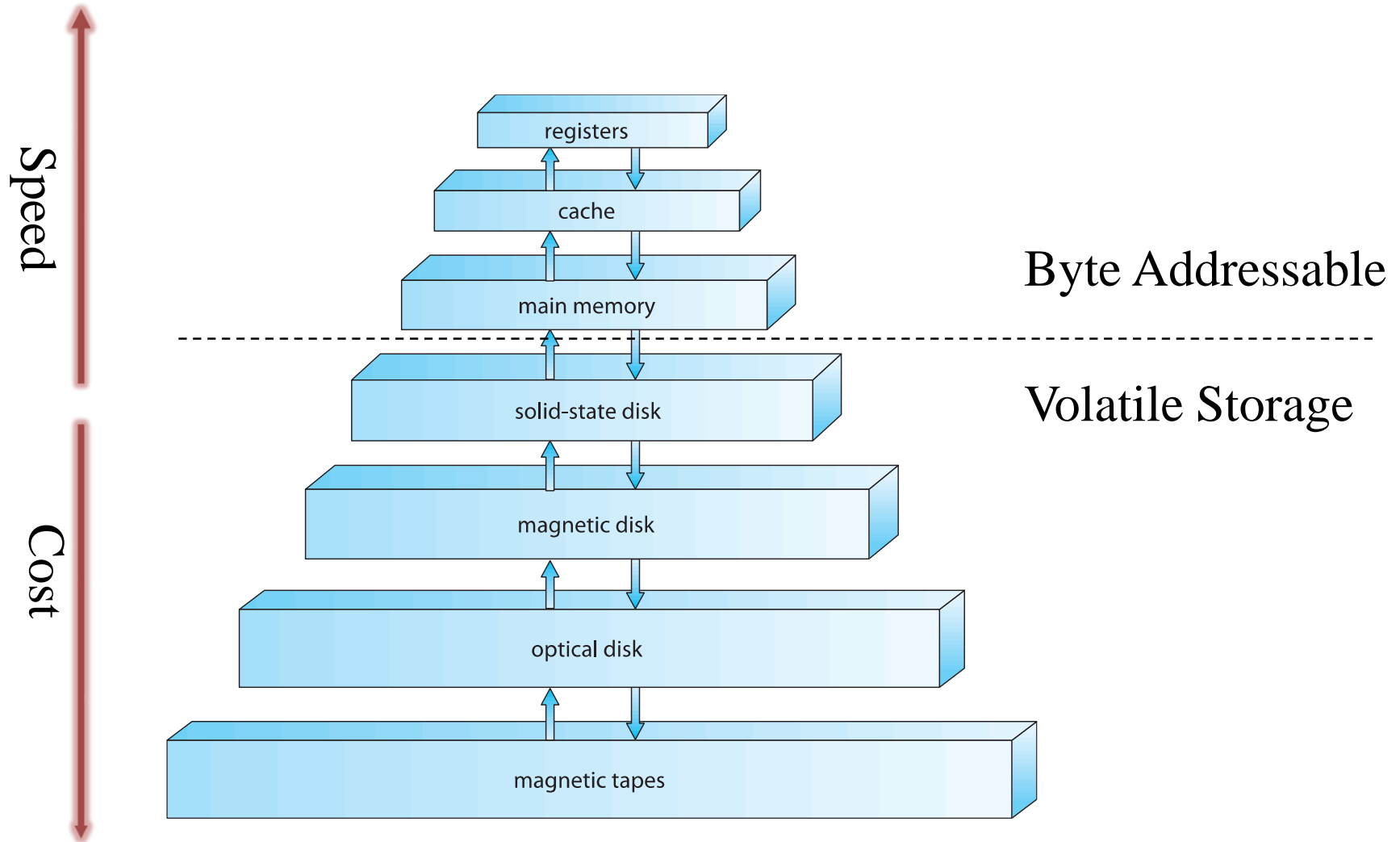
- Cache size and the replacement policy

▶ Movement of Information Between Hierarchy

- Hardware design & operating system control

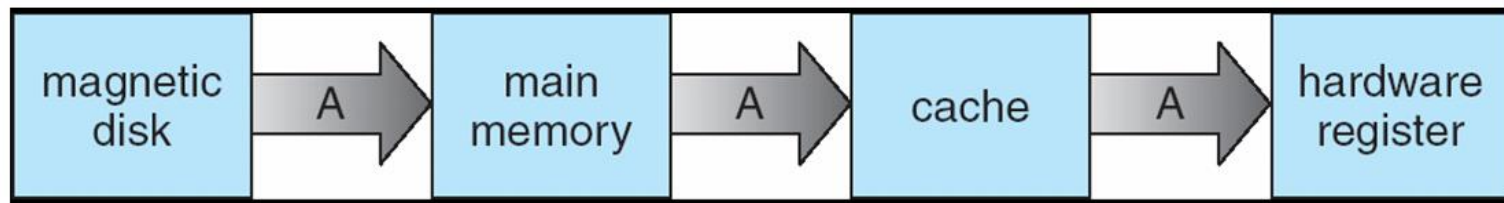


Caching (2/2)



Migration of Integer 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
- ▶ Distributed environment situation even more complex
 - Several copies of a datum can exist

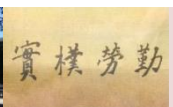
File-System Management

- ▶ Goal:
 - A uniform logical view of information storage
 - Each medium controlled by a device
 - Magnetic tapes, magnetic disks, optical disks, etc.
- ▶ OS provides a logical storage unit: File
 - Formats:
 - Free form or being formatted rigidly
 - General Views:
 - A sequence of bits, bytes, lines, records



File Management Activities

- ▶ 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



I/O System Management

- ▶ Goal:
 - Hide the peculiarities of specific hardware devices from users
- ▶ Components of an I/O System
 - A buffering, caching, and spooling system
 - A general device-driver interface
 - Device drivers



Protection and Security (1 / 2)

▶ Goal

- Resources are only allowed to be accessed by authorized processes

▶ Definitions:

- Protection – any mechanism for controlling the access of processes or users to the resources defined by the computer system
- Security – Defense of a system from external and internal attacks, e.g., viruses, denial of services, etc



Protection and Security (2 / 2)

- ▶ Protected Resources
 - Files, CPU, memory space, etc
- ▶ Protection Services
 - Detection & controlling mechanisms
 - Specification mechanisms
- ▶ Distinguishing of Users
 - User names and ID's
 - Group names and GID's
 - Privilege Escalating, e.g., Setuid in Unix
 - To gain extra permissions for an activity





Advanced Topics

Distributed Systems (1 / 2)

- ▶ Definition: Loosely-Coupled Systems – processors do not share memory or a clock
- ▶ Advantages or Reasons
 - Resource sharing: computation power, peripheral devices, specialized hardware
 - Computation speedup: distribute the computation among various sites – load sharing
 - Reliability: redundancy → reliability



Distributed Systems (2 / 2)

- ▶ Distributed systems depend on networking for their functionality
- ▶ Networks vary by the protocols used
 - TCP/IP, ATM, etc.
- ▶ Types – different distance
 - Local-area network (LAN)
 - Wide-area network (WAN)
 - Metropolitan-area network (MAN)
 - Small-area network – distance of few feet
- ▶ Media – copper wires, fiber strands, ...



Real-Time Embedded Systems (1 / 2)

- ▶ Embedded Computers— Most Prevalent Form of Computers
 - Have a wide variety ranged from car engines to VCR's
 - Tend to have specific tasks and almost always run real-time operating systems
- ▶ Definition:
 - A real-time system is a computer system where a timely response by the computer to external stimulation is vital!



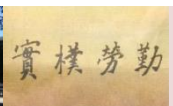
Real-Time Embedded Systems (2/2)

- ▶ Hard real-time system: The system has failed if a timing constraint, e.g. deadline, is not met
 - All delays in the system must be bounded
 - Many advanced features are absent
- ▶ Soft real-time system: Missing a timing constraint is serious but does not necessarily result in a failure
 - A critical task has a higher priority
 - Supported in most commercial OS
- ▶ Real-time means **on-time** instead of **fast**



Computing Environments— Mobile Devices

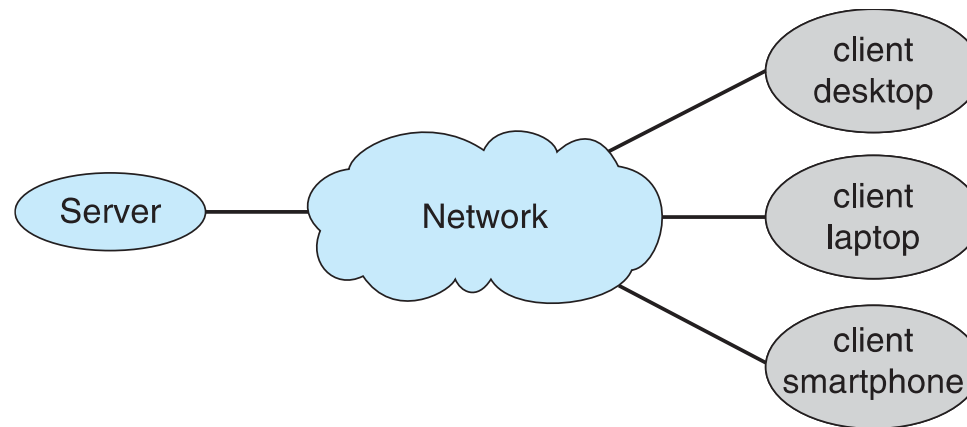
- ▶ Target devices: handheld smartphones, tablets, ...
- ▶ Extra features: GPS, gyroscope, ...
- ▶ New types of Application: augmented reality, ...
- ▶ Use IEEE 802.11 wireless, or cellular data networks for connectivity
- ▶ Leaders are Apple iOS and Google Android



Computing Environments— Client–Server

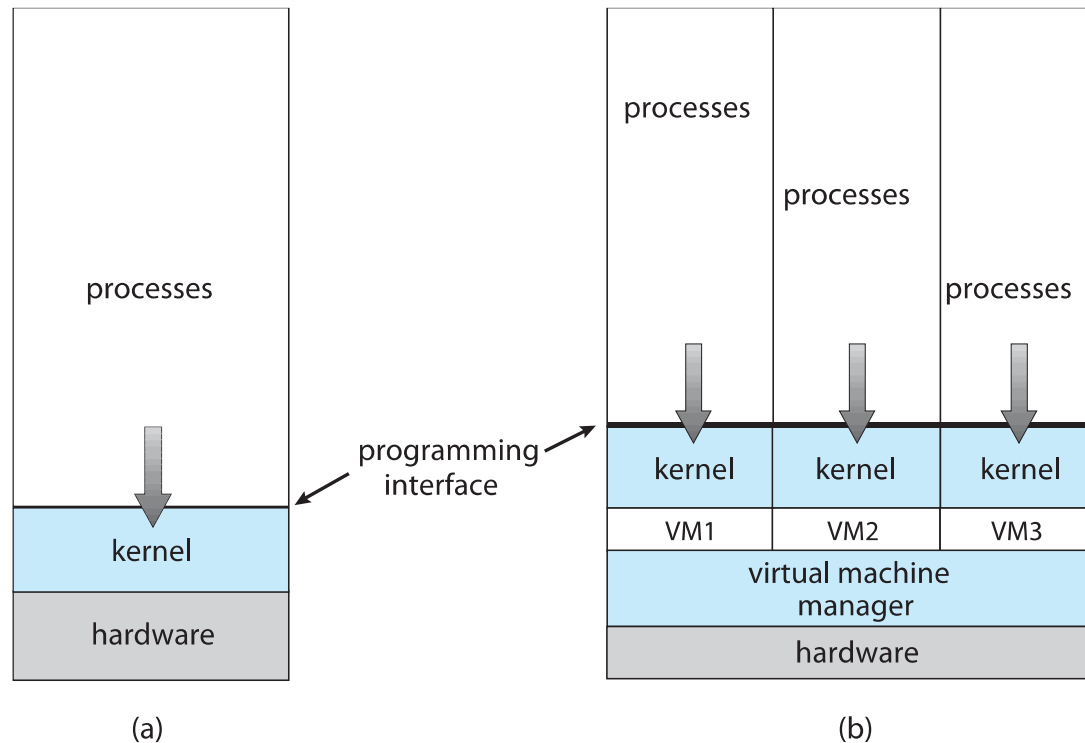
► Client-Server Systems

- Trend:
 - The functionality of clients is improved in the past decades
- Categories:
 - Compute-server systems
 - File-server systems



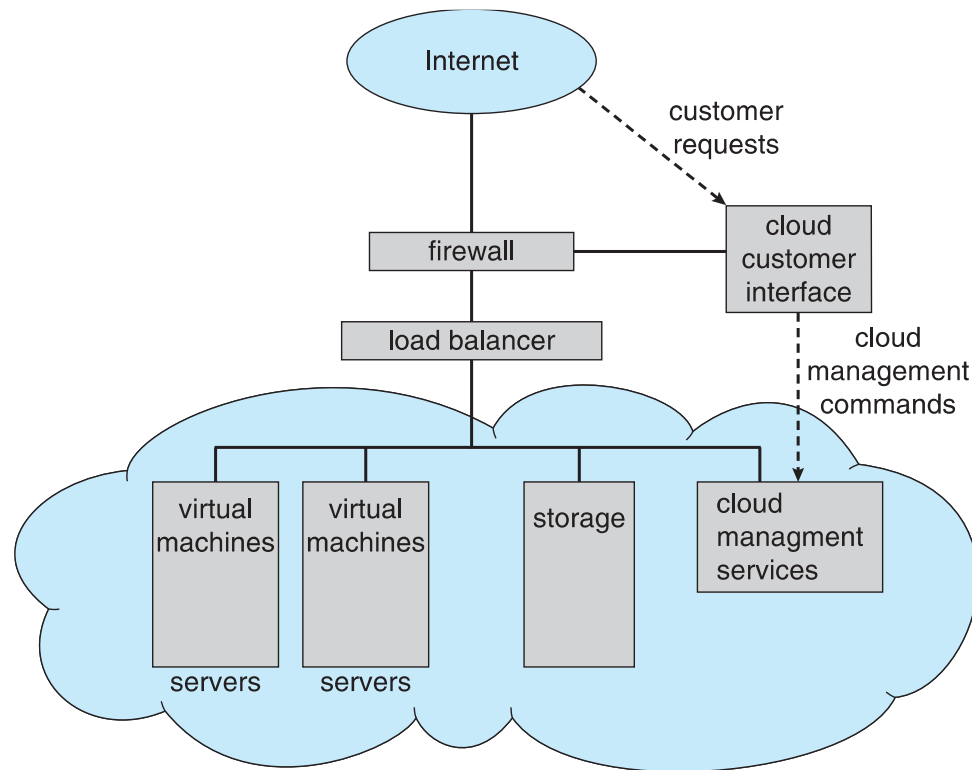
Computing Environments— Virtualization

- Use cases involve laptops and desktops running multiple OSES for exploration or compatibility



Computing Environments— Cloud Computing

- ▶ Cloud computing environments are composed of traditional OSeS, plus virtualization tools plus cloud management tools





We will go through the details in the following lectures!