Operating System Concepts

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Syllabus

- **Lecturer**: Che-Wei Chang <chewei@mail.cgu.edu.tw>
- **TA**: 張凱傑 <jay19990830@gmail.com>
- **Lecture Hours**: Wednesday 9:10 am – 12:00 pm
- **Office Hours**: Send an email or FB message to me
- **Classroom**: B0105R
- **Textbook**: Silberschatz, Galvin, and Gagne, "Operating System Principles," 9th/10th Edition, John Wiley & Sons
- **Website:** https://icechewei.github.io/webpage/teaching.html
- **Grading**:
  - Quiz and Attendance: 20%
  - Project: 20%
  - Midterm: 30%
  - Final: 30%

Rules

- Closed Book Examinations
  - All books and papers should be collected into your backpacks
- Only One Project
  - No late submission will be accepted
- Some Quizzes
  - The announcement is not always provided
- No Grade Adjustment
  - Some bonus might be provided in the project and exams

Contents

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

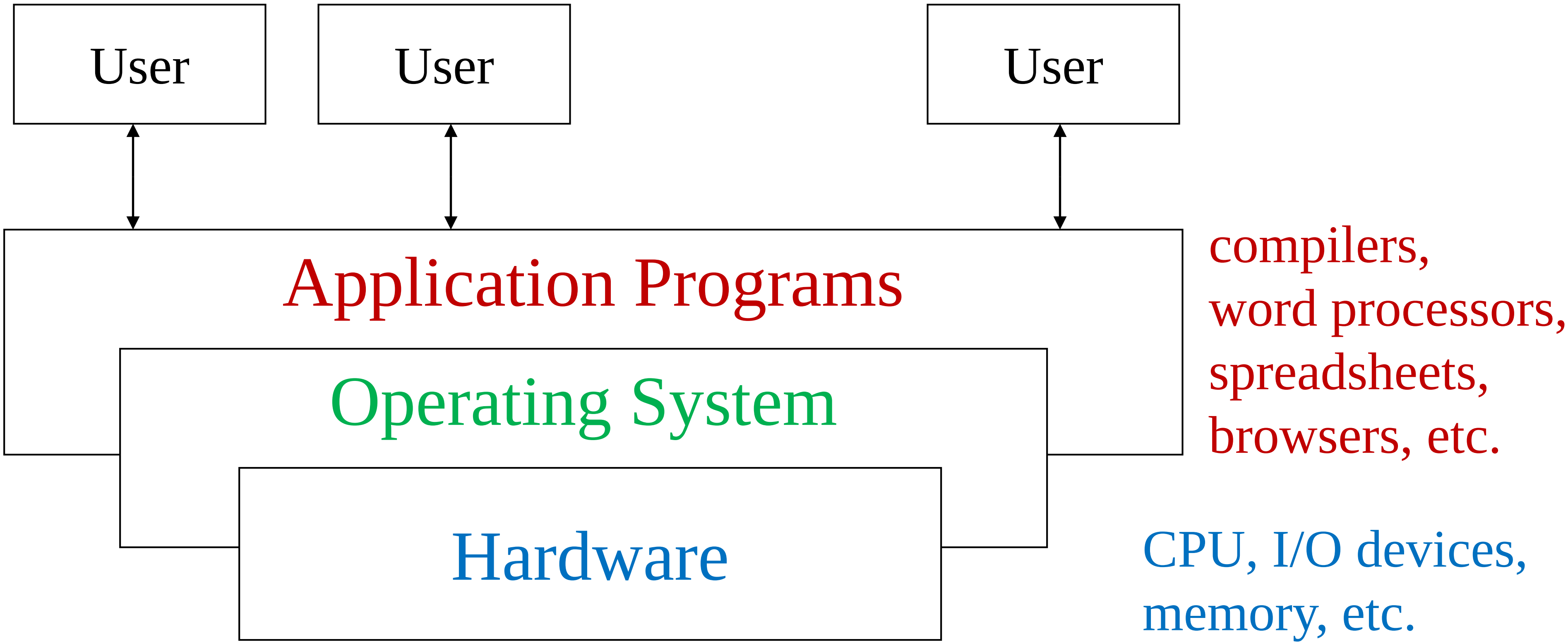
Overview

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

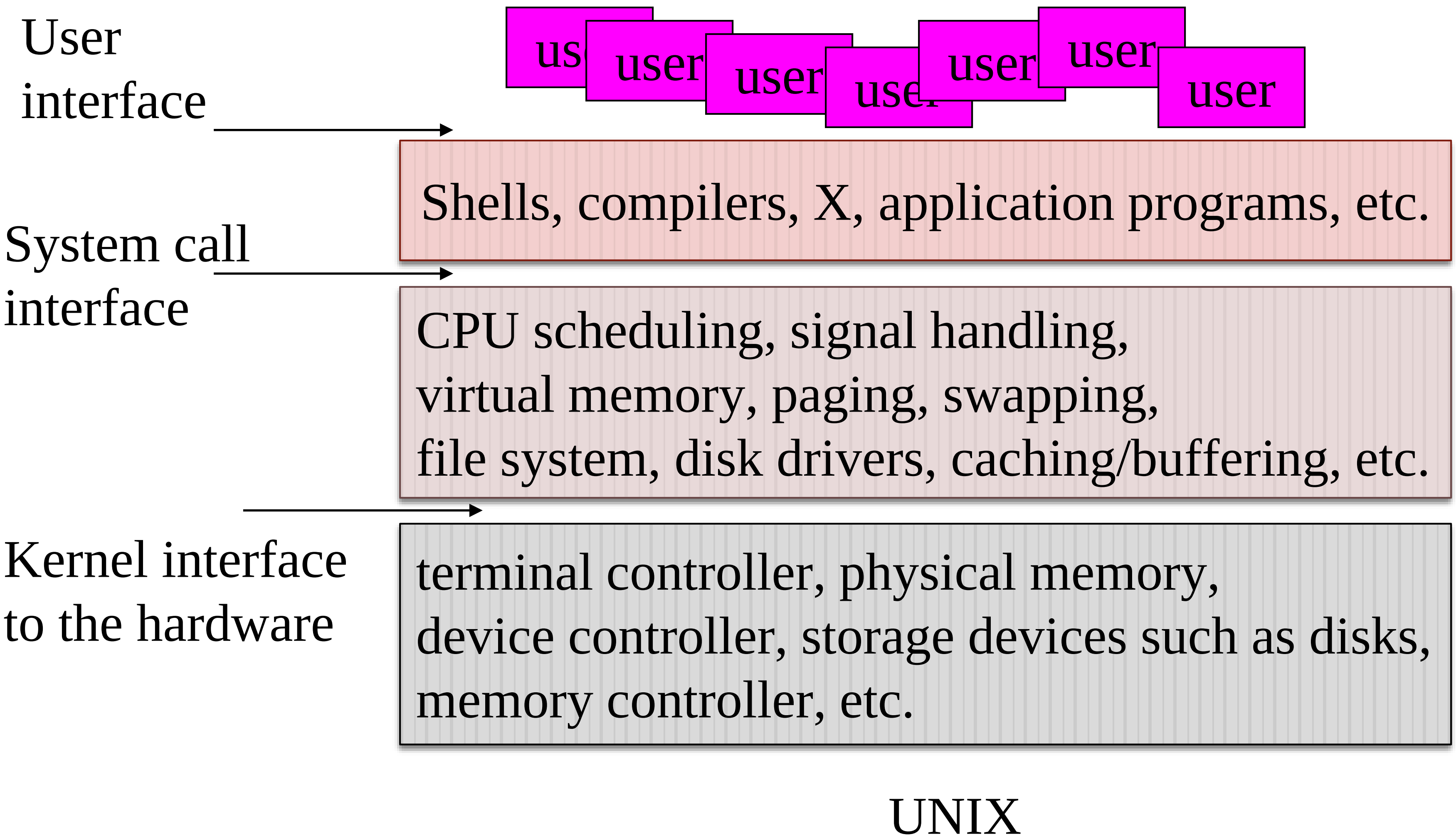
- A Resource Allocator
  - CPU time, Memory Space, File Storage, I/O Devices, Shared Code, Data Structures, and more
- A Control Program
  - Control execution of user programs
  - Prevent errors and misuse
- OS Definition – US Department of Justice against Microsoft in 1998 (Netscape Navigator)
  - The 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

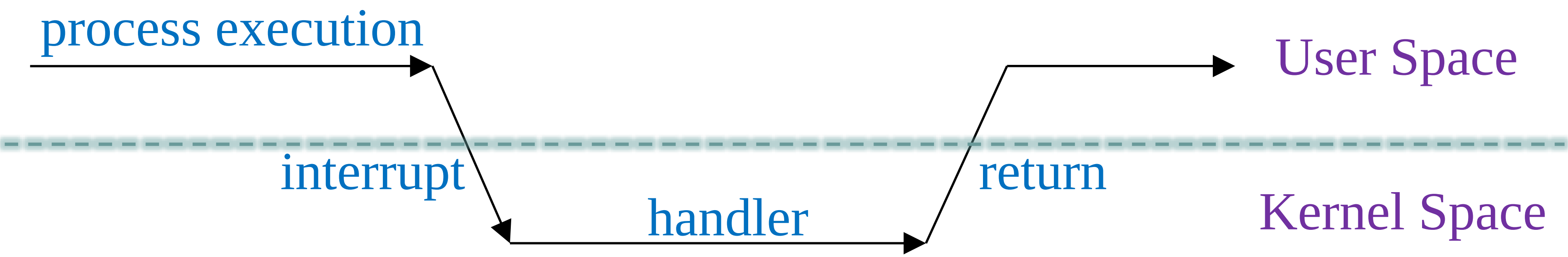


Computer Startup

- 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

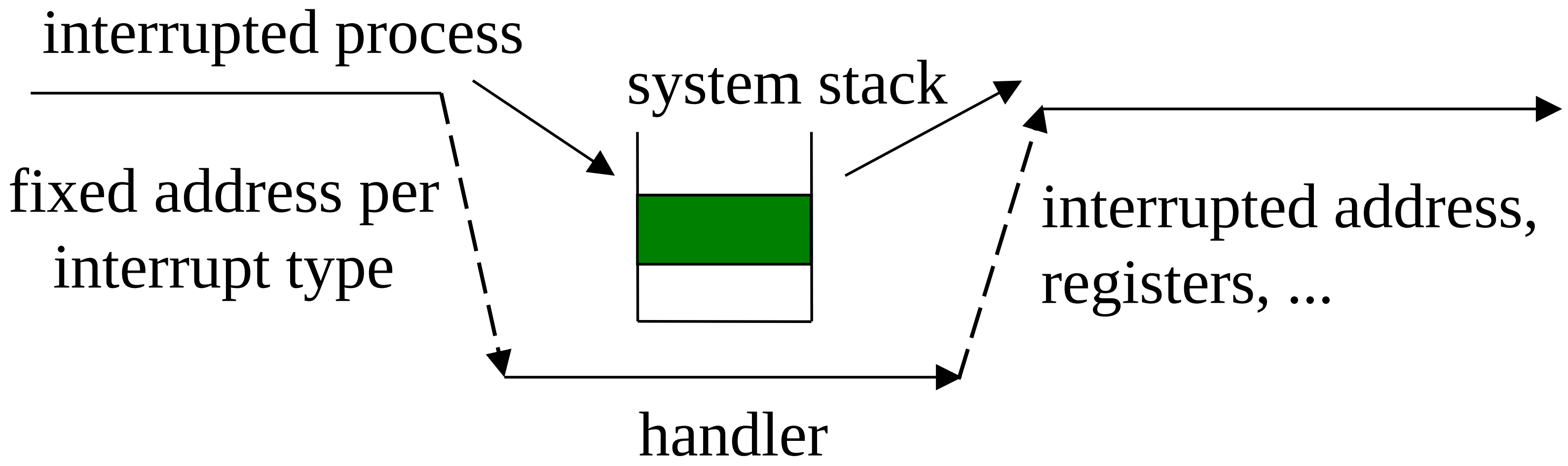
Interrupt

- 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)

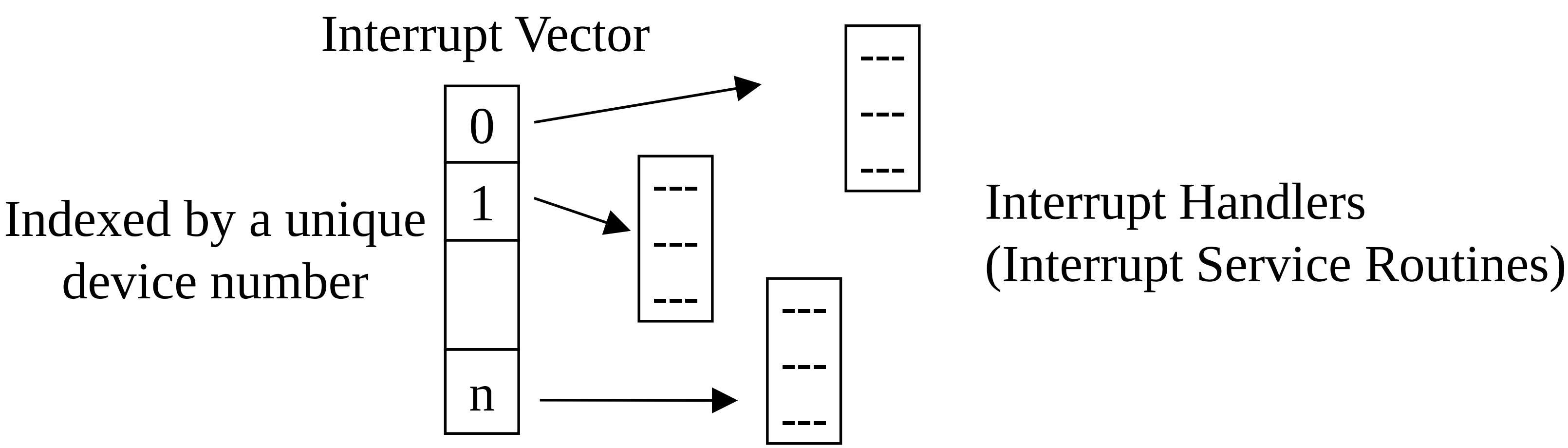
Interrupt Handling Procedure (1/2)



- 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)

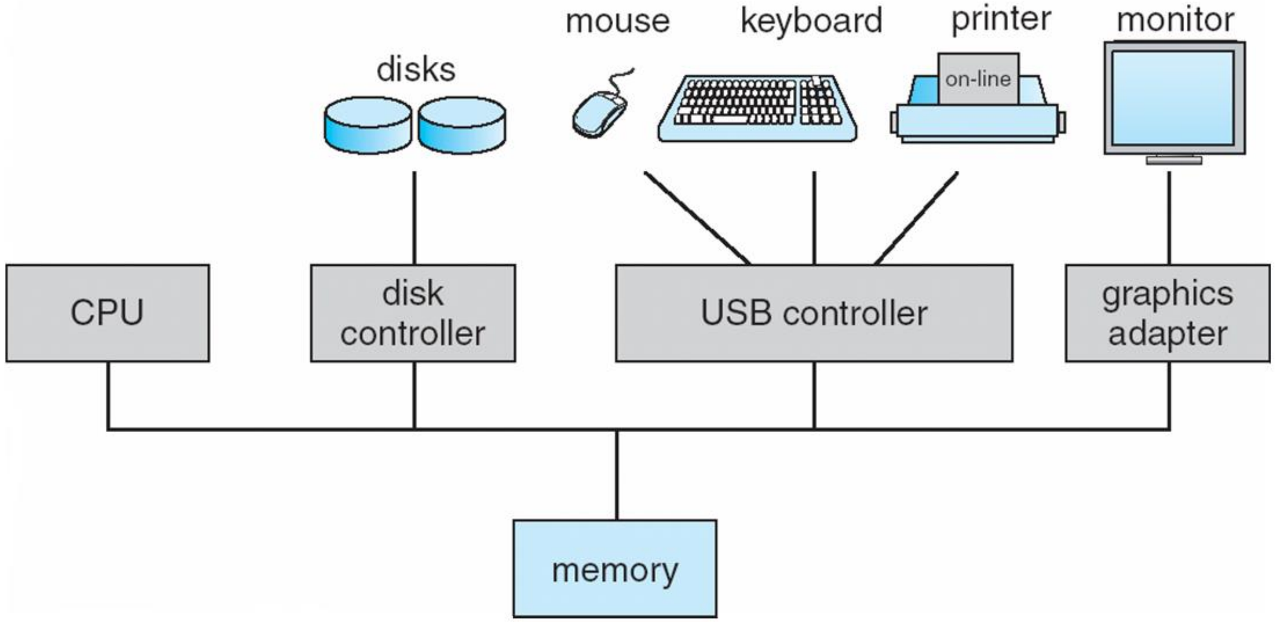
- Interrupt Handling
  - Save interrupt information
  - OS determine the interrupt type
  - Call the corresponding handlers
  - Return to the interrupted job by the restoring important information (e.g., saved return address and program counter)



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

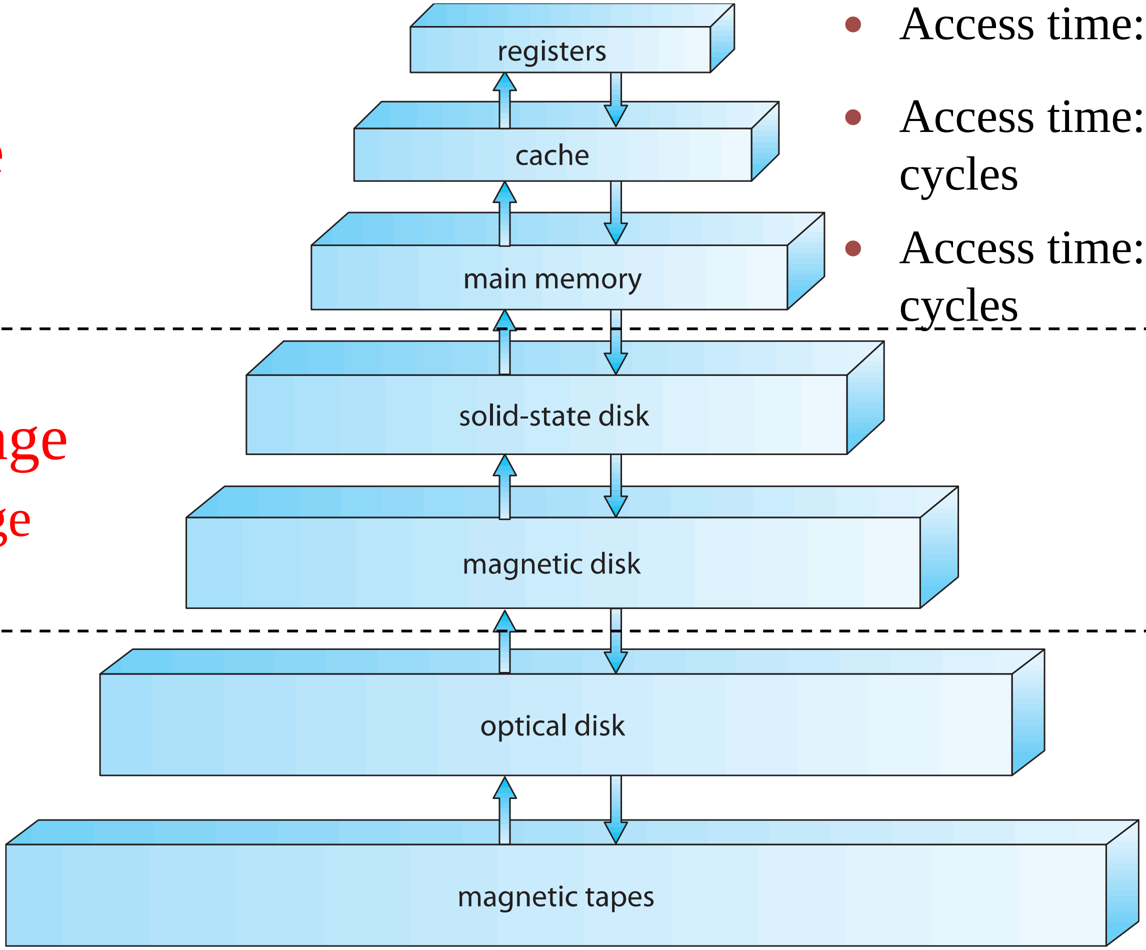
- volatile storage

Secondary Storage

- nonvolatile storage

Tertiary Storage

- removable media



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

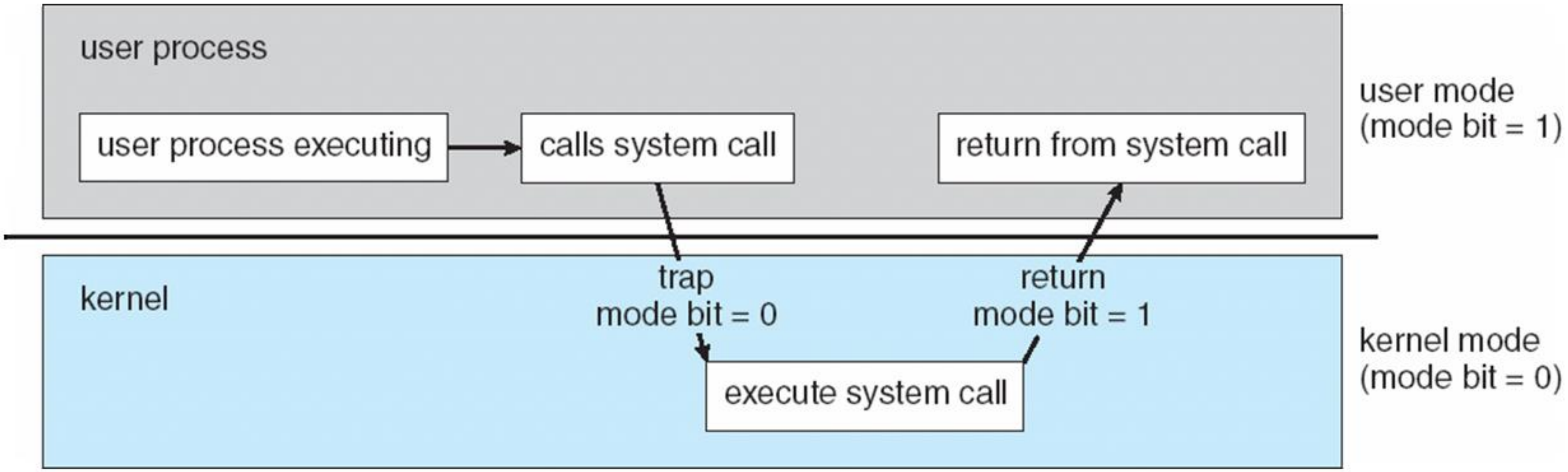
I/O Devices

- 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

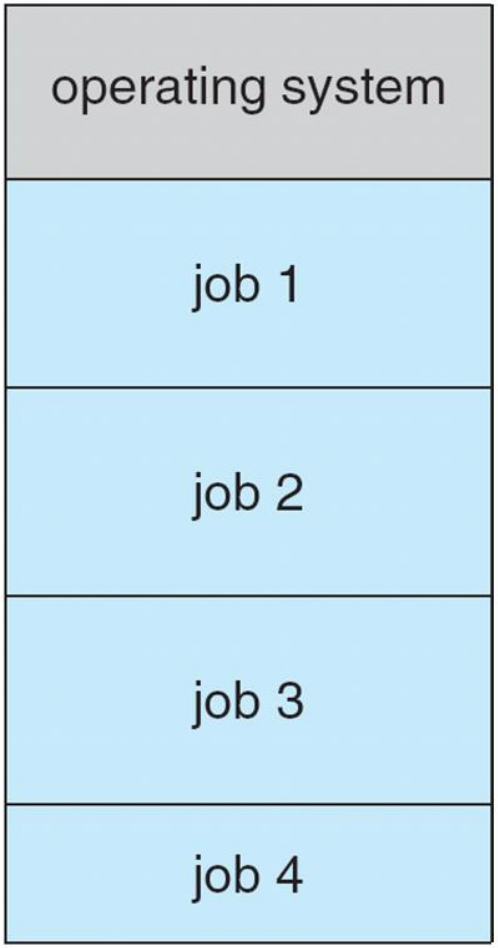
- A process is a program in execution
  - A program is a passive entity
  - A process is an active entity
- Process needs resources to accomplish its task
  - CPU, memory, I/O, files
  - Initialization data
- Process termination requires to reclaim any reusable resources
- Typically system has many processes, 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



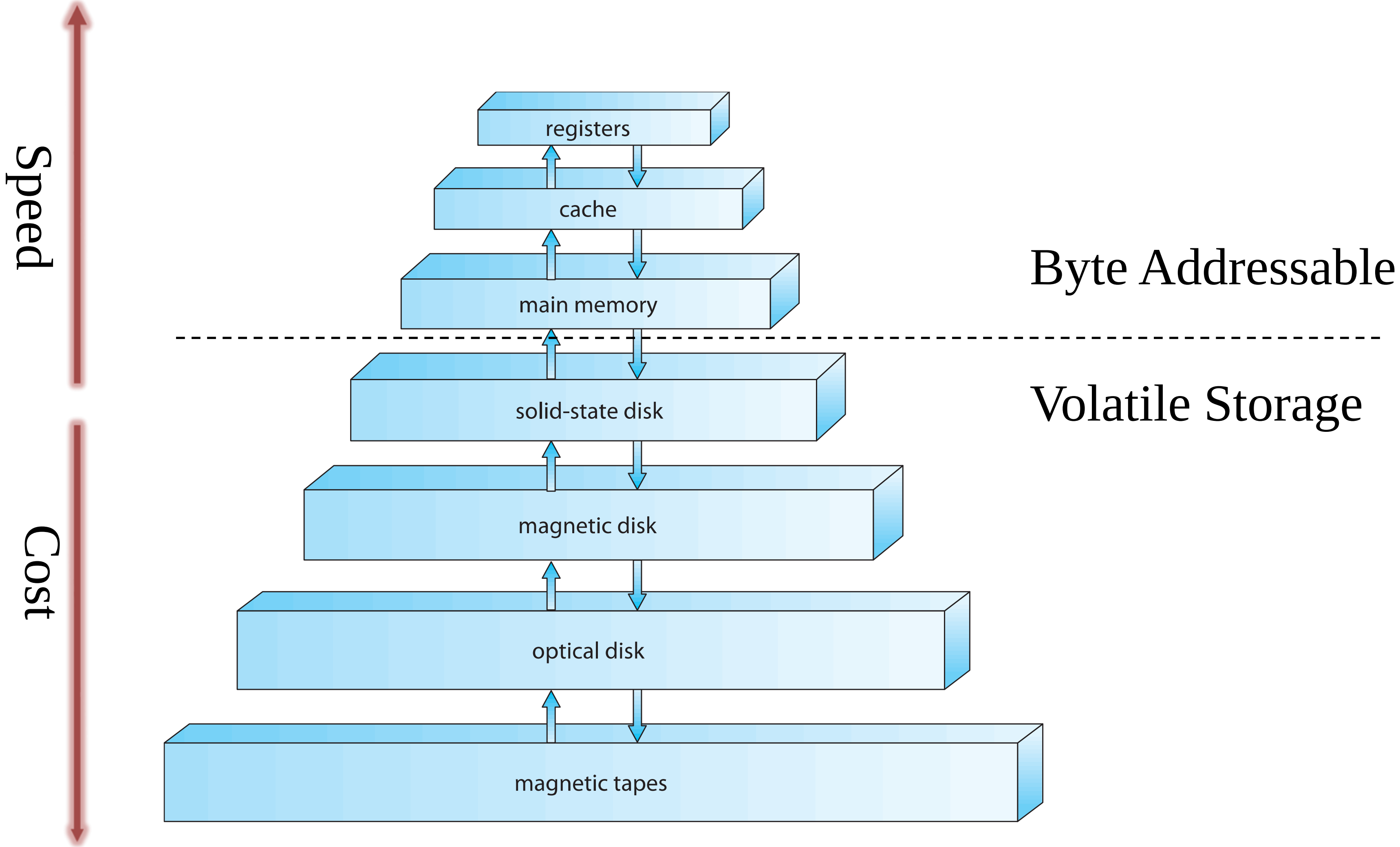
Timesharing

- 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)

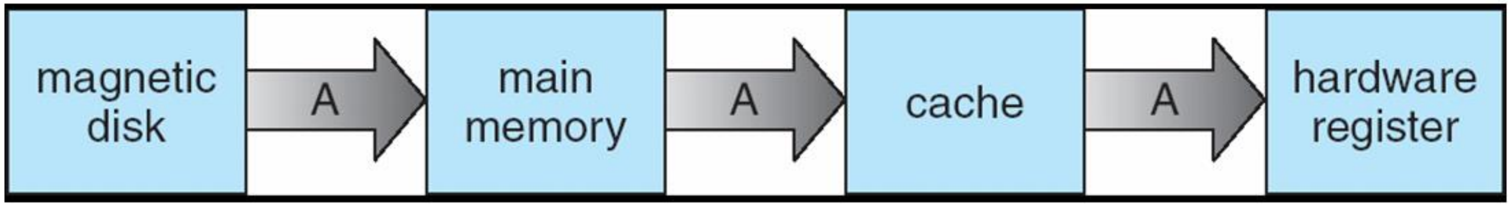
- Caching
  - Information is copied to a faster storage system on a temporary basis
  - Assumption: Data or binaries will be used again soon
    - Programmable registers, instruction cache, etc.
- Cache Management
  - Cache size and the replacement policy
- Movement of Information Between Hierarchy
  - Hardware design & operating system control

Caching (2/2)


Speed
Cost
registers
cache
main memory
solid-state disk
magnetic disk
optical disk
magnetic tapes
Byte Addressable
Volatile Storage

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)

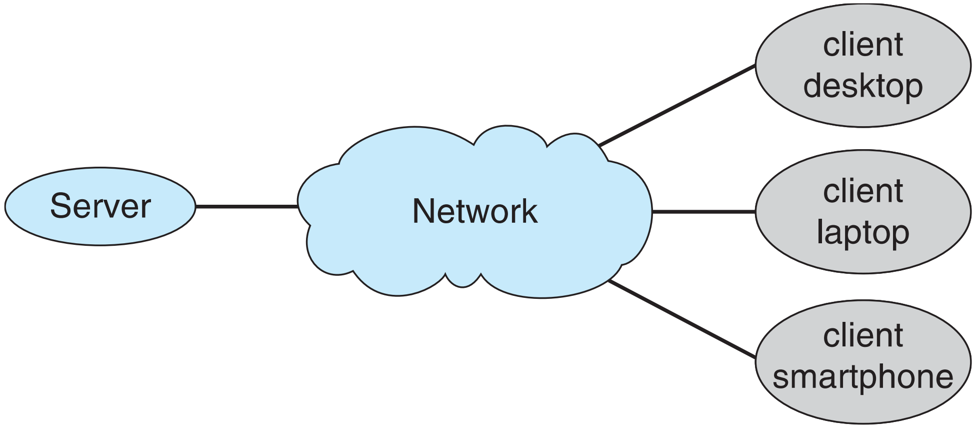
- Hard real-time system: The system has failed if a timing constraint, e.g. deadline, is not met
  - All delays in the system must be bounded
  - Many advanced features are absent
- Soft real-time system: Missing a timing constraint is serious but does not necessarily result in a failure
  - A critical 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

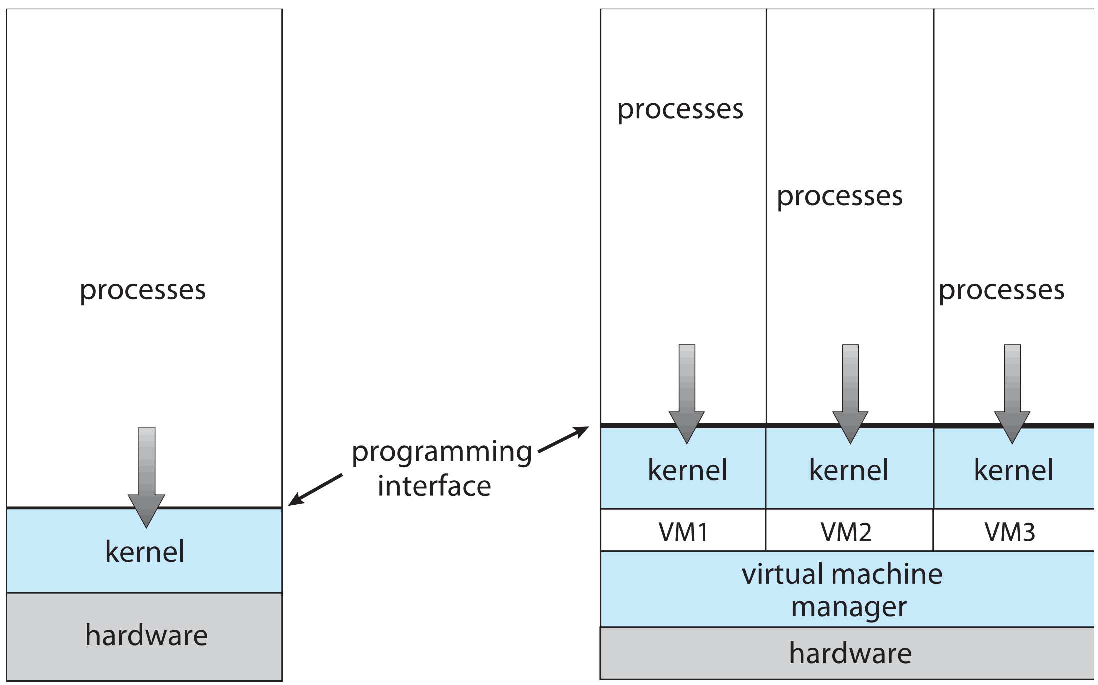
Computing Environments—Client–Server

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



Computing Environments—Virtualization

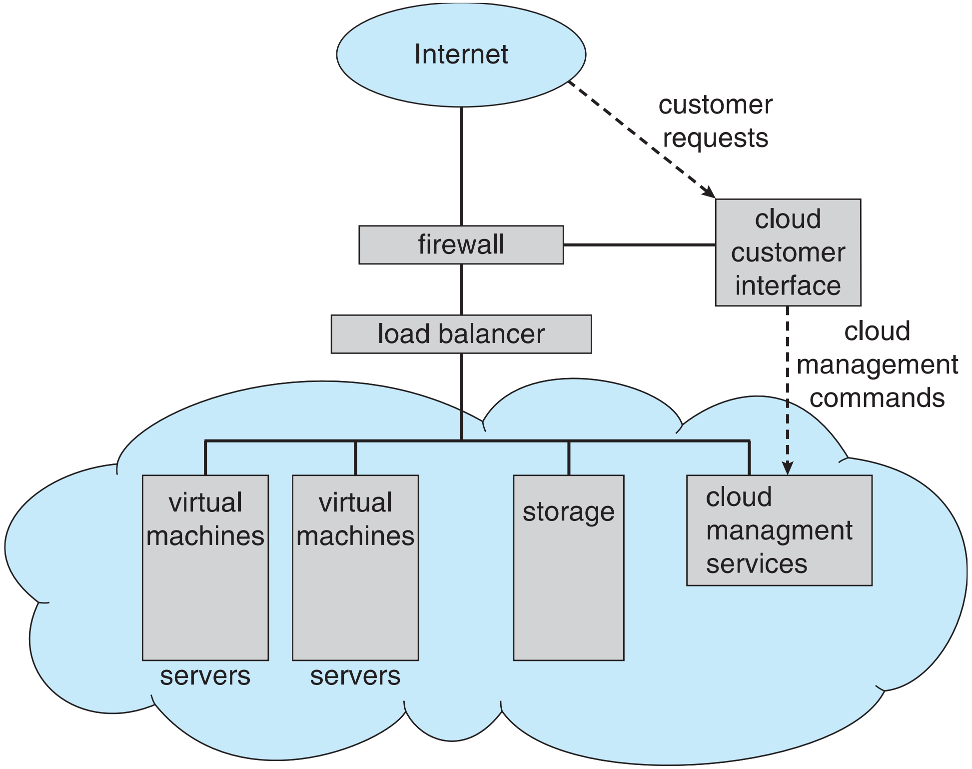
- Use cases involve laptops and desktops running multiple OSes for exploration or compatibility



(a) (b)

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!