CS2106
Introduction to OS

Lecture 1 Introduction

Overview

- **Operating Systems basic concepts:**
  - What is OS?
  - Brief History
    - Motivation for OS
  - Overview of Modern OSes

- **Operating System Structures**
  - OS components
  - Types of kernel

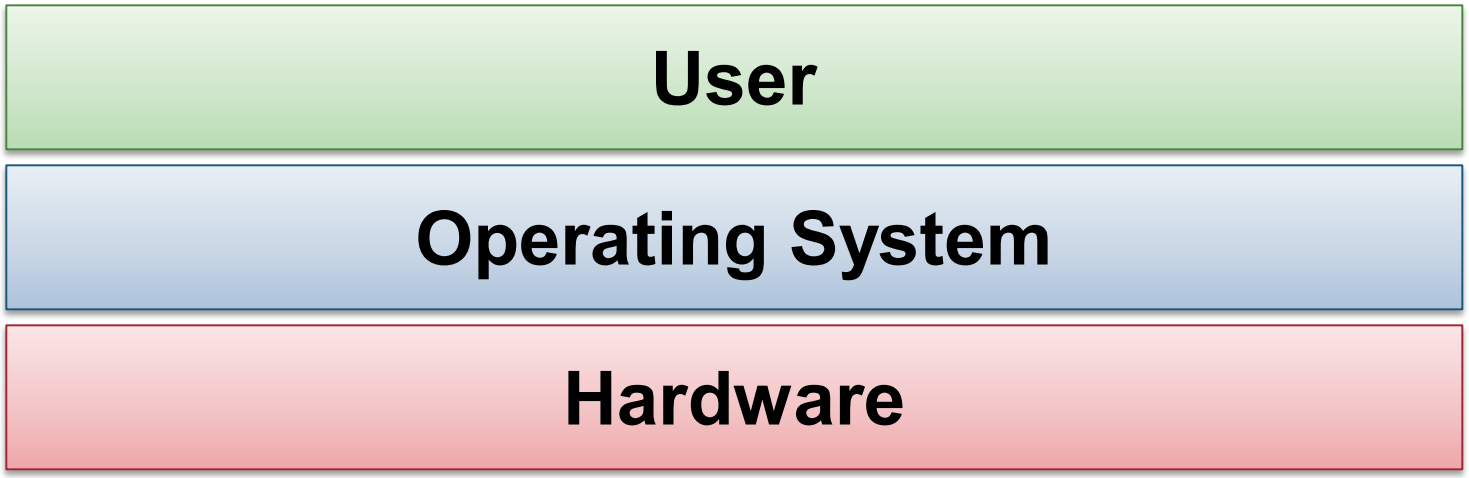
- **Virtual Machines**

What is OS?

- Incorrect/Incomplete definition:
  - It is the desktop when you boot up your PC
  - The "thing" that stores your games
  - Windows! (or Mac!) (or Linux!)

- One simple definition:
  - A **program** that acts as an **intermediary** between a **computer user** and the **computer hardware**
  - **Wikipedia:** An operating system (OS) is system software that manages computer hardware, software resources, and provides common services for computer programs.

Illustration: What is an OS?



- A simplified view:
  - Will be refined as we move along
- The most general version:
  - Hardware (not only computer!)
  - User (can be application programs or actual person!)

Example of Common OS

- On Computer:
  - Windows 10/8/XP
  - Mac OS X
  - Linux distros: Ubuntu, Redhat, Debian, Fedora, CentOS
  - Solaris, FreeBSD

- On Smartphone:
  - iOS, Android, Windows Mobile

- Other hardware with OS:
  - Game console: PS4, Xbox, Nintendo Switch, …
  - Home appliance: Blueray/DVD Player, Mio Box, …

To invent the future, you must understand the past

BRIEF HISTORY OF OS

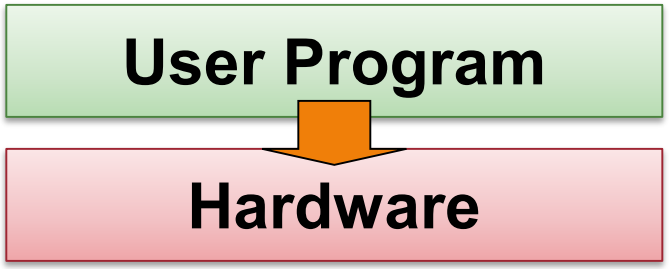
Brief History of OS

- Essentially, OS evolves with:
  - Computer hardware
  - User application and usage pattern

- The "first" computers:
  - **E**lectronic **N**umerical Integrator **A**nd **C**omputer (**ENIAC**)
    - 1945
    - Program controlled by cables and switches
  - Harvard Mark I:
    - 1944
    - Program controlled by punched paper tape

OS for the first computers

- OS Type:
  - **NO** OS



- Programs directly interact with hardware
  - Reprogram by changing **physical** configuration of hardware
- **Advantage:**
  - Minimal overhead
- **Disadvantage:**
  - Not portable
  - Inefficient use of computer!

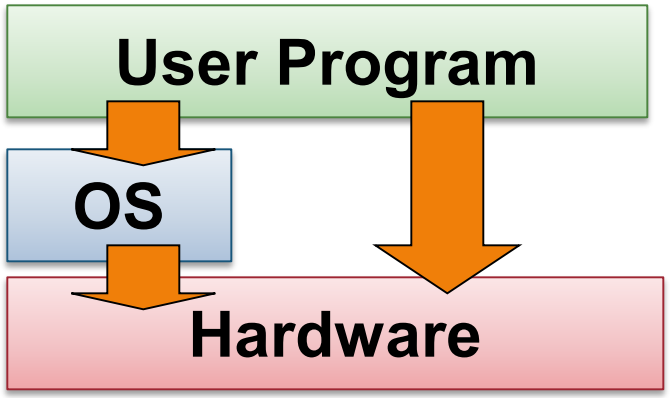
Mainframes: The "Big Iron"

- Commonly used by large corporations in 60s, 70s

- Common features:
  - No interactive interface
  - Accept programs in the form of:
    - Paper tape, magnetic tape, punch card
  - Support batch processing only
  - Very costly
    - Usually "rented" instead of owned
- Example:
  - IBM 360
    - Cost 5 billion US dollars in 1964 to develop
    - Cost 130k US dollar in 1965 to buy

OS for Mainframes

- OS Type:
  - **Batch** OS



- Batch OS:
  - Execute user program (a.k.a ***job***) one at a time
    - Load job from media, execute, collect result
- User Job:
  - Still interact with hardware directly
  - With additional information for the OS
    - Resource required
    - Job specification

OS for Mainframes: Improvements

- Simple batch processing is inefficient:
  - CPU idle when perform I/O

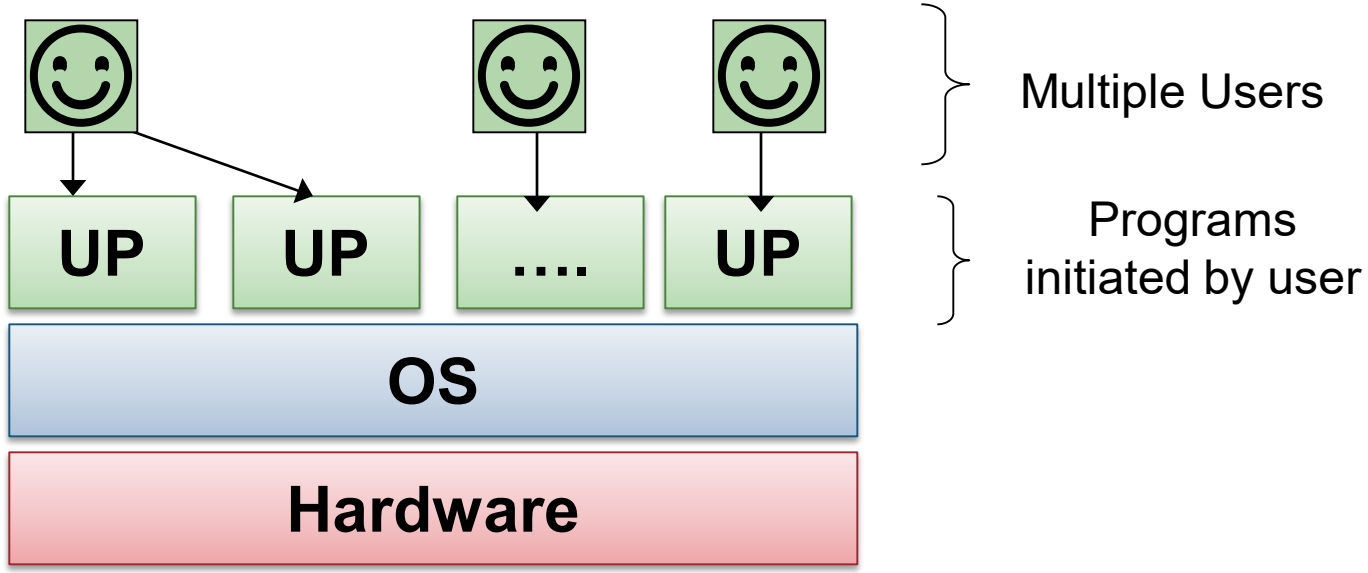
- One possible Improvements:
  - Multiprogramming:
    - loads multiple jobs and runs other jobs when I/O needs to be done
    - Overlaps computation with I/O

- Another development of OS during this period (70s):
  - Time-Sharing OS

Time-Sharing OS

- Features:
  - Allow multiple users to interact with machine using terminals (***teletypes***)
  - User job scheduling
    - Illusion of Concurrency
  - Memory management
- Famous Examples:
  - CTSS developed at MIT 1960s
  - Multics (1970s)
    - Considered as the *parent of Unix*
  - Pushed the state of art in virtual memory, security
- Similar to Unix servers today but more primitive

Time-sharing OS: Illustration



- OS manages the sharing of:
  - CPU time, memory and storage
- ***Virtualization*** of hardware:
  - Each program executes ***as if*** it has all the resources to itself

Minicomputer and Unix

- Minicomputer follows the mainframe:
  - A "mini" version of mainframe:
    - Smaller and cheaper
  - Example:
    - Digital Equipment Corp (DEC) PDP-11
- Famous OS:
  - Unix
    - Developed by AT&T employees, including Ken Thompson, Dennis Ritchie, Douglas McIlroy, and Joe Ossanna
    - Ken Thompson and Dennis Ritchie
      - Invented the C programming language as well!!

Personal Computer

- Apple II PC (1977):
  - First successfully produced mass home computer
  - Designed by Steve Wozniak (alone!)

- IBM PC (1981):
  - The first generic PC
  - PC becoming a collection of **commodity** hardware components
  - Leads to dominance of Microsoft OSes on PCs: MSDOS (1981) then Windows (1985)

OS on Personal Computer

- Machine (can be) dedicated to user, not timeshared between multiple users
  - Give rise to **personal OS**

- Several Models:
  - Windows model:
    - Single user at a time but possibly more than 1 user can access
    - Dedicated machine
  - Unix model:
    - One user at the workstation but other users can access remotely
    - General time sharing model

Abstraction
Resource Allocator
Control Program

Why do we need OS?

MOTIVATIONS OF OS

Motivation for OS: Abstraction

- Large variation in hardware configurations

- Example (Hard disk):
  - Different capacity (500mb, 320gb, 1.5tb etc)
  - Different capabilities:
    - Rotation per minutes (RPM)
    - Access (read/write) speed
    - etc.

- However, hardware in the same category has well defined and common functionality
  - Example (Hard disk): Store and retrieve information

Motivation for OS: **Abstraction**

- Operating System serves as an **abstraction**:
  - Hide the different low level details
  - Present the common high level functionality to user

- The user can then perform essential tasks **through** operating system
  - no need to concern with low level details

- Provides:
  - Efficiency, programmability and portability

Or if the program follows POSIX, then it can be used between different OS

Motivation for OS: **Resource Allocator**

- Program execution requires multiple resources:
  - CPU, memory, I/O devices etc.

- For better utilization of resources, multiple programs should be allowed to execute simultaneously

- OS is a **resource allocator**
  - Manages all resources
    - CPU, Memory, Input/Output devices
  - Arbitrate potentially conflicting requests
    - for efficient and fair resource use

Motivation for OS: **Control Program**

- Program can misuse the computer:
  - Accidentally: due to coding bugs
  - Maliciously: virus, malware etc.

- Multiple users can share the computer:
  - Tricky to ensure separate user space

- OS is a **control program**
  - Controls execution of programs
    - Prevent errors and improper use of the computer
    - Provides security, isolation and protection

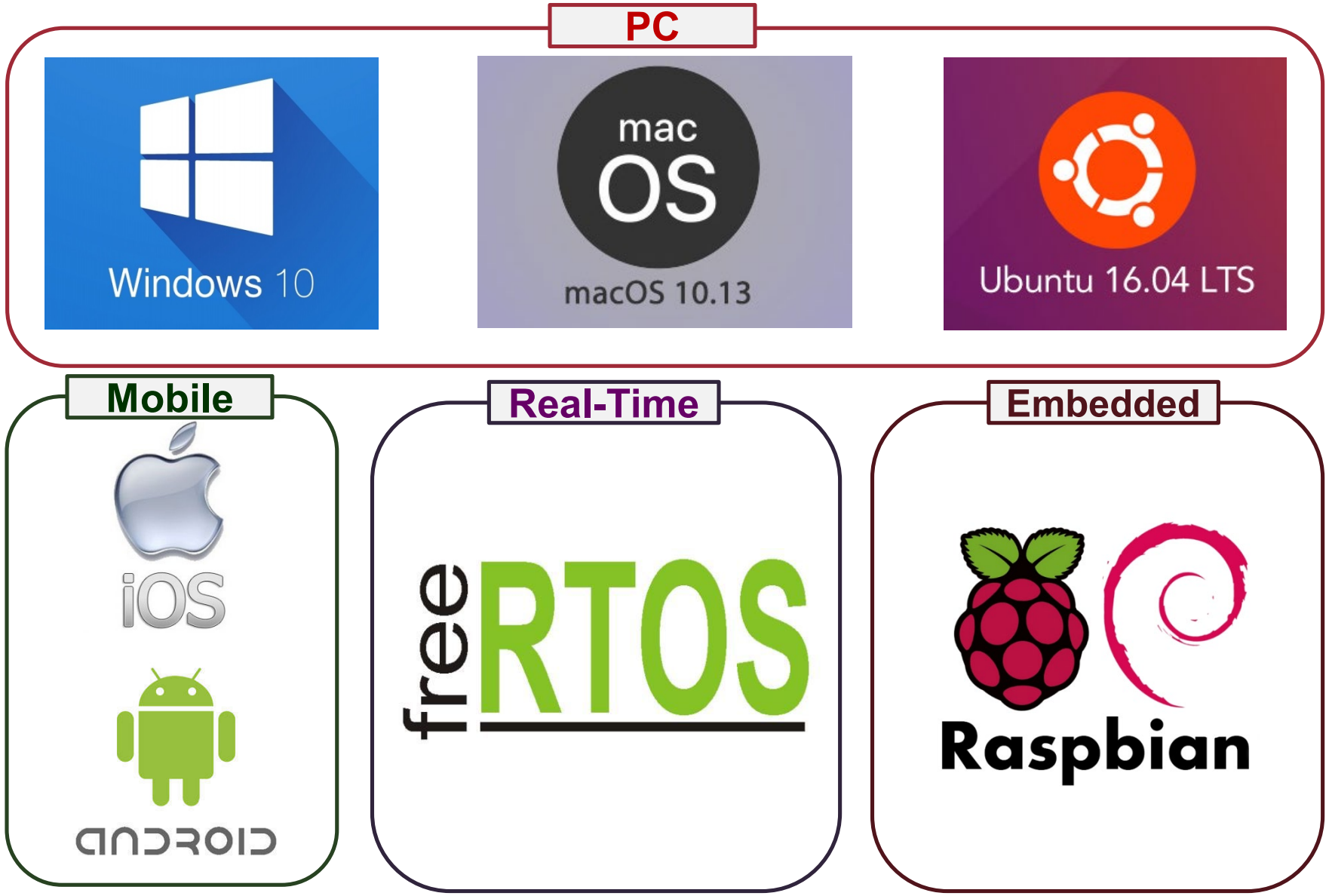
Motivation for OS: Summary

- Manage resources and coordination
  - process synchronization, resource sharing
- Simplify programming
  - abstraction of hardware, convenient services
- Enforce usage policies
- Security and protection
- User Program Portability:
  - Across different hardware
- Efficiency
  - Sophisticated implementations
  - Optimized for particular usage and hardware

The families of modern OS

OVERVIEW OF MODERN OS

Modern OS: Overview



Common Architecture for OS

OS STRUCTURE

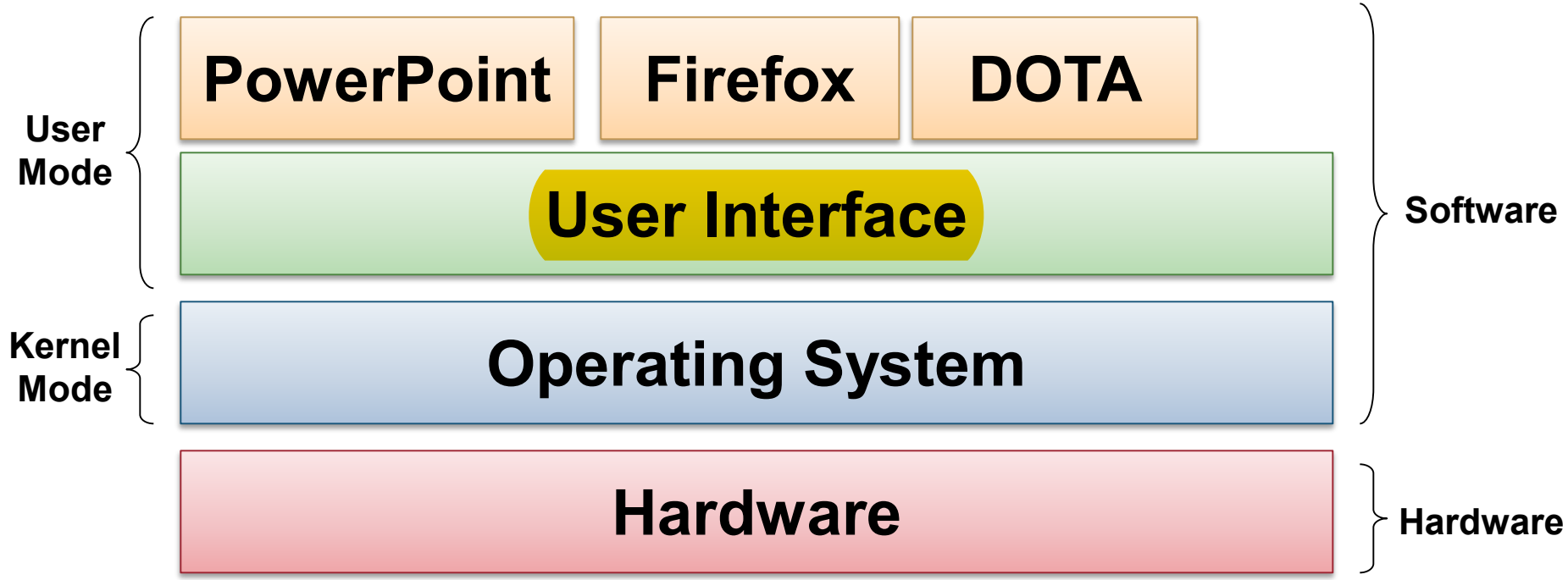
Operating System Structures

- We have identified the major capabilities of an OS
  - i.e. the *specification* of the OS

- Let us now consider:
  - The best way to provides these capabilities
  - i.e. the *implementations* of the OS

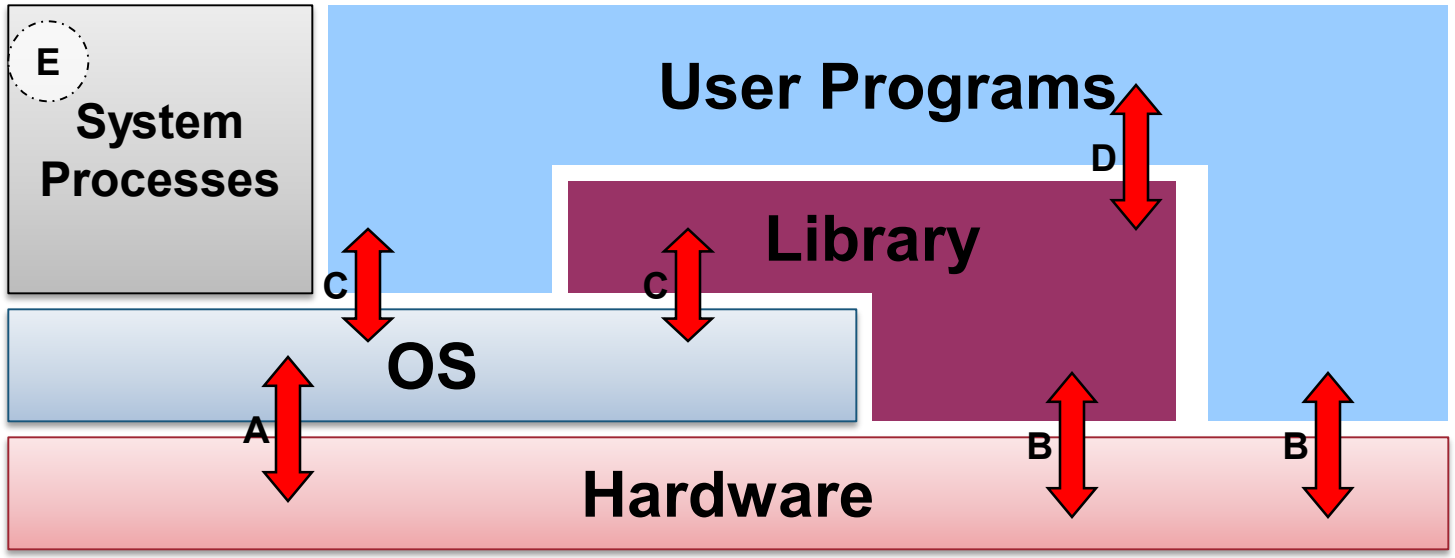
- Operating system structure:
  - *Organization* of the various components
  - Important factors:
    - Flexibility
    - Robustness
    - Maintainability
    - Performance

Illustration: High level view of OS



- Operating System is essentially a software
  - Runs in ***kernel mode***: complete access to all hardware resources
- Other software executes in ***user mode***
  - With limited (or controlled) access to hardware resources

Illustration: Generic OS Components



- **A**: OS executing machine instructions
- **B**: normal machine instructions executed (program/library code)
- **C**: calling OS using ***system call interface***
- **D**: user program calls library code
- **E**: system processes
  - Provide high level services, usually part of OS

OS as a Program

- OS is also known as the **kernel**
  - Just another program with some special features
    - Deals with hardware issues
    - Provides system call interface
    - Special code for interrupt handlers, device drivers

- Kernel code has to be different than normal programs:
  - no use of system call in kernel code
  - can't use normal libraries
  - no normal I/O

- Consider this:
  - Normal programs use OS: what does OS use? ☺

Implementing Operating System

- **Programming Language:**
  - Historically in assembly/machine code
  - Now in ***HLLs***:
    - Especially C/C++
  - Heavily hardware architecture dependent
- **Common code organization:**
  1. Machine independent HLL
  2. Machine dependent HLL
  3. Machine dependent assembly code
- **Challenges:**
  - "No one else" to rely on for nice services
  - Debugging is hard
  - Complexity
  - Enormous Codebase

OS Structures

- Several ways to structure an OS:
  - **Monolithic**
  - **Microkernel**
  - Layered
  - Client-Server
  - Exokernel
  - Hybrid
  - etc.

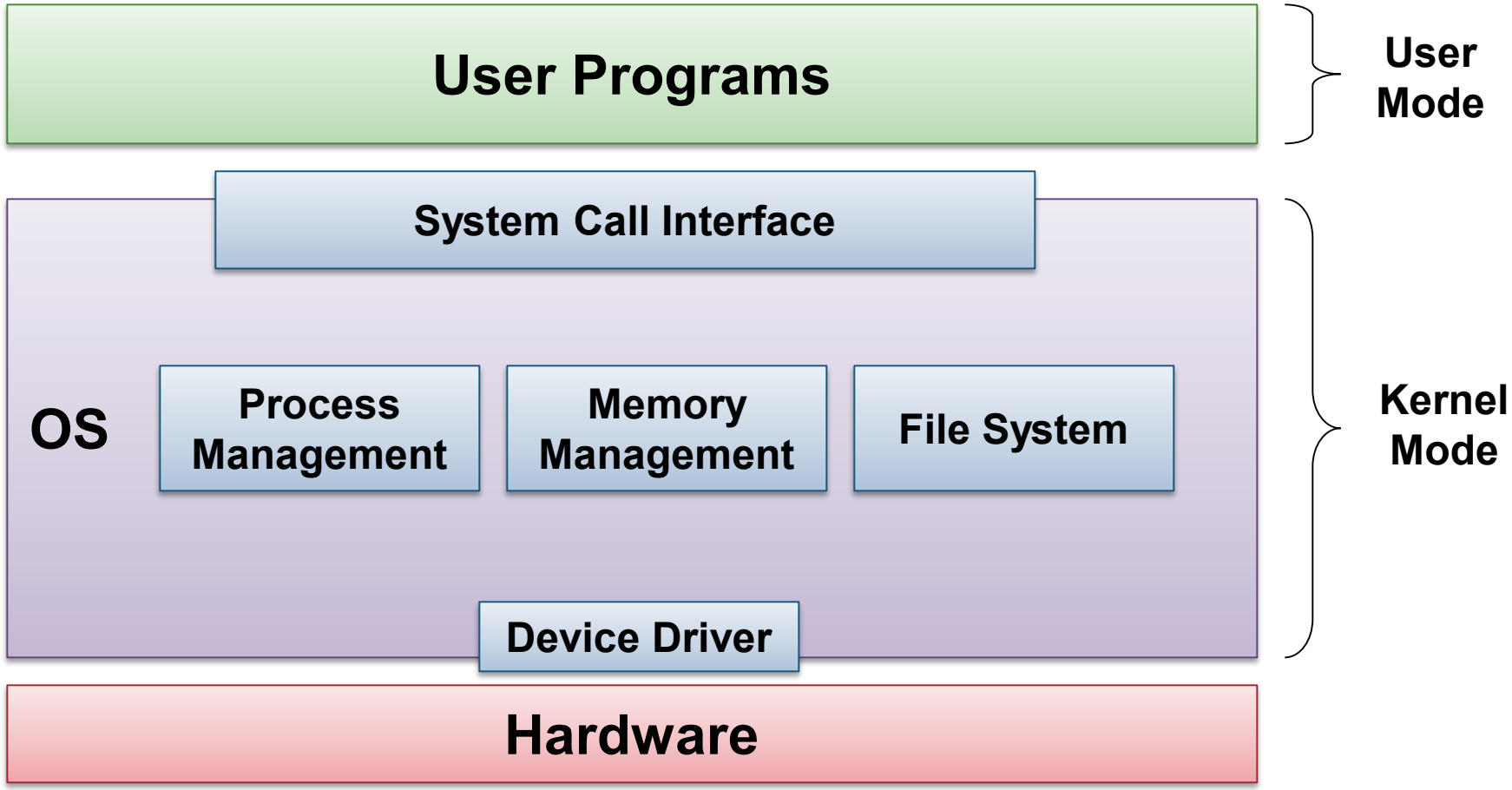
- We will cover the first two in details:
  - They represent the whole range of possibilities
  - Most other approaches are variant or improvement

Monolithic OS

- Kernel is:
  - One **BIG** special program
    - Various services and components are integral part
  - Good SE principles are still possible with:
    - modularization
    - separation of interfaces and implementation
- This is the traditional approach taken by:
  - Most Unix variants, DOS, Windows 9x

- **Advantages:**
  - Well understood
  - Good performance
- **Disadvantages:**
  - Highly coupled components
  - Usually devolved into very complicated internal structure

Monolithic Kernel Illustration



Generic Architecture of Monolithic OS Components

Microkernel OS

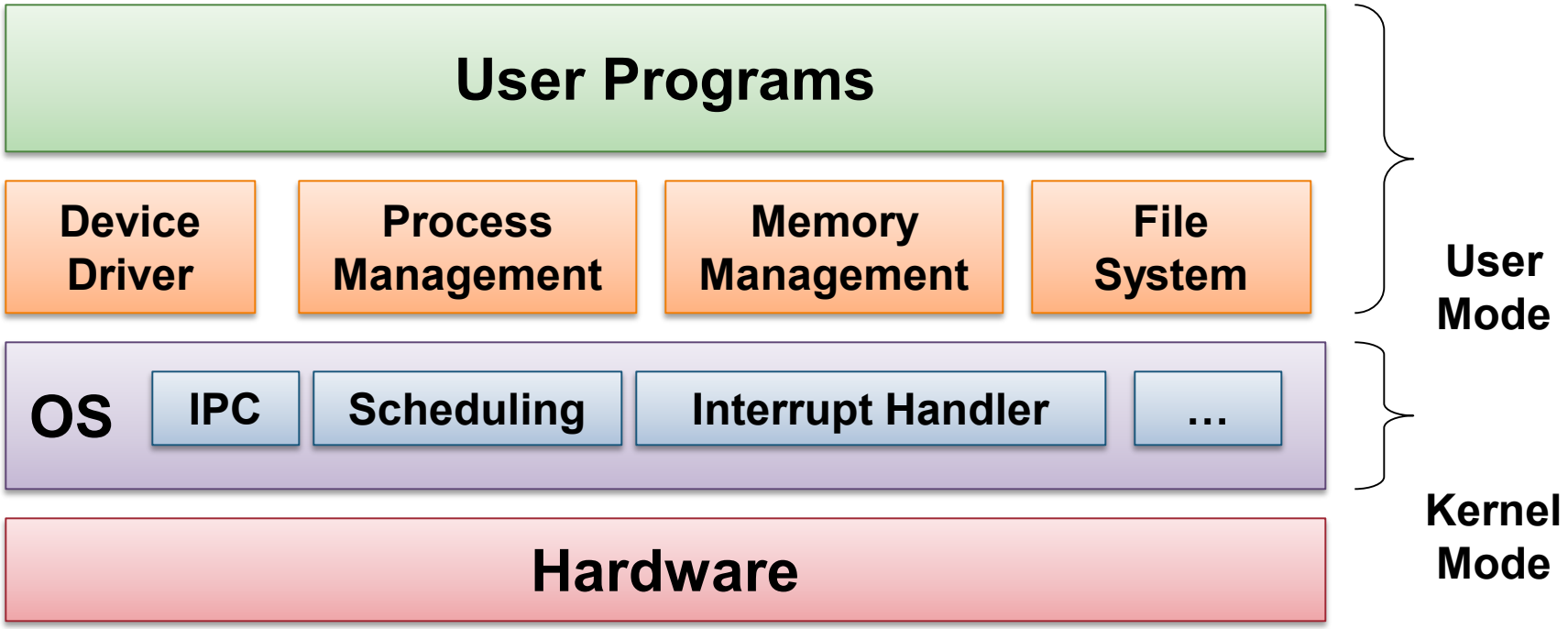
- Kernel is:
  - Very small and clean
  - Only provides basic and essential facilities:
    - Inter-Process Communication (IPC)
    - Address space management
    - Thread management
    - etc.
- Higher level OS services:
  - Built on top of the basic facilities
  - Run as server process ***outside*** of the kernel
  - Use IPC to communicate

such as file system

- Advantages:
  - Kernel is generally more robust and more extendible
  - Better isolation and protection between kernel and high level services

- Disadvantages:
  - Lower Performance

Microkernel Components



Generic Architecture of Microkernel OS Components

Other Operating System Structure

- Layered Systems:
  - Generalization of monolithic system
  - Organize the components into hierarchy of layers
    - Upper layers make use of the lower layers
    - Lowest layer is the hardware
    - Highest layer is the user interface
- Client-Server Model
  - Variation of microkernel
  - Two classes of processes:
    - Client process request service from server process
    - Server Process built on top of the microkernel
    - Client and Server process can be on separate machine!

Ways of running OSes

VIRTUAL MACHINES

Motivation: Why Virtual Machines

- OS assumes total control of the hardware:
  - What if we want to run several OSes on the same hardware at the same time?
  - Cloud computing (IaaS)

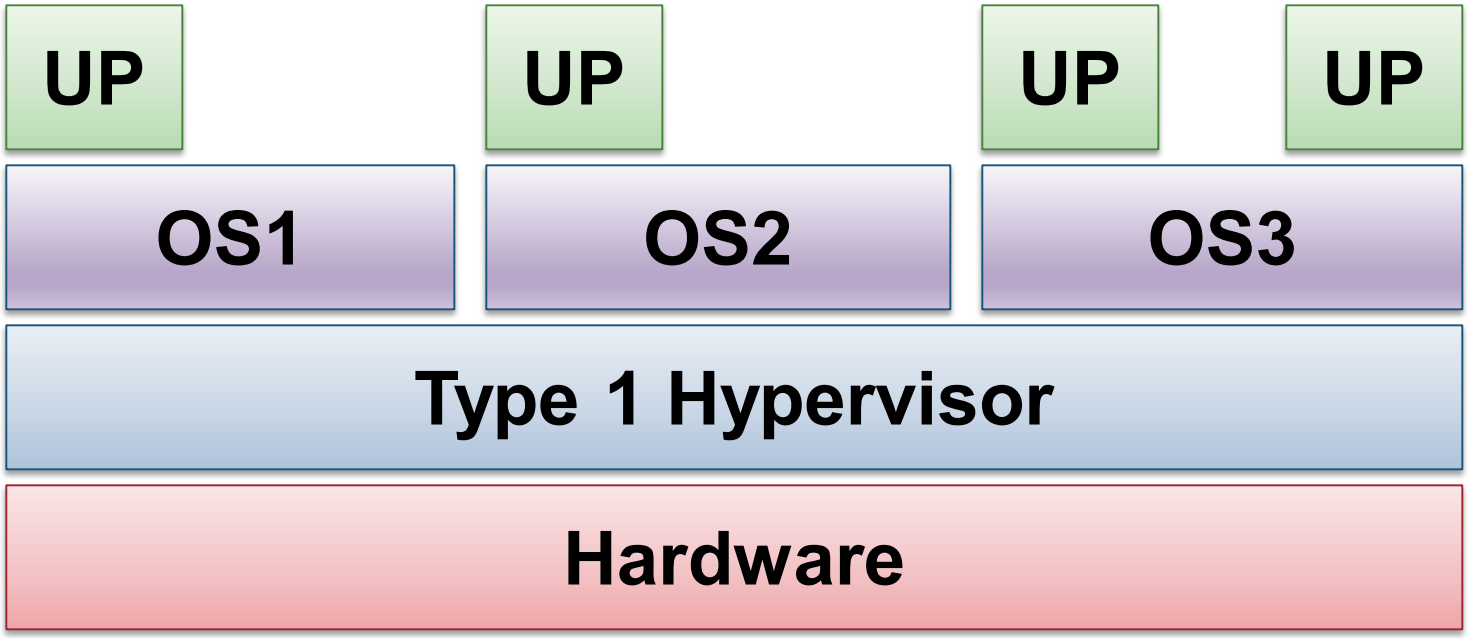
- OS is hard to debug / monitor:
  - How do we observe the working of the OS?
  - How do we test a potentially destructive implementation?

Definition: Virtual Machine

- Virtual Machine:
  - A software emulation of hardware
  - **Virtualization** of underlying hardware
    - Illusion of complete hardware to level above: memory, CPU, hard disk etc…
  - Normal (primitive) operating system can then run on top of the virtual machine

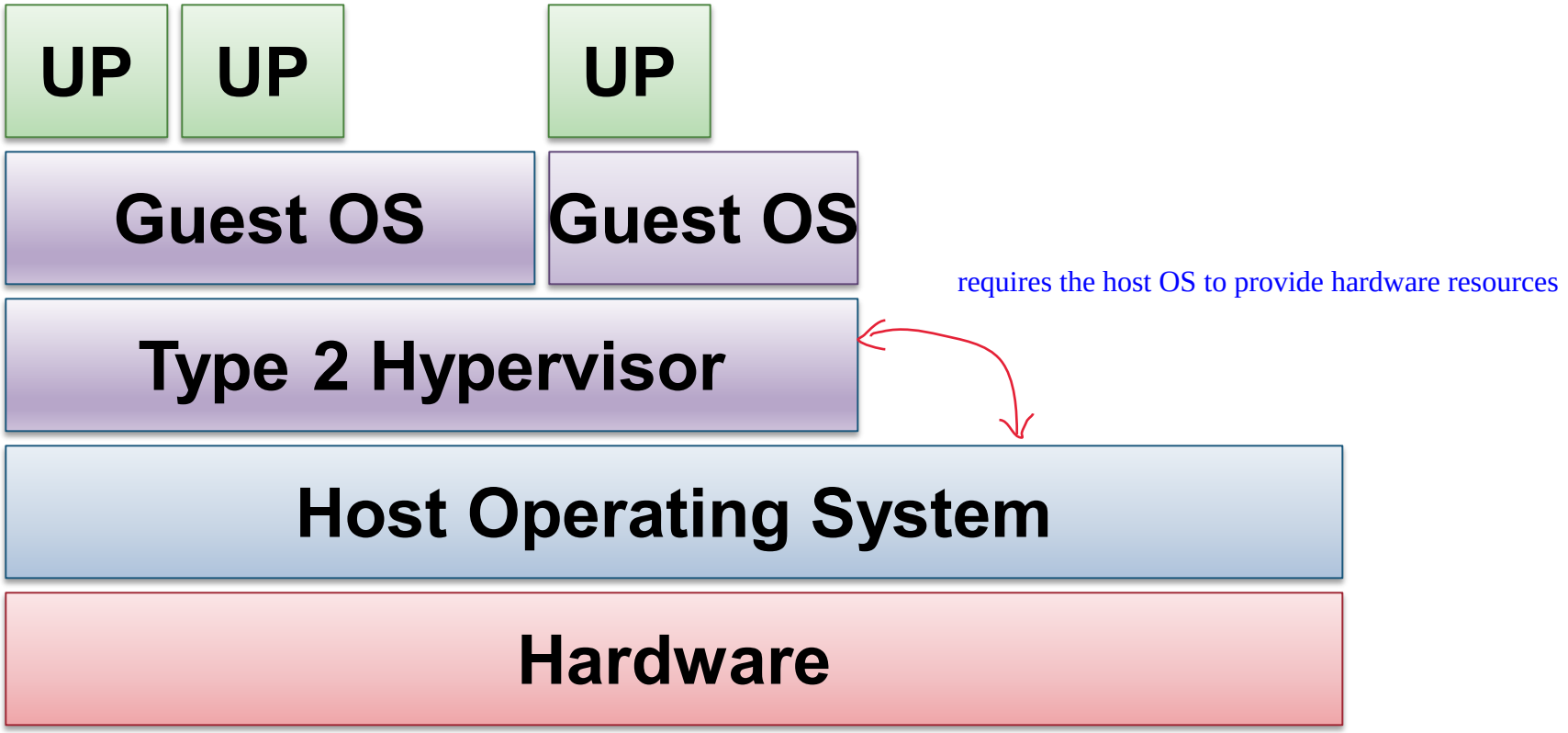
- Created and managed by **Hypervisor**
  - Also known as **Virtual Machine Monitor (VMM)**
  - Two classes of implementations shown next

Type 1 Hypervisor



- Type 1 hypervisor:
  - Provides individual *virtual machines* to guest OSes
  - eg. IBM VM/370

Type 2 Hypervisor



- Type 2 hypervisor OS
  - Runs in host OS
  - Guest OS runs inside Virtual Machine
  - e.g. VMware

Summary

- Definition of Operating System
- Roles of Operating System
- Common Operating System families
- Operating System structure

Reference

- Modern Operating System (4th Edition)
  - By Andrew S.Tanenbaum
  - Published by Pearson

- Operating System Concepts (8th Edition)
  - By Abraham Silberschatz, Peter Baer Galvin & Greg Gagne
  - Published by McGraw Hill